Testing for asymmetries in monetary aggregates

AC Phiri
16818458

Thesis submitted in fulfillment of the requirements for the degree *Philosophiae Doctor* in Economics at the Potchefstroom Campus of the North-West University

Promoter: Prof W Krugel

November 2014

DEDICATION

All my research efforts are meaningless if they do not reflect the constant and undeserving mercy that Jesus has shown throughout my life. My research efforts are humbly dedicated to him. This thesis would be meaningless if it does not attain its objective of reflecting Jesus Christ's constant working and support that he has undeserving shown me in my life. He has taught me that in order to reap in joy, one must sow in tears with a broken or contrite spirit. I am literally worthless without Jesus Christ and hence I primarily dedicate this study to him as my Lord, my saviour and my God. I also dedicate this study to the best gift that the Lord Jesus Christ has ever given me, that being, my newly-wedded wife, Naomi. A prudent wife is from the Lord (Proverbs 19:14) and whosoever findeth a wife findeth a good thing, and obtaineth favour from the Lord (Proverbs 18:22). For the LORD God said, it is not good that the man should not be alone; I will make an help meet for him (Genesis 2:18). Wifey, remember that you are next in line to get this doctorate degree.

ABSTRACT

The thesis comprises of four articles with the common theme of examining asymmetries within South African monetary aggregates with the intention of examining whether the South African Reserve Bank's (SARB) inflation target regime of 3-6 percent (1) is the most efficient and effective inflation target range which monetary policy can chose (2) has resulted in the maximization of economic growth gains or, similarly, in the minimization of economic growth losses; and (3) whether unemployment is affected by the inflation targeting regime via improvements in the levels of economic growth. In pursuing this objective we make use various regime-switching econometric models.

Keywords: Monetary policy; Inflation, Interest rates; Economic growth; Unemployment, TAR models; MTAR models; TVAR models; TVEC models, South Africa.

ACKNOWLEDGEMENTS

I first and foremost feel most obliged to give sincere glory to my lord, my saviour, my redeemer, my sanctifier and above all things my great master and divine teacher, JESUS CHRIST. In my excitement to having first acknowledged the existence of Jesus's grace bestowed upon my life, I was overwhelmed and felt like a blessed saint who had been exalted by a favourable King above all other sinners. A continued personal walk with Christ Jesus has now lowered me to feel like a blind, miserable, toothless, torn-clothed criminal bound by chains on both my hands and feet; and I am whole-heartedly clinging onto the feet of this fearsome judge who has shown undeserving mercy upon my life despite the countless disappointments that I have shown towards him. I acknowledged that you, O Christ Jesus, art my Lord, my saviour and my God. I acknowledge that you have not only taken me through this journey but you have cleansed my mind, changed my heart and are still in the process of completely purifying my soul. I acknowledge that you carried me throughout the writing of this thesis and I hope that you can be glorified through it.

I would also like to express my sincere gratitude to my newly-wedded wife, Naomi. Your presence and your encouraging yet humorous talks have preserved my sanity and reflect God's presence during the writing of this thesis. I am further obliged to extend my gratitude to the School of Economics at the North West University, Potchefstroom Campus, in particular, those individuals who have provided me with the adequate support throughout the course of the writing of this thesis. You surely know yourselves. A special mention also goes out to Prof.

Lumengo Bonga-Bonga of the department of Economics and Econometrics at the University of Johannesburg. Truly, you were God sent to help advance my academic aspirations.

PREFACE

The research conducted as part of the thesis was carried out at the School of Economics, North West University, Potchefstroom Campus under the supervision of Prof. Waldo Krugell. The contents of this thesis represent an original work of the author and have not been submitted, in part or full, to any other university for the purpose of obtaining a degree. With the exception of the introductory and concluding chapters, the remaining contents of the thesis present published articles in peer-reviewed journals.

The study on threshold effects in the persistence of South African aggregated and disaggregated inflation measures has been published in Volume 4, Number 3 of the Journal of Financial and Economic Policy (Phiri, 2012) under the title of “Threshold effects and inflation persistence in South Africa”.

The empirical work investigating asymmetric effects between nominal interest rates and inflation has also been published in Volume 31, Issue 3 of *Economics Bulletin* (Phiri and Lusanga, 2011) under the heading “Can asymmetries account for the empirical failure of the Fisher effect in South Africa?”.

The case study evaluating the compatibility of the South African Reserve Banks (SARB) 3-6 percent inflation target with the 4-7 percent economic growth target set by the New Growth Path (NGP) and the National Development Plan (NDP); has been published in Volume 9, Issue 3 of *Business and Economics Horizons* (Phiri, 2013) as “An inquisition into bivariate threshold effects in the inflation-growth correlation: Evaluating south Africa’s macroeconomic objectives”.

The empirical study which re-evaluates the relationship between unemployment and economic growth for South Africa’s post inflation target era has been published in Volume 12, Number 2 of *Managing Global Transitions* (Phiri, 2014) under the heading “Nonlinear co-integration between unemployment and economic growth in South Africa”.

TABLE OF CONTENTS

LIST OF TABLES

CHAPTER 1: INTRODUCTION

1.1 BACKGROUND TO THE THESIS

A dominant trend in the practice of monetary policy has been its dedication to price stability as well as Central Bank independence. Monetary authorities worldwide have undertaken these commitments, either by statutory mandates issued from their governments or by exercises of discretion granted to them by relevant authorities. Amongst a host of other Central Banks, the South African Reserve Bank (SARB) has demonstrated its commitment to both price stability and Central Bank independence through the adoption of an 'inflation-targeting' regime. According to Epstein (2003), inflation targeting framework is a neo-liberal approach to central banking in which monetary authorities attempt to; keep inflation at a defined low level; reduce central bank support for government deficits; help manage the country's integration into world trade and financial markets; and vigorously reduce the influence of democratic social and political forces on central bank policy. Other commentators, such as Mishkin and Schmidt-Hebbel (2001), have outlined the key elements of a 'full fledged' inflation targeting regime, as consisting of an institutional commitment to price stability; in the absence of nominal anchors and fiscal dominance; yet dependent on policy instrument independence as well as on policy transparency and policy accountability. In a nutshell, this policy framework predicts that the stability of inflation, employment and potential output-growth are determined by the outcomes of transparent monetary policy choices, exogenous shocks as well as policy responses to these shocks. As an operative policy instrument for policy conduct in South Africa, the SARB has been granted, at its discretion, the manipulation of short-term nominal interest rates which it uses as a means of achieving a financial stable environment. In turn, a financially stable environment has been explicitly defined by the SARB as inflation rates ranging between 3-6 percent. While financial stability may not exclusively guarantee the development required for the attainment of employment growth, it is recognized that without financial stability the sustainment of a conducive economic environment for growth cannot be attained (Swanepoel, 2004).

A substantial body of literature advocates on the assumed advantages of inflation targeting as a superior framework for monetary policy in comparison to other policy alternatives (Levin et. al., 2004; Gurkaynak et. al., 2006; and Goncalves and Salles, 2006). One widely acknowledged view as to why inflation targeting has gained so many adherents is based upon the perception of monetary policy being unable to simultaneously attain capital mobility, a fixed exchange rate and independent monetary policy. This phenomenon is popularly referred to as a monetary policy 'tri-lemma' and implies that an open economy can achieve only two of the three stated goals at a given time (Zaidi, 2006). Following the Asian crisis in 1998, the International Monetary Fund (IMF) recommended monetary authorities worldwide to adopt a combination of free float exchange rates and inflation rate targets as a means of lessening the probability of a currency crisis while pursuing policy objectives focused on the stability of domestic prices (Ito, 2007). Moreover, unconventional monetary policy such as quantitative easing and forward guidance had to be used as alternative policy strategies. For the specific case of South Africa, financial liberalization and a diluted relationship between the growth in money supply, output growth and prices made previously employed monetary growth targets less useful as policy objectives (Levin et. al., 2004). Also taking into account South Africa's financial integration on an internationally platform with high levels of international capital flows, it would have been extremely challenging for the SARB to gear monetary policy by targeting monetary aggregates, or by pegging an exchange rate without harming employment and output growth. Inflation targets were therefore deemed as being the ideal monetary policy framework in light of the aforementioned macroeconomic developments.

As of February 2000 up to date, the South African Reserve Bank (SARB) adopted and is currently utilizing an inflation-targeting (IT) regime as its main policy instrument. The policy strategy entails that the Reserve Bank should keep inflation within a target range or regime which is currently specified as inflation rates that range between 3-6 percent. However, despite these efforts made by the monetary authorities, some economists and other observers claim that this policy strategy places too much emphasis on price stability which by doing so has adverse effects on economic development (Aron and Meullbauer, 2006). Weeks (1999), for example, shows that the stringent monetary policies undertaken by the South African Reserve Bank (SARB) are inappropriate for the attainment of maximum possible economic welfare. The implication in Weeks (1999) is that economic growth could be higher and unemployment lower under policies tolerating moderately higher inflation rates. Nell (2000) identifies unnecessary high interest rates imposed by the South African Reserve Bank (SARB) as the reason as to why strictly conducted monetary policy is unsuitable for improved economic growth and employment creation within the economy. Akinboade et. al. (2001) further establish that inflation in South Africa is more structural in nature which in turn undermines the ability of the Reserve Bank to control inflation through the altering of short-term interest rates. Epstein (2002) also notes that fundamental processes as openness; political instability and tax policy play a larger role in promoting economic prosperity in developing countries like South Africa, as opposed to the macroeconomic policy objective of price stability. Pollin et. al. (2006) have further advocated for the implementation of an employment-targeting framework in South Africa as an alternative policy preference to the inflation targeting regime. This alternative policy framework is based on the ideology that macroeconomic target rules are more effective than the use of instrument rules in the conduct of macroeconomic policy as a whole. Moreover, over the past 15 years the Reserve Bank has only managed to achieve their set target 54 percent of the time, whereas for the remaining 46 percent, they were well outside of their target range. Also following the financial crisis, monetary policymakers have to be concerned with inflation and maintaining a large interest rate differential between international and South Africa rates in order to secure capital inflows. There is also an issue of inflationary pressures and the need to maintain external balance, a stable exchange rate and sustainable balance of payments position.

1.2 PROBLEM STATEMENT

Altogether, the presented arguments and suggested policy alternatives make for vigorous criticism of the orthodox, instrument-based policy rule approach of the Central Bank in the conduct of monetary policy. The underlying theme of the presented criticisms are motivated by the Reserve Bank's implicit assumption that once the set inflation target of 3-6 percent is achieved and maintained through the sole manipulation of short-term interest rates; economic growth gains; employment creation (lower unemployment levels) and; efficient and effective monetary policy conduct will be instantaneous end results. In other words, it is believed that the Reserve Banks policy objective of reducing South Africa's inflation rate to the relatively low levels associated with that of its main industrialized trading partners is likely to be particularly slow and costly to the economy in terms of output and employment stability, given that this goal is pursued exclusively by interest rates manipulation. The current thesis therefore argues that within the design of an inflation targeting framework, Central Banks should not only be prioritized with stabilizing actual inflation around a pre-determined inflation range; but they should also be concerned with selecting a pre-determined inflation rate which would contribute towards minimizing unemployment and maximizing economic growth. Thus due to the complex nature of inflation targeting, it is crucial for Central Banks to select an optimal inflation target after conducting a rigorous and comprehensive analysis of inflation-unemployment dynamics (Odhiambo, 2011). If policymakers, for instance, mistakenly adopt a specific optimal inflation target while their understanding of the macroeconomy is inaccurate, then any prolonged instability associated with output growth and employment might be an outcome of chasing overambitious policy targets (Orphandes, 2001). In light of the aforementioned, the presented thesis puts forth the proposed argument that the direct attainment of inflation-targets can be viewed as an appropriate policy strategy if these targets are specified within a range of some established optimal inflation rate(s). Such optimal rates of inflation, should in turn, be directly linked to the attainment of other desirable macroeconomic objectives within the South African macroeconomy.

1.3 OBJECTIVES OF THE THESIS

a) To model threshold effects in the persistence of inflation in South Africa.

b) To model thresholds effects between inflation and interest rates for South African data.

c) To model threshold effects between inflation and economic growth for South African data.

d) To model threshold effects between unemployment and economic growth for South African data.

e) To draw associated policy implications derived from the results obtained in objectives a) - d).

1.4 METHODS

As previously indicated, the present thesis deviates from the traditional norm of inflation analysis by adopting nonlinear empirical techniques to estimating optimal inflation rates from four different perspectives; those being; (1) from the perspective of an inflation rate that monetary policy can most effectively and efficiently contain (2) from an economic growth maximization perspective (or similarly, where economic growth losses can be minimized); (3) from an unemployment minimization perspective. Thus, in pursuing these innovative propositions, the thesis considers a number of sample splitting estimation techniques based on the following threshold econometric models:

- Threshold Autoregressive (TAR) model;
- Momentum Threshold Autoregressive (MTAR) model;
- Threshold Vector Autoregressive (TVAR) models and
- Threshold Error Correction Model (TECM).

Thus in contextualizing the overall research for the specific case of South Africa, the actual content of the thesis can be outlined as follows:

- Firstly, in the context of inflation persistence in South Africa, this paper estimates a threshold level of inflation, at which inflation persistence switches between regimes. In addition to estimating such a threshold, this research takes into consideration that inflation may be characterized by regime switching in the inflation process between stationary and unit root processes. We employ univariate TAR models to achieve this objective.
- Secondly, by applying TAR unit root testing procedures and TVEC models we are able to examine nonlinearities in the relationship between inflation rates and interest rates. Alternatively stated, the nonlinear relationship within Fisher's (1912) equation is investigated for South African data.
- Thirdly, we proceed to investigate threshold estimates of inflation at which economic growth is maximized or similarly where economic growth is minimized. To this end, we employ bivariate threshold autoregressive and threshold error correction (BTAR-BTEC) models.
- And in lastly closing the theses, we examine nonlinear co-integration relations between unemployment and economic growth by making use of the momentum threshold autoregressive (MTAR) approach. We consider this exercise as being beneficial, since the relationship between unemployment and economic growth is considered important for the outcomes of monetary policy conduct.

1.5 OUTLINE OF THE THESIS

The entire thesis can be more formally categorized into 6 chapters consisting of the current introductory chapter, four independent article publications as well as a final chapter which concludes the whole thesis.

The first article forms the second chapter of the dissertation and is entitled '*Threshold effects and inflation persistence in South Africa'*. In this publication, threshold effects within the persistence of South African aggregated and disaggregated inflation time series is evaluated. To this end, the article makes use of univariate two-regime and three-regime threshold autoregressive (TAR) models and associated unit root testing procedures. By applying this empirical framework, it is possible to evaluate whether the South African Reserve Bank's (SARB) current inflation target mandate of 3 to 6 percent does indeed encompass a non-stationary inflation range.

The second article forms the third chapter of the thesis and is entitled "*Can asymmetries account for the empirical failure of the Fisher effect in South Africa?* In this second article we rectify the previous-failed Fisher effect for South African data by introducing asymmetries in the empirical framework. By utilizing TAR unit root testing procedures and TVEC modelling of interest rates, the empirical exercises not only produces results similar to that obtained in the original hypothesis of Fisher (1921), but more importantly we are able to identify an inflation range at which this relationship holds.

The third article forms the fourth chapter of the dissertation and is entitled "*An inquisition into bivariate threshold effects in the inflation-growth correlation: Evaluating South Africa's macroeconomic objectives*". This third article examines whether the SARB's inflation target of 3 to 6 percent is compatible with the 4-7 percent economic growth target as set by the New Growth Path (NGP) and the National Development Plan (NDP). Through the estimations of the inflation-growth bivariate threshold vector autoregressive model with corresponding bivariate threshold vector error correction (BTAR-BTVEC) econometric models, we are able to evaluate a combination of optimal inflation rates which would lead to corresponding optimal economic growth rates.

The fourth paper forms the fifth chapter of the dissertation and is entitled '*Re-evaluating Okun's law in South Africa: A nonlinear co-integration approach'*. This chapter is primarily concerned with examining the asymmetric co-integration adjustment between unemployment and economic growth in South Africa. The objective is tackled through the use of the momentum threshold autoregressive (MTAR) econometric framework which accounts for both co-integration and causality analysis. When viewed from this perspective, our empirical results hold relevant for policymakers seeing that lower unemployment and higher economic growth are consider valuable outcomes of policy conduct. In other words, the results obtained from this empirical exercise may serve as guideline for policymakers when considering which variables to ultimately target in their design of policy mandates.

The overall contribution of this thesis thus becomes apparent when considering that no previous efforts have been taken to pursue this empirical task of investigating optimal inflation rates which are most compatible with the attainment of potential maximum economic welfare, which in this case study is identifiable through monetary policy effectiveness and efficiency; maximum economic growth gains (or similarly minimum economic growth losses) and unemployment reduction.

REFERENCES

Akinboade O.A., Niedermeier E.W. and Siebrits F.K. (2001), "South Africa's inflation dynamics: Implications for policy", *Paper presented at the 75th Anniversary conference of the Economic Society of South Africa*, September.

Aron J. and Meullbeur J. (2006), "A review of monetary policy in South Africa since 1994", *CSAE Working Paper Series No. 2006-07.*

Epstein G. (2002), "Employment-oriented central bank policy in an integrated world economy: A reform proposal for South Africa", *PERI Working Paper No.39.*

Epstein G. (2003), "Alternatives to inflation targeting monetary policy for stable and egalitarian growth: A brief summary", PERI Working Paper No. 62.

Fischer I. (1921), "The rate of interest", New York: Macmillan.

Goncalves C. and Salles J. (2006), "Inflation targeting in emerging economies: What do the data say?", Journal of Development Economies",

Gurkaynak S., Levin A., Swanson T., (2006), "Does inflation targeting anchor long-run inflation expectations? Evidence from long-term bond yields in the US, UK and Sweden", Federal Reserve Bank of San Francisco Working Paper No. 2006/09.

Ito T. (2007), “The role of the exchange rate in inflation targeting”, *In: Challenges To Inflation Targeting In Emerging Market Countries, Proceedings Of An International Symposium Organized By The Bank Of Thailand*, Bank Of Thailand, Bangkok, 243-275, November.

Levin A., Natalucci F. and Piger J. (2004), “The macroeconomic effects of inflation targeting”, *Federal Reserve Bank Of St. Louis Review*, 86(4), 51-80, July/August.

Mishkin F. and Schmidt-Hebbel K. (2001), “One decade of inflation targeting in the world: What do we know and what do we need to know?” NBER Working Paper No. 8397.

Nell K.S. (2000), "Is low inflation a precondition for faster growth? The case of South Africa", *Working Papers in Economics*, Department of Economics, Keynes College, University of Kent.

Odhiambo N. (2011), “Twenty years of inflation targeting: What can African countries learn from this policy?” *Africagrowth Agenda*, 11-12, January-March.

Orphandes A. (2001), “Monetary policy rules, macroeconomic stability and inflation: A view from the trenches”, ECB Working Paper No. 115, December.

Pollin R., Epstein G., Heintz J. and Ndikumana L. (2006), “An Employment Targeted Economic Program for South Africa”, *PERI Working Paper.*

Swanepoel J. (2004), “The monetary-fiscal policy mix in South Africa”, *South African Journal of Economics*, 72(4), 730-758.

Weeks J. (1999), "Stuck in Low GEAR? Macroeconomic Policy in South Africa, 1996-1998", *Cambridge Journal of Economics*, 23(6), 795-811.

Zaidi I. (2006), “Exchange rate flexibility and monetary policy framework in Pakistan”, *SBP Research Bulletin*, 2(1), 115-140.

CHAPTER 2: THRESHOLD EFFECTS AND INFLATION PERSISTENCE IN SOUTH AFRICA

Abstract: The purpose of this paper is to evaluate threshold effects in the persistence of South African aggregate and disaggregate inflation data. The conventional approach for assessing the degree of persistence within an inflation process is via its integration properties. This study makes use of univariate threshold autoregressive (TAR) models and associated unit root testing procedures to investigate the integration properties of the inflation data. Out-of-sample forecasts are further performed for the TAR models and their linear counterparts. The empirical results confirm threshold effects in the persistence of all employed aggregated measures of inflation, whereas such asymmetric effects are ambiguous for disaggregated inflation measures. None of the observed series is found to be stationary in their levels. The out-of-sample forecasts for all TAR models outperform their linear counterparts. Given the scope of the study, the empirical analysis provides insight with concern to the performance of inflation subsequent to the adoption of the inflation target regime in South Africa. Of particular interest are the low persistence levels observed at inflation rates of below 4.7 and 4.4 percent for core and CPI inflation, respectively, as both these aggregated measures of inflation play an essential role in guiding monetary policy conduct within the economy. the overall findings imply that on an aggregate level, the South African Reserve Bank's (SARB's) current inflation target of 3-6 percent encompasses a non-stationary inflation range and thus proves to be restrictive on monetary policy conduct. The paper fills and important gap in the academic literature by evaluating asymmetric effects in the integration properties of inflation, at both aggregated and disaggregated levels, for the exclusive case of South Africa.

2.1 INTRODUCTION

In the field of practical macroeconomic analysis, policy formulators are primarily concerned with the behavioural characteristics of macroeconomic variables as they converge towards a described or desired equilibrium steady-state. Macroeconomic shocks and associated policy directives implemented in response to such shocks often result in unprecedented fluctuations in macroeconomic variables, which under inconsistent or irregular occurrence, lead to temporary shifts of these macroeconomic variables from their steady-states. With reference to monetary policy conduct, inflation bears no exception to this rule. Following a particular shock to the inflation process, monetary policy actions would ensure that shocks to inflation only exhibit temporary effects, and consequentially, monetary authorities may aspire to randomly fluctuate inflation around a certain mean or steady-state target (Chiquiar, Noriega and Ramas-Francia, 2010). Any observed deviations of inflation from its mean or steady-state are assumed to be an outcome of persistence. The notion of inflation persistence depicts that in the event of a shock to the macroeconomy, inflation may non-permanently deviate from its long-run equilibrium state. Inflation persistence, in this sense, provides a rather convenient measure of the speed of convergence on the adjustment of inflation towards its steady-state equilibrium following the occurrence of an economic shock. The quicker inflation adjusts back to its established equilibrium, the less persistent inflation is assumed to be.

In monetary policy jargon, the aforementioned translates to a less persistent inflation process being preferred by Reserve Banks since this implies that inflation will adjust less resiliently to its equilibrium level in the presence of a macroeconomic shock. The higher the speed at which inflation converges back to its equilibrium after an economic shock, the less complicated the central bank's task of maintaining price stability (Darvas and Varga, 2006). High inflation persistence ultimately presents itself as a major challenge for monetary policy and is believed to have been the underlying factor behind the failure of a number of stabilization programmes (Moreno and Villar, 2009). Therefore, an inflation process exhibiting low levels of persistence reflects a macroeconomic environment in which policymakers are presumptuously able to 'effectively' control prevailing or intended inflation levels. In maintaining low levels of persistence in the inflation process, monetary authorities may be regarded as enhancing their policy obligation of credibility.

An important aspect pertaining to the measurement of inflation persistence is found in its integration properties. Stationarity is considered important from the perspective of macroeconomic modeling, since monetary authorities and macroeconomic model builders tend to dwell on the assumption of the inflationary process assuming a stationary data-generating process (DGP). In view of a non stationary variable having infinite variance and crossing the estimated mean infrequently, inflation targeting is meaningless when inflation is established to contain a unit root (Halunga, Osborn and Senseir, 2009). When inflation behaves as a random-walk process, then the best forecast of the following year's inflation is the most recent observed inflation and the predictability of inflation never tends to an average value. It is standard practice for empirical works pertaining to inflation persistence to diagnose the integration properties of a univariate autoregressive (AR) function of inflation by using a 'naïve' technique as proposed by Andrews and Chen (1994). This method entails that if the sum of autoregressive coefficients

(SARC) is greater than or equal to unity, then the observed inflation series is assumed to contain a unit root i.e. shocks to inflation are permanent and the series never returns to its original value. Conversely, if the SARC is of a positive integer below unity, shocks to inflation will eventually dissipate and the time series will revert to its equilibrium level.

For instance, Gadzinski and Orlandi (2004) establish that for the European Union, the Euro area and the United States, the SARC for consumer price index (CPI) inflation data across different monetary regimes has being significantly below unity. Similarly, Filardo and Genberg (2010) find an SARC below unity for Korea, New Zealand and Australia subsequent to the adoption of inflation targeting regimes. For non-inflation targeting Asian economies, Gerlach and Tillmann (2011) find that the SARC of inflation has been close to unity across monetary regimes while for the case of inflation targeting economies the same authors establish that the SARC has subsequently dropped significantly below unity. On the other hand, there also exists a number of empirical works that apply conventional unit root tests to determine the integration properties of the observed inflation series. Typically the results obtained from conventional unit root tests tend to contradict those obtained using the naïve technique of Andrews and Chen (1994). For Euro CPI, O'Reilly and Whelan (2005) find a unit root in the inflation process for the period 1970 to 2002. Benati (2008) is also unable to reject the unit root hypothesis for US inflation subsequent to 1951. With the focus on G7, Latin American, Asian and African economies, Charemza, Hristova and Burridge (2005) establish that between 1951 and 2001, a stationary inflation process is more prominent for G7 economies whereas for the remaining economies, inflation developed as a non-stationary process. Darvas and Varga (2006) highlight the possibility of the observed ambiguity concerning the integration properties of inflation being attributed to the fact that a linear approximation of an otherwise nonlinear underlying structure may be poor in capturing the inflation dynamics. Cuestas and Harrison (2010) further point out that conventional linear unit root tests suffer from important power distortions when nonlinearities exist in the data generating process.

Recently, there has been a shift of focus in the empirical literature which attempts to capture the asymmetric behavior of inflation using a family of threshold econometric models. Despite linear models providing the standard benchmark for macroeconomic modeling, publications by Arango and Gonzalez (2001); Gregoriou and Kontonikas (2009); and Cuestas and Harrison (2010) have shown how the inflation process can be best modeled as regime-switching processes. Essentially, regime-switching models assume that the DGP of a time-series can be captured in differing regimes that are segregated by unique threshold variable point(s). Above and below the identified threshold level(s), the autoregressive (AR) properties of the observed time series are deemed to differ in statistical composition. In application to measuring inflation persistence, this presents an intriguing appeal as the SARC in the DGP of the univariate AR process of inflation is incidentally considered the most suitable reduced-form measure of its persistence (Rangasamy, 2009). In this sense, the segregation of inflation data into different regimes allows for the determination of inflation bandwidths in which the SARC (and interpretively the persistence in the inflation process) can be kept minimal.

With reference to the case of South Africa, Khadaroo (2005) employs a two-regime threshold autoregressive (TAR) specification and finds low persistence in CPI levels at rates exceeding 14% inflation. Khadaroo's (2005) study offers support towards the South African

Reserve Bank (SARB) inflation target of 3-6 percent as being an over-restrictive policy strategy in controlling the inflation process. More recently, Mourelle, Cuestas and Gil-Alana (2011) captured the nonlinear dynamics of South African CPI inflation within a two-regime smooth transition autoregressive (STAR) model. The authors find that above rates of 0.84%, inflation is unstably persistent and therefore bears a risk to being effectively controlled by the Reserve Bank. Based on the empirical evidence presented in the aforementioned studies, there would be little reason to doubt the existence of two estimated thresholds in South African inflation. It is also noteworthy that while the studies of Khadaroo (2005) and Mourelle, Cuestas and Gil-Alana (2011) provide evidence of existing asymmetries in South African inflation, the integration properties of the data have not been previously investigated using formal asymmetric unit root tests. Presented with these circumstances, our study adopts a three-regime TAR model in preference to other alternatives on the basis of the model's ability to simultaneously capture asymmetric behaviour of inflation and investigate possible unit roots for higher order threshold levels i.e. two threshold points. Our paper further takes heed of allegations in the literature that are suggestive of a certain biasness ascribed towards pragmatic studies which fail to account for persistence associated with disaggregated measures of inflation. This phenomenon implies that idiosyncratic shocks tend to disappear when a substantial number of series are aggregated (Clark, 2006). Our study therefore widens the scope of investigation and employs higher-order TAR frameworks to quantify and contrast the integration properties of aggregated as well as disaggregated measures of South African inflation.

The remainder of the paper is structured as follows. The following section provides an overview of monetary policy developments in South Africa while section 3 of the paper presents the theoretical motivation for the study. Section 4 of the paper formally outlines methodology used in the paper. The empirical analysis is then conducted in section 5 and the paper is concluded in section 6 by integrating the overall empirical findings of the study with theoretical and policy implications.

2.2 AN OVERVIEW OF MONETARY POLICY IN SOUTH AFRICA

Sichei (2005) conveniently identifies five distinct monetary policy regimes adopted by the South African Reserve Bank (SARB) following the termination of the Bretton Woods system namely; liquid-asset based system, mixed system, cost of cash reserves based system with monetary targeting, repurchase agreement (repo) system with both monetary targeting and informal inflation targeting; and a repo system with a formal inflation target. The first two monetary policy regimes are representative of conservative Keynesian policies as employed from the 1960's until the mid-1980's. These regimes were regarded as ineffective monetary policies on the basis of their non-market approach towards monetary policy. Following the de Kock Commission's report in 1986, the SARB decided to adopt a pragmatic monetarist approach to policy conduct in which M3 money supply targets became the anchor of monetary policy in South Africa. However, due to financial liberalization and other structural changes experienced in South Africa during the 1990's, money supply targeting proved to be an inappropriate means of controlling inflation. This was mainly due to instabilities found in the demand for money function (Nell, 2000). Accordingly the SARB sought to take a more eclectic approach towards monetary policy which involved the monitoring of a wide-range of financially-related economic indicators. Following the Asian financial crisis of 1997-1998, an informal inflation targeting regime became active policy for the SARB until February 2000.

Entering a new millennium, the SARB decided to shift from its eclectic monetary policy approach and announced the adoption of a formal inflation target framework with targets of between 3 and 6 percent set to have been met in 2002. The SARB viewed this shift as necessary since the eclectic framework created uncertainties and the Reserve Bank's decisions were seen to be in conflict with the stated guidelines for the growth in money supply and bank credit extension (Muhanna, 2006). The inflation target mandate was favoured based on the premise of its transparency and accountability which are intended to enhance policy credibility as a means of curbing inflation expectations of economic agents. Whilst such an inflation targeting regime may appear feasible for industrialized economies, concerns have been raised about whether such a policy framework is suitable for the South African macroeconomy in face of its more severe problems such as unemployment and job creation. Take for instance, Kaseeram and Contogiannis (2011) who find that the adoption of the SARB's inflation target regime has not been effective in controlling inflation through the uncertainty channel. Bonga-Bonga and Kabundi (2010) also establish that shocks to the repo rate do not produce desirable effects in curbing inflation through the channel of money demand in South Africa whilst Gupta and Uwilingiye (2008) demonstrate on how the Reserve Bank would have produced lower inflation rates had monetary authorities shown consistency in intermediate policy objectives prior to the inflation target regime. A recent study by Phiri (2010) further suggests that a mid-range inflation target of 8% is sufficient in terms of maximizing economic growth in South Africa. Comert and Epstein (2011) more formally encompass the aforementioned arguments by putting forth the implication that the sole manipulation of short-term interest rates is not the most effective policy instrument for South African monetary authorities. Besides, the *forecastability* of inflation depends on the observed persistence in the inflation process and Mourelle, Cuestas and Gil-Alana (2011) have demonstrated how South African inflation has been highly persistent throughout the entire inflation targeting era.

Despite the current success of the inflation target regime being, for a greater part of it, due to its credibility, commentators such as McKinley (2008) have highlighted the risk that supply shocks pose towards the Reserve Bank in adopting a narrowly defined inflation target. Initially, the inflation targeting regime did not begin on a positive note, as indicated by a target breach of inflation performance in 2002-2003; caused by a sudden burst in the outflow of short-term capital which resulted in a depreciation of the Rand (Gil-Alana, 2010). Accompanied with the currency depreciation, were sharp increases in domestic and imported food prices while in the international arena, CPI inflation was being further aggravated by increases in world oil prices. Another noteworthy period depicting significant supply shocks is acquainted with the global financial crisis of 2007-2008 caused by the closing down of major banks in United States. This period accounts for the highest inflation rates experienced in South Africa during the inflation targeting period. During both inflationary periods, the SARB's response was reserved towards aggressively manipulating interest rates in fear of further aggravating macroeconomic instability. However, it was after the 2008 financial crisis that the SARB began paying more attention to volatility of exchange rates and placing emphasis on the role of asset prices as a means of ensuring stability in financial markets and the South African economy as a whole. The policy responses taken by the SARB have raised concerns as to whether the Reserve Bank may have adopted a subjective inflation target mandate intended to restrict aggregate demand yet a majority of its experienced problems are caused by supply-oriented factors. Overall, there are a lot of indications as to why acquiring new tools of monetary policy is likely to be necessary in addressing problems of financial stability, unemployment and inequality in the South African economy (Comert and Epstein, 2011).

2.3 THEORETICAL MOTIVATION OF THE STUDY

From a theoretical perspective, inflation persistence is often considered as a post-Keynesian phenomenon and can be derived from models that incorporate nominal rigidities generating price stickiness. The price formation mechanism that characterizes these sticky price models have their roots theoretically embedded in the works of Taylor (1979, 1980) and Calvo (1983). Theoretical models based on price stickiness are concerned with describing the micro foundational dynamics of inflation adjustment in response to various economic shocks and monetary policy actions. Specifically, the dynamic inflation adjustments have been deemed a theoretically important component in determining the significance of the recently popularized New Keynesian Phillips Curve (NKPC) which is fundamentally based on the principles of price stickiness (Kang, Kim and Marley, 2009). The ability of the NKPC model to efficiently analyze important macroeconomic variables within a monetary policy framework has been what Brissimis and Magginas (2008) refer to as "*…the closest [theoretical model framework] there is to standard perfection…*". The nature of inflation dynamics is arguably the most distinctive feature of the forward-looking NKPC and this bears a close theoretical relation with the framework of the forward-looking inflation target monetary regime (du Plessis and Burger, 2006). Therefore, the paper intentionally employs the New Keynesian specification of the

Phillips curve as a baseline model to capture the level of persistence in the inflation process. In its basic structural form the NKPC expresses inflation as a function of expected future inflation and some measure of a firm's real marginal costs or excess demand:

$$\pi_t = \alpha E_t \pi_{t+1} + \beta \chi_t \qquad (1)$$

This traditional structural inflation equation identifies two types of persistence associated with the model's inflation dynamics; one being expectations-based inflation persistence (i.e. $\alpha E_t \pi_{t+1}$) and the other being extrinsic inflation persistence (i.e. $\beta \chi_t$). Expectations-based inflation persistence is theorized as a result of the distorted formation of expected future inflation. On the other hand, extrinsic inflation persistence is determined by the real marginal costs of firms or by the output gap of the macroeconomy. Both expectations-based and extrinsic persistence are categorized as '*inherited*' inflation persistence since inflation, in both circumstances, inherits its persistence from the unrelenting movements in its driving variables (Dossche and Everaert, 2007). In practice, empirical sources of difficulty concern the characteristics of the proper measure of the driving variable or excess demand as well as the assumption concerning an appropriate proxy of expected inflation (Brissimis and Magginas, 2008).

In consequence of its strictly forward-looking nature, the 'traditional' NKPC has been criticized for being able to generate price stickiness without reflecting inflation inertia which inevitably leads to the unrealistic postulation of complete flexibility in the inflation process. The 'traditional' NKPC therefore predicts that once factors that give rise to high inflation have passed, inflation can return to its equilibrium without suffering a temporary reduction in economic activity (Sheedy, 2010). According to Karanassou and Snower (2007), this controversial phenomenon of inflation ‘jump behavior’ has been labeled ‘the persistence puzzle’. In an attempt to rectify the much debated ‘persistence puzzle’ several models address this issue by introducing the lagged value of inflation into the NKPC. Fuhrer and Moore (1995) show that a staggered wage contract model in which agents care about relative wages can account for the backward looking component of inflation. Gali and Gertler (1999) present an alternative theory in which a fraction of firms rely on a rule-of-thumb when setting prices while Mankiw and Reis (2002) introduce inflation inertia through information lags in price setting mechanisms. Christiano, Eichenbaum and Evans (2005) argue that in times when actual pricing decisions are made, firms continually re-index their prices in line with past inflation. All-in-all, these price-setting developments in the New Keynesian inflation dynamics have resulted in the formation of a ‘hybrid’ version of the NKPC. The hybrid New Keynesian Phillips Curve (HNKPC) incorporates both forward-looking and backward-looking elements into the New Keynesian framework and is reflected in the following structural inflation equation:

$$\pi_t = \rho\pi_{t-1} + \alpha E_t\pi_{t+1} + \beta\chi_t \quad (2)$$

The backward-looking dynamic behavior allows for deviations of observed inflation rates from the equilibrium to persist due to consecutive prior periods of inflation (Dossche and Evereart, 2005). Overall, the general classification of identifiable lag persistence (i.e. $\alpha\pi_{t-1}$) in the structural inflation dynamics is known as *‘intrinsic or inherent’* inflation persistence. The extent to which inflation determination is dominantly backward-looking as opposed to forward-looking has been empirically proved in the studies of Sbordone (2002), Rudd and Whelan (2005), Fuhrer (2007) and Whelan (2007). However, it has been argued that the obtained results are sensitive to the statistical methods employed and the observed persistence may be due to the existence of unaccounted structural changes (Gadea and Mayoral, 2006). Furthermore, Sheedy (2007) highlights a particular danger in these studies assuming a constant hazard function associated with the inflation dynamics of the NKPC. The empirical performance of an estimated nonlinear DSGE model of inflation persistence, as demonstrated in the works of Amisano and Tristani (2010) confirms the plausibility of these arguments. Theoretically, developments by Charemza and Makarova (2009) have integrated a nonlinear component into the intrinsic portion of inflation in the HNKPC. The motivation behind their theory is prompted by the fact that the standard HNKPC and other macroeconomic policy models assume stationarity in the inflation process where such a presumption may not conform to actual time-series data. Their approach into incorporating nonlinearities within the inflation process is achieved by modeling inflation expectations as a collective function of the expected real marginal cost or output gap ($E_t\chi_t$) and an error representative of a monetary shock induced by policy-makers i.e. $((-\lambda g_{t-1})(\pi_{t-1}))$. Expected inflation ($E_t\pi_{t+1}$) within the model is expressed as:

$$E_t\pi_{t+1} = \beta E_t \chi_t + (-\lambda g_{t-1})\pi_{t-1} \qquad (3)$$

The parameter measuring the monetary policy effect, λ, is bound by the condition $0<\lambda<1$ and is introduced as a means of ensuring that inflation strictly fluctuates between a stationary I(0) process and a nonstationary I(1). By making use of equations (2) and (3), monetary policy actions can be contained within the following structural inflation equation:

$$\pi_t = (1- \lambda g_{t-1})\pi_{t-1} + \beta E_t \chi_t \quad (4)$$

Within the model, the effects of monetary policy on inflation persistence can be described as follows. When the policy factor is a non-zero integer i.e. $\lambda \neq 0$, then monetary policy is effective in the sense of containing inflation within the limits of being a stationary I(0) process. On the other hand, when the policy factor is $\lambda=0$; then inflation evolves as a nonstationary I(1) process and the monetary authorities do not have effective control over it. Ideally, inflation persistence would be measured in a multivariate autoregressive model as a lag between monetary policy shock and the peak response in inflation. However, given the possibility of the inflation process switching between an I(0) and I(1) process, the nonlinear inflation mechanism within the described theoretical framework cannot be captured within a conventional multivariate vector autoregressive (VAR) specification. As indicated by Batini (2002), a VAR system would require all the observed data variables to be constantly integrated of similar I(0) order thereby giving rise to this empirical limitation. Based on the available academic literature, an alternative and highly standardized practice in quantifying the persistence in inflation is to capture it as an *intrinsic or inherent* process within a univariate AR specification. This approach has an advantage in terms of simplicity and Batini (2002) describes it as "…*a reduced-form property [analysis] of inflation that [simultaneously] manifests the underlying pricing process, the conduct of monetary policy and the expectations formation process of price-setting agents. Changes in any of these three factors will influence the autocorrelation properties of inflation*…". Incidentally inflation in South Africa is largely subject to intrinsic inflation persistence and is responsible for aggravating the overall containment of inflation within the economy (South African Reserve Bank, 2009).

Therefore, this paper's approach into capturing the described theoretical nonlinear inflation dynamics in application to South African time-series data is via a univariate regime-switching econometric framework.

2.4 METHODOLOGY

2.4.1 Quantifying Inflation Persistence Within A Three-Regime SETAR Model

Empirically, inflation persistence is typically captured as the positive serial correlation in a univariate AR inflation model (see Dossche and Evereat, 2005; Darvas and Varga, 2006; Rangasamy, 2009; and Sheedy, 2010 for examples):

$$\pi_t = \Sigma\alpha_{1i}\ \pi_{t-i} + \mu_t \tag{5}$$

From (5), the persistence of inflation (ρ) is estimated as the sums of the AR coefficients of lag order i (i.e. $\rho_{\pi 1} = \Sigma\alpha_{1i}$) and directly measures the sluggishness of which inflation responds to external shocks (Hondroyiannis and Lazareto, 2004). The examination of potential nonlinearities in inflation persistence is prompted via Hansen's (2000) estimation and testing of the TAR model. The extension of linear AR model equation (5) into a three-regime TAR model is facilitated by determining whether two supplementary regimes of inflation coefficients (i.e. $\rho_{\pi 2}=\Sigma\alpha_{2i}\ \pi_{t-i}$ and $\rho_{\pi 3}=\Sigma\alpha_{3i}\ \pi_{t-i}$) can significantly be accommodated within the AR framework. Denoting γ_i as a threshold breakpoint and I(.) as the indicator functions of the TAR process that segregates the function into different regimes, the encompassing three-regime TAR model of inflation is specified as:

$$\pi_t(\gamma) = \alpha_1 + \Sigma\alpha_{1i} + \mu_{t1}\ \mathrm{I}.(\pi_t \leq \gamma)$$
$$+ \alpha_2 + \Sigma\alpha_{2i} + \mu_{t2}\ \mathrm{I}.(\gamma_1 < \pi_t < \gamma_2) \quad (6)$$
$$+ \alpha_3 + \Sigma\alpha_{3i} + \mu_{t3}\ \mathrm{I}.(\pi_t > \gamma_2)$$

The empirical process is instigated by reducing equation (6) into a two-regime TAR by assuming $\gamma_2 = 0$, such that initially there exists one threshold estimate point (i.e. $\gamma_1 = \gamma$). Hansen (1996) suggests that the least squares (LS) estimator of the threshold γ can be attained by minimizing the residual sum of squares (RSS) within a search region defined by $\Gamma_1 = [\hat{\gamma}_{1min}, \hat{\gamma}_{1max}]$. In attaining a threshold estimate of $\hat{\gamma}_1$, Hansen (2000) has shown that the estimation technique can be extended to the context of a multiple change point model. The joint least squares estimates of double threshold points (γ_1, γ_2) are defined as the values which jointly minimize the function of RSS(γ_1, γ_2) given the threshold condition of $\gamma_1<\gamma_2$ and a search region $\Gamma_2 = [\hat{\gamma}_{2min}, \hat{\gamma}_{2max}]$. It should be noted that since the first threshold estimate, $\hat{\gamma}_1$, is initially obtained from a sum squares of errors function which ignores the presence of a third regime, then $\hat{\gamma}_1$ cannot be deemed as an asymptotically efficient threshold estimate in a double-threshold TAR model. Hansen (2000) thereby proposes that an asymptotically efficient estimate of the first threshold value, $_r\hat{\gamma}_1$, can be obtained via a refinement criterion.

Attributing to the Davies (1987) problem in which inference complexities are associated with the unknown threshold parameters (γ_1, γ_2), Hansen (2000) suggests the use of a bootstrap procedure on likelihood ratio (LR) test statistics in constructing asymptotically valid p-values.

Firstly, the hypothesis of a linear versus a two regime process is tested via an LR test statistic denoted as ${}_{r}LR_{1}(\gamma)$. The null hypothesis of no threshold effects is accepted if the ${}_{r}LR_{1}(\gamma)$ statistic is of a smaller value when compared with its associated bootstrapped critical value, $c_{\zeta}(1-\alpha)$. In such a case, inflation is best captured as a linear AR process as given equation (5). However, when ${}_{r}LR_{1}(\gamma) > c_{\zeta}(1-\alpha)$, a higher-order LR statistic i.e. ${}_{r}LR_{2}(\gamma)$; is then used to test the hypothesis of a two-regime against an alternative of a three regime TAR process. If the alternative hypothesis of a three-regime model is rejected (i.e. ${}_{r}LR_{2}(\gamma) \leq c_{\zeta}(1-\alpha)$), then the singular threshold estimate is applicable whereas when ${}_{r}LR_{2}(\gamma) > c_{\zeta}(1-\alpha)$ then two refined threshold points, ${}_{r}\hat{\gamma}_{1}$ and ${}_{r}\hat{\gamma}_{2}$, can be estimated. Once the optimal threshold values are estimated and validated, the conditional-heteroskedastic covariance matrix of β from equation (6) is estimated via backward substitution.

2.4.2 Unit Root Tests

Given the possibility of linear and nonlinear econometric structures associated with the time-series, three unit root tests are proposed for diagnosing the integration properties of the time series, namely; the Augmented Dickey-Fuller (ADF), Enders and Granger (1998) and Bec, Salem and Carrasco (2004) unit root tests. Suppose that the both LR statistics fail to reject their null hypotheses of linearity, this implies that the inflation processes are best fit using linear AR models. In this regard, the ADF unit root test is designed to accommodate linear AR specifications and is based on the following test regression:

$$\Delta\pi_t = \psi\pi_{t-1} + \sum^{k}_{j=1}\gamma_j\Delta\pi_{t-j} + \varepsilon_t \quad (7)$$

Under the null hypothesis of a unit root π_t is I(1), which implies that ψ=0. The Dickey Fuller (DF) t-statistic, ${}^{DF}\varphi_u$, is then applied in testing the null hypothesis of ψ=0. The test statistic rejects the null hypothesis unit root when the ${}^{DF}\varphi_u$ statistic is of a lower absolute value compared with the critical values given by Mackinnon (1996).

The second proposed unit root test has been devised by Enders and Granger (1998) (E-G hereafter) who generalize the Dickey Fuller (DF) methodology to consider the null hypothesis of a unit root against the alternative of a two-regime TAR model. This unit root test is applied when one threshold is established within an inflation series. Formally, the nonlinear unit root test can be depicted and described in the following specification:

$$\Delta\pi_t = \psi_1\pi_{t-1}I.(\pi_{t-1} \geq 0) + \psi_2\pi_{t-1}I.(\pi_{t-1} < 0) + \varepsilon_t \quad (8)$$

Where the governing Heaviside indicator function used to accommodate possible asymmetric effects within the autoregressive decay is given as:

$$I._t = 1 \text{ if } \pi_{t-1} \geq 0 \quad (9)$$

$$0 \text{ if } \pi_{t-1} < 0$$

A modified F-statistic (${}^{NDF}\varphi_u$) is used to test the null hypothesis of a unit root (i.e. $\psi_1 = \psi_2 = 0$) against the alternative of an otherwise stationary two-regime process. The hypothesis of a unit root can only be rejected if the ${}^{NDF}\varphi_u$ statistic is larger in absolute value in comparison with the critical values as tabulated in Enders and Granger (1998).

A final scenario may occur in which the null hypotheses of linearity and one threshold point, which are respectively tested by the ${}_rLR_1(\gamma)$ and ${}_rLR_2(\gamma)$ statistics, are both rejected for a given series. The integration properties of such existing series are examined through a nonlinear unit root testing procedure proposed by Bec, Salem and Carrasco (2004). Their econometric specification suggests an application of a first difference operator to Hansen's (2000) three-regime TAR model. The following condensed auxiliary nonlinear inflation function can best represent the above described unit root test:

$$\begin{aligned}\pi_t = {} & \alpha_1\Delta\pi_{t-1} + \psi_1\pi_{t-1} + \zeta\varepsilon_{t1} \text{ (if } \pi_{t-1} \leq -\gamma*) \\ & + \alpha_2\Delta\pi_{t-1} + \psi_2\pi_{t-1} + \zeta\varepsilon_{t2} \text{ (if } |\pi_{t-1}| < \gamma*) \\ & + \alpha_3\Delta\pi_{t-1} + \psi_3\pi_{t-1} + \zeta\varepsilon_{t3} \text{ (if } |\pi_{t-1}| < \gamma*)\end{aligned} \quad (10)$$

Restrictions of $\gamma_1 = -\gamma_2 = -\gamma$ and $\alpha_i \leq 1$, $\psi_i \leq 1$ are imposed on the parameter variables of equation (10) to rule out the possibility of explosive behaviour in any existing unit roots. This also ensures that nonstationarity can only be detected in the middle regime of significant three-regime processes in which the entire series remains globally ergodic. Kapetanois and Shin (2006) highlight the importance of a geometric ergodicity as it implies ”…*the existence of a unique stationary distribution for a [time series] such that [it] converges to stationarity exponentially fast when it is initialized at an arbitrary finite value ... [and] further implies B-mixing [coefficients] with geometric decay* ...”. Under the null hypothesis of a unit root in the middle regime i.e. H_0: $\alpha_1 = \alpha_2 = \alpha_3$; $\psi_1 = \psi_2 = \psi_3 = 0$, a unit root process of $\Delta\pi_\tau = \alpha\Delta\pi_{t-1} + \zeta\varepsilon_t$ is tested, whereas under the alternative hypothesis of H_1: $|\psi_1|<1$, $|\psi_2|<0$, $|\psi_3|\leq 0$, the regression reduces to a stationary three-regime TAR process. In order to effectively test these described hypotheses, there must be a singular threshold value of, γ which is plugged-into the unit root test regression. Bec, Salem and Carrasco (2004) suggest that the threshold value can be selected a prior by the econometrician in testing for the unit root hypothesis. The asymptotic distributions of these unit root tests are derived from Supremum-based tests on the Wald, Lagrange multiplier (LM) and Likelihood-ratio (LR) statistics i.e. $^{BBC}W_{SUP}$, $^{BBC}LR_{SUP}$ and $^{BBC}LM_{SUP}$. From these unit root connotations, a time series can only be rendered as a stationary three-regime process if the above test statistics are of a smaller value in comparison to their computed critical values.

2.5 DATA AND EMPIRICAL ANALYSIS

Having detailed the empirical procedures in the previous section, this section of the study presents the application of the described methodology on empirical data. Given that the objective of the study seeks to substantiate threshold effects in the inflation process for periods subsequent to the adoption of the inflation targeting mandate, the inflation data that is collected and analyzed is bound between the monthly periods of 2000:02 and 2010:12. The data consist of both aggregated and disaggregated price indices. The aggregated series consists of the core inflation index, the total consumer price index (CPI), the total prices of goods and the total prices of services, with the latter three series being obtained from the SARB database. The series of core inflation is obtained from the Statistics South Africa (SSA) database and by purpose serves to capture the underlying inflationary pressures that exclude highly volatile products from its computation. The consumer price index (CPI) data is considered as a plausible aggregated measure of inflation for the study since it provides a "…measure [of] inflation in the economy so that macroeconomic policy is based on comprehensive and up-to-date price information…" (Statistics South Africa, 2009). The CPI is constructed using the classification of individual consumption by purpose (COICOP) for individual components of various commodities and service products which in aggregation forms the total prices in commodities and services, respectively. In addition, the individual components of the COICOP are used as the disaggregated measures of commodities and service inflation in this study. Table 1 below provides a more formal decomposition of the aggregated and disaggregated price indexes used in this study. The estimation results of the aggregated inflation data is presented in Table 2, whereas those for disaggregated measures of commodities and services are provided in Tables 3 and 4. The results of the unit root tests are reported in Table 5, whereas Table 6 presents the out-of-sample forecasting performance of the time-series.

Table 1: Decomposition of the aggregated and disaggregated price indexes

		Core Inflation	
		Total CPI	
Aggregated Measures	Total Consumer Prices of Goods		Total Consumer Prices of Services
Disaggregated Measures	Food Alcohol and Tobacco Clothing and Footwear Housing and Utilities Household Contents, Equipment and Maintenance Health Transport Communication Recreation and Culture Miscellaneous		Housing and Utilities Household Contents, Equipment and Maintenance Health Transport Communication Recreation and Culture Education Miscellaneous

Source: Author's own tabulation.

As is shown in Table 2 below, the ${}_{r}LR_1(\gamma)$ statistic manages to reject the null hypothesis of linear autoregressive processes for all the observed aggregated inflation data while the ${}_{r}LR_2(\gamma)$ statistic cannot reject the hypothesis of a three-regime model for all the series with the exception of inflation in total CPI. Further referring to the results presented in Table 2, it can be seen that a single threshold of 4.4% is established for inflation in total CPI where above this level a significant higher, close-to-unity SARC is observed. Between inflation rates of 4.7% and 8.5%, core inflation exhibits the highest persistence with the SARC being above unity in this regime, and the lowest SARC is established at rates below 4.7%. Similarly for total goods and total services, the highest SARC exists in the middle regimes (i.e. between 3.2%-8.7% for total goods and 2.7%-7.6% for total services). The lowest SARC for both of these series is found in the high regimes at inflation rates of above 8.7% for total goods and 7.6% for total services. Given these relatively high SARC estimates obtained from the TAR models, it is tempting to interpret these results as evidence of unit roots existing in the data series. At this stage, such an interpretation is tentative and warrants more formal unit root tests to confirm these preliminary speculations.

Table 2: Empirical TAR estimation results for aggregate measures of inflation

TIME SERIES	LR STATISTICS		INFLATION THRESHOLDS		LAG ORDER	PERSISTENCE MEASURES		
	${}_rLR_1(\gamma)$	${}_rLR_2(\gamma)$	${}_r\hat{\gamma}_1$	${}_r\hat{\gamma}_2$		$\rho_{\pi1}=\Sigma\alpha_{1i}$	$\rho_{\pi2}=\Sigma\alpha_{2i}$	$\rho_{\pi3}=\Sigma\alpha_{3i}$
CORE INFLATION	60.62*** (0.00)	24.84* (0.1)	4.7% [3.8%,5.5%]	8.5% [7.8%,9.1%]	6	0.37	1.00	0.80
TOTAL CPI	46.60*** (0.00)	21.23 (0.7)	4.4% [3.9%,4.9%]	-	6	0.92	0.94	-
TOTAL GOODS	37.93** (0.00)	29.51** (0.00)	3.2% [2.6%,4.1%]	8.7% [7.9%,9.6%]	6	0.71	0.98	0.60
TOTAL SERVICES	66.37*** (0.00)	52.64*** (0.00)	2.7% [2.1%,3.5%]	7.6% [6.8%,6.4%]	6	0.87	1.17	0.01

NOTES: "***", "**' AND '*' DENOTE THE 1%, 5% AND 10% SIGNIFICANCE LEVELS RESPECTIVELY. THE BOOTSTRAP P-VALUES OF THE LR TESTS ARE REPORTED IN () AND THE OPTIMAL LAG LENGTH OF THE TAR REGRESSIONS IS SELECTED BY MINIMIZING THE AIC. THE 90% CONFIDENCE INTERVALS OF THRESHOLD ESTIMATES ARE GIVEN [].THE OLS STANDARD ERRORS ARE SIGNIFICANT FOR THE COEFFICIENT ESTIMATES.

The results in Table 3 present evidence of an aggregation bias in the data, that is, of lower persistence in individual components of commodity products in comparison with the total prices of commodities. Approximately 60% of the disaggregated series of commodities do not contain sums of autoregressive coefficients (SARC) which can substantially indicate nonstationary in their processes (i.e. recreation, household contents, clothing, health, alcohol and transport). The remaining 40% of the commodity series (i.e. communication, housing, food and miscellaneous commodities) appear to reflect random walks in their series and have similar SARC to those of their aggregated counterparts. With regards to asymmetric effects in the data, both of Hansen's (2000) LR test statistics fail to reject the hypothesis of no threshold effects for a majority of the observed disaggregated series of commodities (i.e. communication, housing, food recreation, household contents, clothing, health and alcohol). On the other hand, the hypothesis of a two-regime TAR process is accepted for transport and a three regime TAR for miscellaneous commodities. For the case of transport in commodities, one threshold point is estimated at 3.7% of which above this level, inflation exhibits a slightly higher SARC. Two significant thresholds of 1.6% and 7.5% are also found for miscellaneous commodities. The highest SARC estimates for miscellaneous commodities goods are established between 1.6% and 7.5% inflation rates while the lowest SARC exists at rates above 7.5%.

Table 3: Empirical TAR estimation results for disaggregate measures of commodities

TIME SERIES	LR STATISTICS		INFLATION THRESHOLDS		LAG	PERSISTENCE MEASURES		
	${}_rLR_1(\gamma)$	${}_rLR_2(\gamma)$	${}_r\hat{\gamma}_1$	${}_r\hat{\gamma}_2$	ORDER	$\rho_{\pi1}=\Sigma\alpha_{1i}$	$\rho_{\pi2}=\Sigma\alpha_{2i}$	$\rho_{\pi3}=\Sigma\alpha_{3i}$
COMMUNICATION	8.66 (0.4)	-	-	-	2	1.04	-	-
HOUSING	7.03 (0.9)	-	-	-	3	0.97	-	-
FOOD	13.68 (0.8)	-	-	-	5	0.97	-	-
RECREATION	18.21 (0.2)	-	-	-	5	0.94	-	-
HOUSEHOLD CONTENTS	17.94 (0.2)	-	-	-	4	0.93	-	-
CLOTHING	18.68 (0.3)	-	-	-	3	0.93	-	-
HEALTH	11.81 (0.7)	-	-	-	5	0.92	-	-
ALCOHOL	18.97 (0.2)	-	-	-	5	0.91	-	-
TRANSPORT	31.09** (0.0)	17.41 (0.6)	3.7% [2.5%,5.6%]	-	6	0.73	0.77	-
MISCELLANEOUS	26.09* (0.1)	26.22* (0.1)	1.6% [0.1%,2.7%]	7.5% [5.4%,8.9%]	6	0.90	1.07	0.78

NOTES: "***", "**' AND '*' DENOTE THE 1%, 5% AND 10% SIGNIFICANCE LEVELS RESPECTIVELY. THE BOOTSTRAP P-VALUES OF THE LR TESTS ARE REPORTED IN (). THE OPTIMAL LAG LENGTH OF THE TAR REGRESSIONS IS SELECTED BY MINIMIZING THE AIC. THE 90% CONFIDENCE INTERVALS OF THRESHOLD ESTIMATES ARE GIVEN [].THE OLS STANDARD ERRORS ARE SIGNIFICANT FOR THE COEFFICIENT ESTIMATES.

The results displayed in Table 4, display similar evidence of an aggregation bias with respect to disaggregated measures of services as only housing and transport services have SARC estimates that are closely emulated with those found in the total prices of services. The SARC in individual components of services are found to be generally higher and display more asymmetric effects than for the case of individual commodity items. This result can be expected since production in the service sectors is more labour intensive compared to the production of commodities (Lunneman and Matha, 2005). In particular, Hansen's (2000) threshold test results indicate that 71% of the series (i.e. housing, communication, recreation, health, transport and education) can be fitted into nonlinear TAR processes, while the remaining series of household contents and miscellaneous services are best represented as linear AR processes. The SARC estimates associated with household contents, recreation, health, transport, education and miscellaneous services indicate the possibility of unit roots in these processes. A singular threshold is identified for each of the following services; housing (0.1%), communication (3.2%), recreation (3.3%) and health (4.3%). Lower persistence is associated with inflation in the lower regimes of communication and health, while lower persistence is found in the higher regimes of housing and recreation. Two thresholds estimates of 0.9% and 4.4% are established for transport with the highest measures of persistence existing in the middle regime of the TAR process and the lowest persistence being in the high regimes. The SARC estimates associated with household contents, recreation, health, transport, education and miscellaneous services indicate the possibility of unit roots in these processes.

Table 4: Empirical TAR estimation results for disaggregate measures of services

TIME SERIES	LR STATISTICS $_{r}LR_1(\gamma)$	$_{r}LR_2(\gamma)$	INFLATION THRESHOLDS $_{r}\hat{\gamma}_1$	$_{r}\hat{\gamma}_2$	LAG ORDER	PERSISTENCE MEASURES $\rho_{\pi1}=\Sigma\alpha_{1i}$	$\rho_{\pi2}=\Sigma\alpha_{2i}$	$\rho_{\pi3}=\Sigma\alpha_{3i}$
MISCELLANEOUS	16.30 (0.7)	-	-	-	5	0.96	-	-
HOUSEHOLD CONTENTS	14.89 (0.5)	-	-	-	6	0.98	-	-
HOUSING	34.03** (0.0)	19.88 (0.7)	0.1% [1.1%,0.6%]		6	0.90	0.89	
COMMUNICATION	135.86*** (0.0)	-1.29 (0.7)	3.2% [2.5%,3.9%]	-	6	0.93	1.06	-
RECREATION	107.41*** (0.1)	12.18 (0.7)	3.3% [2.8%,4.2%]	-	6	0.97	0.26	-
HEALTH	48.19*** (0.0)	13.23 (0.0)	4.3% [3.4%,5.2%]]	-	1	0.41	0.95	-
TRANSPORT	29.70* (0.1)	37.38*** (0.1)	0.9% [0.1%,2.2%]	4.4% [3.2%,5.3%]	6	0.69	2.61	0.61
EDUCATION	35.04*** (0.0)	28.51** (0.1)	6.5% [5.6%,7.7%]	7.0% [5.7%,8.2%]	3	0.13	6.36	0.97

NOTES: "***", "**' AND '*' DENOTE THE 1%, 5% AND 10% SIGNIFICANCE LEVELS RESPECTIVELY. THE BOOTSTRAP P-VALUES OF THE LR TESTS ARE REPORTED IN (). THE OPTIMAL LAG LENGTH OF THE TAR REGRESSIONS IS SELECTED BY MINIMIZING THE AIC. THE 90% CONFIDENCE INTERVALS OF THRESHOLD ESTIMATES ARE GIVEN [].THE OLS STANDARD ERRORS ARE SIGNIFICANT FOR THE COEFFICIENT ESTIMATES.

In drawing comparisons between the unit root test results shown in Table 5 with the SARC estimate results presented through Tables 2 to 4, the compliance of these results with concern to the integration properties of disaggregated inflation measures produces mixed results. Contrary to the implications drawn from the SARC estimates for disaggregated items, the unit root tests cannot reject the hypothesis of stationarity in their levels for only three disaggregated series i.e. food (goods), transport (goods) and housing (services). The remainder of the disaggregated series are established to contain unit roots in their process with transport (services) and education (services) being the only indices that are found to be integrated of an order high than I(1). The nonlinear unit root test performed on the aggregated inflation series show that in their levels, the null hypothesis of a unit root process in the middle regime (i.e.=$\rho_{\pi2} = \Sigma\alpha_{2i}$) cannot be rejected in their levels by the employed test statistics for all observed series. Stationary, nonlinear processes are attained for all aggregate series in their respective first differences. It is worth noting that the implied integration properties of the SARC estimates for the aggregated time series and their associated unit root tests seem to be in mutual compliance with each other as they are suggestive of existing unit roots in the middle regimes of the observed processes.

Table 5: Unit root tests for aggregated and disaggregated measures of inflation

LINEAR TIME SERIES	$^{DF}\varphi_u$	TWO-REGIME TIME SERIES	$^{NDF}\varphi_u$	THREE-REGIME TIME SERIES	$^{BBC}W_{SUP}$	$^{BBC}LM_{SUP}$	$^{BBC}LR_{SUP}$
Food [Goods]	-1.91 (-2.25) {-5.04}	Total CPI	3.71 (2.75)	Core Inflation	18.32 (11.34)	15.10 (10.01)	16.61 (10.65)
Communication [Goods]	-2.14 (-8.23)	Transport [Goods]	2.16	Total Goods	25.72 (10.85)	19.80 (9.63)	22.50 (10.22)
Housing [Goods]	-1.16 (-5.61)	Housing [Services]	2.57	Total Services	28.04 (12.75)	21.14 (11.09)	24.27 (10.42)
Recreation [Goods]	-1.49 (-9.44)	Communication [Services]	5.31 (1.85)	Miscellaneous [Goods]	23.09 (15.96)	17.92 (13.25)	23.09 (14.52)
Household Contents [Goods]	-2.53 (-6.75)	Recreation [Services]	6.39 (2.64)	Transport [Services]	47.98 (35.63) {21.28}	33.26 (27.16) {11.94}	43.36 (31.78) {14.31}
Clothing [Goods]	-1.77 (-9.01)	Health [Services]	5.82 (2.94)	Education [Services]	54.83 (37.49) {22.78}	42.61 (30.22) {15.69}	52.38 (32.18) {17.94}
Health [Goods]	-1.94 (-8.15)						
Alcohol [Goods]	-1.91 (-8.85)						
Miscellaneous [Services]	2.47 (-6.41)						
Household Contents [Services]	0.55 (-9.57)						
10%	-2.58		2.83		16.18	15.59	15.77
5%	-2.90		3.60		18.4	17.63	17.89
1%	-3.51		5.38		23.01	21.76	22.23

Notes: The Test Statistics Associated With The First Differences Of The Time-Series Are Reported In () And For Second Differences Are Given In {}. The Lag Length For The ADF Test Statistic Is Selected By Minimizing The AIC.

The evaluation of the performance of the nonlinear TAR processes against their counterpart linear AR processes is presented in an exposition of an out-of-sample analysis for the observed time series. The objective of these out-of-sample fit exercises is to determine whether a nonlinear or linear fitted time series provides a better indication of their predictive ability of the observed time series. In extracting out-of-sample forecast plots, a 'skeleton method' is used to derive the one-step-ahead forecasts and entails setting the errors of the observed linear and threshold processes to zero such that an approximation of an expectational function of random variables is drawn through a function of its expectation (Clements and Smith, 1997). The forecasts are designed on the premise of assuming that the time series evolves through the following mapping function:

$$\hat{\pi}_{t+S} = \hat{f}(\pi_t, \pi_{t-1}, \ldots, \pi_{t-(m-1)});\theta) \quad (11)$$

A prediction function is then designed inorder to extend the observations of the original time-series and is used to estimate the model encapsulated within the 'skeleton' of the fitted model. From equation (11), we define the generic vector of parameters that govern the shape of the mapping function $\hat{f} = f(\hat{\theta})$ using the historical time series $\{\pi_t, \pi_{t+1}, \ldots, \pi_N\}$, to obtain the following one-step-ahead (i.e. s=1) forecasting function:

$$\hat{\pi}_{N+1} = \hat{f}(\pi_{N-S}, \pi_{N-S-1}, \ldots, \pi_{N-S-(m-1):}\ \theta) \quad (12)$$

The forecasts for the two-regime and three-regime TAR model specifications are obtained by substituting the forecasting function given in equation (10) into TAR regressions (3) and (5). To accommodate threshold effects, the indicator functions incorporated in the forecasting functions are then revised to $x_{TAR2}(\gamma *_1)=(x_t' \; I.(\pi_{N+S} \leq \gamma_1) \; , x_t' \; I.(\pi_{N+S} > \gamma_1))$ for the two-regime TAR specification; and $x_{TAR3} \; (\gamma *_1, \; \gamma *_2) = (x_{TAR3}' \; I.(\pi_{N+S} \leq \gamma_1) \; , x_{TAR3}' \; I.(\gamma_1 < \pi_{N+S} \leq \gamma_2) \; , x_{TAR3}' \; I.(\pi_{N+S} > \gamma_2))$ for the three-regime TAR model in order to produce the forecasts for $\hat{\pi}_{N+S}$. In assessing the performance of the forecasts, we estimate the mean absolute percentage error (MAPE):

$$MAPE = [1/n \sum^{n}_{i=1} abs((\hat{\pi}_t - \pi_t)/\pi_t)]*100 \tag{13}$$

Where n is the number of forecast periods (i.e. n=1) and $\hat{\pi}_t$ is the forecast value of π_t. As noted by Dacco and Satchell (1999), if the time series is generated by a regime-switching process, the MAPE of a linear model may be smaller than the MAPE of the true nonlinear model. Therefore, we also apply the root mean square error (RMSE) for evaluating the forecast estimates:

$$RMSE = [(1/n \sum^{n}_{i=1}((\hat{\pi}_t - \pi_t)/\pi_t)^2]*100)^{1/2} \tag{14}$$

Table 6 presents the results of the of the forecast values for TAR and AR models in comparison with the original time series. The lower comparative RMSPE and MAPE values associated with data estimates of the TAR model specifications prove that TAR model estimates provide superior in-sample fits when compared with the linear AR model estimates for all observed inflation series. These results are in coherence with those presented by Clements and Smith (1997) who observe that TAR specifications are more appropriate in fitting univariate macroeconomic data in comparison to linear AR counterparts.

Table 6: Out-of-sample forecast for one-step-ahead predictions: AR vs TAR specifications

	INFLATION MEASURE	AR(p)		TAR2(p)		TAR3(p)	
		RMSE	MAPE	RMSE	MAPE	RMSE	MAPE
AGGREGATE SERIES	Core Inflation	0.25	0.07	0.17	0.06	0.15	0.05
	Total CPI	0.29	0.17	0.19	0.14	N/A	N/A
	Total Goods	0.37	0.14	0.31	0.14	0.29	0.12
	Total Services	0.88	0.25	0.53	0.18	0.37	0.12
DISAGGREGATE SERIES OF COMMODITIES	Transport	1.28	1.02	1.09	0.90	N/A	N/A
	Miscellaneous	0.35	0.19	0.27	0.18	0.20	0.16
DISAGGREGATE SERIES OF SERVICES	Housing	3.46	1.54	2.44	0.93	N/A	N/A
	Communication	0.65	0.44	0.62	0.41	N/A	N/A
	Recreation	3.80	0.35	2.33	0.28	N/A	N/A
	Health	1.69	0.13	1.09	0.11	N/A	N/A
	Transport	1.88	0.29	1.45	0.29	1.22	0.26
	Education	0.18	0.02	0.17	0.03	0.11	0.02

NOTES: 120 HISTORIC TIME-SERIES OBSERVATIONS WERE USED FOR THE OUT-OF-SAMPLE FORECASTS

2.6 CONCLUSIONS

This study sought to investigate asymmetric behaviour in South African inflation by exploiting monthly data of 4 aggregate inflation indices and 18 disaggregate components of commodities and services for the post inflation-target period 2000:02 to 2010:12. In addressing the issue of asymmetry in the South African inflation process, this paper has reached three main conclusions. Firstly, the analysis depicts the presence of an aggregation bias, that is, aggregate inflation is shown to be more persistent than a majority of its underlying components. This result reflects the need for improved measures of aggregate inflation if monetary policy is to accommodate the underlying factors of inflation in its targeting practices. A similar view is held by the Sveriges Riksbank (2011) in believing that decision making and communication from a monetary policy standpoint can be improved by making the operational measures of inflation more precise.

Secondly, in view of inflation persistence having been incorporated in recent theoretical analysis of monetary policy, the findings of this study also have clear-cut theoretical implications. Most existing macroeconomic models assume that inflation evolves as a linear process and thus anticipate a uniform response of inflation to monetary policy shocks. However, our findings suggest that persistence in the inflation process is highly asymmetric and this, in turn, implies that the response of inflation to policy shocks may not be homogeneous. Our work can be extended by examining whether an asymmetric inflation process can be modeled as a stylized fact in sophisticated models of monetary policy analysis. This development would be complementary to the existing asymmetric versions of the Phillips curve and Okun's law specifications already incorporated in monetary policy analysis. Moreover, it would be of interest to evaluate whether these asymmetric models could be used to produce better inflation forecasts as a means of enabling monetary authorities to apply better policy decisions in their attempts to keep inflation under control.

Lastly, in bridging the obtained empirical results to practical policy conduct, South African monetary authority efforts may prove ineffective in controlling inflation within band-widths defined by the middle regimes of the estimated TAR models. Of particular interest pertaining to the obtained results, are the existing unit roots found between the rates of 4.7%-8.5% for core inflation and for rates of above 4.4% for CPI inflation. These band-widths are of importance as both of the aforementioned aggregated measures of inflation play an essential role in guiding the SARB in their policy conduct. Within these identified band-widths, inflation would be best controlled by focusing on alternative market-based policies that aim at simultaneously influencing the demand as well as the supply-side of the macroeconomy. Only at levels below 4.5%-4.7%, when the persistence measured in core inflation and CPI inflation is minimal, would the sole use of direct monetary instruments prove to be most effective in policy conduct.

The policy implications drawn from these results are essentially two-fold. On one hand, the inflation target may have to be re-adjusted to accommodate higher and/or lower target ranges if short-term policy instruments are continued to be relied on for policy conduct. On the other hand, if the narrow inflation target of 3-6 percent where to remain unchanged, the adoption of other market-based policies may prove useful in ensuring that inflation remains within its target. On the frontier of such suggested policies are dual inflation and employment/output targets as well as real exchange rate targeting frameworks.

REFERENCES

Andrews D. and Chen W. (2001), "Approximately median-unbiased estimation of autoregressive models", *Journal of Business and Economic Statistics*, 12, 187-204.

Amisano G. and Tristani O. (2010), "Euro area inflation persistence in an estimated nonlinear DSGE model", *Journal of Economic Dynamics and Control*, 34 (10), 1837-1858.

Arango L. and Gonzalez A. (2001), “Some evidence of smooth transition nonlinearity in Colombian inflation”, *Applied Economics*, 33, 155-162.

Babetskii I., Coricelli F. and Horvath R. (2007), “Measuring and explaining inflation persistence: Disaggregate evidence on the Czech Republic”, Working Paper Series 1, Czech National Bank, Research Department, September.

Batini N. (2002), “Euro area inflation persistence”, Working Paper Series No. 201, European Central Bank, December.

Bec. F, Salem M. and Carrasco M. (2004), “Tests for unit-root versus threshold specification with an application to the purchasing power parity relationship”, *Journal of Business and Economic Statistics*, 22(4), 382-395.

Benati L. (2008), “Investigating inflation persistence across monetary regimes”, The Quarterly Journal of Economics, 19 (1), 3-24.

Bonga-Bonga L. and Kabundi A. (2010), “Monetary policy action and inflation in South Africa: An empirical analysis”, The African Finance Journal, 13(2), 25-37.

Brissimis S. and Magginus N. (2008), “Inflation forecasts and the New Keynesian Phillips Curve”, *International Journal of Central Banking*, 4(2), 1-22.

Calvo G. (1983), “Staggered prices in a utility-maximizing framework”, *Journal of Monetary Economics*, 12 (3), 383-398.

Charemza W., Hristova D. and Burridge P. (2005), “Is inflation stationary?”, *Applied Economics*, 37(8), 901-903.

Charemza W. and Makarova S. (2009), “Nonlinear inflationary persistence and growth: theory and empirical comparative analysis”, *Romanian Journal of Economic Forecasting*, 2/2009.

Chiquiar D., Noriega A.E. and Ramos-Francia M. (2010), ‘A time-series approach to test a change in inflation persistence: The Mexican experience”, *Applied Economics*, 42(24), 3067-3075.

Christiano L., Eichenbaum M. and Evans C. (2005), “Nominal rigidities and the dynamic effects of a shock to monetary policy”, *Journal of Political Economy*, 113, 1-45.

Clark T. (2006), “Disaggregate evidence on the persistence of consumer price inflation”, *Journal of Applied Econometrics*, 21, 563-587.

Clements M. and Smith J. (1997), “The performance of alternative forecasting methods for SETAR models”, *International Journal of Forecasting*, 13, 463-475.

Comert H. and Epstein G. (2011), “Inflation targeting in South Africa: Friend or foe of development?”, *Economic History of Developing Regions*, 26 (1), 94-113.

Cuestas J. and Harrison B. (2010), “Inflation persistence and nonlinearities in Central and Eastern European countries”, *Economic Letters*, 106, 81-83.

Dacco R. and Satchell S. (1999), “Why do regime-switching models forecast so badly?”, *Journal of Forecasting*, 18, 1-16.

Darvas B. and Varga Z. (2006), “Inflation persistence in the Euro-area, US and members of the EU: Evidence from time-varying coefficients”, MMF Research Group Conference 2006, Paper No. 137.

Davies R. (1987), “Hypothesis testing when a nuisance parameter is present only under the alternative”, *Biometrika*, 74, 382-395.

Dickey D. and Fuller W. (1979), “Distribution of the estimators for autoregressive time series with a unit root”, *Journal of the American Statistical Association*, 74, 427-431.

Dossche M. and Evereart G. (2005), “Measuring inflation persistence: A structural time series approach", Working Paper No. 495, European Central Bank, June.

Du Plessis S. and Burger R. (2006), "A New Keynesian Phillips Curve for South Africa", South African Reserve Bank Conference Series: Macroeconomic Policy Challenges for South Africa.

Enders W. and Granger C. (1998), "Unit root tests and asymmetric adjustment with an example using the term structure of interest rates", *Journal of Business and Economic Statistics*, 16(3), 304-311.

Filardo A. and Genberg H. (2009), "Targeting inflation in Asia and the Pacific: Lessons from the recent past", unpublished, Bank for International Settlements.

Fuhrer J. (2007), "The (Un)Importance of forward looking behaviour in price setting", *Journal of Money, Credit and Banking*, 29 (3), 338-350.

Fuhrer J. and Moore G. (1995), "Inflation persistence", The Quarterly Journal of Economics, 110 (1), 127-159.

Gadea M. and Mayoral L. (2006), "The persistence of inflation in OECD countries: A fractionally integrated approach", *International Journal of Central Banking*, 2(1), 51-104.

Gadzinski G. and Orlandi F. (2004), "Inflation persistence in the European Union, the Euro area and the United States", ECB Working Paper Series No. 414, November.

Gali J. and Gertler M. (1999), "Inflation dynamics: A structural econometric analysis", *Journal of Monetary Economics*, 49(2), 195-222.

Gerlach S. and Tillmann P. (2011), "Inflation targeting and inflation persistence in Asia-Pacific", Working Paper Series No. 25/2011, Hong Kong Institute for Monetary Research, August.

Gil-Alana L. (2010), “Inflation in South Africa: A time-series view across sectors using long-range dependence”, *South African Journal of Economics*, 78(4), 325-343.

Gregoriou A. and Kontonikas A. (2009), “Modeling the nonlinear behaviour of inflation deviations from the target”, Economic Modeling, 26 (1), 90-95.

Gupta R. and Uwilingiye J. (2008), “Measuring the welfare cost of inflation in South Africa, South African Journal of Economics, 76(1), 16-25.

Halunga A., Osborn D. and Sensier M. (2009), “Changes in the order of integration of US and UK inflation”, Economic Letters, 102(1), 30-32.

Hansen B. (2000), “Sample splitting and threshold estimation”, *Econometrica*, 68(3), 575-603.

Hondroyiannis G. and Lazareto S. (2004), “Inflation persistence during periods of structural change: An assessment using Greek data”, Working Paper Series No. 370, European Central Bank, June.

Kang K., Kim C. and Marley J. (2009), “Changes in US inflation persistence”, *Studies in Nonlinear Dynamics and Econometrics,* 13(4).

Karanassou M. and Snower D. (2007), “Inflation persistence and the Phillips curve revisited”, IZA Discussion Paper Series No. 2600, Institute for the study of Labour, February.

Kaseeram I. and Contogiannis E. (2011), “The impact of inflation targeting on inflation volatility in South Africa”, *The African Finance Journal*,13, 34-52.

Khadaroo A. (2005), “A threshold in inflation dynamics: Evidence from emerging countries”, Applied Economics, 37(6), 719-723.

Kumar M. and Okimoto T. (2007), “Dynamics of persistence in international inflation rates”, *Journal of Money, Credit and Banking*”, 39(6).

Lunneman P. and Matha T. (2005), “Regulated and services prices and inflation persistence”, Working Paper Series No. 466, European Central Bank, April.

MacKinnon J. (1996), "Numerical distribution functions for unit roots and cointegration tests", *Asia-Pacific Development Journal*, 8(1).

Mankiw N. and Reis R. (2002), “Sticky information versus sticky prices: A proposal to replace the New Keynesian Phillips Curve”, Quarterly Journal of Economics, 117(4), 1295-1328.

Moreno K. and Villar A. (2010), “Monetary policy and the measurement of inflation: Prices, wages and expectations”, Paper No. 49, Bank for International Settlements, January.

Mourelle E., Cuestas J. and Gil-Alana L. (2011), “Is there an asymmetric behavior in African inflation? A non-linear approach”, *South African Journal of Economics*, 79(1), 68-90.

Muhanna E. (2006), “Inflation targeting and its impact on monetary policy: A South African insight”, Banks and Bank systems, 1(4), 65-82.

Nell K. (2000), “Is inflation a precondition for faster growth? The South African case”, (unpublished paper).

O’Reilly G. and Whelan K. (2005), “Has Euro-Area inflation persistence changed over time?”, The review of Economics and Statistics, 87(4), 709-720.

Phiri A. (2010), “At what level is inflation least detrimental towards finance-growth activity in South Africa?”, *Journal of Sustainable Development in Africa*, 12(6).

Rangasamy L. (2009), “Inflation persistence and core inflation: The case of South Africa”, *South African Journal of Economics*, 77(3), 430-444.

Rudd J. and Whelan K. (2005), “New tests of the New Keynesian Phillips Curve”, *Journal of Monetary Economics*, 52 (6), 1167-1181.

Sbordone A. (2002), “Prices and unit labour costs: A new test of price stickiness”, *Journal of Monetary Economics*, 49, 235-256.

Sheedy K. (2010), “Intrinsic inflation persistence”, *Journal of Monetary Economics*, 57(8), 1049-1061.

Sichei M. (2005), “Bank lending channel in South Africa: Bank-level dynamic panel data analysis, University of Pretoria, Working Paper No. 2005-10, November.

South African Reserve Bank (2009), “Monetary policy and the measurement of inflation: Prices, wages and expectations - A South African perspective”, Policy Papers No. 49, Bank for International Settlements, January.

Statistics South Africa (2009), “The South African CPI source and methods manual”, Release v.1, February, http://www.statssa.gov.za/cpi/documents/CPI_Sources_Methods.pdf.

Sveriges Riksbank (2011), “Monetary Policy Report”, February 2011.

Taylor B. (1979), “Staggered wage setting in a macro model”, *American Economic Review*, 68, 108-113.

Taylor B. (1980), “Aggregated dynamics and staggered contracts”, *Journal of Political Economy*, 88 (1), 1-23.

Whelan K (2007), “Staggered price contracts and inflation persistence: Some general results”, *International Economics Review*, 48 (1), 111-145.

CHAPTER 3: CAN ASYMMETRIES ACCOUNT FOR THE EMPIRICAL FAILURE OF THE FISHER EFFECT IN SOUTH AFRICA?

ABSTRACT: The paper investigates whether unobserved asymmetries can account for irregularities in the Fisher effect for the exclusive case of South Africa. This objective is attained by investigating unit roots within a threshold autoregressive (TAR) models and estimating a threshold vector error correction (TVEC) models for the data. The empirical analysis depicts significant long-run Fisher effects whereas such effects are deficient with regards to the short-run. These results improve on those obtained in preceding studies for South Africa, in the sense of being closely emulated with the original hypothesis as presented by Fisher (1907).

3.1 INTRODUCTION

Ever since the South African Reserve Bank's (SARB) adoption of an inflation targeting regime, the comprehension of interest rate movements with respect to inflationary behaviour has played a pivotal role in the conduct of monetary policy. In this regard, the Fisher effect provides a hypothetical rationale for keeping monetary authorities concerned with managing inflation expectations as a means of stabilizing real interest rates. This in turn, would bear a positive influence on saving-investment decisions in the economy. Specifically, a full Fisher effect would have nominal interest rates reflect movements in the expected rate of inflation in a proportionate ratio of one-to-one without exerting any direct influence on real interest rates. Such a described hypothesis has generally been found with varying degrees of success in the empirical literature. With direct reference to South African case studies, a full Fisher effect has, however, not been successfully established. This conclusion is deduced based on a review of the works presented by Mitchell-Innes, Aziakpono and Faure (2007) and Alangideal and Panagiotidis (2010).

Taking into consideration a real world with no market rigidities, homogenous behaviour of the agents and opportunistic behaviour of monetary authorities, it would be irrational to expect a perfect fit for the Fisher effect. Given no evidence of any of these theoretical conditions being empirically fulfilled, a considerable amount of energy has been devoted towards providing systematic reasoning as to why the relationship between the nominal interest rate and inflation expectations may only be approximate in the real world. Inclusive of credible attempts in accounting for such potential stochastic heterogeneities in the Fisher effect is the recently-popularized threshold cointegration approach. Generally, studies which employ such asymmetric frameworks tend to generate more satisfactory results in comparison to studies which adopt linear frameworks. For instance, Million (2004) and Ahmed (2010) are able to account for significant Fisher effects by employing threshold autoregressive models (TAR) and smooth transition autoregressive (STAR) econometric models in their respective studies. The aforementioned studies investigate the Fisher hypothesis on the basis of real interest rate equilibrium adjustments whilst bearing no regards for co-equilibrium adjustments between nominal interest rates and expected inflation rates. In this sense, the use of a threshold vector error correction (TVEC) model, as introduced by Blake and Fombly (1997), holds a certain appeal towards establishing cointegration asymmetries in the Fisher effect. To the best of our knowledge, asymmetries in the cointegration relation between nominal interest rates and the expected rate of inflation within a TVEC framework has not been effectively captured in previous studies (see Bajo-Rubio, Diaz-Roldan and Esteve (2005) and Dutt and Ghosh (2006) for practical examples).

All in all, asymmetries in the cointegration relation between nominal interest rates and the expected rate of inflation in South Africa have not been investigated in any manner with regards to previous case studies. Our study is concerned with filling the existing void in the literature which can be encompassed by examining the asymmetric relationship between nominal interest rates and inflation within the context of TAR and TVEC econometric models for the exclusive case of South Africa. The remainder of the paper is structured as follows. The following section lays forth the empirical foundations to the study. The third section of the paper formulates the data and presents the empirical analysis. Section four concludes the overall study.

3.2 EMPIRICAL FOUNDATIONS OF THE STUDY

Due the strong presumption of the presence of stochastic trends in both the nominal interest rates and the inflation rate, it has been viewed as necessary to test for the Fisher effect within a cointegration framework. The standard procedure in empirically testing for the Fisher effect is by means of a bivariate cointegrating regression of nominal interest rate (i_t) on a constant plus the expected rate of inflation ($\pi^e{}_t$):

$$i_t = \alpha + \beta\pi^e{}_t \quad (1)$$

Nominal interest rates (i_t) and expected inflation ($\pi^e{}_t$) are regarded as reflecting a full Fisher effect if the above regression satisfies the condition of $\beta = 1$. An alternative method of testing for the validity of the Fisher effect, involves testing whether the real interest rate i.e. $r_t = i_t - \pi^e{}_t$, evolves as a stationary process. To test for stationarity, the real interest rate can be placed subject to the following generalized autoregression:

$$r_t = \phi r_{t-1} + \varepsilon_t \qquad (2)$$

Where ϕ is the least squares estimate and ε_t is an iid error process meeting the requirement of $\varepsilon_t \sim (0,\sigma^2)$. For the Fisher effect to be valid, the hypothesis of $|\phi|<1$ should not be capable of being rejected such that r_t can be modelled as a mean reverting autoregressive process with a finite variance. In scope of a cointegration system of variables in context of Engle and Granger's (1987) definition, if the real rate of interest (r_t) is a stationary I(0) process, then the nominal interest rate (i_t) and the expected inflation rate ($\pi^e{}_t$) can be expected to be cointegrated under the restriction of both variables retaining stationarity in their first differences. According to Engle and Granger (1987) if two economic time series are integrated of similar order I(1), then there exists an error correction mechanism governing the equilibrium dynamics of the system which can be directly derived from the first differences of the linear combination of the observed I(1) variables. For the case of the Fisher equation, the error correction mechanism ($\zeta_{\tau-1}$) can be depicted in the following bivariate cointegration system of nominal interest rates and expected inflation:

$$\Delta i_t = \alpha_{10} + \alpha_{11}\,\zeta_{\tau\text{-}1}(\beta) + \alpha_{12}\,\Delta i_{t-1} + \alpha_{13}\,\Delta\pi_{t-1}^{e} + \varepsilon_{t1} \tag{3.1}$$

$$\Delta\pi_t^{e} = \alpha_{20} + \alpha_{21}\zeta_{t-1}(\beta) + \alpha_{22}\,\Delta i_{t-1} + \alpha_{23}\,\Delta\pi_{t-1}^{e} + \varepsilon_{t2} \tag{3.2}$$

The error correction coefficients α_{11} and α_{21} respectively capture the dynamics of how i_t and π_t^e respond to deviations from the equilibrium relationship. Only if the condition of $\alpha_{11}<0$ and/or $\alpha_{21}<0$ are satisfied, can i_t and π_t^e be deemed as converging towards a unique equilibrium described by a singular cointegration vector relation [1, β].

As highlighted in the introductory section, this study is concerned with shifting focus of methodology by estimating asymmetric versions of the above-described Fisher cointegration systems. Firstly, the examination of asymmetric effects in the unit root process of real interest rates is attained through the use of Kapetanois and Shin (2006) nonlinear unit root tests. These tests are based on Hansen's (2000) three-regime TAR model:

$$r_t = \alpha_{1i} r_{t-i}\,\mathrm{I.}(r_{t-1} \leq \gamma_1) + \alpha_{2i} r_{t-i}\mathrm{I.}(\gamma_1 \leq r_{t-i} \leq \gamma_2) + \alpha_{3i} r_{t-i}\,\mathrm{I.}(r_{t-i} > \gamma_2) + \varepsilon_t \tag{4}$$

From which asymmetric unit root testing procedures are derived within the following auxiliary three-regime TAR regression:

$$\Delta r_t = \psi_1 r_{t-1}\,\mathrm{I.}(r_{t-1} \leq \gamma_1) + \psi_0 r_{t-1}\,\mathrm{I.}(\gamma_1 \leq r_{t-1} \leq \gamma_2) + \psi_2 r_{t-1}\,\mathrm{I.}(r_{t-1} > \gamma_2) + \varepsilon_t \tag{5}$$

Under the null hypothesis i.e. H_0: $\psi_0=1$, $\psi_1=\psi_2=0$, regression (5) reduces to a unit root process in the corridor regime:

$$\Delta r_t = r_t - r_{t-1} = \varepsilon_t \tag{6}$$

Whereas under the alternative hypothesis i.e. H_1: $\psi_0 = 0$, $|\psi_1|<0$, $|\psi_2|<0$, the regression reduces to a globally stationary three-regime TAR process:

$$\Delta r_t = \psi_1 r_{t-1} \, I.(r_{t-1} \leq \gamma_1) + \psi_2 r_{t-1} \, I.(r_{t-1} > \gamma_2) + \varepsilon_t \tag{7}$$

An appropriate test of the joint null hypothesis of a unit root against an alternative of a threshold stationary process is achieved through the standard Wald statistic. However, due to inference complexities associated with the unidentified threshold parameters under the null hypothesis, Kapetanois and Shin (2006) opt to derive asymptotically valid distributions from Supremum, average and exponential average-based tests of the Wald statistics. These statistics are respectively defined as:

$$^{KS}W_{SUP} = SUP_{(i \in \Gamma)} W_{(\gamma 1, \gamma 2)}, \tag{8.1}$$

$$^{KS}W_{AVE} = \frac{1}{\#\Gamma} \sum_{i=1}^{\#} W_{(\gamma 1, \gamma 2)}, \tag{8.2}$$

$$^{KS}W_{EXP} = \frac{1}{\#\Gamma} \sum_{i=1}^{\#} \frac{W(\gamma 1, \gamma 2)}{2} \tag{8.3}$$

The optimal values of the threshold parameters γ_1 and γ_2 are obtained by maximizing the above-defined Wald statistics over the selection grid, Γ, and summary statistics are then constructed for these estimates. To ensure that the thresholds estimates are optimally selected whilst simultaneously maintaining a finite width in the corridor regime under both the null and alternative hypotheses, the threshold parameters contained within the grid Γare bound by the conditions:

$$\gamma_{1,} = \tilde{\gamma} + 3/\sqrt{T}, \gamma_2 = \tilde{\gamma} - 3/\sqrt{T} \tag{9}$$

Where $\tilde{\gamma}$ denotes the sample quantile corresponding to zero and the sample size is given by T.

The second examination in respect of investigating asymmetric Fisher correlations, involves an extension of the linear cointegration models (3.1) and (3.2) to include asymmetries in the adjustment process of the error correction model. As described in Blake and Fombly (1997), this can be depicted in the following threshold vector error correction (TVEC) regression:

$$\Delta Y_t = \Theta_1 \, \Delta X_{t-1} \, I.\{\zeta_{\tau-1}(\beta) \leq \zeta^*_{\tau-1}\} + \Theta_2 \, \Delta X_{t-1} \, I.\{\zeta_{\tau-1}(\beta) > \zeta^*_{\tau-1}\} + \varepsilon_t \tag{10}$$

In applying Fisher's equation to the TVEC regression (10), the following parametric representations are specified:

$$\Delta Y_{\tau} = \begin{bmatrix} \Delta i \\ \Delta \pi_t^e \end{bmatrix},$$

$$\Delta X_{\tau-1} = \begin{bmatrix} 1 \\ \zeta_{t-1}(\beta) \\ \Delta i_{t-1} \\ \Delta \pi_{t-1} \end{bmatrix},$$

$$\Theta_1 = \begin{bmatrix} \alpha_{10} & 0 & 0 & 0 \\ 0 & \alpha_{11} & 0 & 0 \\ 0 & 0 & \alpha_{12} & 0 \\ 0 & 0 & 0 & \alpha_{13} \end{bmatrix},$$

$$\Theta_2 = \begin{bmatrix} \alpha_{20} & 0 & 0 & 0 \\ 0 & \alpha_{21} & 0 & 0 \\ 0 & 0 & \alpha_{22} & 0 \\ 0 & 0 & 0 & \alpha_{23} \end{bmatrix}$$

The estimation of the TVEC equation, as suggested by Hansen and Seo (2002), is prompted by considering the following Gaussian likelihood function:

$$L_n (\Theta_1, \Theta_2, E, \beta, \zeta^*_{\tau\text{-}1}) = \text{-}n/2 \log - ½ \sum u_t (\Theta_1, \Theta_1, E, \beta, \zeta^*_{\tau\text{-}1})' E^{-1} u_t(\Theta_1, \Theta_2, E, \beta, \zeta^*_{\tau\text{-}1}) \quad (11)$$

The maximization of above likelihood function is feasible via quasi-maximum likelihood estimates (MLE). This procedure is instigated by holding (Θ_1, Θ_1, E) fixed and concentrating out (β, $\zeta^*_{\tau\text{-}1}$) from which the following concentrated likelihood function is yielded:

$$L_n (\beta, \zeta^*_{\tau\text{-}1}) = \text{-}n/2 \log \left|E(\beta, \zeta^*_{\tau\text{-}1})\right| - np/2 \quad (12)$$

The above function serves as a foundation in obtaining the true values of β and $\zeta^*_{\tau\text{-}1}$, from which the remainder of the parameters in the TVEC specification are estimated via backward substitution. Denoting 'n' as the trimming parameter of the data which is set at 0.05 (5%), the MLE of the cointegration vector (β) and the threshold parameter ($\zeta^*_{\tau\text{-}1}$) are obtained through a two-dimensional grid search as the values that minimize ($\log|E(\beta, \zeta^*_{t\text{-}1})|$) subject to the constraint:

$$n \le n^{-1} \sum I.(x_t'\beta \le \zeta^*_{\tau-1}) \le 1\text{-}n \qquad (13)$$

Testing for significant threshold cointegration effects is conducted via a two-staged testing procedure. In the first stage, Hansen and Seo's (2002) supremum LM test (${}^{HS}LM_{sup}$) is used in testing the null hypothesis of linear cointegration (i.e. $\Theta_1 = \Theta_2 \neq 0$), against the alternative hypothesis of threshold cointegration (i.e. $\Theta_1 \neq \Theta_2 \neq 0$). Given that the test of Seo and Hansen (2002) exempts the possibility of testing for no cointegration effects within the TVEC system, the second stage of the testing procedure relies on Seo's (2006) supremum Wald test (${}^{Seo}W_{sup}$) to test the null hypothesis of no cointegration (i.e. $\Theta_1 = \Theta_2 = 0$) against the alternative of threshold cointegration (i.e. $\Theta_1 \neq \Theta_2 \neq 0$). The critical values and p-values for the test statistics are computed through the use of a residual bootstrap method as suggested by each of the aforementioned authors. In both of the described threshold tests, the alternative hypothesis of threshold cointegration can only be accepted if the test statistics exceed their critical values.

3.3 DATA AND EMPIRICAL ANALYSIS

The data used in the study is available from the SARB website (http://www.resbank.co.za/Research/Statistics/Pages/OnlineDownloadFacility.aspx). The empirical analysis uses seasonally adjusted, monthly time-series data obtained for periods between January 1980 and April 2011. The dataset consists of the three-month banker's acceptance (i_{ba}) and the 10-year yield on government bonds ($i_{govbond}$) which are used as proxies for short term and long-term nominal interes t rates, respectively. As is the norm in empirical studies, the actual inflation in total consumer prices is used as a proxy for inflation expectations (see Bajo-Rubio, Diaz-Roldan and Esteve (2005) and Dutt and Ghosh (2006), Alangideal and Panagiotidis (2010)). By further adopting Fisher's (1930) real interest rate definition of $r_t = i_t - \pi^e{}_t$, two additional time series are formulated to represent the short-run real interest rate ($r_{ba} = i_{ba} - \pi^e{}_t$) and the long-run real interest rate ($r_{govbond}= i_{govbond} - \pi^e{}_t$).

As mentioned in the previous section, Fisher's hypothesis is in part crucially dependent on the integration and stationary properties of the real rate of interest. In this regard, Kapetanois and Shin's (2006) nonlinear unit root test are performed on the formulated short-run and long-run real interest rate data with the results reported in Table 7.

Table 7: Kapetanois and Shin (2006) nonlinear unit root tests on South Africa's real interest rate

	Critical value	$r_{govbond} = i_{govbond} - \pi_t^e$	$r_{ba} = i_{ba} - \pi_t^e$
λ_1^*		0.10	1.15
λ_2^*		4.92	2.88
$^{KS}W_{SUP}$	6.01	0.52	0.531
		(6.77)*	(6.59)*
$^{KS}W_{AVE}$	6.01	0.49	0.531
		(6.76)*	(6.48)*
$^{KS}W_{EXP}$	7.49	1.28	0.531
		(29.49)*	(27.87)*

Asterisk '*' denotes 10 percent significance levels. Test statistics for first differences reported in ().

In their levels, both long-run and short-run real interest rates contain a unit root in the corridor regime whilst retaining stationary threshold processes in their first differences at 10% significance levels. What is most commendable about Kapetanois and Shin's (2006) unit root testing procedure in application to examining Fisher effects is its ability to define a specific range at which real interest rates contain a unit root. This range is defined by the threshold estimate points which are 0.10 and 4.92 for the long-run real interest rate, whereas for the short-run data the obtained estimates are 1.15 and 2.88. Interpretively, these estimates determine the range of short-run and long-run real interest rates at which potential Fisher effects become invalid. However, this analysis is incomplete without establishing cointegration effects between the alternative definition of a Fisher correlation as described by co-movements between the nominal rate of interest and inflation expectations.

Table 8 below presents the threshold cointegration tests on designated pairs of variables representing the short-run and long-run Fisher effects. The short-run Fisher effect is represented by pairing the variables (i_{ba}, π^e) and the long-run Fisher relation is defined by the pairing of ($i_{govbond}$, π^e). Both Hansen and Seo (2002) and Seo (2006) threshold tests fail to reject the alternative hypothesis of threshold cointegration for short-run and long-run Fisher effects. With the exception of Seo's test on short-run effects being significant up to a critical level of 5%, all other results are verified at all significance levels.

Table 8: Threshold cointegration tests for fisher effect

	Test type	Test statistic value	Critical values 10%	5%	1%
Short-run fisher hypothesis (i_{ba}, π_t^e)	$^{Seo}W_{sup}$	12.07 (0.01)**	11.58	11.96	12.73
	$^{HS}LM_{sup}$	19.91 (0.00)***	11.77	12.12	13.69
Long-run fisher hypothesis $(i_{govbond}, \pi_t^e)$	$^{Seo}W_{sup}$	14.91 (0.00)***	11.72	12.12	13.97
	$^{HS}LM_{sup}$	13.93 (0.01)***	11.41	12.93	13.33

'***', '**' and '*' denote the 1%, 5% and 10% significance levels respectively. Bootstrap p-values computed with a residual bootstrap of 1000 replications are reported in ().

In view of significant cointegration effects being established, the estimation of the TVEC models for both short-run and long-run Fisher effects is implemented. In examining the significance of Fisher effects within the TVEC model, two conditions are taken into consideration. Firstly, the threshold error correction term (ζ^*_{t-1}) must be of a negative value to ensure the possibility of convergence in both regimes. If ζ^*_{t-1} is found to be a positive integer, then equilibrium convergence is only possible in the lower regime of the TVEC. Secondly, there must be at least one significantly negative error correction term (ζ_{t-1}) associated with the nominal interest rate or/and the inflation expectations equations under regimes encompassed by negative values of the threshold parameter, ζ^*_{t-1}. Given negative ζ^*_{t-1} estimates of -1.51 for the short-run and -0.34 for long-run Fisher effects as is respectively shown in Tables 9 and 10, implies the possibility of convergence towards equilibrium in both the upper and lower regimes of the TVEC models. This result bears full satisfaction to the first condition. However, significant negative error correction terms i.e. $\zeta_{t-1,}$ are only established in regimes associated with the long-run nominal interest rate equations and not with the inflation expectations equations. Therefore the paper concludes on significant Fisher effects existing solely in the long-run with inflation expectations being weakly exogenous within the cointegration system i.e. inflation expectations granger causes nominal interest rates. This result emulates the original hypothesis as presented by Fisher (1907) in which changes in inflation expectations are expected to granger-cause changes in the long-term nominal rate of interest. In view of a cointegration vector of [1, -1.19] established for the long-run Fisher effect, Crowder and Wohar (1999) have suggested that cointegration relations of between the ratios of [1, -1.1] and [1, -1.7] may be delegated towards tax effects for Fisher elasticities that are found to be of a ratio greater than unity. Since our study does not account for such tax effects in nominal interest rates, this is rendered as a plausible explanation for our obtained results. In comparison to the Fisher ratios of [1, -0.23] and [1, -2.27] depicted in the respective works of Mitchell-Innes, Aziakpono and Faure (2007) and Alangideal and Panagiotidis (2010), the overall results presented in our study prove to be a positive development in the academic literature.

Table 9: TVEC estimates for short-run fisher effect

	Lower regime ($\xi_{t-1} \leq \xi^*_{t-1}$)		Upper regime ($\xi_{t-1} > \xi^*_{t-1}$)	
	nominal interest rate (Δi_t)	inflation expectations ($\Delta \pi^e_t$)	nominal interest rate (Δi_t)	inflation expectations ($\Delta \pi^e_t$)
Constant (α_i)	4.83 (0.00)***	0.15 (0.13)	0.21 (0.63)	0.01 (0.87)
ECT (ξ_{t-1})	0.61 (0.00)***	0.04 (0.00)***	-0.09 (0.38)	0.01 (0.36)
nominal interest rate (Δi_{t-1})	0.03 (0.57)	-0.01 (0.84)	-0.91 (0.00)***	-0.01 (0.44)
inflation expectations ($\Delta \pi^e_{t-1}$)	-1.29 (0.24)	-0.34 (0.00)***	0.49 (0.50)	0.87 (0.00)***
Cointegration vector (β)	[1, -1.20]			
Threshold ECT (ξ^*_{t-1})	-1.51			

'***', '**' and '*' denote the 1%, 5% and 10% significance levels respectively. P-values are reported in ().

Table 10: TVEC estimates for long-run fisher effect

	Lower regime ($\xi_{t-1} \leq \xi^*_{t-1}$)		Upper regime ($\xi_{t-1} > \xi^*_{t-1}$)	
	nominal interest rate (Δi_t)	inflation expectations ($\Delta \pi^e_t$)	nominal interest rate (Δi_t)	inflation expectations ($\Delta \pi^e_t$)
Constant (α_i)	-0.12 (0.07)*	-0.13 (0.07)*	0.09 (0.07)*	0.01 (0.93)
ECT (ξ_{t-1})	-0.04 (0.05)*	-0.01 (0.58)	-0.02 (0.01)*	0.01 (0.44)
nominal interest rate (Δi_{t-1})	0.32 (0.00)***	-0.11 (0.24)	0.28 (0.00)***	0.01 (0.96)
inflation expectations ($\Delta \pi^e_{t-1}$)	0.09 (0.19)	0.03 (0.71)	0.15 (0.02)*	0.90 (0.00)***
Cointegration vector (β)	[1, -1.19]			
Threshold ECT (ξ^*_{t-1})	-0.34			

'***', '**' and '*' denote the 1%, 5% and 10% significance levels respectively. P-values are reported in ().

3.4 CONCLUSION

Despite the increasing surge of interest found in empirical literature opting to rectify Fisher's hypothesis through threshold cointegration techniques, such econometric frameworks have not been employed within the context of the South African economy. This paper contributes to the literature by demonstrating how significant long-run Fisher effects for South African data are more effectively captured by introducing asymmetries into the empirical framework. Moreover, a richer interpretation of the results obtained from the empirical analysis can be deduced; thus widening the scope in which the obtained results bear towards monetary policy conduct. In this regard, we discover that the equilibrium relationship between nominal interest rates and inflation is not entirely stable across all levels of the real interest rate. Specifically, we note that in the short-run, the Fisher effect is invalid when the differential between the nominal interest rate and the inflation rate is in the range of 1.15 to 2.88 percent; whereas for the long-run this differential is in the range of 0.1 to 4.92 percent. The invalidity of the Fisher effect within these boundaries implies that external factors play a direct role in the determination of the domestic interest rate, an observation which is reasonable for an open economy such as South Africa, where capital flows are not prohibited. Conversely, when the Fisher effect is valid outside these boundaries, monetary policy will have no effect on the real interest rate, as any change in the expected inflation rate will be offset by a change in the nominal interest rate, thus leaving the real interest rate unchanged. Therefore, when the Fisher effect is valid outside these aforementioned boundaries, then borrowers will be encouraged to make productive investments that will promote economic growth and encourage the advancement of more sophisticated banking systems. Also considering that the supportive evidence that the long-run Fisher effect is valid when the difference between the nominal interest rates and inflation is low, it is expected that monetary policy influence over the inflation rate will work better if the Reserve Bank preserves a low differential between nominal interest rates and inflation. Attempts to widen the gap between nominal interest rates and the inflation rate may prove futile unless this gap is increased to a relative high rate of at least 4.92 percent which would have adverse effects over the macroeconomy such as increased cost of borrowing, decreases in consumption, investment and export trade.

REFERENCES

Ahmed S. (2010), “Fisher effect in nonlinear STAR framework: some evidence from Asia”, Economics Bulletin, 30, 2558-2566.

Alangideal, P. and T. Panagiotidis (2010), “Can common stocks provide a hedge against inflation? Evidence from African countries”, The Rimini Centre for Economic Analysis Working Paper Number 10-06.

Bajo-Rubio, O., Diaz-Roldan, C. and V. Esteve (2005), “Is the Fisher effect nonlinear? Some evidence for Spain, 1963-2002”, Applied Financial Economics, 15, 849-854.

Blake, N. and T. Fomby (1997), “Threshold cointegration”, International Economic Review, 38, 627-645.

Crowder, W. And M. Wohar (1999), “Are tax effects important in the long-run Fisher relationship? Evidence from the municipal bond market”, The Journal of Finance, 54, 307-317.

Dutt, S. and D. Ghosh (2007), “A threshold cointegration test of the Fisher hypothesis: Case study of 5 European nations”, South-Western Economic Review, 34, 41-50.

Engle, R. and C. Granger (1987), “Cointegration and error correction representation, estimation and testing”, Econometrica, 55, 251-276.

Fisher, I. (1907), “The rate of interest”, New York: Macmillan.

Hansen, B. (2000), “Sample splitting and threshold estimation”, Econometrica, 68, 575-603.

Hansen, B. And B. Seo (2002), “Testing for threshold cointegration in vector error correction models”, Journal of Econometrics, 110, 293-318.

Kapetanois, G. and Y. Shin (2006), “Unit root tests in three-regime SETAR models”, Econometrics Journal, 9, 252-278.

Million, N. (2004), “Central Banks intervention and the Fisher: A threshold cointegration investigation”, Economic Modelling, 21, 1051-1064.

Mitchell-Innes, H., Aziakpono, M. and A. Faure (2007), "Inflation targeting and the Fisher effect in South Africa: An empirical investigation", South African Journal of Economics, 75, 693-707.

Seo, M. (2006), “Bootstrap testing for no cointegration in a vector error correction model”, Journal of Econometrics, 134, 129-150.

CHAPTER 4: AN INQUISITION INTO BIVARIATE THREHSOLD EFFECTS IN THE INFLATION-GROWTH CORRELATION: EVALUATING SOUTH AFRICA'S MACROECONOMIC OBJECTIVES

Abstract: Is the South African Reserve Bank's (SARB) inflation target of 3-6% compatible with the 4%-7% economic growth objective as set out across different macroeconomic initiatives such as the New Growth Path (NGP) and the National Development Plan (NDP)? Estimations of inflation-growth bivariate threshold vector autoregressive with corresponding bivariate threshold vector error correction (BTVAR-BTVEC) econometric models for sub-periods coupled with the South African inflation-growth experiences between 1960 and 2010, suggest an optimal inflation-growth combinations for South African data presenting a two-fold proposition. Firstly, for the performance of economic growth to improve so it coincides with the 4-7% target objective as defined by the NGP and NDP initiatives may require the sustainment of an inflation rate of below 3.08%. Secondly, given the current economic environment with inflation averages of above 3.08% and economic growth rates of below 5.58%, lower inflation rates are to be best pursued through the attainment of higher economic growth rates. Consequentially, the overall implication of the study offers support in favour of a lower, 'close-to-zero' inflation target as a means of ensuring optimal macroeconomic performance within the economy.

4.1 INTRODUCTION

In entering a new decade, two prominent policy frameworks instituted within the South African economy are monetary policy's 'inflation-targeting' regime and fiscal policy's New

Growth Path (NGP) and the National Development Plan (NDP) initiatives. Implemented in 2000 and still in use to date, the inflation-target rule specifies that the South African Reserve Bank (SARB) should regulate inflation at levels of between 3-6%; whereas the NGP and NDP programmes are directed towards a 4-7% economic growth rate intended to be achieved per annum. This paper is principally motivated by the absence of empirical evidence assessing the compatibility of the aforementioned policy objectives.

Over the past couple of decades, Central banks worldwide have embarked on 'price stability' economic policies with emphasis placed on the attainment of low and stable inflation rates. Despite efforts shown by monetary authorities in striving for low inflation environments, these policies strategies have not being unanimously accepted and applicable as structural macroeconomists have speculated on inflation, up to certain levels, helping to 'grease the wheels' of the economy by encouraging investment, productivity and growth in wages (Khan, Bukhari and Ahmed, 2007). The empirical works of Fischer (1993) and Bruno and Easterly (1995) were amoung the first to substantiate the structuralist argument by providing evidence on the adverse effects of inflation on economic growth differing across specified inflation bandwidths. However, the policy implications associated with the obtained results of these studies proved to be vague as these authors were unable to determine an exact optimal inflation point at which economic welfare can be maximized or similarly, the level of inflation where economic welfare losses are minimized.

This shortcoming was initially overcome by Sarel (1996) and later improved by IMF macroeconomists Khan and Senhadji (2001) who, by utilizing sample-splitting econometric techniques, estimated an exact inflation *threshold* point at which economic welfare can be deemed as being maximized. The studies of Sarel (1996) and Khan and Senhadji (2001) set a 'trend' of published articles on the subject matter and it has become a norm for panel-data studies in the literature to include South Africa in the analysis of such inflation nonlinearities. The panel-data studies include South African data amoungst a host of high inflation outlier economies and generalize on the established optimal range or level of inflation as being applicable to all observed economies (see Drukker et. al. (2005); Mi (2006); and Kremer et. al. (2009)). The estimated thresholds or optimal levels of inflation serve as a benchmark for which monetary policy should strive to preserve inflation at. In keeping the prevailing inflation rate on par with the obtained threshold level or range of inflation, as suggested in these studies, it is explicitly assumed that maximum economic growth will be realized for (amongst a host of other nations) the South African economy.

The paper builds into the literature by addressing certain limitations allied with the existing empirical evidence, and applies remedies with reference to the exclusive experience of South African data. Firstly, the empirical analysis is conducted over differing sub-periods instituted within the data. Nell (2000) and Rangasamy (2009) have stressed the importance of incorporating structural breaks into the econometric analysis of South African data as a means of circumventing the Lucas (1976) critique. While Nell (2000) suggests break points at 1970, 1985 and 1994, the breakpoint in the study of Rangasamy (2009) is established in the year 2000. Secondly, the paper utilizes bivariate thresholds vector error correction (BTVEC) models as a means of eradicating any spurious correlations associated for the data associated with the coupled sub-periods under analysis. Finally, for the sub-periods in which significant cointegration effects exist, inflation and corresponding economic growth threshold rates are estimated. This enables the paper to assess the specific optimal economic growth rate expected as a result of the attainment of the established optimal inflation level for significantly cointegrated periods. Estimations, in this sense, are conducted within the context of bivariate threshold vector autoregressive (BTVAR) models. The BTVAR-BTVEC empirical models are specified in section 2, whilst section 3 presents an outline of the utilized data and the estimation results are presented in section 4 of the paper.

The conclusions made from the empirical study are drawn in section 5 of the paper and generally imply significant nonlinear cointegration relations between inflation and growth for data associated with the periods of 1960-1970 and 2000-2013. This of particular relevance as none of the panel data studies, which include South Africa in the data analysis, conducts their empirical analysis within the timeframe of any of these identified periods. Furthermore, the significant period of 2000-2013 represents the era in which both the inflation-targeting regime and the NGP and NDP initiatives were adopted as policy objectives. Section 5 hence draws policy conclusions by integrating the empirical findings of the study with reference to the above-mentioned policy programmes. The central contribution of the paper which is reflected in the derived conclusions, bridges two opposing contentions on policy conduct found in recent South African economic literature. On one hand, the presented evidence supports Gupta and Uwilingiye (2009) view of a lower, 'close-to-zero' inflation target as a means of minimizing welfare costs in South Africa. On the other hand, the paper simultaneously supports arguments depicted in the study of Bonga-Bonga and Kabundi (2010), which criticizes the South African

Reserve Bank's (SARB) policy intention of achieving low inflation rates through the sole manipulation of interest rates.

4.2 EMPIRICAL FRAMEWORK

In line with the study of Ahmed and Mortaza (2005) and Chowdury and Ham (2009), the paper restricts the empirical analysis of threshold effects in the inflation-growth correlation to the bivariate case. Ahmed and Mortaza (2005) investigate threshold effects in the bivariate inflation-growth correlation by estimating Hansen's (1997) threshold model whereas Chowdury and Ham (2009) opt for the use of a bivariate threshold autoregressive (BTVAR) model. Derivation of the BTVAR model is instigated through an augmentation of Hansen (1997) TAR model, which according to Chowdury and Ham (2009), is achieved by replacing the dependent and independent variables in the TAR model with vectors of bivariate endogenous variables. This paper builds on Chowdury and Ham (2009) by specifying a vector of bivariate endogenous (inflation and economic growth) threshold variables, which is directly incorporated into the BTVAR model specification. In limiting the study to a bivariate case study the paper is able to follow in pursuit Lo and Zivot (2001) in deriving an associated bivariate threshold vector error correction (BTVEC) mechanism directly from the BTVAR model. Developments by Lo and Zivot (2001) provide a unique approach into accommodating equilibrium adjustment mechanisms as a means of eliminating spurious relations which could possibly arise within the threshold vector autoregressive (TVAR) models. Our baseline BTVAR model is specified as:

$$Y_t = \psi_1(L)X_{t-p}\ I.\{\lambda \leq \lambda^*\} + \psi_2(L)X_{t-p}\ I.\{\lambda > \lambda^*\} + \varepsilon_t \qquad (1)$$

Where $Y_t = [\Delta gdp_t, \pi_t]$; $X_{t-p} = [1, \pi_{t-1},..., \pi_{t-p}, \Delta gdp_{t-1},..., \Delta gdp_{t-p}]$ with (L) being the lag operator and ψ_i being the associated coefficients of X_{t-p}. The paper specifies the vector of endogenous threshold variables as $\lambda = [\pi, \Delta gdp]$. Therefore equation (1) can be decomposed into two separate BTVAR estimation equations:

$$Y_t = \psi_1 X_{t-p}\ I.\{\pi \leq \pi^*\} + \psi_2 X_{t-p}\ I.\{\pi > \pi^*\} + \varepsilon_t \tag{2}$$

$$Y_t = \psi_1 X_{t-p}\ I.\{\Delta gdp \leq \Delta gdp^*\} + \psi_2 X_{t-p}\ I.\{\Delta gdp > \Delta gdp^*\} + \varepsilon_t \tag{3}$$

In testing for significant threshold effects, Hansen (1997) suggests the use of a likelihood ratio (LR) statistic which tests the null hypothesis of no threshold effects ($\psi_1=\psi_2$) against the alternative of threshold effects ($\psi_1\neq\psi_2$). The LR statistic is given by:

$$^{HANSEN}LR_\lambda = n\ [(S_\lambda - S_\lambda\hat{})/ S_\lambda\hat{}] \tag{4}$$

The null hypothesis $H_0 : (\psi_1=\psi_2)$ is accepted if $^{HANSEN}LR_\lambda \leq c_\zeta\ (1-\ \alpha)$ and $H_1 : (\psi_1\neq\psi_2)$ is rejected if $^{HANSEN}LR_\lambda > c_\zeta(1-\alpha)$, where $c_\zeta(1-\ \alpha)$ are the computed bootstrapped critical values. In the case of the null hypothesis of no threshold effects being rejected, estimation of equations (2) and (3) can be conducted using Hansen's (1996) conditional least squares (CLS) method. This estimation technique entails a grid-search over a predetermined range of threshold variable estimates (π_{min},…, π_{max} and gdp_{min},…, gdp_{max}) with the optimal estimates (π^*,gdp^*) chosen by minimizing the following objective functions;

$$\pi^* = argmin\ \{SSR_{\pi^*},\ \pi = \pi_{min},\ldots,\ \pi_{max}\} \qquad (5)$$

$$gdp^* = argmin\ \{SSR_{GDP^*},\ gdp = \Delta gdp_{min},\ldots,\ \Delta gdp_{max}\} \qquad (6)$$

The study employs the grid search over π_{min} = 1%, π_{max} = 16% and Δgdp$_{min}$ = 0%, Δgdp$_{max}$ = 7%. Once the values of π^* and gdp* which maximize the explanatory power of regressions of (2) and (3) are estimated, Hansen (1997) proposes the use of backward substitution to estimate the corresponding slope coefficients and residual errors of equations (2) and (3).

Lo and Zivot (2001) demonstrate that if significant threshold effects are established within a BTVAR model, an associated BTVEC model can be derived as an appropriate method of modelling cointegration effects within the nonlinear framework. By taking the first differences of the BTVAR encompassing equation (1) and rearranging the terms, the following BTVEC model is specified:

$$\Delta Y = \Theta_1\ \Delta X_{t-1}\ I.\{\zeta_{\tau-1} \leq \zeta^*_{\tau-1}\} + \Theta_2\ \Delta X_{t-1}\ I.\{\zeta_{\tau-1} > \zeta^*_{\tau-1}\} + \varepsilon_t \qquad (7)$$

Where ΔY_t = [$\Delta\Delta$gdp$_t$, $\Delta\pi_t$], $\Delta X_{t-1} = [1, \zeta_{t-1}, \Delta\pi_{t-1}, \Delta\Delta gdp_{t-1}]$; Θ_i are the coefficients of ΔX_{t-p}; ζ_{t-1} as the error correction term and ζ^*_{t-1} is its threshold estimate. To validate the presence of threshold cointegration effects, Seo (2006) proposes the use of the Supremum of the Wald statistic (SupWald) to test the null hypothesis of no cointegration (i.e. $\Theta_1 = \Theta_2 = 0$) against the alternative of threshold cointegration (i.e. $\Theta_1 \neq \Theta_2 \neq 0$. The SupWald statistic is defined as:

$$^{Seo}W_{sup} = supWald_1(\gamma) \qquad (8)$$

Seo (2006) relies on a residual-based bootstrap to approximate the asymptotic distribution of the SupWald statistic. If significant cointegration relations are established, estimation of TVEC equation (1.3) is conducted via Hansen and Seo (2002) quasi-Maximum Likelihood Estimators (q-MLE) method. This approach is prompted under the assumption of holding ε_t as an i.i.d. process which is embodied in a vector martingale difference sequence (VMDS) matrix denoted as E=E(ε_t,ε_t'). The VMDS is then incorporated into the following Gaussian likelihood function:

$$L_n\ (\Omega) = -n/2\ log - ½ \sum u_t\ (\Omega)'\ E^1\ u_t(\Omega) \qquad (9)$$

Where:

$$\Omega = (\Theta_1,\ \Theta_2,\ E,\ \beta,\ \zeta^*_{\tau\text{-}1}) \qquad (10)$$

Hansen and Seo (2006) propose estimating the likelihood function through maximum likelihood (ML) by means of holding (Θ_1, Θ_1, E) fixed and concentrating out (β, $\zeta^*_{\tau-1}$) yields the following concentrated likelihood function:

$$L_n\ (\beta, \zeta^*_{\tau-1}) = -n/2\ log\left| E(\beta, \zeta^*_{\tau-1})\right| - np/2 \qquad (11)$$

The maximum likelihood estimates of the cointegration vector (β) and the threshold parameter (ζ^*_{t-1}) are obtained through a two-dimensional grid search as the values that minimize ($log\left| E(\beta, \zeta^*_{\tau-1})\right|$) subject to the constraint:

$$n \leq n^{-1} \sum I.(x_t{'}\beta \leq \zeta^*_{\tau-1}) \leq 1\text{-}n \qquad (12)$$

Where 'n' denotes the trimming parameter of the data under analysis. Following Hansen and Seo (2002) n is set at 0.05 (5%). In obtaining the true values of β and ζ^*_{t-1}, backward substitution is employed to estimate the remainder of the parameters in equation (7).

4.3 DATA

The data utilized in the study was retrieved from the South African Reserve Bank (SARB) website. The dataset consists of inflation in the total consumer price index (π) as well as the growth rate of real gross domestic product at market prices (Δgdp). Quarterly data for ΔGDP and π has being collected between the period of 1960:02 to 2013:02 and are given at constant prices using 2000 as a base year which is seasonally adjusted at an annual rate. The paper pursues the study of Fischer (1993) by incorporating structural breaks in the employed data. Deriving from the studies of Nell (2000) and Rangasamy (2009) structural breaks are identified at 1970, 1985, 1994 and 2000. Subsequential sub-periods are extracted by setting 1960, 1970, 1985, 1994 and 2000 as base periods for analysis. Incorporating the suggested breakpoints and extracting subsequential sub-periods associated with each of these break-periods yields a total of 15 sample periods under analysis. For instance:

- Using 1960 as a base period produces subsequent sub-periods of 1960-1970, 1960-1985, 1960-1994, 1970-2000 and 1960-2013;
- Setting 1970 as a base periods produces sub-periods 1970-1985, 1970-1994, 1970-2000 and 1970-2013;
- For 1980 the sub-periods of 1985-1994, 1985-2000 and 1985-2013 are extracted;
- For 1994; 1994-2000 and 1994-2013; and
- For the last base period of 2000, the only existing sub-period is 2000-2013.

4.4 EMPIRICAL ANALYSIS

In view of drawing possible ‘spurious’ conclusions from the estimates of the BTVAR-BTVEC specifications, Hansen (1997) LR test for threshold effects and Seo (2006) threshold cointegration tests are, as a preliminary step, employed on the data for the sub-periods under analysis. The asymptotic p-values for the employed threshold tests are obtained by using 1000 bootstrapped replications with the results being displayed in Table 11.

Table 11: Hansen;s LR test for threshold effects between inflation and economic growth in South Africa

start year	*end year*	$^{HANSEN}LR_{\lambda}$ *equation (2)*	$^{HANSEN}LR_{\lambda}$ *equation (3)*	$^{SEO}W_{SUP}$ *equation (7)*	*decision*
1960	*1970*	*245.76 (0.00)****	*245.76 (0.00)****	*253.91 (0.00)****	*significant correlations*
	1985	*111.13 (0.00)****	*111.13 (0.00)****	*89.49 (1.00)*	*no significant correlations*
	1994	*66.667 (0.30)**	*73.789 (0.06)**	*92.18 (1.00)*	*no significant correlations*
	2000	*73.300 (0.04)**	*74.660 (0.06)**	*72.42 (1.00)*	*no significant correlations*
	2013	*71.831 (0.09)**	*65.350 (0.260)**	*79.00 (1.00)*	*no significant correlations*
1970	*1985*	*230.14 (0.00)****	*189.21 (0.00)****	*99.37 (1.00)*	*significant correlations*
	1994	*88.272 (0.10)**	*90.219 (0.04)***	*135.60 (1.00)*	*no significant correlations*
	2000	*68.301 (0.30)**	*87.175 (0.00)****	*110.74 (1.00)*	*no significant correlations*
	2013	*61.268 (0.58)*	*56.216 (0.640)*	*213.74 (1.00)*	*no significant correlations*
1985	*1994*	*152.52 (0.00)****	*51.902 (0.00)****	*334.42 (0.00)****	*significant correlations*
	2000	*189.19 (0.00)****	*164.53 (0.00)****	*322,36 (1.00)*	*no significant correlations*
	2013	*117.63 (0.00)****	*82.650 (0.10)***	*290.60 (1.00)*	*no significant correlations*
1994	*2000*	*185.33 (0.00)****	*130.94 (0.00)****	*110.55 (1.00)*	*no significant correlations*
	2013	*185.46 (0.00)****	*187.76 (0.00)****	*110.55 (1.00)*	*no significant correlations*
2000	*2013*	*185.33 (0.00)****	*187.76 (0.00)****	*587.97 (0.00)****	*significant correlations*

Significance Level Codes:"***", "**' and '*' denote the 1%, 5% and 10% significance levels respectively. Asymptotic bootstrapped p-values are reported in parentheses.

The results indicate that with the exception of the period of 1970-2013, Hansen's (1999) LR test fails to reject the alternative hypothesis of threshold effects present in regressions (2) and (3) for all remaining sub-periods. However, based on the results of Seo's (2006) cointegration test, significant nonlinear cointegration effects are present for periods of 1960-1970, 1985-1994 and 2000-2013. Following the above analysis, the next sub-section conducts BTVAR-BTVEC model estimations for the identified significant nonlinear cointegrated periods. Having identified periods in which inflation and growth are significantly nonlinearly cointegrated for South African data, estimations of BTVAR-BTVEC equations (2), (3) and (7) are conducted for each of these periods. For 1960-1970, the results are given in Table 12, for 1985-1994 in Table 13 and for 1999-2013 in Table 14. The BTVAR model specifications (2) and (3) are estimated using Hansen's (1999) conditional lest squares (CLS) method with the lag order of the regressions being selected on the basis of minimizing the AIC. The coefficients and threshold values for the BTVEC model (7) are estimated using Hansen and Seo (2002) q-MLE method.

Table 12: BTVAR-BTVEC model estimates of inflation-growth correlation for 1960-1970

π^*	*3.04%*					
Δgdp^*	*5.59%*					
ζ^*_{t-1}	*0.033*					
β	*-0.44*					
	equation (2)		*equation (3)*		*equation (7)*	
ssr	*0.00011*		*0.00013*		*0.0547*	
aic	*-1081.76*		*-1073.26*		*-1365.20*	
below threshold						
regressor→ regressand ↓	*π*	*Δgdp*	*π*	*Δgdp*	*$\Delta\pi$*	*$\Delta\Delta gdp$*
constant	*-0.07 (0.007)****	*0.05 (0.01)****	*0.01 (0.03)*	*-0.06 (0.06)*	*0.05 (0.00)****	*-0.09 (0.00)*
π_{t-1}					*-0.004 (0.80)*	*-0.25 (0.00)****
$\Delta\pi_{t-1}$					*-0.72 (0.00)****	*-0.14 (0.14)*
$\Delta\Delta gdp_{t-1}$					*-0.19 (0.01)***	*-0.85 (0.00)****
π_{t-1}	*2.33 (0.03)****	*-0.76 (0.06)****	*2.18 (0.03)****	*-0.06 (0.05)*		
π_{t-2}	*-1.26 (0.03)****	*0.69 (0.05)****	*-1.20 (0.03)****	*0.07 (0.06)*		
Δgdp_{t-1}	*0.39 (0.02)****	*1.68 (0.03)****	*-0.20 (0.02)****	*2.07 (0.03)****		

Δgdp_{t-2}	-0.40 (0.02)***	-0.65 (0.03)***	0.20 (0.02)***	-1.06 (0.03)***		
above threshold						
constant	0.34 (0.09)***	0.45 (0.17)*	-0.08 (0.01)***	0.15 (0.02)***	0.01 (0.21)	-0.08 (0.00)***
π_{t-1}					0.11 (0.00)***	-0.01 (0.06)*
$\Delta\pi_{t-1}$					-1.04 (0.00)***	0.02 (0.75)
$\Delta\Delta gdp_{t-1}$					0.12 (0.27)	-0.98 (0.00)***
π_{t-1}	1.96 (0.09)***	-0.35 (0.15)*	2.36 (0.02)***	-0.50 (0.04)***		
π_{t-2}	-0.98 (0.09)***	0.35 (0.16)*	-1.28 (0.02)***	0.44 (0.04)***		
Δgdp_{t-1}	-0.21 (0.11)*	1.78 (0.20)***	0.43 (0.02)***	1.69 (0.03)***		
Δgdp_{t-2}	0.16 (0.12)	-0.87 (0.22)***	-0.45 (0.02)***	-0.68 (0.03)***		

Significance Level Codes: '***', "**' and '*' denote the 1%, 5% and 10% significance levels respectively. P-values are reported in parentheses

For the period of 1960-1970 inflation thresholds of 3.04% and economic growth thresholds of 5.59% are estimated. Given a positive error correction threshold estimate (ζ^*_{t-1}) for equation (5), the upper regime of the BTVEC model is in continuous disequilibrium while equilibrium can only exist in the lower regime. Since the only significant adjustment parameter (ζ_{t-1}) is found for the growth equation in the lower regime of the BTVEC model, inflation can be considered as the driving trend in the system, causing economic growth in the granger sense, being weakly exogenous. The larger absolute lagged inflation coefficients of the economic growth regressors in the lower regime for equation (2) and the upper regime for equation (3), points to economic growth being more responsive to a change in inflation when the combination of inflation rates are below 3.04% and economic growth rates above 5.59% are simultaneously realized. The cointegration vector (β) further provides a measure of the inflation-growth elasticity in equilibrium (Risso and Sanchez-Carrera, 2009). The -0.44 elasticity estimate associated with the data interprets to a 1% increase in the inflation rate producing a decrease in economic growth levels of 0.44%.

Table 13: BTVAR-BTVEC model estimates of the inflation-growth correlation for 1985-1994

π*	15.01%					
Δgdp*	1.15%					
$\zeta^*_{\tau-1}$	1.18					
β	-9.36					
	equation (2)		*equation (3)*		*equation (7)*	
ssr	*0.0543*		*0.1874*		*0.8162*	
aic	*-549.93*		*-449.31*		*-805.89*	
below threshold						
regressor→ regressand ↓	π	Δgdp	π	Δgdp	$\Delta\pi$	$\Delta\Delta gdp$
constant	*-1.12 (0.06)****	*1.18 (0.07)****	*-1.23 (0.18)****	*1.39 (0.12)****	*-0.33 (0.00)****	*0.20 (0.00)****
$\zeta_{\tau-1}$					*-0.01 (0.27)*	*0.004 (0.28)*
$\Delta\pi_{t-1}$					*-1.24 (0.57)*	*0.69 (0.63)*
$\Delta\Delta gdp_{t-1}$					*-0.47 (0.90)*	*0.20 (0.93)*
π_{t-1}	*1.06 (0.004)****	*-0.08 (0.005)****	*1.07 (0.01)****	*-0.10 (0.01)****		
Δgdp_{t-1}	*0.12 (0.01)****	*0.91 (0.02)****	*0.09 (0.05)*	*0.98 (0.04)****		
above threshold						
constant	*0.24 (0.56)*	*-3.33 (0.68)****	*-0.61 (0.21)****	*0.70 (0.15)****	*0.01 (0.77)*	*0.001 (0.96)*
ζ_{t-1}					*-0.02 (0.00)****	*-0.001 (0.76)*
$\Delta\pi_{t-1}$					*-0.51 (0.00)****	*-0.02 (0.08)*
$\Delta\Delta gdp_{t-1}$					*-0.40 (0.05)**	*-0.01 (0.91)*
π_{t-1}	*1.04 (0.04)****	*0.23 (0.04)****	*1.05 (0.01)****	*-0.04 (0.01)****		
Δgdp_{t-1}	*-0.69 (0.06)****	*0.85 (0.07)****	*-0.07 (0.08)*	*0.91 (0.05)****		

Significance Level Codes: '***', "**' and '*' denote the 1%, 5% and 10% significance levels respectively. P-values are reported in parentheses

For 1985-1994 data, the error correction threshold estimate is insignificantly positive. Thus only the regression coefficient estimates of the lower regime in BTVEC equation (5) are taken into consideration. Based on insignificant error correction terms being estimated for both inflation and growth regressions, it is deduced that no functional significant cointegration can be extracted from the data associated with this sub-period.

Table 14: BTVAR-BTVEC model estimates of the inflation-growth correlation for 2000-2013

π^*	6.08%					
Δgdp^*	3.12%					
$\zeta^*_{\tau-1}$	1.88					
β	-1.65					
	equation (2)		*equation (3)*		*equation (7)*	
SSR	0.00044		0.00044		1.573	
AIC	-549.93		-449.31		-805.89	
Below threshold						
regressor→ regressand ↓	π	Δgdp	π	Δgdp	$\Delta\pi$	$\Delta\Delta gdp$
constant	1.53 (0.09)***	-0.21 (0.04)***	-2.19 (0.62)**	0.81 (0.22)***	0.03 (0.1)	0.01 (0.25)
$\zeta_{\tau-1}$					-0.02 (0.06)*	-0.01 (0.35)
$\Delta\pi_{t-1}$					-0.48 (0.07)*	-0.19 (0.28)
$\Delta\Delta gdp_{t-1}$					-0.79 (0.06)*	-0.31 (0.27)
π_{t-1}	1.82 (0.03)***	-.003 (0.02)*	2.15 (0.06)***	-0.20 (0.02)***		
π_{t-2}	-1.01 (0.03)***	0.05 (0.01)***	-0.88 (0.08)***	0.10 (0.03)***		
Δgdp_{t-1}	-1.27 (0.11)***	2.22 (0.05)***	1.73 (0.45)***	1.31 (0.16)***		
Δgdp_{t-2}	1.16 (0.10)***	-1.21 (0.04)***	-1.58 (0.40)***	-0.37 (0.14)*		
Above threshold						
constant	1.12 (0.27)***	0.33 (0.12)*	1.22 (0.10)***	-0.07 (0.03)*	0.40 (0.0002)***	-0.35 (0.00)***
$\zeta_{\tau-1}$					-0.02 (0.20)	-0.01 (0.61)
$\Delta\pi_{t-1}$					-0.93 (0.18)	0.21 (0.65)
$\Delta\Delta gdp_{t-1}$					0.003 (1.00)	-0.86 (0.02)*
π_{t-1}	2.25 (0.05)***	-0.18 (0.02)***	1.92 (0.02)***	-0.05 (0.01)***		
π_{t-2}	-1.37 (0.04)***	0.14 (0.02)***	-1.07 (0.02)***	0.06 (0.01)***		

Δgdp_{t-1}	*-0.37*	*1.65*	*-0.91*	*2.09*
	(0.22)	*(0.10)****	*(0.08)****	*(0.03)****
Δgdp_{t-2}	*1.16*	*-1.21*	*-1.07*	*0.06*
	*(0.10)****	*(0.04)****	*(0.02)****	*(0.01)****

Significance Level Codes: '***', "**' and '*' denote the 1%, 5% and 10% significance levels respectively
P-values are reported in parentheses

Between 2000 and 2013, inflation thresholds of 6.08% with associated economic growth thresholds of 3.12% are obtained. Given a positive error correction threshold estimate (ζ^*_{t-1}) for equation (5), the upper regime of the BTVEC model is in disequilibrium while equilibrium can only be established in the lower regime. The only significant negative error correction term estimate (ζ_{t-1}) in equation (5) is obtained for the inflation equation in the lower regime. This result suggests on causality being driven from economic growth to inflation for data associated with this sub-period. The larger absolute lagged growth coefficients of the inflation regressors in the lower regime for equations (2), implies on inflation being more responsive to changes in economic growth when inflation rates are below 6.08%. The elasticity for inflation-growth (as measured by β) is -1.65 which means that a unit increase in the inflation rate for the observed data is associated with a decrease in economic growth of 1.65%.

4.5 CONCLUSION

Is the SARB's currently utilized inflation-target regime of 3-6% suitable for the attainment of the 6% percent economic growth rate objective defined by NGP and NDP initiatives? By estimating BTVAR-BTVEC econometric models for sub-periods between 1960-2010 in which inflation-and growth are significantly correlated, this paper sought to shed light on this policy question. Exploitations of BTVEC models imply significant nonlinear correlations between the macroeconomic variables only occur for the data associated with sub-periods of 1960-1970 and 2000-2013. Of primary interest is the period of 2000-2013 which represents the era in which both the inflation-targeting regime as well as the NDP and NGP programmes were adopted. Estimates of BTVAR models for data associated with this period indicate optimal inflation levels of 6.08% with corresponding optimal economic growth rates of 3.12%.

Given that the currently obtainable optimal economic growth rate is below NGP and NDP initiatives set objective, what then is the level of inflation required to attain the 4-7% economic growth objective? Based on the overall findings, inflation rates of below 3.04% are associated with the attainment of optimal economic growth rates above 5.59%. However, caution is prescribed when interpreting these findings as causality between the data is established to run from inflation to economic growth at inflation levels of below 3.04%, whereas at higher levels of inflation (between 3.04%- 6.08%), causality runs from economic growth to inflation. Therefore, pursuing a *strict* inflation targeting regime can only efficiently support the intended growth rate of 4-7% once the realization of inflation levels below 3% are accompanied with economic growth levels above 5.59%. The prevailing idea is that fast economic growth makes the South African economy run into supply constraints such as energy, transport and skilled labour constraints. In turn, this pushes up factor prices thus resulting in increases in the inflation rate. As a natural development the current study, future research can thus be concerned with identifying appropriate channels through which such a disinflationary policy strategy can be worked through by taking into consideration other important structural economic factors such as investment.

REFERENCES

Ahmed S. and Mortaza M.G. (2005), "Inflation and Growth in Bangladesh: 1981-2005", *Policy Analysis Unit, Working Paper Series: WP 0604.*

Bonga-Bonga L. and Kabundi A. (2010), "Monetary policy instrument and inflation in South Africa: an empirical analysis", *The African Finance Journal*, 13(2), 25-37.

Bruno M. and Easterly W. (1995), "Inflation Crisis and Long-run growth", *NBER Working Paper No. 5209*.

Chowdury A. and Ham R. (2009), "Inflation targeting in Indonesia: Searching for a threshold", Singapore Economic Review, 54(4), 1-11.

Drukker D., Gomis-Porqueras P. and Hernandez-Verme P. (2005), "Threshold effects in the relationship between inflation and growth: A new panel-data approach", *Reserve Bank of New Zealand Bulletin*: 71(3), September.

Fischer S. (1993), "The role of macroeconomic factors in economic growth", *Journal of Monetary Economics*, 32, 485-512.

Gupta R. and Uwilingiye J. (2009), "Some benefits of reducing inflation in South Africa", University of Pretoria, Department of Economics, *Working Paper No. 2009-15.*

Hansen B.E. (1997), "Inference in TAR models", *Studies in Nonlinear Dynamics and Econometrics,* 2(1).

Khan A., Bukhari S. and Ahmed Q. (2007), "Determinants of recent inflation in Pakistan", *Working Paper Research Report No. 66.*

Khan M. and Senhadji A. (2001), "Threshold effects in the relationship between inflation and growth", *IMF Staff Papers*, 48, 1-21.

Kremer S., Bick A. And Nautz D. (2009), “Inflation and growth: New evidence from a dynamic panel threshold analysis”, *Empirical Economics*, 44(2), 861-878.

Lo M. and Zivot E. (2001), “Threshold cointegration and nonlinear adjustment to the law of one price”, *Macroeconomic Dynamics*, 5(4), 533-576.

Lucas R. (1976), “Econometric policy evaluation: A Critique”, *Carnegie-Rochester Conference Series on Public Policy*, 1(1), 19-46.

Mi L. (2006), "Inflation and Economic growth: Threshold effects and transmission mechanisms", *Department of Economics, University of Alberta*, 8-14.

Nell K.S. (2000), "Is low inflation a precondition for faster growth? The case of South Africa", *Working Papers in Economics*, Department of Economics, Keynes College, University of Kent.

Rangasamy L. (2009), “Inflation persistence and core inflation: The case of South Africa”, *South African Journal of Economics*, 77(3)*, 430-440.*

Risso W. and Sanchez-Carrera E. (2009), “Inflation and Mexican economic growth: Long-run relation and threshold effects”, *Journal of Financial Economic Policy*, 1(3), 246-263.

Sarel M. (1996),”Nonlinear effects of inflation on economic growth”, *IMF Staff Papers,* 43, 199-215.

CHAPTER 5: RE-EVALUATING OKUN'S LAW IN SOUTH AFRICA: A NONLINEAR COINTEGRATION APPROACH

ABSTRACT: This study undertakes an examination of asymmetric co-integration adjustment in Okun's law for South Africa between the periods of 2000-2013. This objective is tackled through the use of momentum threshold autoregressive (MTAR) econometric framework. Contrary to conventional theory, the results show that unemployment granger causes economic growth in the long-run, a result which may account for the job-less growth experienced by South Africa over the last decade or so. The obtained results have important implications for policy conduct in South Africa. Firstly, they prove that increases of economic growth in the long run may not cause a decrease in the unemployment rate yet a decrease in the unemployment rate will lead to increases in output growth. Secondly, these results further highlight the importance of labour market policies in improving economic growth in South Africa as opposed to policy authorities depending on higher economic growth to be the driving force behind reducing unemployment rates.

Keywords: Okun's law; South Africa; Nonlinear Unit Root Tests; Nonlinear Cointegration, Nonlinear granger tests.

JEL Classification Code: C22, C51, E23, E24.

5.1 INTRODUCTION

High economic growth in conjunction with low unemployment under a low inflation environment can be deemed as the ultimate objective of macroeconomic policy in South Africa. Over the last decade or so, two prominent macroeconomic policy frameworks have embodied these objectives, those being, monetary policy's 'inflation-targeting' regime and fiscal policy's Accelerated and Shared Growth Initiative of South Africa (ASGISA). Implemented in February 2002 and still in use to date, the inflation-target policy rule specifies that the South African Reserve Bank (SARB) should contain inflation at levels of between 3 and 6 percent, whereas the ASGISA initiative seeks to halve unemployment and attain a 6% economic growth rate by the year 2014. The assumed compatibility of the aforementioned policy objectives is inevitable demonstrated as monetary policy in South Africa is designated towards manipulating nominal variables like interest rates and inflation as a means of influencing real variables such as output growth and employment. Ultimately, the success of disinflation policy is reflected in its effect on unemployment and output growth. However, up-to-date South Africa has not only to managed to achieve arguably the highest economic growth rates in Africa since 1994, but the economy simultaneously boasts one of the highest youth unemployment rates in the world. So even though the South African Reserve Bank (SARB) can be credited for containing inflation within its set target which has been accompanied with steadily improved economic growth, such acquired growth has been characterized by what is popularly referred to as a 'jobless growth' syndrome (Hodge, 2009). A mystery is warranted since the 'jobless growth' phenomenon contradicts the epic rise of unemployment caused by the sharp decline of real output experienced worldwide during the great depression. Therefore, a classical challenge for academics and policymakers alike is to provide an adequate account of unemployment-growth correlations in the South African economy.

The question regarding the linkage between economic growth and unemployment gained prominence after Okun (1962) depicted the extent to which the unemployment rate is negatively correlated with output growth. By analyzing data over the period of 1947 to 1960, Okun (1962) documented that unemployment in the United States tends to fall by a one percentage point for every 3 percentage point rise in output growth. Thereafter, the United States was dubbed as having an estimated "Okun coefficient" of 3 and a plethora of subsequent authors sought to estimate Okun's coefficient by either adopting a single-country approach (see Caraiani, 2010; Ahmed et al, 2011), panel-data approach (see Dixon and Shepard, 2002, 1997; Lal et al, 2010) or a multi-regional approach (see Freeman, 2000; Adanu, 2002; Villaverde and Maza, 2009). The appeal of Okun's relationship is attributed to its simplicity and its extensive empirical support qualifies it to belong at the core of modern macroeconomics (Jardin and Gaetan, 2011). As noted by Silvapulle et al (2004), estimating the Okun coefficient has important implications for the business cycle since it relates the level of activity in the labour market to the level of activity in the product market. Whilst Okun's law implies that more labour is typically required for increased productivity levels, Okun's coefficient serves as an indication of the cost of unemployment in terms of output growth (Noor et al, 2007). And in consolidation with the Phillips curve; Okun's relationship assists macroeconomic policy in determining the optimal or desirable growth rate as a prescription for reducing unemployment (Moosa, 1997). Overall, Okun's law is recommended as "a rule of thumb" which provides policymakers with an understanding of how different markets adjust, and thus allowing for correct policies to be selected when facing shocks (Pereira et al, 2009).

In reality, Okun's law is more of a statistical relationship rather than a structural feature of the macroeconomy (Knotek, 2007). The development of a pure theoretical foundation for Okun's relationship has been largely neglected in the academic literature, such that empirically, no functional form has been dominantly preferred to any other on the basis of theory (Weber and West, 1995). As a consequence, the empirical examination of Okun's law is typically subject to revisions with the co-movement between output growth and unemployment frequently being analyzed under different settings. So while there is no contention on the importance of Okun's law, debates have evolved on the econometric techniques used to establish this relationship; how the cyclical components are extracted; and whether a dynamic or static specification is adopted (Turturean, 2007). Recently, the possibility of asymmetric behaviour between economic growth and the unemployment rate has added a new dimension in the development of the academic literature. Take for instance Jardin and Gaetan (2011) who consider asymmetries in Okun's relationship as being important because asymmetric behaviour can adequately account for the varying effectiveness of structural and stabilization policies. Other commentators, such as Geldenhuys and Marnikov (2007), consider the impact of asymmetric behaviour on policy forecasting practices. In particular, these authors argue that if Okun's relationship is indeed found to be asymmetric, forecasts based on linear estimates of Okun's coefficient can lead to biased error terms. And yet another cluster of authors can also be identified, who advocate on the necessity of incorporating asymmetries in Okun's relationship as a means of reinforcing asymmetric behaviour in the Phillips curve. The rationale behind this line of thought is that if Okun's coefficient changes between regimes, then the sacrifice ratios should also change between regimes. In other words, different degrees of gradualism in the disinflation process may imply different impacts on unemployment for the same reduction in inflation (Beccarini and Gros, 2008).

Our study contributes to the literature by addressing the economic significance of asymmetric behaviour in Okun's relationship for South African data. To this end, our study makes use of the momentum threshold (MTAR) autoregressive framework of Enders and Granger (1998). The logic behind the choice of our adopted approach can be described as follows. Engle and Granger (1987) argue that evidence of unit roots between a pair of time series variables necessitates the use of cointegration analysis prior to the estimation of any regression formed by the variables. According to the authors, the presence of cointegration would then imply that the variables follow a common long-run trend and the OLS estimation of the time series will not yield spurious results. This is an important implication for our case study since previous empirical works have cautioned of unit root I(1) behaviour in output growth and unemployment variables for South African data (see Hodge, 2006; and Phillip and Burger, 2006; Gupta and Uliwingiye, 2010). And yet it should also be noted that these conclusions are based on studies which assume a linear data generating process (DGP) among the series. Of recent, it has become widely accepted that standard unit root tests, suffer from low power when a linear approximation of an otherwise nonlinear time series is used to evaluate the integration properties of a time series (Enders and Granger, 1998). A similar contention has risen for cointegration analysis, in which researchers like Enders and Dibooglu (2001) prove that the implicit assumption of symmetric adjustment is problematic if the adjustment towards long-run equilibrium is not linear. In particular, the authors argue that the presence of nonlinearities between a pair of time series signifies a high probability of nonlinear adjustment processes towards the long-run equilibrium for the data. With this in mind, our paper probes into the possibility of asymmetric behaviour between the unemployment rate and output growth using the MTAR model. We choose this model because it represents a simple yet flexible framework that can simultaneously facilitate for (1) nonlinear unit root tests, (2) nonlinear cointegration analysis; and (3) nonlinear causality analysis.

In a nutshell, our study interweaves the issue of asymmetries in Okun's law for the case of South Africa from three interrelated perspectives. Firstly, the paper examines asymmetries in the stochastic processes for the individual time series variables of output growth and the unemployment rate. Secondly, the paper examines asymmetric effects in the cointegration relationship between output growth and unemployment. Lastly, we examine granger causal effects between the observed time series variables. A point of departure in our study is that aforementioned objectives are developed and tackled under an interrelated econometric framework. Therefore, against this backdrop, we present the remainder of the paper as follows. The following section gives a survey of the related literature. The third section of the paper presents the empirical framework of the study whereas section four presents the empirical results of the study. The paper is concluded in section five by providing policy recommendations and suggesting avenues for future research.

5.2 A SURVEY OF THE RELATED LITERATURE

The notion of asymmetries existing within economic time series can be traced back to Keynes (1936), who discovered that the variation in unemployment and output would differ, depending on whether the economy was in an expansion or a recession phase of the business cycle. Courtney (1991) and Palley (1993) took the initiative of formally exploring the asymmetric behaviour in Okun's law on the basis of labour market dynamics. Using an aggregate production approach, Courtney (1991) discovered that by ignoring asymmetries in Okun's relationship, the OLS regression estimates of the unemployment rate at different phases of the business cycle would produce erroneous results. However, it was Palley (1993) who was firsts to formally establish the theoretical foundations governing the asymmetric relationship between unemployment and output growth. Specifically, Palley (1993) discovered that the distribution of female labour supply is less affected during the recession phase of the business cycle as opposed to expansionary periods. By implication Palley's model highlights the need for policymakers to distinguish between gender imbalances when formulating labour policies. Campbell and Fischer (2000) and Kosfeld and Dreger (2004) develop similar theoretical models which attribute asymmetries in Okun's law to labour market dynamics. However, in Campbell and Fischer's model, asymmetric behaviour in Okun's relationship is based on micro-foundational adjustment costs incurred by heterogeneous firms; which aggravate asymmetric adjustments in cycles of job creation and job destruction. Similarly, Kosfeld and Dreger (2004) insinuate that due to capacity reserves of firms, output growth needs to exceed a certain threshold level in order to create jobs in the labour market. Thus the threshold level represents the minimum growth rate which is sufficient for inducing a decrease in unemployment. And even beyond the traditional assumption of asymmetric behaviour being attributed to labour market dynamics, there has also emerged a more recent branch of literature whose theoretical ground for establishing asymmetric co-movements in Okun's relationship is based on the dynamics governing industrial structures. A popular model under this branch of literature is that of

Fernandez and Simes (2006) who establish asymmetries in Okun's relationship based on the characteristics of highly regulated industries. Under this model, the exit costs of firms are inferior compared to their entrance costs thus inducing asymmetric behaviour between labour capacity and industrial productivity. Extending along this line of theoretical reasoning, Lang and de Peretti (2009) build a hysteresis version of Okun's relationship, based on discontinuous adjustments of heterogeneous firms caused by business growth fluctuations. These authors deduced that hysteresis in Okun's relationship offsets an asymmetric equilibrium adjustment between unemployment and production output over time.

Regardless of the overall diversity in establishing theoretical micro-foundations for asymmetric behaviour in Okun's law, it is the choice of econometric modelling which is paramount to qualifying and quantifying the asymmetric dynamic properties of unemployment and output growth. Typically, empirical economists attempt to model fluctuations of unemployment in correspondence to movements in output growth during various phases of the business cycle. Take for instance Crespo-Cauresma (2003), who is able to fit a TAR model to cyclical output and cyclical unemployment data for the US and discovers that Okun's coefficient is higher during periods of recessions than during expansions. Caraiani (2010) as well as Beccarini and Gros (2008) apply Markov-switching (MS) models to Euro and Romanian data, respectively, and draw similar conclusions to those obtained by Crespo-Cauresma (2003). Likewise, Kavkler et. al. (2008) investigate the relationship between GDP growth and the unemployment rate for German data, however, using a smooth transition regression (STR) model. The authors establish that regime switching behaviour is facilitated by the unemployment rate; of which Okun's law only holds at relatively high levels of labour market deficiency. In proposing a different empirical approach, Lee (2000) augments Okun's relationship by allowing for different effects between negative and non-negative values in the unemployment data. The author finds that for leading industrialized economies, Okun's coefficient is significantly higher during decreases in the unemployment rate as opposed to periods of increasing unemployment. Lee (2000) also notes that the extent of asymmetries varies remarkably across time periods as well as amongst various classifications of economies. Therefore, the study indirectly highlights the effectiveness of single country analysis over panel data approaches. In an exclusive case study for South African data, Geldenhys and Marnikov (2007) adopt the estimation technique proposed by Lee (2000) and find that Okun's law is only significant during recessions with a 1% increase in the output gap being associated with a 0.18% decrease in cyclical unemployment. Similarly, for EU state economies, Mayes and Viren (2002) observe that rapid downturns in these economies appear to have more than a proportionate downward effect on the unemployment rate. Other authors such as Harris and Silverstone (2001); Viren (2001), Silvapulle et. al. (2004) and Arabaci and Arabaci (2010) have modified the approach initially proposed by Lee (2000) and split the error correction terms in Okun's relation into positive and negative values hence enabling for the construction of regime dependent error correction equilibrium paths. In doing so, the aforementioned authors are able to demonstrate that in a nonlinear environment, the speed and magnitude of equilibrium adjustments paths are dependent on whether the economy is in an upturn or downturn of the business cycle.

Notwithstanding the positive developments made in modelling asymmetric behaviour in Okun's relationship, a litigious issue within the literature concerns the modelling of causality effects between output growth and unemployment. As eloquently argued by Turturean (2009), the two-way relationship commonly established between output growth and unemployment are two distinct models which do not suggest a reciprocal and unique two way relationship between output growth and unemployment. While the overall sign of the relation has been generally established to be negative, the existence of a causal relation has been highly ignored by researchers and thus remains ambiguous. Consequentially, there exists a misapprehension in interpreting the coefficients estimated within direct and reverse regressions of unemployment on output growth (Barreto and Howland, 1993). For instance, the implication of causality running from unemployment to economic growth is that policies aimed at expanding output productivity may not necessary result in the lowering of unemployment levels. This would stand as a reasonable explanation for the 'jobless growth' syndrome as experienced in South Africa. Likewise, non-causality established between the variables would similarly serve as an adequate explanation the jobless growth phenomenon experienced in South Africa. Conversely, causality from economic growth to unemployment signifies that a decrease in unemployment levels is a direct result of expansionary policies. Finally, bi-directional causality encourages the risk-averse policymaker to be more experimental in implementing a diversity of both labour market and output productivity policies. Based on the aforementioned, it is clear that the establishment of causal effects between unemployment and output growth has strong bearing on policy conduct. It is, thus, perplexing that very little attention has been direct towards discriminating between the various forms of causal effects among unemployment and output growth despite the ever-expanding methodological advancements made in causality analysis within the time series literature.

5.3 MODELING ASYMMETRIES IN OKUNS LAW

Our paper uses two classes of Okun's law specifications; namely, the first differences model and the gap model. To ensure that we obtain a balanced, robust view on the estimation results, we specify the Okun's specifications on both the direct and the reverse regressions of unemployment on output growth. For instance, in specifying the "first differences" version of Okun's law, the link between the unemployment rate (*ur*) and economic growth (r*gdp*) is represented as:

$$\begin{pmatrix} \Delta rgdp_t \\ \Delta rur_t \end{pmatrix} = \begin{pmatrix} \beta_1 & 0 \\ 0 & \beta_2 \end{pmatrix} \begin{pmatrix} \Delta ur_t \\ \Delta rgdp_t \end{pmatrix} + \begin{pmatrix} \xi_{t1} \\ \xi_{t2} \end{pmatrix} \qquad (1)$$

Where Δ is the first difference operator such that $\Delta gdp_t = gdp_t - gdp_{t-1}$ *and* $\Delta ur_t = ur_t - ur_{t-1}$. On the other hand, the 'gap model' measures these variables in terms of their deviations from long-run trends and is specified as:

$$\begin{pmatrix} rgdp_t^c \\ ur_t^c \end{pmatrix} = \begin{pmatrix} \beta_1 & 0 \\ 0 & \beta_2 \end{pmatrix} \begin{pmatrix} ur_t^c \\ rgdp_t^c \end{pmatrix} + \begin{pmatrix} \xi_{t1} \\ \xi_{t2} \end{pmatrix} \qquad (2)$$

Where $ur_t^c \equiv ur_t - ur_t^*$ and $rgdp_t^c \equiv rgdp_t - rgdp_t^*$ are representative of the cyclical components of the unemployment rate and real output, respectively; with $rgdp_t^*$ denoting a measure of potential output gap and ur_t^* the unemployment gap variable. Having specified our baseline theoretical models, we can proceed to introduce cointegration analysis amongst the variables. We, therefore, take heed of Enders and Granger (1998) and model asymmetric adjustment between the unemployment and real output growth variables by allowing the residual deviations (i.e. ξ_{ti}) from the long-run equilibrium of regressions (1) and (2) to behave as a TAR process. Formally, these residuals are modelled as follows:

$$\Delta\xi_{ti} = I_t\rho_1\xi_{t-1} + (1 - I_t)\rho_2\xi_{t-1} + \sum_{i=1}^{p}\beta_i\,\Delta\xi_{t-i} + \varepsilon_t \qquad (3)$$

In our paper, we identify four types of cointegration relations which govern the asymmetric dynamics within Okun's law, namely; TAR with a zero threshold; consistent TAR with a nonzero threshold; MTAR with a zero threshold; and consistent MTAR with a nonzero threshold. In the TAR model with a zero threshold, the indicator function, I_t, is set according to:

$$I_t = \begin{cases} 1, if\,\xi_{t-1} \geq 0 \\ 0, if\,\xi_{t-1} < 0 \end{cases} \qquad (4)$$

Under the TAR model with a nonzero threshold, we set I_t, as:

$$I_t = \begin{cases} 1, if\,\xi_{t-1} \geq \tau \\ 0, if\,\xi_{t-1} < \tau \end{cases} \qquad (5)$$

Where τ is the value of the threshold variable. Enders and Granger (1998) suggest the use of a grid search procedure, as demonstrated in Hansen (1997), to derive a consistent estimate of the threshold i.e. the threshold estimate yielding the lowest RSS is considered the true threshold estimate. The TAR models are designed to capture potential asymmetric deep movements in the residuals if, for example, positive deviations are more prolonged than negative deviations (Enders and Dibooglu, 2001). Enders and Granger (1998) and Caner and Hansen (2001) suggest that by permitting the Heaviside indicator function, I_t, to rely on the first differences of the residuals, $\Delta\xi_{t-1}$, a MTAR version of equation (11) can be developed. The implication of the MTAR model is that correction mechanism dynamic since by using $\Delta\xi_{t-1}$, it is possible to access if the momentum of the series is larger in a given direction relative to the direction in the alternative direction. In other words, the MTAR model can effectively capture large and smooth changes in a series whereas the TAR model shows the "depth" of the swings in equilibrium relationship. In modelling MTAR threshold cointegration with a zero threshold, the indicator function M_t, is set as:

$$M_{.t} = \begin{cases} 1, if\ \Delta\xi_{t-1} \geq 0 \\ 0, if\ \Delta\xi_{t-1} < 0 \end{cases} \tag{6}$$

While in the MTAR model with a nonzero threshold, M_t, is set as:

$$M_{.t} = \begin{cases} 1, if\ \Delta\xi_{t-1} \geq \tau \\ 0, if\ \Delta\xi_{t-1} < \tau \end{cases} \tag{7}$$

For both TAR and MTAR specifications, Enders and Silkos (1998) demonstrate that a sufficient condition for stationary of ξ_{t-1} is that ρ_1, $\rho_2 < 0$. If ξ_{t-1} is found to be stationary, the least squares estimates of ρ_1 and ρ_2 have an asymptotic multivariate normal distribution for any given value of a consistently estimated threshold. Moreover, the null hypothesis of no cointegration (i.e. H_{01}: $\rho_1 = \rho_2 = 0$) can be formally tested using a standard F-statistic for both TAR and MTAR models. If the null hypothesis of no cointegration is rejected, it is possible to test for the null hypothesis of symmetric adjustment (i.e. H_{02}: $\rho_1 = \rho_2$) against the alternative of asymmetric adjustment (i.e. H_{12}: $\rho_1 \neq \rho_2$) using a similar F-test. The empirical F-distribution for the null hypothesis; $\rho_1 = \rho_2 = 0$ is tabulated in Dibooglu and Enders (2001) whereas Enders and Siklos (2001) report critical values for testing the null hypothesis of $\rho_1 \neq \rho_2$. If both null hypotheses of no cointegration and no asymmetric cointegration can be simultaneously rejected, the granger representation theorem is satisfied and thus an associated error correction model can be estimated for the pair of time series variables. Thus in validating the presence of threshold cointegration, the error correction model can be modified to take into account asymmetries as in Blake and Fombly (1997). In our study we augment each of our threshold cointegration regressions with thresholds error correction specifications. In particular, the TAR-TEC model can be expressed as:

$$\begin{pmatrix} \Delta gdp_t \\ \Delta ur_t \end{pmatrix} = \lambda_{11} I_{\cdot t}\, \xi_{t-1} + \lambda_{12}(1 - I_{\cdot t})\xi_{t-1} + \sum_{i=1}^{p} \alpha_{1i} \Delta gdp_{t-i} + \sum_{i=1}^{p} \beta_{1i} \Delta ur_{t-i} \quad (8)$$

Whereas the MTAR-TEC model is specified as:

$$\begin{pmatrix} \Delta gdp_t \\ \Delta ur_t \end{pmatrix} = \lambda_{21} M_{\cdot t}\, \xi_{t-1} + \lambda_{22}(1 - M_{\cdot t})\xi_{t-1} + \sum_{i=1}^{p} \alpha_{2i} \Delta gdp_{t-i} + \sum_{i=1}^{p} \beta_{2i} \Delta ur_{t-i} \quad (9)$$

Where the indicator functions for the TAR and MTAR model specifications are represented by $I._t$ and $M._t$ respectively. Through the above described systems of error correction models, two types of joint hypotheses can be tested. Firstly, the presence of asymmetries between the variables could initially be examined by examining the signs on the coefficients of the error correction terms. This involves testing the null hypothesis of H_{03}: $\lambda_{i2}\xi_{t-1} = \lambda_{i2}\xi_{t-1}$ against the alternative H_{13}: $\lambda_{i1}\xi_{t-1} \neq \lambda_{i2}\xi_{t-1}$. The second type of hypothesis tested is that of granger causality effects which relatively examines whether all $\Delta rgdp_{t-k}$ and Δur_{t-k} are statistically different from zero. In particular, the null hypothesis that ur_t does not lead to gdp_t can be denoted as: H_{04}: $\alpha_i = 0$, i=1, ..., k; whereas the null hypothesis that gdp_t does not lead to ur_t is: H_{05}: $\beta_i = 0$, i=1, ..., k. All aforementioned hypotheses are based on a standard F-test. Furthermore, three types of joint hypotheses can be formed from the TEC model. Firstly, granger causality tests can be implemented by testing whether all $\Delta rgdp_{t-k}$ and Δur_{t-k} are statistically different from zero based on a standard F-test and if the λ coefficients of the error correction are also significant.

5.4 EMPIRICAL ANALYSIS

5.4.1 Empirical Data and Unit Root Tests

The data used in the empirical analysis consists of the annual percentage change in the real gross domestic product which is gathered from the South African Reserve Bank (SARB) online database whereas the unemployment rate for all persons aged above 15 years of age is collected from various issues of the quarterly labour force surveys (QLFS) as complied by Statistics South Africa (STATSSA). Our empirical analysis uses quarterly adjusted data obtained for the periods extending from 2000 to 2014. The choice of our sample period and periodicity reflects the limitations in the availability of the time-series data on unemployment and economic growth for South Africa. Although it would be desirable to employ a longer span of data, the available data provides the advantage of avoiding the issue of potential structural breaks related to South Africa's political and structural reforms such as those experienced in 1994. Moreover, we take note that while our data is relatively short, it is, however, up-to-date and further eliminates them problem of data unreliability associate with the South African unemployment series before 2000. Further given that gross domestic product is available on a quarterly basis and the unemployment rate is limited to half-yearly data, we use cubic spline interpolation to convert the half-yearly unemployment data into quarterly data over the same time period.

As a part of our data construction, we introduce the de-trending methods used to extract the 'potential output' and 'unemployment gap' variables necessary to estimate the gap version of Okun's specification. The construction of these 'gap variables' is necessary since there exists no observable data on the trend components of the unemployment and output growth variables. Also taking into consideration that a majority of these de-trending techniques are not without scepticism, it is standard practice to apply a variety/different de-trending techniques to ensure robustness in the regressions analysis. Therefore in following along this course of reasoning, our study considers three alternative de-trending techniques, namely the Hodrick-Prescott (HP) filter; the Baxter-King (BK) filter and the Butterworth (BW) digital filter as respectively introduced by Hodrick and Prescott (1997), Baxter and King (1999); and Pollock (2000). The purpose of using these three de-trending techniques is to enable a robust analysis concerning the sensitivity of the estimated Okun's coefficient to the different choices of our gap variable estimates.

Before we can make analytical use of the collected time series variables, it is necessary to examine the integration properties of the time series variables through appropriate unit root tests. Given the nature as well as the span period of the data used in the study, it is advisable to account for structural breaks in the data when testing for unit roots. Since conventional unit root tests such as the augmented Dickey Fuller (ADF) and the Phillip and Perron (PP) tests will not suffice for detecting structural breaks, we opt to apply the Zivot and Andrews (1992) unit root test with one structural break existing under the alternative hypothesis of a stationary time series process. Pragmatically, Zivot and Andrews (1992) suggest that three models be used to test for unit roots in the time series data, namely, (a) the model which permits a one-time change in the level of the time series i.e.

$$\Delta x_t = a + \alpha x_{t-1} + \beta t + \lambda DU_t + \sum_{j=1}^{k} d_j \, \Delta x_{t-j} + \varepsilon_t \qquad (10)$$

(b) the model which permits a one-time change in the slope of the trend function of the time series i.e.

$$\Delta x_t = a + \alpha x_{t-1} + \beta t + \varphi DT_t + \sum_{j=1}^{k} d_j \, \Delta x_{t-j} + \varepsilon_t \qquad (11)$$

And, (c) the model which combines one-time changes in the level and slope of the trend function of the time series i.e.

$$\Delta x_t = a + \alpha x_{t-1} + \beta t + \lambda DU_t + \varphi DT_t + \sum_{j=1}^{k} d_j \, \Delta x_{t-j} + \varepsilon_t \tag{12}$$

From the unit root tests regressions (10) – (12), DU_t is a dummy indicator variable which accounts for the mean shift occurring at each possible break date (TB) while DT_t represents the trend shift variable. The indicator functions for the dummy variables are specified as follows:

$$DU_t = \begin{cases} 1, & if\ t > TB \\ 0, & otherwise \end{cases} \tag{13}$$

And

$$DT_t = \begin{cases} 1, & if\ t > TB \\ 0, & otherwise \end{cases} \tag{14}$$

Furthermore, from the unit root test regressions (10) – (12), the null hypothesis of a unit root with no structural break is tested as $\alpha = 0$, while the alternative hypothesis $\alpha < 0$, implies that the times series is a trend-stationary process with a one-time structural break. Since the break-point is unknown under the alternative hypothesis, Zivot and Andrews (1992) run regressions for all possible breakpoints and select the breakpoint as one which minimizes the one-sided t-statistic for testing $\underline{\alpha}$ (= α - 0) = 1. The empirical results of these tests as performed on economic growth and the unemployment rate as well as their breakpoint dates are reported in Table 15 below. The optimal lag length which is used to facilitate these tests are determined by the AIC information criterion and is found to be of value 2.

Table 15: Zivot and Andrews (1992) unit root tests on unemployment and economic growth

time series	t-statistic			breakpoint		
	intercept	trend	Both	intercept	trend	Both
rgdp	-4.11	-3.58	-4.28			
Δrgdp	-6.28***	-5.84***	-6.20***	2009:01	2001:03	2009:01
ur	-4.34	-4.66**	-4.05			
Δur	-6.10***	-5.74***	-6.15***	2002:04	2003:02	2002:04

Significance levels are given as follows: '***', '**' and '*' represent the 1 percent, 5percent and 10 percent significance levels respectively. The test statistics for first differences are reported in parentheses. The critical values for the Zivot and Andrews (1992) unit root tests inclusive of an intercept only are as follows: 1 percent: -5.34, 5 percent:-4.80 and 1 percent: -4.58; the critical values for the unit root test inclusive of a trend are as follows: 1 percent: -4.93, 5 percent: -4.42 and 1 percent: -4.11 whereas the critical values for the unit root test inclusive of a trend are as follows: 1 percent: -5.57, 5 percent: -5.08 and 1 percent: -4.82.

As is evident from Table 15, all the time series fail to reject the null hypothesis of a unit root and only retain stationarity in their first differences. An exception is warranted for the testing of a unit root in the unemployment series, when a trend is included in the testing regression of which we find that the series is stationary in its levels. However, this is more of an exception than a rule, since the remaining tests indicate that unemployment rate is indeed first difference stationary. Another thing worth noting from the unit root tests in Table 1 is that the various structural breaks detected in the time series correspond to the monetary policy shift towards inflation targeting in 2001-2002 as well as to the global financial crisis of 2007-2008 which lead to a period of worldwide depression. All in all, we can conclude that all utilized time series appear to be both nonlinear yet stationary processes in their first differences. Therefore, the results obtained from our preliminary unit root analysis paves the way for the threshold cointegration analysis which we conduct next.

5.4.2 Cointegration Analysis

Having investigated the integration properties of the unemployment and economic growth variables, we proceed to investigate threshold cointegration and error correction effects amongst the times series. However, prior to estimating any threshold models, we must first test a number of hypotheses to select which models best capture asymmetric behaviour in Okun's specification. To this end, we employ three threshold tests which have been previously discussed previously discussed. To recall, (1) we test for cointegration effects; (2) we test for threshold cointegration effects and (3) we test for threshold error correction effects. The results of these tests are reported in Table 2. In referring to these results, we find that at least one type of threshold model manages to reject all three hypotheses at least a 10 percent significance level for all variations of Okun's law. This is quite an encouraging result since it implies that the data displays at least one form of nonlinearity for each version of Okun's specification. Another interesting result is that the MTAR specification is most suitable for modelling nonlinear behaviour between unemployment and economic growth for South African data. The only exception holds for the CF filter estimates which favour a TAR model specification. Furthermore, all estimated versions of Okun's law unveil significant asymmetric cointegration behaviour only when output growth is placed as the dependent variable in the regression.

Table 16: Threshold cointegration and error correction tests for Okun's law in South Africa

Model	Dependent variable	Independent variable	TAR-TEC			MTAR-TEC		
			$H_0^{(1)}$	$H_0^{(2)}$	$H_0^{(3)}$	$H_0^{(1)}$	$H_0^{(2)}$	$H_0^{(3)}$
First differences	Δgdp_t	Δur_t	25.36 (0.00)***	4.10 (0.05)*	0.47 (0.50)	32.71 (0.00)***	9.16 (0.01)**	2.47 (0.13)*
	Δur_t	Δgdp_t	41.82 (0.00)***	0.68 (0.42)	0.01 (0.91)	50.82 (0.00)***	1.66 (0.21)	0.01 (0.95)
HP filter	gdp_t^c	ur_t^c	6.84 (0.01)**	1.07 (0.31)	0.66 (0.43)	6.15 (0.01)**	0.16 (0.69)	0.25 (0.62)
	ur_t^c	gdp_t^c	4.36 (0.02)*	0.22 (0.64)	2.78 (0.11)*	4.46 (0.02)*	1.19 (0.28)	0.49 (0.49)
BK filter	gdp_t^c	ur_t^c	28.51 (0.00)***	3.56 (0.07)*	2.94 (0.11)*	33.43 (0.00)***	6.70 (0.02)*	1.59 (0.23)
	ur_t^c	gdp_t^c	27.28 (0.00)***	0.01 (0.91)	0.23 (0.64)	32.79 (0.00)***	0.09 (0.76)	1.10 (0.32)
BW filter	gdp_t^c	ur_t^c	26.51 (0.00)***	4.34 (0.05)*	0.65 (0.43)	34.03 (0.00)***	9.29 (0.01)**	3.51 (0.08)*
	ur_t^c	gdp_t^c	54.27 (0.00)***	1.06 (0.31)	0.01 (0.94)	55.93 (0.00)***	0.96 (0.34)	0.66 (0.43)
			c-TAR-TEC			c-MTAR-TEC		
			$H_0^{(1)}$	$H_0^{(2)}$	$H_0^{(3)}$	$H_0^{(1)}$	$H_0^{(2)}$	$H_0^{(3)}$
First differences	Δgdp_t	Δur_t	29.08 (0.00)**	6.84 (0.02)*	0.79 (0.39)	32.75 (0.00)***	9.19 (0.01)**	2.78 (0.11)*
	Δur_t	Δgdp_t	42.23 (0.00)***	0.86 (0.36)	0.96 (0.34)	67.86 (0.00)***	8.18 (0.01)**	1.85 (0.19)
HP filter	gdp_t^c	ur_t^c	6.84 (0.01)**	1.06 (0.31)	0.01 (0.98)	10.04 (0.00)***	5.27 (0.03)*	3.75 (0.07)*
	ur_t^c	gdp_t^c	5.20 (0.01)*	1.47 (0.24)	3.64 (0.07)*	6.85 (0.01)*	4.81 (0.04)*	5.26 (0.03)**
BK filter	gdp_t^c	ur_t^c	28.74 (0.00)***	3.71 (0.07)*	1.08 (0.32)	33.91 (0.00)***	7.01 (0.01)*	1.82 (0.20)
	ur_t^c	gdp_t^c	27.71 (0.00)***	0.27 (0.61)	0.23 (0.64)	32.79 (0.00)***	0.09 (0.76)	1.10 (0.32)
BW filter	gdp_t^c	ur_t^c	32.08 (0.00)***	8.35 (0.01)**	1.27 (0.28)	33.28 (0.00)***	8.77 (0.01)**	2.22 (0.15)
	ur_t^c	gdp_t^c	56.83 (0.00)***	1.99 (0.17)	0.24 (0.63)	60.65 (0.00)***	2.58 (0.12)	0.44 (0.52)

Significance level codes: '***", '**' and '*' denote the 1%, 5% and 10% significance levels respectively.

In summing up the test results reported in Table 16, we can draw two broad conclusions thus far. Firstly, our analysis infers significant asymmetric behaviour between unemployment and economic growth for South African data. In this respect, our results adhere with those obtained in Geldenhuys and Marnikov (2007). However, in slightly differing from Geldenhuys and Marnikov (2007), we find smooth nonlinear adjustment behaviour in the data as opposed to an abrupt one. This result is expected since the otherwise abrupt nonlinearity is most suited for data containing structural break periods. Seeing that our data does not cover such periods, it therefore becomes reasonable that we detect smooth nonlinear behaviour among the data. Our second conclusion is that we establish economic growth as being the driving variable in the asymmetric relationship detected between the time series. This is worth observing since it serves as a guideline on how to estimate each of the selected threshold regressions. In our instance, we specify the MTAR models under the assumption that economic growth is regressed on the unemployment rate. This is ofcourse with the exception of the CF filter regression in which we model TAR nonlinearity and yet retain economic growth as the dependent variable in the regression. Our estimation results of the first difference model specifications are reported below in Table 3 whereas the results obtained for the gap model versions are reported in Table 17.

Table 17: Threshold cointegration and error correction estimates for Okun's first difference model specification

	MTAR-TEC		c-MTAR-TEC	
	Y	X	Y	X
	Δgdp	Δur	Δgdp	Δur
β_i	-0.09		-0.09	
	(0.00)***		(0.00)***	
$\rho_1 \xi_{t-1}$	-0.72		-0.72	
	(0.01)**		(0.01)**	
$\rho_2 \xi_{t-1}$	-1.76		-1.76	
	(0.00)***		(0.00)***	
τ	0		0.11	
$\Delta\Delta gdp_{t-k}^{+}$	-0.39	-1.18	-0.38	-1.26
	(0.47)	(0.31)	(0.47)	(0.27)
$\Delta\Delta gdp_{t-k}^{-}$	-0.30	-0.50	-0.29	-0.47
	(0.36)	(0.47)	(0.36)	(0.50)
$\Delta\Delta ur_{t-k}^{+}$	-0.04	-0.80	-0.04	-0.80
	(0.64)	(0.00)***	(0.66)	(0.00)***
$\Delta\Delta ur_{t-k}^{-}$	-0.09	-0.99	-0.09	-0.99
	(0.28)	(0.00)***	(0.29)	(0.00)***
$\lambda^{+} \xi_{t-1}$	0.21	2.39	0.19	2.53
	(0.83)	(0.27)	(0.85)	(0.23)
$\lambda^{-} \xi_{t-1}$	-1.82	-1.05	-1.81	-1.06
	(0.00)***	(0.14)*	(0.00)***	(0.13)*
R^2	0.80	0.86	0.80	0.85
DW	1.61	2.42	1.61	2.39
p-value	0.37	0.31	0.35	0.31
LB	0.31	0.55	0.27	0.59
JB	3.59	3.82	3.65	3.98

Significance level codes: '***", '**' and '*' denote the 1%, 5% and 10% significance levels respectively. DW and LB respective denote the Durbin Watson and Ljung-Box test statistics for autocorrelation whereas JB denotes the Jarque-Bera normality test of the residuals.

Starting with the results reported in Table 17 for first differences model, we take note of a long-run coefficient estimate of -0.09. Technically speaking, the magnitude of this coefficient estimate as obtained under both first difference models implies that a 1 percent decrease in the unemployment rate is associated with a -0.09 percent increase in productivity output. This result is seemingly plausible as it does not violate traditional theory of a negative unemployment-growth co-relationship as initially postulated by Okun (1962). Furthermore, the magnitude of this relationship is consistent with some of the Okun coefficient estimates obtained in previous studies. Among these previous studies are the works of Adanu (2005) who obtain a similar estimate of -0.09 for Alberta province in Canada; Villaverde and Maza (2009) who find a -0.08 estimate for a regional group of Spanish data and also Geldenhuys and Marnikov (2007) who obtain an estimate of -0.11 for South African data.

In moving on to examining the regime switching behaviour among the cointegration error terms, we firstly note that all threshold estimates are encouragingly close to zero in value. Moreover, the threshold error term estimates satisfy the convergence condition of error term stationarity i.e. $\rho_1, \rho_2 < 0$ and $(1-\rho_1)(1-\rho_2) < 1$. In further diagnosing these cointegration threshold error terms, we observe that negative deviations are eliminated quicker than positive ones. We can make such inference since the estimate of ρ_1 is of a lower absolute value in comparison to its ρ_2 counterpart. Notably, Harris and Silverstone (2001) make similar inferences in their study for both US and UK data. In addition, our estimates of the threshold error correction terms also bear a slight resemblance to those obtained in Harris and Silverstone (2001), in the sense of producing correct negative estimates in the lower regimes of the estimated models. However in differing from these authors, we are able to obtain significant values for the estimates of the threshold error correction terms and thus we can draw meaningful interpretations of the error correction coefficients. In this respect, we not only discover that the long-run error correction terms for both MTAR-TEC and c-MTAR-TEC models are almost identical in magnitude, but we more importantly note that the speed of adjustment in both models is quicker when there is a shock to economic growth as opposed to a shock to the unemployment rate. Meanwhile, we are only able to identify significant short-run effects for the lagged coefficients of the economic growth variable when shock has been induced on the unemployment rates, whilst we are find no short-run effects for shocks to economic growth variable.

Table 18: Threshold cointegration and error correction estimates for Okun's gap model specification

	HP FILTER				BK FILTER		BW FILTER	
	c-MTAR-TEC		c-MTAR-TEC		TAR-TEC		MTAR-TEC	
	Y	X	Y	X	Y	X	Y	X
	Δgdp	Δur	Δur	Δgdp	Δgdp	Δur	Δgdp	Δur
β_i	-0.2		-0.15		-0.09		-0.10	
	(0.02)**		(0.01)		(0.03)*		(0.01)**	
$\rho_1\xi_{t-1}$	-0.13		-0.88		-0.97		-0.73	
	(0.66)		(0.01)**		(0.01)**		(0.01)**	
$\rho_2\xi_{t-1}$	-0.98		-0.16		-1.68		-1.77	
	(0.00)***		(0.48)		(0.00)***		(0.00)***	
τ	-0.286		-1.747		0		0.254	
$\Delta\Delta gdp^{+}_{t-k}$	0.32	0.37	0.44	0.48	-0.30	-0.56	-0.32	-1.55
	(0.27)	(0.55)	(0.45)	(0.11)	(0.40)	(0.34)	(0.55)	(0.19)
$\Delta\Delta gdp^{-}_{t-k}$	0.32	-0.26	-1.09	-1.29	-1.22	0.32	-0.30	-0.30
	(0.61)	(0.84)	(0.10)*	(0.00)***	(0.05)*	(0.74)	(0.35)	(0.66)
$\Delta\Delta ur^{+}_{t-k}$	0.08	-1.07	-0.48	0.13	0.06	-1.14	-0.02	-0.78
	(0.63)	(0.00)***	(0.23)	(0.54)	(0.73)	(0.00)***	(0.82)	(0.00)***
$\Delta\Delta ur^{-}_{t-k}$	-0.09	-0.39	-0.48	-0.19	0.12	-0.36	-0.10	-0.99
	(0.42)	(0.14)	(0.07)*	(0.16)	(0.50)	(0.22)	(0.23)	(0.00)***
$\lambda^{+}\xi_{t-1}$	0.09	-1.63	-0.64	-0.05	-0.09	1.82	0.08	3.03
	(0.83)	(0.07)*	(0.03)	(0.73)	(0.91)	(0.19)	(0.94)	(.017)
$\lambda^{-}\xi_{t-1}$	-0.88	-0.53	0.12	0.18	-0.44	-1.54	-1.83	-1.16
	(0.07)*	(0.61)	(0.59)	(0.12)*	(0.57)	(0.24)	(0.00)***	(0.12)
R^2	0.54	0.57	0.61	0.50	0.46	0.80	0.80	0.85
DW	2.10	1.56	1.43	1.68	2.42	1.85	1.60	2.63
p-value	0.89	0.23	0.09	0.28	0.39	0.62	0.31	0.13
LB	0.54	0.62	0.25	0.18	0.50	0.58	0.23	0.44
JB	3.56	4.10	3.89	4.86	3.79	4.26	3.98	4.58

Significance level codes: '***", '**' and '*' denote the 1%, 5% and 10% significance levels respectively. DW and LB respective denote the Durbin Watson and Ljung-Box test statistics for autocorrelation whereas JB denotes the Jarque-Bera normality test of the residuals.

In diverting our attention to the empirical results of the estimated gap versions of Okun's law as reported in Table18, we generally observe that the regression estimates, more or less, bear close resemblance to those attained for the first difference models. For instance, the long-run regression coefficient obtained from the gap version models produce similarly negative estimates, albeit the magnitude of these estimates vary between 0.09 and 0.98 for the different de-trending methods employed. In further considering the absolute coefficient values of the threshold error terms formed by the long-run regressions, we note that the gap model estimates also bear similarities to those obtained for the first difference models. Specifically, we observe that the absolute values of p_1 are significantly higher when the unemployment rate is the driving variable, whilst the values of p_2 are higher when the unemployment rate is the dependent variable in the cointegration system. As previously explained, this result infers that negative shocks are eliminated quicker when economic growth is the driving variable, whereas positive shocks are eliminated quicker when the unemployment rate is the dependent variable.

However, after scrutinizing through the threshold error correction model estimates, we find the estimates from the gap models to be less encouraging. This especially becomes apparent when mainly considering the long-run error correction terms, from which we observe that only two models manage to produce negative and significant estimates i.e. the HP and BW filter specifications with economic growth placed as the driving variables in both models. Therefore, we are restricted to interpreting the error correction coefficient estimates solely for these two model specifications. In drawing inference from these estimates, we conclude equilibrium reverting behaviour over the business cycle for the HP filter model when a shock has been induced on either the economic growth or the unemployment variables. Similarly, for the BW filter estimates, long-run equilibrium reversions occur only in the event of a shock to economic growth. It is also interesting to find that for both cases of the first difference models, we obtain significant short-run coefficient estimates of the lagged unemployment variable when a shock has been induced on the unemployment rate. Thus we collectively observe a distinct pattern over the business cycle, in which the unemployment rate is a driving factor of equilibrium conversions over the short-run whilst economic growth is responsible for equilibrium adjustment over the long-run.

Having established various forms of threshold cointegration within Okun's law for the data implies that there must exist some form of causality between the variables in the granger sense. However, the direction of causality cannot be assumed a prior and thus should be investigated through a formal analysis. We are permitted to examine causality effects amongst the variables via a standard F-test. The construction of these tests has been adequately discussed in the previous section of the paper. Table 19 reports the results of the causal analysis. The most striking feature of our obtained results is that, in all cases save one, we are able to reject the null hypothesis of unemployment not causing output growth at conventional levels of significance. Conversely, we fail to reject the null hypothesis of economic growth not leading the unemployment rate. We have noted an exceptional case for the HP filter model with economic growth as the driving variable, in which we detect no causal effects within the data. In summing up these results, we can safely assume that our results depict unidirectional causality running from the unemployment rate to economic growth for the data as a whole. This result is plausible seeing that we have already established that economic growth is regressed as being the dependent on the unemployment rate but not vice versa.

Table 19: Granger causality tests for Okun's law in South Africa

Model		Y	X	H_{03}: Y→X	H_{03}: X→Y	Decision
First differences	MTAR-TEC	gdp	ur	1.11 (0.35)	34.71 (0.00)***	ur→gdp gdp ≠ ur
	c-MTAR-TEC	gdp	ur	1.19 (0.33)	35.24 (0.00)***	ur→gdp gdp ≠ ur
HP filter	c-MTAR-TEC	gdp	ur	0.65 (0.54)	0.36 (0.70)	gdp ≠ ur gdp ≠ ur
	c-MTAR-TEC	ur	gdp	3.97 (0.04)**	1.50 (0.25)	ur→gdp gdp ≠ ur
CF filter	c-TAR-TEC	gdp	ur	0.49 (0.62)	12.61 (0.00)***	ur→gdp gdp ≠ ur
BW filter	c-MTAR-TEC	gdp	ur	1.27 (0.31)	32.37 (0.00)***	ur→gdp gdp ≠ ur

Significance level codes: '***", '**' and '*' denote the 1%, 5% and 10% significance levels respectively. Definitions of notations: →, ↔ and ≠ represent unidirectional causality, bi-directional causality and no causality, respectively.

5.5 CONCLUSION

The goal of this paper was to examine nonlinear cointegration and causality effects in Okun's law for South African data dating between the periods of 2000 and 2013. This objective was facilitated through the use of MTAR modelling techniques. We favour this approach on the premise of allowing for unit root testing, cointegration analysis and causality analysis under a single, comprehensive framework. Moreover, our study differs from previous South African case studies as we are able to introduce nonlinearity in a strict cointegration sense. Having applied the MTAR framework to South African unemployment and economic growth data has produced a number of interesting policy considerations. First of all, in quantifying the long run correlation coefficient, we find negative Okun coefficients ranging from -0.09 to -0.20 for all estimated threshold models. Clearly, these observations have far reaching ramifications as they give rise to the intriguing possibility of a long run trade-off between unemployment and economic growth. However, the aforementioned observations are of limited policy value in absence of knowing the causal relations amongst the variables.

In examining the empirical results obtained from the causal analysis, we discover that during abrupt shocks to the economy there are no causal effects between the variables. This essentially means that in the event of sharp or anticipated shocks to the economy there is very little that policy intervention can do for long-run equilibrium restoration between unemployment and economic growth. However, during smooth shocks, unemployment granger causes economic growth thus allowing for direct labour policies to have an impact on output productivity. We substantiate these smooth shocks as carefully implemented and monitored policies directives which are aimed at narrowing the existing gap between the demand and supply within South African labour markets. Inclusive of such shocks are policy programmes aimed at improving the higher education system through intensifying further education and training (FET) programmes and the recently proposed 'target wage subsidy' programme which is intended to facilitate for the school-to-work transition within the youth population. We also note that under no circumstance does economic growth granger cause unemployment thus insinuating that policies aimed directly at improving economic growth such as foreign exchange policies would exert little or no influence on eradicating unemployment over the long run. This is particularly worth noting since it has been previously assumed that the stability of the exchange rate would lead to a direct improvement of employment growth in import-competitive and export-oriented sectors, especially the manufacturing sectors. Our study implies that, whilst these macro-policies may create a sustainable environment for improved economic growth, they are of little use with regards to directly eradicating unemployment. Therefore, the overall finding of uni-directional causality from unemployment to economic growth provides an adequate explanation for the 'job-less' growth pandemic experienced in South Africa over the last two decades or so.

In recent South African recession periods, unemployment has continued to rise despite economic growth seemingly returning to its previous long-run trend. Deriving from our study, there exists two rational explanations to this pandemic. Firstly, negative shocks to economic growth are eradicated quicker than negative shocks to unemployment. This implies that in the event of smooth shocks to output productivity, it should be expected that economic growth should return back to its long-run steady state at a quicker rate than its unemployment counterpart. Secondly, our general finding of causality running from unemployment to economic growth highlights the ineffectiveness of macroeconomic policies aimed at reducing unemployment through improved productivity growth. Specifically, our empirical estimates suggest that smooth unemployment shocks, in the form of structural labour policies, would help stabilize the structural and cyclical components of unemployment over both the short and the long run. Overall, we conclude that labour policies aimed at stabilizing and eradicating unemployment within the economy may be a panacea towards simultaneously reducing overall unemployment and boosting economic growth over the long run.

REFERENCES

Adanu K. (2005), "A cross-province comparison of Okun's coefficient for Canada", *Applied Economics*, Vol. 37, No. 5, pp. 561-570.

Ahmed K., Khali S. and Saeed A. (2011), “Does there exist Okun’s law in Pakistan?”, *International Journal of Humanities and Social Science*, Vol. 1, No. 12, pp. 293-299.

Arabaci R. and Arabaci O. (2010), “Asymmetries in Okun’s law: Evidence from Turkey”, Industrial Relations in Europe Conference (IREC), Olso, Norway.

Barreto H. and Howland F. (1993), “There are two Okun’s law relationships between output and unemployment”, Working Paper, Wabash College.

Baxter M. and King R. (1999), “Approximate band-pass filter for economic time series”, *The Review of Economics and Statistics*, Vol. 81, No. 4, pp. 575-593.

Beccarini and Gros D. (2008), “At what cost price stability? New evidence about the Phillips curve in Europe and the United States”, *CEPS Working Document No. 302*, September.

Blake N. and Fomby T. (1997), “Threshold cointegration”, *International Economic Review*, Vol. 38, pp. 627-645.

Burger P. and Marinkov M. (2006), “The South African Phillips curve: How applicable is the Gordon model?”, *South African Journal of Economics*, Vol. 74, No. 2, pp. 172-189.

Campbell J. and Fischer J. (2000), “Aggregate employment fluctuations with micro-economic asymmetries”, *American Economic Review*, Vol. 90, pp. 1325-1345.

Caner M. and Hansen B. (2001), “Threhsold autoregression with a unit root”, *Econometrica*, Vol. 69, No. 6, 1555-1596.

Caraiani P. (2010), “Bayesian linear estimation of Okun coefficient for Romania: Sensitivity to prior distributions”, *The Romanian Economic Journal*, Vol. 13, No. 38, pp. 53-65.

Courtney H. (1991), “The Beveridge curve and Okun’s law: a re-examination of fundamental relationships in the United States”, PhD Thesis, MIT.

Crespo-Cauresma J. (2003), “Revisiting Okun’s law: a piecewise-linear approach”, *Oxford Bulletin of Economics and Statistics*, Vol. 65, pp. 439-451.

Dixon R. and Shepard D. (2002), “Economic growth and unemployment in Europe”, *European Business Journal*, Vol. 12, No. 4, pp. 185-198.

Enders W. and Dibooglu S. (2001), “Long-run purchasing power parity with asymmetric adjustment”, *Southern Economic Journal*, Vol. 68, No. 2, pp. 433-445.

Enders W. and Granger C. (1998), “Unit-root tests and asymmetric adjustment with an example using the term structure of interest rates”, *Journal of Business and Economic Statistics*, Vol. 16, No. 3, pp. 304-311.

Enders W. and Silkos P. (2001), “Cointegration and threshold adjustment”, *Journal of Business and Economic Studies*, Vol. 19, No. 2, pp. 166-176.

Engle R. and Granger C. (1987), “Cointegration and error correction representation, estimation and testing”, *Econometrica*, Vol. 55, pp. 521-276.

Fernandez R. and Simes H. (2006),”Fulfillment of Okun’s law in the city of Posadas, Argentina, using dynamic models”, *Vision de Futuro (RevistaCientifica)*, Vol. 3, No. 6, July.

Freeman D. (2000), “A regional test of Okun’s law”, *International Advances in Economic Research*, Vol. 6, pp. 557-570.

Geldenhuys J. and Marnikov M. (2007), “Cyclical unemployment and cyclical output: An estimation of Okun’s coefficient for South Africa”, *South African Journal of Economics*, Vol. 75, No. 3, pp. 373-390.

Gupta R. and Uliwingiye J. (2010), “Dynamic time inconsistency and the South African Reserve Bank”, *South African Journal of Economics*, Vol. 78, No. 1, pp. 76-88.

Hansen B. (1997), "Inference in TAR models", *Studies in Nonlinear Dynamics and Econometrics*, Vol. 2, pp. 1-14.

Harris R. and Silverstone B. (2001), "Testing for asymmetry in Okun's law: A cross-country comparison" *Economics Bulletin*, Vol. 5, No. 2, pp. 1-13.

Hodge D. (2009), "Inflation, unemployment and economic growth in South Africa", *South African Journal of Economics,* Vol. 77, No. 4, pp. 488-504.

Hodrick R. And Prescott E. (1997), "Postwar US business cycle: An empirical investigation", *Journal of Money, Banking and Credit*, Vol. 29, No. 1, pp. 1-16.

Holmes M. and Silverstone B. (2005), "Okun's law, asymmetries and jobless recoveries in the United States: A Markov-Switching approach", University of Waikato, *Department of Economic Working Paper No. 6/05,* December.

Keynes J. (1936), "The general theory of employment, money and interest", London, Macmillan.

Kosfeld R. And Dreger C. (2004), "Thresholds for employment and unemployment: A spatial analysis of German regional labour markets 1992-2002", University of Kasel, Department of Economics Working Paper No. 52/2004.

Knotek E. (2007), "How useful is Okun's law?" *Federal Reserve Bank of Kansas City Economic Review*, Issue Q IV, pp. 73-103.

Lal I., Muhammad S., Jalil A. and Hussian A. (2010), "Test of Okun's law in some Asian countries: Cointegration approach", *European Journal of Scientific Research*", Vol. 40, No. 1, pp. 73-80.

Lang D. and C. de Peretti (2009), "A strong hysteresis model for Okun's law: Theory and preliminary investigation", International Review of Applied Economics, 23 (4), 445-462.

Lee J. (2000), “The robustness of Okun’s law: Evidence from OECD countries”, Journal of Macroeconomics, Vol. 22, No. 2, pp. 331-356.

Mayes D. and Viren M. (2002), “Asymmetry and the problem of aggregation in the Euro area”, *Empirica*, Vol. 29, No. 1, pp. 47-73.

Moosa I. (1997), “A cross country comparison of Okun’s coefficient”, *Journal of Comparative Economics*, Vol. 24, pp. 335-356.

Noor Z., Nor N. and Ghani J. (2007), “The relationship between output and unemployment in Malaysia: Does Okun’s law exist”, *International Journal of Economics and Management*, Vol. 1, No. 3, pp. 337-344.

Okun A. (1962), “Potential GNP: Its measurement and its significance”, *American Statistical Association, Proceedings of the Business and Economics Section*, pp. 98-103.

Palley T. (1993), “Okun’s law and the asymmetric and changing behavior of the USA economy”, *International Review of Applied Economics*, Vol. 7, No. 2, 144-162.

Pereira E., Bento C. and Silva R. (2009), “Cointegration and asymmetric adjustment between output and unemployment”, University of Aveiro, *Department of Economics, Management and Industrial Engineering Working Paper No. 52/2009*.

Pollock D. (2000), “Trend estimation and de-trending via rational square-waves filters”, *Journal of Econometrics*, Vol. 99, pp. 317-334.

Silvapulle P., Moosa I. and Silvapulle M. (2004), “Asymmetry in Okun’s law”, *The Canadian Journal of Economics*, Vol. 37, No. 2, pp. 353-374.

Terasvirta T. and Anderson H. (1992), “Characterizing nonlinearities in business cycle using smooth transition autoregressive models”, Journal of Applied Econometrics, Vol. 7, pp. 119-136.

Turturean I. (2007), “Okun’s law for Romania during 1992-2004”, *MPRA Working Paper No. 10638*, October.

Villaverde J. and Maza A. (2009), “The robustness of Okun’s law in Spain, 1980-2004 regional evidence”, *Journal of Policy Modeling*, Vol. 31, pp. 289-297.

Viren M. (2001), “The Okun curve is nonlinear”, *Economic Letters*, Vol. 70, pp. 253-257.

Weber C. and West J. (1996), “Functional form I regression models of Okun’s law” *Applied Economics Letters*, Vol. 3, pp. 607-609.

Zivot E. and Andrews K. (1992), “Further evidence on the great crash, the oil price shock and the unit root hypothesis”, *Journal of Business and Economic Studies*, Vol. 10, No. 10, pp. 251-270.

CHAPTER 6: SUMMARY AND CONCLUSION OF THE THESIS

6.1 INTRODUCTION

The main objective of the current thesis is to determine whether there is an optimal level of inflation at which (1) monetary authorities can effectively and efficiently control; (2) maximize economic growth (or minimize the economic growth losses); and (3) minimize unemployment rates. The thesis specifically addresses these concerns by making use of nonlinear estimation techniques, in particular, regime switching econometric analysis. The main advantage of using regime switching models over other model alternatives lies in the depth of analytical interpretation of empirical estimations. For instance, Hodge (2006) makes use of simple ordinary least squares (OLS) analysis to establish a negative relationship between inflation and economic growth. However, given the analytical limitations of the empirical analysis, the author is unable to answer the fundamental question, as to how low of an inflation rate is beneficial towards economic growth. Similarly, Rangasamy (2009) uses an autoregressive (AR) framework to establish that the inflation process within the South African economy has become less persistent subsequent to the adoption of the inflation target mandate, but ultimately fails to address the concern as to what precise rate of inflation produces the lowest levels of persistence. Using a vector error correction (VECM) analysis, Mithcell-Innes et. al. (2007) also discover that inflation expectations and nominal interest rates move in the same direction over the long-run but fail to indicate whether this relationship holds at all levels of inflation. Therefore, using regime switching econometric analysis the objective of the current thesis is to provide answers to these deeper policy questions and in doing so, the thesis has been written as four independent research articles, with a common theme of investigating asymmetric effects in monetary aggregates which are linked to desirable macroeconomic objectives within the South African macroeconomy.

6.2 SUMMARY

In the first article, the research was dedicated towards evaluating threshold effects in the persistence levels of South African aggregated and disaggregated inflation measures. The empirical analysis provides an insight with relevance to the performance of inflation subsequent to the adoption of the inflation target regime in South Africa. Of particular interest are the low persistence levels observed at inflation rates below 4.7 and 4.4 percent for core and CPI inflation, respectively, as both these aggregated measures of inflation play an essential role in guiding monetary policy conduct within the economy. The overall findings of this article imply that on an aggregate level, the SARB's current inflation target of 3 to 6 percent encompasses a non-stationary inflation range and thus proves to be too restrictive for monetary policy conduct.

In the second article we investigated asymmetries in the relationship between inflation and interest rates (i.e. Fisher's (1907) hypothesis) for South Africa. Two objectives were achieved in doing so; those being, (1) producing results which improve on those obtained in preceding studies for South Africa, in the sense of closely emulating the original hypothesis as presented in Fisher (1907); and (2) identifying a range in which in the difference between nominal interest rates and inflation rates (i.e. real interest rates) renders the Fisher effect as being invalid. With regards to this latter point, we are able to establish that when the difference between nominal interest rates and inflation rates lies between 0.10 and 4.92 percent in the long-run, then Fisher's relation does not hold. Collectively, these results imply that the introduction of a negative interest rate policy by the Reserve Bank may suffice for maintaining effective control over the inflation rate over the long-run.

The third article investigates bivariate threshold effect between inflation and economic growth in South Africa, post-inflation targeting era. As a by-product of this empirical exercise, we are able to evaluate as to whether the Reserve Bank's inflation target of 3 to 6 per cent is compatible with the 6 per cent economic growth objective set by macro-economic strategies like the NDP. The results obtained in this research article present a two-fold proposition. Firstly, for the performance of economic growth to improve so it coincides with the 6 percent objective, may require sustaining an inflation rate below 3.08 per cent. Secondly, given the current economic environment with inflation averages above 3.08 per cent and economic growth rates below 5.58 per cent, lower inflation rates are best pursued through the attainment of higher economic growth rates. Consequentially, the article offers support in favour of a lower, 'close-to-zero' inflation target as a means of ensuring improved macroeconomic performance within the economy, while simultaneously contending that it would prove beneficial for stabilization economic policies to be devised such that these low levels of inflation are attained through higher economic growth rates.

The final research article undertook an examination of asymmetric co-integration adjustment in the relationship between unemployment and economic growth (i.e. Okun's law) for South Africa. Contrary to conventional theory, the results showed that, while the time series variables are indeed asymmetrically cointegrated, unemployment granger causes economic growth in the long-run, a result which may account for the job-less growth pandemic experienced in South Africa over the last decade or so. Therefore, the obtained results from this particular article have two important implications for policy conduct. Firstly, the empirical analysis proves that increase in economic growth in the long run may not cause a decrease in the unemployment rate yet a decrease in unemployment will lead to increases in output growth. Secondly, these results further highlight the importance of labour market policies in improving economic growth in South Africa as opposed to policy authorities depending on higher economic growth to be the driving force behind reducing unemployment rates.

6.3 RECOMMENDATIONS

Overall, this thesis has contributed to policy debate on the efficiency and effectiveness of the inflation targeting regime from a number of perspectives. Firstly, we observe that the optimal inflation rate lies below that of the current inflation target mandate of 3 to 6 percent. Secondly, in immediately pursuing these low rates of inflation, it is best that policymakers make use of other macroeconomic policy strategies as opposed to the aggressive use of interest rates. Thirdly, in the event that inflation rates can be kept at low, close-to-zero percentage points accompanied by high economic growth rates above 6 percent, then it would be advisable for the South African Reserve Bank to follow in pursuit of other Central Banks in developed economies (e.g. European Central Bank), by adopting a low-to-negative interest rate policy. Lastly, in evaluating which policies would best lead to higher economic growth rates, the thesis concludes that policy conduct in South Africa should place more emphasis on labour market strategies or on fiscal policies on larger platform. A greater focus on labour market and other structural-related policies would then lead to higher economic growth rates; which, in turn, would ultimately lead to lower rates of inflation thus creating a stable financial environment. Thereafter, policymakers can then directly focus on striving to keep inflation rates at low levels through interest rate manipulation. As a natural development of the research presented in this current thesis, it would be worthwhile to extend future empirical research efforts into investigating monetary policy channels through which unemployment could ultimately affect economic growth as well as the deigning an associated monetary policy function which could be best suited to invoking such monetary policy transmission mechanisms.

RERENCES

Hodge D. (2006), "Inflation and growth in South Africa", *Cambridge Journal of Economics*, 30, 163-180.

Mitchell-Innes, H., Aziakpono, M. and A. Faure (2007), "Inflation targeting and the Fisher effect in South Africa: An empirical investigation", South African Journal of Economics, 75, 693-707.

Rangasamy L. (2009), “Inflation persistence and core inflation: The case of South Africa”, *South African Journal of Economics*, 77(3), 430-444.