UNIVERSITY OF KWAZULU-NATAL

Residential property as a hedge against inflation in South Africa

By

Nikita Ramsaran

216007988

A dissertation submitted in fulfilment of the requirements for the degree of Master of Commerce (Finance)

School of Accounting, Economics and Finance

College of Law and Management Studies

Supervisor: Dr Peter Moores-Pitt

2021

DECLARATION

I, Nikita Ramsaran, declare that:

(i) The research reported in this dissertation/thesis, except where otherwise indicated, is my original research.

(ii) This dissertation/thesis has not been submitted for any degree or examination at any other university.

(iii) This dissertation/thesis does not contain other persons' data, pictures, graphs or other information, unless specifically acknowledged as being sourced from other persons.

(iv) This dissertation/thesis does not contain other persons' writing, unless specifically acknowledged as being sourced from other researchers. Where other written sources have been quoted, then:

a) their words have been re-written but the general information attributed to them has been referenced;

b) where their exact words have been used, their writing has been placed inside quotation marks, and referenced.

(v) Where I have reproduced a publication of which I am author, co-author or editor, I have indicated in detail which part of the publication was written by myself alone and have fully referenced such publications.

(vi) This dissertation/thesis does not contain text, graphics or tables copied and pasted from the Internet, unless specifically acknowledged, and the source being detailed in the dissertation/thesis and in the References sections.

ACKNOWLEGEMENTS

"When you want something, all the universe conspires in helping you to achieve it" – Paulo Coelho

I would like to extend my gratitude to the following individuals, as without their assistance and support, this dissertation would not have been possible.

Firstly, to my supervisor, Peter Moores-Pitt, thank you for your time, consistent guidance and understanding throughout this entire writing process.

Secondly, to my mother, who provided me the opportunity to complete my research and supported me through this journey. No words can truly express my appreciation for all that you have done for me. I am eternally grateful for your presence in my life, you are my pillar of strength.

Thirdly, to Shivek, for getting me through the hardest parts and being there for me every step of this journey. Thank you for always going above and beyond for me. I am forever grateful for you.

Lastly, this dissertation is dedicated in memory of my father.

ABSTRACT

The empirical evidence regarding the magnitude of the relationship between inflation and residential property has had conflicting results. Although the issue of inflation-hedging has been discussed by multiple authors, the results have been inconsistent with regard to the ability of property to act as a hedge against inflation. This topic has been explored largely in an international context, with limited studies on South African grounds. Over the years the topic of inflation-hedging has been examined using multiple cointegration techniques, which have been adapted over the years to accommodate various limitations. The conventional Autoregressive Distributive Lag (ARDL) model has been a solid model for the purpose of this topic as it has proven to have various advantages over other models. However, this model assumes linearity and symmetry with regard to the relationship. In order to overcome the limitations of this model, the Nonlinear Autoregressive Distributive Lag (NARDL) model was developed, as it accounts for possible asymmetric adjustment. Both these models were employed for the purpose of this study with the intent of determining whether the relationship between the variables is nonlinear and asymmetric. This study utilized quarterly data for a 30-year time period from 1989-2019, a period which was extremely relevant in the context of South African history, because of the transition period from the apartheid regime. The data chosen for the inflation rate is represented by the consumer price index (CPI) and housing prices was represented by both the housing price index (HPI), as well as segmented housing prices. The results from this study confirmed that property is able to hedge against inflation, with strong evidence supporting the existence of an asymmetric relationship between the variables. All segments were confirmed to effectively hedge against inflation, with only the affordable segment being a partial hedge for the purpose of the NARDL model. Evidence of asymmetry was confirmed, indicating that when inflation increases, housing prices increase at a rate greater than unity. However, in periods of decreasing inflation, the increase in absolute value is far greater. Investors can, therefore, profit off investing in property during all inflationary periods, and generate greater wealth in periods of decreased inflation.

Keywords: Inflation-hedging, residential property, asymmetric adjustment and nonlinearity

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS

ABSA :	Amalgamated Bank of South Africa
ADF :	Augmented Dickey-Fuller
AIC :	Akaike Information Criterion
AR :	Autoregressive
ARDL :	Autoregressive Distributive Lag
ARMA:	Autoregressive Moving Average
CAPM :	Capital Asset Pricing Model
CLT :	Central Limit Theorem
CMBS :	Commercial Mortgage-Backed Securities
CPI :	Consumer Price Index
DS :	Difference stationary
ECM :	Error Correction Model
ECT :	Error Correction Term
GDP :	Gross Domestic Product
H0 :	Null Hypothesis
H1 :	Alternative Hypothesis
HPI :	Housing Price Index
HQIC :	Hannan and Quinn Information Criterion
KPSS :	Kwiatkowski-Phillips-Schmidt-Shin
LR :	Likelihood Ratio
NARDL:	Nonlinear Autoregressive Distributive Lag
OLS :	Ordinary Least Squares
PP :	Phillips-Perron
REIT :	Real Estate Investment Trusts
SARB :	South African Reserve Bank
SIC :	Schwarz Information Criterion
SPSM :	Sequential Panel Selection Method
STATSSA:	Statistics South Africa
TS :	Trend Stationary

UECM	:	Unrestricted Error Correction Model
UK	:	United Kingdom
USA	:	United States of America
VAR	:	Vector Autoregressive
VEC	:	Vector Error Correction
VECM	:	Vector Error Correction Model

CHAPTER 1: INTRODUCTION AND BACKGROUND

"Invest in inflation. It is the only thing going up." – Will Rogers

1.1 Overview

Inflation is defined as the general increase in the average price level, which results in a decrease in the purchasing power of the consumer (Chen, 2019). Inflation erodes the real value of money and has become a key concern for investors as it has the ability to erode the real returns from their investments (Rubens, Bond, and Webb, 1989). It is, therefore, of the utmost importance to be able to identify an inflationary hedge in order to effectively protect the wealth of an investor against the adverse effects of inflation (Rubens *et al.,* 1989). An investor will, therefore, seek out investment opportunities that protect their currency from the loss of value, in addition to the decrease in purchasing power that takes place due to the increase in prices. Long-term investors are continually looking to maintain their purchasing power when deciding on assets to invest in (Le Long, De Ceuster, Annaert and Amonhaemanon, 2013). Assets that are able to safeguard investors from the loss of wealth due to inflation are known as inflation hedges (Rubens *et al.,* 1989).

The three primary categories of hedging mechanisms include minerals, equities, and real estate (Smith, 2019). The two former categories have been assessed in literature. Kim and Ryoo (2011) examined common stocks as a hedge against inflation, and Van Hoang, Lahiani, and Heller (2016) studied the use of gold as a hedge against inflation. Residential property is widely recognised as a powerful investment asset as it generally increases in value over time (Aqsha and Masih, 2018). From the perspective of an investor, property can be seen as an excellent investment opportunity, as well as a tool to use as a hedge against inflation (Van Staden, 2016). This can be achieved by examining the magnitude of the relationship between inflation and housing prices over time (Van Staden, 2016).

1.2 Background to the research problem

Inflation is a significant problem in South Africa, as it has had many detrimental effects on the economy. This is evident due to the decrease in purchasing power, as well as the reduction in returns of investments faced by investors (Rubens *et al.*, 1989). This is the reason why it has become such a key topic in literature. In order to avoid a loss in wealth, investors have a motive to find a way to protect against the detrimental effects of inflation (Munyeka, 2014). South Africa represents a perfect natural experiment for this type of analysis due to the exceptionally high historical volatility, which has an inflation rate ranged from almost 0% to just under 20% over the period of this study (Plecher, 2019). For that reason, the need to identify an inflationary hedge arose. Investors need to consider that certain investment options are subject to decreases in the real returns that are caused by inflation. This is an important factor to consider as countries that experience high rates of inflation, such as South Africa, result in more detrimental effects on the real value of investments. This is a reason why South Africa presented an environment for this type of study, as the rates of inflation are relatively higher than that of American and European countries. Inflation-hedging has become of great importance not only for the private investors, who view inflation as a direct threat to their investment's purchasing power but also a risk to pension funds, due to the pension payments being fixed to consumer prices (Arnold and Auer, 2015).

The increasing of the inflation rate is one of the major fears for investors due to the reduction of the real returns on their investments (Schotman and Schweitzer, 2000). Investments in certain asset classes have a tendency to lose their purchasing power due to inflation. Hence, the investment decreases in value as inflation increases (Okereke, 2019). As with any of the risks within the financial market, an investor would attempt to limit the risk exposure through the adjustment of the asset composition in the portfolio (Schotman and Schweitzer, 2000). Investors will pursue investment options that have the ability to act as a hedging mechanism and, therefore, will form a protection for their funds. Related assets, such as minerals and equities, have been known to provide a suitable hedge against the effects of inflation (Smith, 2019). Direct property investment can attend to the need of the consumer to own a house, in addition to the investor, who wishes to guard their investment against the effects of inflation (Aqsha and Masih, 2018). The viewpoint that inflation is one of the main concerns of both researchers and investors originated at the peak of American inflation, which occurred in the 1970s and is just as pertinent today (Arnold and Auer, 2015). Inflation forecasts now specify new price level increases are fuelled by higher food and energy costs, which result from a reverse of current influences, such as depressed oil prices (Arnold and Auer, 2015).

Property investment plays a crucial part in expressing the political, social, and economic situations of a society. This, therefore, represents a persuasive prospect for investors who aim to create income that is sustainable from viable investment options (Okereke, 2019). Due to the negative effects that inflation has on the future consumption of the majority of economic agents, most agents attempt to protect their future wealth stream through investing in assets that yield a nominal return. This return should be higher than the inflation rate (Demary and Voigtländer, 2009). The returns of assets and the inflation rate are constantly fluctuating over time, which makes it insufficient to compare the current asset return with the current rate of inflation. For hedging purposes, an asset should be able to yield, on average a higher return than that of the inflation rate (Demary and Voigtländer, 2009). The housing sector is known to provide many long-term benefits through diversification, healthy income benefits, as well as a hedge against inflation (Okereke, 2019). An asset can be classified as a hedge if it is able to provide a certain degree of immunization (or protection) against inflation over a specified timeframe (Fama and Schwert, 1977).

The types of inflation-hedging assets can be classified into two groups, namely soft and hard assets (Rohlfs, 2020). Soft assets are assets that include bonds and stocks, and these assets have the ability to hold their intrinsic value. Hard or real assets comprise of precious metals, commodities, and real estate. This intrinsic value is what allows these investment assets to hedge against increases in inflation. An asset is able to hold its intrinsic value if it is scarce or naturally limited in supply, as well as if it can be utilized to buy or produce goods or services that serve a fundamental human need i.e., in demand (Rohlfs, 2020). Examples of this include diamonds, gold, and oil, as they can all be used to buy and to produce goods and services. However, the value of actual paper money can be devalued and also cannot be used to produce a product that serves an essential need. Assets such as real estate, whether it be through land or physical structures, are able to serve basic needs and are naturally limited in terms of their supply (Rohlfs, 2020). Hard assets are known to have a low correlation with various stocks and bonds, which makes them able to contribute to the diversification of an investment portfolio. Real estate is a distinctive hard asset because, unlike the other types of hard assets, real estate has the ability to earn income while simultaneously hedging against inflation (Rohlfs, 2020).

There are different types of inflation-hedges that the investment can be classified as. Certain asset classes are able to offer a partial hedge against inflation, which implies that the response of the investment is either lower than required or that they sometimes respond, and sometimes do not (Leung, 2010). There are also asset classes that are known as a complete hedge, which is at the same rate as required, or an effective hedge, which is greater than required. Furthermore, certain asset classes also provide no hedge against inflation, or a perverse hedge, which refers to returns that are opposite to that required (Leung, 2010). This study, therefore, aims to determine whether residential property is an effective hedge against inflation.

Essentially, if by investing in property, an investor is able to gain a return that is greater than that of the inflation rate.

Theoretically, at face value, one might expect property to be a natural hedge as the value is based on a fixed underlying asset. This can be explained by looking at the value of a building, which can be leased out to a tenant at a fixed rent, without considering costs such as maintenance, utilities and taxes (Goetzmann and Volaitis, 2006). These costs are adversely affected by inflationary shocks. However, if a building is leased net of maintenance, utilities, and taxes, with contractual rent increases that are tied to inflation increases, a property may represent an excellent hedge against inflation (Goetzmann and Volaitis, 2006). This is motivated by Graff and Cashden (1990), who stated that real estate returns should be decomposed into capital appreciation and income components with different inflation exposures. Ultimately, the question of whether residential property is an effective hedge against inflation is an empirical one, and it depends on the data that is available for testing (Goetzmann and Volaitis, 2006). Furthermore, this topic has been tested using multiple estimation techniques, which are mentioned below. The models utilized for interpreting the relationship between the variables play an important role due to certain models having limitations that need to be accounted for in order to determine the most reliable and accurate results.

The relationship between interest rates and inflation has been examined in literature. The notion is if the ex-ante real interest rate is assumed to be constant, the individuals will require a nominal rate that will have the ability to provide adequate compensation (Alagidede and Panagiotidis, 2010). This will be a compensation for the marginal utility of the foregone current consumption, which is measured by the real rate, as well as the reduction in the purchasing power of the money. This notion infers that the nominal interest rate moves on a one-for-one basis with the inflation rate. Hence, if there is a permanent change in the inflation rate, it will have no long-run impacts on the real interest rate (Alagidede and Panagiotidis, 2010). This is known as the Fisher (1930) hypothesis. This hypothesis laid the foundation for the topic of inflation-hedging. Fisher (1930) concluded that the expected nominal return on an investment includes an expected return and the expected inflation rate. This implies that when the expected inflation increases, the expected return on the investment will also increase. Fama and Schwert's (1977) regression model is an empirical test of Fisher's hypothesis and is the most extensively utilized model used for evaluating the inflation-hedging characteristics of an asset. This model became the theoretical framework for research on the relationship between asset returns and inflation (Fama and Schwert, 1977).

However, in the more recent studies, such as the study by Dabara (2015), the author noticed that Fama and Schwert's (1977) model was examined without the use of an initial stationary test. This could, therefore, lead to spurious regression results within the analysis of the data. The need for an initial stationary test to be conducted on the data series would avoid the use of spurious regression results. Hence, it is necessary to utilize a model that has the ability to account for both stationary and non-stationary data. Cointegration models become more suitable for examining the inflation-hedging capabilities of assets providing non-stationary data series (Dabara, 2015). Granger (1988) introduced the concept of cointegration as a multivariate problem that is extremely relevant to the issue of determining whether a long-run relationship is present within variables, a long-run relationship, statistically speaking, infers that the variables in a model move together over time (Granger, 1988). Essentially, the short-term disturbances that arise from the long-term trend are said to be correlated. Therefore, if the difference between the two non-stationary series is proven to be stationary, it can be concluded that the two series are cointegrated, and hence, the variables have a long-run relationship (Granger, 1988). The autoregressive distributive lag (ARDL) model has been utilized as a cointegration model for the purpose of examining inflation hedging. This model has been advantageous due to its ability to estimate the cointegrating relationship as well as account for variables that are potentially integrated of different orders.

1.3 Problem statement

Previous studies on the inflation-hedging capabilities of housing in the literature, such as Anari and Kolari (2002) and Lee (2012), have considered the relationship between the variables as symmetric and linear. This study challenges the assumption of linear adjustment in previous literature, by considering asymmetric adjustment. The topic of property as a hedge against inflation has been established from an asymmetric perspective in South African literature by Taderera and Akinsomi (2020). However, this article examined commercial real estate as a hedge against inflation, which differs from the contribution of residential real estate. The nonlinear autoregressive distributive lag (NARDL) model allows for the estimation of both long and short-run asymmetries. This model differentiates between the negative and positive partial sum decompositions (Shin *et al.*, 2014). The regression analysis results will enable a conclusion to be drawn on the relationship between residential property and inflation. The magnitude of the relationship between inflation and residential property is represented by the beta coefficients, which are calculated during the regression analysis of the NARDL model (Shin *et al.*, 2014). By using the most recent and accurate econometric models, it allowed for a more sound understanding of the relationship between the variables. This is beneficial for investors as this understanding allows for more precise hedging, which will lead to better-quality returns on investments and increased profitability.

Inflation can have a substantial effect on the risk-return profile of the investments. Hence, investors should be kept up-to-date with reliable and necessary information regarding inflation in relation to their assets (Dabara, 2015). This will enable individuals to make informed decisions regarding their investments. Previous research in both developed and developing economies have studied the inflation-hedging performance of property in the form of direct and indirect investments in real estate. The results from the inflation-hedging performance of real estate have shown varying results across the different types of real estate (residential, commercial, and industrial) as well as inflation types (expected, unexpected, and actual) even within the same country (Dabara, 2015). However, this study looks specifically at the inflation-hedging performance of residential real estate.

1.4 Research objectives

The objective of a property investment is to capitalize on the investment by letting inflation make the property increase in value. This is done through capital appreciation of property (Ibrahim, Sundarasen, and Shayuti, 2009). Therefore, the main research objective for the purpose of this study lies within the inflation-hedging characteristics of residential property in South Africa. This is for the time period of 30 years from 1989 to 2019. The hedging properties was analysed on average with the housing price index and with respect to the different housing price segments.

The primary objective of this study was:

- Determining whether residential property in South Africa was able to hedge against the effects of inflation.

With the purpose of determining the primary objective, further objectives of this study include:

- Determining whether the relationship between the variables exhibited evidence of asymmetry.
- Examining exactly which of the South African housing segments had the most effective inflation-hedging capabilities.

1.5 Research questions and hypothesis

There are three core research questions that will be answered by this study:

1. Does South African residential property hedge against inflation in the long-run?
2. Does the relationship exhibit evidence of asymmetric adjustment?
3. Do each of the housing segments in South Africa (affordable, middle, and luxury) behave differently with regard to their inflation-hedging properties?

These research questions will be answered as follows:

1. Does South African residential property hedge against inflation in the long-run?

This study's first objective is to conduct a two-variable (bivariate) Autoregressive distributive lag (ARDL) model as a benchmark model for comparative purposes. The ARDL bounds test is utilized to examine the long-run relationship between variables (Nkoro and Uko, 2016). This type of test uses an F-statistic, which is the standard statistics used for testing for the significance of the variables. This statistic is then compared to the asymptotic critical values, and a conclusion is drawn on the relationship between the variables (Aqsha and Masih, 2018). In order to examine the magnitude of the relationship, the equation derived over the past century stems from the early work of Fisher (1930), and shows the form of the relationship between inflation and housing prices, which tests whether the long-run elasticity is equal to unity. This is in the form of a beta coefficient, and if it is equal to one or greater, it can be concluded that residential property is able to hedge against inflation. While the ARDL procedure has been used in prior studies (Anari and Kolari, 2002), limitations to the model have been identified. This is that the ARDL model can only be used to estimate a linear and symmetric relationship.

2. Does the relationship exhibit evidence of asymmetric adjustment?

In order to account for the limitations in the ARDL model, the NARDL model was utilized for the purpose of this study and was discussed in detail in the later chapters. The results of the regression analysis enabled a conclusion to be drawn on the relationship between residential property and inflation. The cointegrating relationship between the variables may be conditioned to both asymmetry and nonlinearity (Shin, Smith, and Greenwood-Nimmo, 2014). These issues are relatively new to econometric analysis, and the application of NARDL in this context is likely to lead to an innovative contribution to existing literature (Aqsha and Masih, 2018). The NARDL model has the capacity to estimate both the long and short-run asymmetries simultaneously in a simple and flexible manner (Shin *et al.*, 2014). This is a critical difference between the NARDL model and a simple ARDL model.

3. Do each of the housing segments in South Africa (affordable, middle, and luxury) behave differently with regard to their inflation-hedging properties?

The data for this study was extended because in South Africa, the prices of residential property differ in accordance with their quality. This varies depending on the location of the housing, as well as other factors such as biases in consumer preferences (Inglesi-lotz and Gupta, 2013). The housing prices are therefore segmented based on their quality, namely affordable, middle, and luxury segments. This, therefore, divides the South African housing market into different income categories of households. This data enabled a conclusion to be drawn on whether there are differences present within the different segments in relation to the different households. The results of the study presented different inflation-hedging properties for each of the above segments.

1.6 Contribution and significance of the study

This study is of significance as investors are always searching for investments that are able to maintain or increase in value (Van Staden, 2016). Inflation is always present, and investors seek investments that are able to hedge against the effects of inflation (Rubens *et al.*, 1989). This study focuses on the capability of residential property to hedge against inflation in South Africa. The hedging ability of residential property in South Africa has not been examined in literature with regard to nonlinearity. This study, therefore, utilizes the ARDL model, as well as the NARDL model in order to provide a framework for examining the long-run relationship between the housing prices and inflation. This is done in order to determine whether or not residential property has had the ability to provide an effective hedge over the 30 year sample period of this study. Furthermore, the issues of structural breaks and asymmetric adjustment, with the application of NARDL in this context is likely to lead to a novel contribution to the literature (Shin *et al.*, 2014). This is beneficial to the analysis as by examining the presence of structural breaks, it allows for changes within the relationship to be identified and discussed in detail. The NARDL model was employed by Aqsha and Masih (2018) and Yeap and Lean (2017) to determine the inflation hedge properties of housing in Malaysia. Furthermore, the inclusion of the housing price segments in this analysis allows investors to have a broader understanding of the investment options within the housing market. This study aims to help investors better understand the potential benefits of investing in real estate as a form of protection against the constant rising of the inflation rate in South Africa.

1.7 Thesis structure

This study comprises of the following chapters:

Chapter 1: Introduction and background of the research problem

This chapter consist of the introduction, which incorporates an overview and background of inflation, as well as housing prices and their ability to act as a hedge against inflation. This chapter also details the research problem, objectives and questions and the way in which this study aims to answer them. Furthermore, the contribution and significance of this study is highlighted in detail.

Chapter 2: Literature review

This chapter explores the existing literature surrounding the research problem in greater detail. This section includes a theoretical and empirical reviews of the literature to enable an adequate comprehension of the topic, which enables investors to be aware of potential benefits of this type of investment in terms of wealth preservation. Fisher (1930) laid the groundwork for inflation hedging, and authors such as Fama and Schwert (1977) have viewed real estate as an effective hedge against inflation. This represents one of the two key reasons for the inclusion of real estate into a portfolio containing mixed-assets. The second reason for this is the potential benefits of diversification that are present in real estate attributable to its correlation with other investment assets (Taderera and Akinsomi, 2020). There are different views regarding the hedging ability of real estate. Authors such as Anari and Kolari (2002), and Parajuli and Chang (2015) found real estate to be an effective hedge against inflation. However, authors such as Hamelink and Hoesli (1996) and Yeap and Lean (2017) have found that real estate is not a hedge against inflation. This topic has been examined by many authors and is discussed in greater detail in the literature review section. It is evident that due to contradicting results that the relationship between property and inflation is extremely intricate. The inflation-hedging ability of residential property investments may vary across many dimensions, such as the country and the nature of the real estate investment (Taderera and Akinsomi, 2020).

Chapter 3: Data and methodology

This study is especially important in the context of South Africa because it examines a time period that is extremely relevant in the context of South African history in that it covers a period of key political, social, and economic volatility. This chapter includes a data and methodology section, which is described in greater detail. Quarterly data from January 1989 to December 2019, which covers a span of 30 years, was used. South Africa represents a perfect environment for this type of analysis due to the exceptionally high historical volatility. Inflation has ranged from almost 0% to just under 20% over the proposed sample period of 30 years (Plecher, 2019). This was an up-to-date analysis as the most recent data available was utilized. Quarterly data was selected as this type of data serves to be easier for identifying trends; therefore, changes in the variables are easier to identify than annual (Reilly, 2013). This type of data is taken every three months, allowing for the adjustment for seasonality (Reilly, 2013). Furthermore, quarterly data is also advantageous for data extracted for more extended time periods (Reilly, 2013). This time period of 30 years chosen for the regression is complemented by an article by Kim and Ryoo (2011), who conducted a similar study on the use of common stocks as a hedge against inflation. They found that the 30-year sample had the highest power properties in the tests they used. Furthermore, the data is the most recent and aids in the reliability of the results.

The methodology section details the estimation techniques necessary to examine whether residential property can be used as a hedge against inflation. Before estimating the model, unit root tests need to be conducted to determine whether the variables used in the model are cointegrated. This can be done by utilizing the Augmented Dickey-Fuller (ADF) test, the Phillips-Perron (PP) test, and the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test, which is employed to test for stationarity among the variables (Brooks, 2014). However, these tests do not account for structural breaks, and hence it would be beneficial to utilize unit root tests that account for structural breaks in the individual series. The Zivot-Andrews (1992) test is a structural breaks test, but it will only show the single most significant break. The Bai-Perron (1998) test is an alternative test that can account for five breaks. This test is utilized and is an additional contribution to the study.

Previous researchers on the topic, such as Anari and Kolari (2002), had found that the ARDL model can be utilized to estimate the long-run relationship. This model was employed as an estimation technique in the methodology section. However, in the more recent studies, limitations to this model have been identified, specifically that it can only be used to estimate a linear relationship (Aqsha and Masih, 2018). Therefore, to account for asymmetric adjustment, the NARDL model was employed for the purpose of this study (Shin *et al*., 2014). The issues of nonlinearity and asymmetric adjustment are relatively new to econometric analysis, and the application of this model in the context of inflation-hedging is likely a novel contribution to the literature. Both models were constructed for comparative purposes to allow for a more accurate conclusion to be drawn on the relationship between residential property and inflation.

Chapter 4: Results and discussion

The methodology section will be followed by a section detailing the regression analysis results and a discussion on each test. This chapter determines the results based on the econometric models that are mentioned in the methodology. These results enable a conclusion to be drawn on the relationship between inflation and residential property. Before the models were examined, each variable was tested to determine the stationarity. The results from the ADF unit root tests were a mixture of I(0), I(1), and I(2). However, further unit root testing with the PP and KPSS tests confirmed a mixture of only I(0) and I(1) variables, which is allowed for the tests for cointegration. Structural breaks were tested for using the Bai-Perron structural breaks test, which allowed for a maximum of five structural breaks to be examined. South Africa has undergone many structural changes during the timeframe of this study, each of which, have been accounted for in the structural breaks testing section of the results. The cointegration testing started with the conventional ARDL model, which confirmed the presence of a long-run relationship between CPI and HPI, as well as the individual housing segments. It was, therefore, concluded that property is an effective hedge against inflation, represented by the beta coefficients, which were all greater than unity. Following the ARDL analysis, the NARDL model also confirmed that cointegration is present between the variables, implying a long-run relationship exists. The decomposition of the beta coefficient showed significant variation between the positive and negative changes. The results stated that for positive changes in inflation, HPI, middle and luxury housing segments are all effective inflation hedges. However, the affordable segment is only a partial inflationary hedge, as seen by the beta coefficient being positive, but lower than unity. Furthermore, the negative coefficient proved that all housing segments are effective hedges, as all values were greater than unity in absolute value. Therefore, in periods of deflation, investors will greatly benefit from investing in housing, as the negative coefficients were greater than the positive. It can be seen by these results that there is strong evidence of asymmetric adjustment, which implies that the NARDL model was a novel contribution to the study.

Chapter 5: Conclusion, extensions and limitations

The final chapter includes concluding remarks detailing a concise summary of the study and will complete the study. Additionally, the extensions and limitations of the study were also presented, concluding the study. Therefore, this study would prove to be pertinent as asset holders in other similar countries will be able to hedge against inflation effects by investing in South African property. Furthermore, both housing prices and inflation are variables that are constantly changing in the economic environment, and therefore, there will always be a need for newer and more relevant research to be conducted.

The next chapter of this study details the literature presented on the topic. This section is broken down into multiple author's views on the topic, which will enable individuals to get a picture of the topic in its entirety. A theoretical and empirical section is provided to allow for a more comprehensive understanding of the topic. The situation of inflation-hedging has been around for several years and dates back to the Fisher (1930) hypothesis. An overview of the history of inflation-hedging is presented to detail the way in which this topic has been adapted over the years.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

This literature review considered various studies in the literature related to the question of whether residential property is an effective hedge against inflation. Inflation is a current and volatile problem around the world as it decreases the purchasing power of currency-based assets through a general rise in the price level of goods and services (Chen, 2019). The use of a literature review proves to be beneficial as it offers an effective and pertinent way to identify existing patterns and gaps within the field of research. This is due to the numerous qualitative and quantitative studies that make literature broad (Rosaz and Klein, 2010). This section initially reviewed the existing literature on this topic that includes both international and South African studies. This literature review is broken down into two sub-sections, specifically the theoretical review and the empirical review. This distinction allowed for a greater understanding of the topic from the perspective of the theory behind the topic, as well as the different studies related to the topic. Furthermore, this also highlighted the importance of an inflationary hedge.

Inflation’s erosion of investor returns created a need for asset investments that have the ability to protect the real value of the investment. As such, this topic has been studied extensively over the years by researchers around the world. The three primary categories of hedging mechanisms, as mentioned, include minerals, equities, and real estate (Smith, 2019). The two former categories have been assessed in the literature. With regard to minerals, gold has been studied as a hedge against inflation by Ghazali, Lean, and Bahari (2015), as well as Bampinas and Panagiotidis (2015). Furthermore, equities were examined as a hedge against inflation by Kim and Ryoo (2011), Spyrou (2004) Moores-Pitt and Strydom (2017), and Eita (2012). The topic of property as a hedge against inflation has been established in South African literature, as discussed below by Taderera and Akinsomi (2020). However, this article examined commercial real estate as a hedge against inflation, which differed from the contribution of residential real estate. The examination of inflation-hedging has changed over time to accommodate the limitations present in the models (Yeap and Lean, 2017).

This chapter provided a detailed analysis incorporating the previous author’s findings on the hedging capacity of residential property with the use of a series of different methodologies is presented below. A comprehensive understanding of the topic is seen in the theoretical component, as well as the empirical, as the topic was examined from local and international viewpoints.

2.2 Theoretical review

The theoretical review component is discussed in greater detail below, beginning with the introduction. The inflation section was broken down into: Inflation in South Africa, inflation theories, causes of inflation, effects of inflation, inflation-targeting, inflation-hedging, inflation-hedging models, and key inflation hedging mechanisms. The property section was broken down into: Real estate investments, and the benefits and limitations of real estate investments.

2.2.1 Introduction

The theoretical review section of the literature review is made up of three sub-sections. The first section details inflation in South Africa by including the definition, types, causes, and consequences of inflation. This includes the effects that inflation has on investors, along with the rest of the economy, and considers the bigger picture of inflation. Furthermore, the history of South Africa's decision to adopt an inflation-targeting regime, in addition to the pros and cons of this decision, and the possible implications, are discussed in further detail. Secondly, the theory behind inflation hedging, which includes a detailed definition, along with the history of the Fisher (1930) hypothesis and other theories and models developed over the years, are all presented below. This hypothesis has been referred to in multiple studies with regard to inflation hedging, such as by Ahmad (2010) and, Arnold and Auer (2015). This section of the review further explores the inflation-hedging ability of real estate as an investment to protect the wealth of the investor. The final section of the theoretical review represents a detailed description of real estate investments, including the definition, types, benefits, and the inclusion of real estate in an investment portfolio. The above theory is beneficial for an investor as it is important for an investor to have access to as much information about an investment as possible before making a decision. This study, therefore, serves to help investors make the best decision regarding their portfolio allocation strategies.

2.2.2 Inflation in South Africa

Inflation is defined by Labonte (2011) as the constant or sustained increase in the price level. Alternatively, it can be defined as the continuous or sustained decrease in the purchasing power of a given unit of currency. The inflation rate looks at how much the prices have increased or decreased during a specified time period (Kumpis, 2019). This is expressed monthly, quarterly, or annually and is a percentage that indicates the rate at which prices increased or decreased. Inflation precisely refers to the movement of the general level of prices and not the change in one price in relation to other prices (Labonte, 2011). However, inflation is very rarely impeccably anticipated, as the effect of inflation will be greater the higher the rate of inflation. A more variable inflation rate, therefore, leads to less anticipation from the public and greater uncertainty (Labonte, 2011).

South Africa has exhibited exceptional levels of inflationary volatility over the years, ranging from 0-20% (STATSSA, 2020). When the general price level increases, it brings about a decrease in savings, which causes a decrease in investments, which, therefore, reduces the country's economic growth level (Munyeka, 2014). Essentially, if prices are said to increase, consumers will spend more now instead of opting to save for the future. Inflation is also known to bring about a level of uncertainty, which discourages investment into the country and leads to lower capital stock (Munyeka, 2014). This also causes investors to rethink their investment decisions. Therefore, investors would typically instead opt for inflationary hedges as investments, as opposed to productive assets that diminish in value, such as plant and equipment (Munyeka, 2014).

Developing countries such as South Africa have been recognized as having a volatile currency in comparison to developed countries, and exchange rate fluctuations tend to have a substantial effect on the general price level (Dornbusch, 1976). Although this study focuses on the reduction of purchasing power in investments, it is important to note that inflation has a relationship with other factors. There is a relationship that exists between the value of a country's currency and inflation. McMahon (2019) stated that as inflation rises, the value of the currency in real terms tends to decrease. This is known as currency devaluation, which occurs when a currency loses its value (McMahon, 2019). This exists when the quantity of the currency increases, which tends to decrease its value. This suggests that a single unit of the currency will buy fewer goods in its country. This effect, coupled with other countries' currencies retaining their value, can lead to an imbalance between the countries. This would lead to the exports becoming cheaper for buyers that own the currency with the higher value, and therefore, causes these buyers to buy more. This increases the demand for the currency, and this, alongside the diluted value of the currency, both play a role in increasing the prices of the locally produced goods, which leads to price inflation (McMahon, 2019).

Inflation can be measured in different ways. In South Africa, the consumer price index or CPI is the most common technique for evaluating inflation. Inflation is essentially calculated by determining a select basket of common goods and services and measuring the change in the prices. The next step is to apply the weight of the good to the change in the price (Pettinger, 2015). The CPI calculation includes taxes and excludes mortgage interest payments and changes in VAT. The second measure, known as CPIX, excludes the mortgage interest payments. The third measure is known as the CPIH, and is based on the CPI and includes the housing amounts such as the mortgage interest payments that were excluded from the CPI. The fourth measure is the CPIY. This measure excludes the impact of indirect taxes on the CPI, such as exercise duty and VAT (Pettinger, 2015). This is a useful measure for defining the underlying inflation level while ignoring tax increases. The fourth measure is known as core inflation, which attempts to strip away the unpredictable factors, namely commodity and food prices. This is, therefore, a reduced basket of goods but an accurate way to represent underlying inflation (Pettinger, 2015). The final measure, which used to be known as the official measure, is the retail price index or RPI. This measurement includes more factors, such as the housing costs that are not included in the CPI.

Central banks identify price stability as their core objective, which highlights the significance that price stability has for an economy (Jan, 2020). This is due to inflation having both implicit and explicit costs. Inflation can be broken down into expected and unexpected inflation. Expected inflation can be defined as the component of inflation that economic agents expect to take place. This is already embedded within their economic decisions (Jan, 2020). However, if the inflation rate from one year to the next differs from what individuals expected, then unexpected inflation has occurred (Ghazali *et al.*, 2015). Consequently, unexpected inflation represents the surprise component of inflation, which individuals have not incorporated into their costing and pricing. Unexpected inflation can have destabilizing effects on the economy. The significant consequence of unexpected inflation is seen in the wealth redistribution from lenders to borrowers (Ghazali *et al*., 2015). In situations where inflation is more than its expected value, borrowers gain at the lender’s expense (Jan, 2020). It increases the risk premium that is required by borrowers due to the inflation uncertainty. This inflation risk premium can be defined as the compensation that is usually demanded by investors in order to hold financial assets that are conditioned to inflation risk (Sueppel, 2017). This may mislead individuals into believing that an increase in prices implies an increase in demand (Jan, 2020).

There are a number of different types of inflation, and they are categorized by their rate of increase (Pettinger, 2019). Creeping inflation is categorized by a slow increase in the rate of inflation over time. This is an increase of 1-4% a year. Walking inflation or moderate inflation is an increase in inflation that is still in the single digits, categorized by a rate of inflation that is less than 10%. Inflation can become a major problem when it increases over 4% and will be a concern for central banks. This is the reason South Africa has a target band of 3-6% (Bishop, 2018). Running inflation occurs when inflation starts to increase at a significant rate of 10-20% a year (Pettinger, 2019). When this happens, inflation starts to impose substantial costs on the overall economy and could simply start to increase further. Galloping inflation arises when the inflation rate is greater than 20% and can increase to 1000%. In this situation, inflation is a serious concern, and it would be increasingly challenging to bring it to a controllable level. Hyperinflation is a term reserved for extreme cases of the inflation rate being greater than 1000%. Pettinger (2019) further explains that in this extreme situation, prices change so fast that it is said to become a daily occurrence, which causes the value of money to decline rapidly. Fernando (2019) discusses a further extreme case of inflation known as stagflation, which arises at a time of economic stagnation, and is combined with inflation. This, therefore, combines low economic growth, high unemployment, and extreme inflation. As a way to combat high inflation, the central banks usually raise the interest rates. However, in periods of stagflation, this could lead to a further increase in unemployment. This type of inflation is said to be the hardest to cope with as decreasing the interest rates could cause the inflation rate to increase even further (Fernando, 2019).

There is also a type of inflation known as negative inflation or deflation, which occurs when the general price level declines. If there is a small money supply increase, the value of money increases, and this leads to decreases in prices. A reduction in demand could occur if the supply is too large or, there is a decline in consumer spending could lead to negative inflation (Fernando, 2019). Deflation may seem beneficial, as it causes prices to decrease, which makes them more affordable for consumers. However, in the long run, it can have adverse effects on the economy. This is due to businesses making less nominal income due to price decreases, which forces them to cut costs with regard to salaries, as fixed costs remain constant and additional variable expenses need to be cut. This, therefore, leads to the laying off of employees, which increases unemployment (Fernando, 2019).

2.2.3 Inflation theories

There have been two theories put forward on what changes inflation (Arnold, 2016). These are economic theories that attempt to explain why prices tend to rise at different speeds over time. The first theory relates to the money supply and is described by considering an increase in money supply, which will be met by higher prices on goods being sold. In this situation, the money supply has an influence on the level of prices (Arnold, 2016). Alternatively, if there is a low level of money supply available, then prices will not be as high, which represents the view of the monetarists. This is based on the belief that inflation can be controlled by changing the level of money that is in circulation in the economy (Arnold, 2016). The second theory is the Keynesian view, which is based on the belief that demand is the dominant reason for price changes. If there is a low supply of goods, there would be a greater demand for them, which will cause the price to rise (Arnold, 2016).

2.2.4 Causes of inflation

The above theories relate to the two core causes of inflation, specifically demand-pull and cost-push inflation (Patti, 2020). Demand-pull inflation arises when consumers increase their demand, which leads to the prices increasing. The leading cause of rising prices arises as soon as consumer's demand for goods and services is greater than the aggregate supply. This is the result of "too much money that is spent on chasing too few goods." Inflation occurs when the economy grows and there is an increase in confidence, which then leads to consumers increasing their spending, and companies increasing their investments (Patti, 2020). There are also ways to prevent demand-pull inflation. Firstly, authorities can take precautions that are intended to delay the rising aggregate demand with the purpose of avoiding the inflation surge it causes. Secondly, government authorities could respond by tightening the fiscal policy (increasing taxes) and monetary policy (increasing interest rates).

Cost-push inflation is due to either a decrease in production or an increase in the cost of production (Patti, 2020). This occurs due to the increase in costs that firms pass onto their consumers. These higher costs that firms incur will be added to the cost of the end product. This is then sold at an increased price, which results in inflation. There are limited tools that monetary authorities can utilize for the prevention of cost-push inflation; it can be prevented through the adoption of supply-side policies. These are intended to increase aggregate supply and is developed with the belief that increasing the rate of production will increase the economic growth rate (Patti, 2020).

2.2.5 Effects of inflation

Aside from the reduction in purchasing power, there are also additional effects of inflation (Reed, 2017). Inflation is known to deter savings and encourage spending, as savings kept in the form of cash loses value at the rate of inflation each year. Inflation has a varying effect on individuals, depending on their form of earning income (Reed 2017). Investment-based income tends to thrive during inflation cycles as market returns tend to be one of the first sectors that reflect accelerating prices. However, in the case of individuals that depend on a fixed income, such as pensioners, inflation harms as their income is fixed while their purchasing power decreases (Reed, 2017). As a taxpayer, inflation also has a negative effect on a salary increase in line with inflation since there is no adjustment made to income tax. This will lead to movement onto a higher tax bracket, and a more considerable sum of the salary will go towards income tax (SARB, 2007). A further effect of inflation relates to the relationship it has with wages. Without inflation, an increase in wages would be an incentive linked to a rise in employee productivity. However, with high levels of inflation, wage increases consist largely of compensation for the inflation increase. These are known as inflation-based wage increases (SARB, 2007). Therefore, due to the effects of inflation, the South African Reserve Bank (SARB) is strongly opposed to inflation and uses its monetary policy in an attempt to combat it. These policy actions aim at contributing to continued economic growth, as well as a fair distribution of income and wealth. With the purpose of achieving these objectives, a strong and stable financial environment with low inflation are prerequisites (SARB, 2007). This is achieved through inflation-targeting, which was adopted in South Africa and aims at achieving a stable inflation rate.

2.2.6 Inflation-targeting

In February 2000, it was confirmed that South Africa would be adopting formal inflation-targeting as a section of the monetary policy framework. Prior to this announcement, the SARB had applied an “informal inflation-targeting” policy. The goal of the adoption of inflation-targeting was to work towards the attainment of price stability. However, the timeframe for this achievement was not specified. In the late 1980s, the consumer price index (CPI) fluctuated around 15% and, by 1999, it declined to 5.2% (Van der Merwe, 2004). The informal inflation-targeting strategy had, therefore, achieved success in lowering the inflation rate. Inflation-targeting is defined as a formalized approach that outlines the synchronised determination necessary to stabilize the inflation rate when in pursuit of extensive economic goals such as creating employment and sustaining high economic growth (Van der Merwe, 2004). The central bank has defined targets in which it must meet. In cases where the actual inflation rate deviates from the targeted values, the central bank is accountable for explaining the reasons for the deviations. This allows the public to have a greater understanding of the monetary policy decisions, which results in improved transparency around decisions made to control inflation. Applying inflation-targeting has an effect on inflationary expectations, which should further enable a decline in the inflation rate. Credible inflation targets serve to form the foundation of both wage and price-setting (Van der Merwe, 2004).

The SARB, along with the South African government, set inflation targets that are based on the CPI for all the metropolitan areas in South Africa exclusive of the interest rates of the mortgage bonds. The inflation target was initially 3-6% and remains today. This is in line with the inflation targets around the world which range from 1-6% depending on the country (Roger and Stone, 2005). With the aim of achieving this inflation target, the repo rate was the core tool utilized by the Reserve Bank (Comert and Epstein, 2011). The initial implementation of the inflation-targeting regime continued until 2008, which was the beginning of the global financial crisis. When the crisis took place, the SARB responded by means of a more flexible monetary policy strategy, which placed additional importance on financial stability, as well as economic growth (Comert and Epstein, 2011). Jonsson (1999) explored the advantages and disadvantages of adopting inflation-targeting in South Africa. One of the most important benefits of adopting inflation-targeting relates to its ability to increase the chances of gaining and maintaining a relatively low and stable inflation rate. With the focus of the central bank on attaining a reduced inflation rate, as well as the improved accountability, in addition to the transparency of the monetary policy, this would reduce the uncertainties about the future inflation rate. This, therefore, would contribute to more accurate and coordinated inflationary expectations. However, a disadvantage to the inflation-targeting regime is that it can be relatively complicated to implement effectively. It is based on a forward-looking perspective, which entails the central bank having access to policy instruments that are able to forecast inflation reliably with reasonable precision (Jonsson, 1999). This relates to the discussion above on the unexpected inflation rate. When the inflation rate is not calculated reliably and differs from one year to the next in comparison to what was expected, then unexpected inflation has occurred (Ghazali *et al.*, 2015). There are also implications of adopting inflation targeting in South Africa. The main implication is linked to the advantage of the increased transparency and accountability of the SARB.

It can be noted that the SARB's key goal is to be able to maintain the value of the country's currency. This can be obtained by stabilizing the inflation rate (Jonsson, 1999). In the event that there is a deviation in the desired inflation, it becomes difficult to determine whether this occurred due to policy failures or external factors that are beyond the control of the central bank. However, due to the increase in accountability and transparency, the central bank has to address these problems further. It was noted by Woglom (2003) that in comparison to other nations that have also implemented an inflation-targeting regime, South Africa had not maintained a calm macroeconomic climate during its inflation-targeting period. The inflation target has rather been confronted by numerous external shocks, which resulted in real depreciation that is beyond the monetary policy's control. The transformation of the monetary policy conduct, although modest, has been consistent with adopting inflation targets. Furthermore, the actions of the monetary policy have become increasingly transparent following this adoption (Woglom, 2003).

2.2.7 Inflation-hedging

The concept of an inflation hedge was well-defined by Arnold and Auer (2015) in three ways. Firstly, an asset can be known as an inflation hedge if it has the ability to eliminate or reduce the opportunity of the investment's real return decreasing under a specific floor value, for instance, zero. Secondly, the effectiveness of the asset's inflation-hedging can be measured by the proportional decrease in the real return's variance, which is obtained on default-free bonds that are achievable when combining the bond with the asset. Lastly, the definition used for empirical purposes, that the asset can be established as an inflationary hedge if the asset's real return is independent of the inflation rate (Arnold and Auer, 2015). This, therefore, implies that there is a positive relationship between the inflation-hedging asset's nominal rate of return and inflation. Arnold and Auer (2015) further describe a perfect hedge, which implies a correlation of one, which is emphasized by the Fisher (1930) hypothesis. This implies that increases in prices are compensated by the equivalent return on the investment. However, if the asset is not a perfect inflationary hedge, it may alternatively provide a stable and positive return relationship with inflation, making it a valuable investment and inflation hedge.

The Fisher hypothesis infers that the nominal interest rate tends to increase point-for-point with the expected inflation rate, while the real interest rates remain unchanged (Barsky, 1987). This hypothesis examines the relationship between expected inflation and interest rates and suggests that a positive relationship exists between them (Berument and Jelassi, 2002). This hypothesis has been studied in a variety of literature due to the important role the nominal interest rate, as well as the real interest rate, plays in the economy. The real interest rate is defined as the interest rate that removes the inflation effects, whereas the nominal rate represents the rate before accounting for inflation (Alimi and Ofonyelu, 2013). The real interest rate can be seen as a critical determinant of both the saving and investment behaviour of businesses and households, which makes it significant in the development and growth of an economy (Alimi and Ofonyelu, 2013). This hypothesis infers that the expected nominal return on any type of investment asset should therefore be equal to the real return of the investment, plus expected inflation (Le Long *et al.*, 2013). This essentially infers that the nominal rate will differ from the real rate by the expected rate of inflation.

Mitchell-Innes (2006) mentioned the reasons why Fisher's hypothesis is an essential study in financial works. Primarily, the interest rate maintains a key factor in economic growth, investments, as well as savings and further affects the trade and capital flows by influencing the exchange rate. Furthermore, there exists a significant volume of evidence that suggests that nominal rates can be utilized to examine inflationary expectations in the future (Mitchell-Innes, 2006). Lastly, the Fisher hypothesis is a key influence of deliberation by the central banks. If there is the presence of a Fisher link between expected inflation and interest rates in the long-run, it will suggest that the real rate is unaffected by the monetary policy and is rather determined solely by real economic influences (Mitchell-Innes, 2006).

Fisher's theory fundamentally divides the nominal interest rate into two separate parts, the real interest rate plus the expected inflation rate. Furthermore, Fisher (1930) proposes the idea that in a perfectly efficient economy, there exists a one-to-one association between the nominal rate and inflation, the difference between the two values being equivalent to the real rate of interest (Le Long *et al.*, 2013). The Fisher hypothesis states that the anticipated inflation rate is wholly incorporated into the ex-ante nominal rate while eliminating the presence of an association between expected inflation and the expected real interest rate (Katzur and Spierdijk, 2010). This notion that the ex-ante nominal interest rates have the ability to incorporate the expected rates of inflation in the market can, therefore, be applied to all assets. This infers that the nominal returns on any type of asset, which includes property, ought to be able to move on a one-to-one basis with the inflation rate (Katzur and Spierdijk, 2010). This proposition specifies the existence of a relation amongst all assets and inflation, which further infers that all real assets should have the ability to act as an inflationary hedge to some extent when their value increases due to an increase in inflation.

To sum up this hypothesis, if the ex-ante real interest rate remains constant, investors would need a nominal return that would have the ability to compensate for any decline in purchasing power of money as a result of inflation (Alagidede and Panagiotidis, 2010). Therefore, in the context of property investment, the Fisher hypothesis implies the existence of a positive one-to-one relationship between property returns and inflation, making residential property an effective hedge against inflation due to the real rate of return on property being able to alleviate the loss of the real wealth that is caused by inflation (Alagidede and Panagiotidis, 2010).

Analysts have identified inflation uncertainty as being a significant cost of inflation (Kantor, 1983). Inflation uncertainty affects the economy in many ways, as it increases the riskiness of the real return on savings. Individuals tend to be risk-averse, and therefore, this riskiness inflicts costs on households. This encourages households to rearrange their investment portfolios in an attempt to protect the real return on their investments from any unexpected inflation changes (Kantor, 1983). This subsequently increases the demand for savings instruments that have a real return that is better protected against the unexpected changes in inflation. If these efforts to hedge against the effects of inflation are successful, they are able to offset the costs of inflation uncertainty on the households (Kantor, 1983). Investors that opt for conservative investments, such as keeping cash in the bank, involve steady returns. However, they fail to account for the inflation risk, the risk that their savings will decline in purchasing power (Ngwane, 2014). The most effective way to measure wealth is through purchasing power, as opposed to the amount of rands. This is the reason the evaluation of real returns are considered, as it looks at the return after the effects of inflation and not nominal returns, which examines the investment growth before accounting for inflation (Ngwane, 2014). The investment return should be high enough to compensate for the timeframe of the investment to ensure that the value of the initial investment, in real terms, is maintained.

2.2.8 Inflation-hedging models

Fisher's (1930) hypothesis represents the core of research on inflation hedging and marks the foundation of inflation-hedging theories (Rodel, 2012). Following Fisher's (1930) theory, the next theory of inflation-hedging was proposed by Fama (1975), who examined the ability of treasury bills to hedge against the expected inflation rate. This theory was then extended by Fama and Schwert (1977). They studied the capacity of short-term bills to hedge against both expected and unexpected rates of inflation over lengthier holding periods. Fama and Schwert (1977) put forward the Ordinary Least Squares (OLS) model to regress the real estate returns against the unexpected, expected, in addition to the actual inflation rate. The proposition put forward stated that the expected nominal returns comprises of the way the market assesses the expected inflation rate. This can be utilized for all assets (Arnold and Auer, 2015). Previous studies have utilized this theory to determine the hedging ability of real estates, such as by Gyourko and Linneman (1988), who concluded that real estate is a hedge against inflation. These approaches were put forward before cointegration analysis was implemented for the purpose of inflation-hedging.

The Fisher regressions are able to estimate the inflation-hedging coefficients for a single investment horizon. The empirical results are known to be sensitive to the investment horizon as it requires testing of the coefficients for multiple intervals independently. Although this is possible with the use of the Fisher framework, inflation tends to be persistent in situations of multi-year horizons (Rodel, 2012). This, therefore, presents the risk of spurious regression. This occurs when there is a long-run relationship present between two independent variables that are trending, even in situations where the two variables are unrelated. In order to deal with this problem, cointegration techniques and vector error correction (VEC) models were developed. These techniques were first applied by Ely and Robinson (1997) in the context of inflation-hedging. This research paper looked at the inflation hedging ability of stocks to determine if stocks are able to preserve their value in relation to the prices of goods. The results concluded that there is a significant and positive relationship between stocks and inflation. Therefore, stocks were able to hedge against inflation in the long-run, as they maintained their value over time.

Cointegration analysis is utilized to test for stationarity in real returns. If proven stationary, it can be concluded that the real returns of the investment are independent of inflation and therefore, provides a long-run hedge against inflation (Rodel, 2012). The vector error correction models (VECM) are applied to simultaneously examine multiple time series. This is the prerequisite model for impulse response functions, which provide insight on the hedging characteristics over a specified timeframe (Rodel, 2012). After the cointegrating relationship has been established, the next test utilizes the error correction method. The VECM allows for the interpretation of both long and short-term equations (Maitra, 2019). The autoregressive distributive lag (ARDL) model was a progression model from the VECM, as it is able to account for variables that are integrated of differing orders. Furthermore, it was also utilized to examine the long-run relationship between variables. The ARDL model generates an F-statistic, and in order to determine whether the variables are cointegrated, this F-statistic has to exceed the upper critical bound (Aqsha and Masih, 2018). Both these models have been employed together for the purpose of inflation-hedging by Moores-Pitt and Strydom (2017). However, the ARDL model has been utilized extensively to establish the inflation-hedging ability of property by authors such as Yeap and Lean (2017) and, Anari and Kolari (2002).

The problem with the above cointegration techniques is that it assumes a symmetric setting, which assumes that positive and negative adjustments to inflationary changes are of the same magnitude (Yeap and Lean, 2017). This examination of symmetry indicates whether housing can be used as a hedge against inflation by considering a possible positive relationship between the asset return and the inflation rate solely. However, there is a need to determine whether housing prices are still able to protect against the effects of inflation in a situation where the magnitude of the adjustment coefficient differs in reaction to both negative and positive changes. Therefore, in a situation where inflation declines, house prices should be able to increase in an attempt to maintain their position as an inflationary hedge (Yeap and Lean, 2017). Frey and Manera (2007) explored a simpler approach to recognise asymmetric price transmission. This is done by observing the increase in the price of a product, which results from an increase in the input costs. However, there are no product price decreases when the input costs decrease. When considering the property market, it can be noted that the property prices are driven by nonlinear macroeconomic variables (Bahmani-Oskooee and Ghodsi, 2016). Therefore, the reaction of housing prices to an increase in the price level may theoretically be different from the reaction to a price level decrease. This indicates that house price responses are asymmetric to the inflation rate, which suggests that the housing returns may be different during inflationary and deflationary periods (Yeap and Lean, 2017).

In the more recent studies, authors have taken the possible asymmetric relationship between the variables into account. This is due to the limitation of a symmetric relationship being challenged, as accounting for both the positive and negative changes independently is a novel extension to current studies. This is evident in studies such as by Aqsha and Masih (2018), who utilized a nonlinear autoregressive distributive lag (NARDL) model to account for possible nonlinearity within the deterministic components. A further article by Kuan, Yuan-Ming, and Binh (2008) made use of a nonlinear vector error correction model to examine the asymmetric inflation hedge of housing returns. These studies will be discussed further in the empirical section, where each of the findings will be highlighted. These studies are examples of the above cointegration techniques in an asymmetric setting to accommodate for nonlinearity. It is, therefore, noticeable the way in which this study has been adapted over the years. Inflation-hedging techniques have been modified to account for the various limitations and have changed substantially since the hypothesis proposed by Fisher in 1930.

2.2.9 Key inflation-hedging mechanisms

Investors are constantly searching for hedging mechanisms that protect the value of their investments. As mentioned above, the three key hedging mechanisms are real estate, minerals and, equities. Due to the fact that housing prices generally increase in value over time, it is seen as a worthy investment opportunity as well as a hedging mechanism tool. It is important to note that investors are not only seeking out opportunities that lead to profit but also investments that are able to protect the investors from any downside risk they may face (Aqsha and Masih, 2018). A positive correlation between the asset's return and the inflation rate implies that the purchasing power can be compensated for, wholly or partially, by an increase in housing returns. Further reasons that residential property is seen as a worthy investment is that in times of financial strain if inflation is expected to increase, investors may be motivated to convert their current assets into residential property in order to protect themselves from this increase in inflation. Furthermore, the value of a property, as well as rental income, are considered worthy investments during times of price instabilities and market distortion (Aqsha and Masih, 2018). The increase in population growth coupled with limited land availability contributes to the increase in demand for housing regardless of the price appreciation. This, therefore, increases its potential to combat the increase in inflation as property generally tends to grow against the currency during these periods of inflationary pressure.

Van Staden (2016) points out the negatives of inflation due to the way that it erodes the true value of the returns on investments. The author confirms that residential property, although having short-term price fluctuations, is seen as a good investment option, as it produces growth that is in line with the growth of inflation. Furthermore, rental income is noted to grow at an average rate of 10% per annum, which is in line with the inflation rate. This, therefore, allows the income earned through renting of property to retain its purchasing power over time. This type of investment is called a buy-to-let property investment, and it has the ability to outperform inflation. In this way, investors are able to secure the value of their investment by generating an income from it that grows with inflation every year, and therefore, is seen as a suitable hedge against inflation (Van Staden, 2016).

Kumpis (2019) explored the ways real estate investing can be used to fight inflation. By owning real estate, one is exposed to asset appreciation. Property values tend to appreciate between 3-

5% annually. Therefore, real estate values keep up-to-date with inflation (Kumpis, 2019). A relationship exists between property prices and the inflation rate. This is the result of the impact that inflation has on any type of good that has a restricted supply. Therefore, increasing the money supply causes both house prices and inflation to increase. With any type of investment, there are advantages and disadvantages to investing while accounting for inflation. The advantages include being able to preserve the real value of your portfolio, as investing during inflation has the ability to protect the buying power of your portfolio (Kumpis, 2019). The advantage of diversification is evident in all investment strategies, as spreading risk through multiple investment assets is important to maintain a strong investment portfolio. Furthermore, investing for inflation, as opposed to stock-piling money, is regarded as a way of maintaining your income's buying power rather than your income deteriorating (Kumpis, 2019). Therefore, in order for diversification to work effectively, investments across multiple asset classes are more beneficial.

2.2.10 Real estate investments

Real estate is referred to as the physical property, the land and buildings, as well as the air rights that are directly above the land and the underground rights that are beneath the actual land (Amadeo, 2020). Real estate can, therefore, be produced, sold, and bought. There are four common categories of real estate, namely, residential, industrial, and commercial real estate, as well as land (Amadeo, 2020). Residential real estate refers to the new construction, as well as the resale homes. These are most commonly categorized as single-family homes. However, there are other types such as townhouses, co-ops, duplexes, or triple-deckers. Furthermore, there are high-value homes, vacation houses, and multi-generational homes (Amadeo, 2020). The commercial real estate category refers to shopping malls, educational and medical buildings, as well as hotels and office buildings. Apartment buildings also fall under this category, as even though they are for residential use, they are owned for the purpose of income generation (Amadeo, 2020). Industrial real estate includes the manufacturing sector, and these are buildings such as warehouses and factories. This type of building is used for the production and distribution of goods, as well as storage and research. A distinction must be made between industrial and commercial real estate because certain buildings that distribute goods fall into the commercial category (Amadeo, 2020). It is important to differentiate between the two because the sales, construction, and zoning are all handled differently. Land is a relatively broad category of real estate and can include any vacant land, which can be broken down into undeveloped land, early development, and subdivision, reuse and, site assembly. Working farms, as well as ranches are included in the land category (Amadeo, 2020).

Amadeo (2020) further explores real estate investing, which refers to any individual who buys or sells real estate. A point of consideration when investing in real estate relates to the possible capital gains, specifically if there will be a rise in the value of the property while you are living in it. Furthermore, if you are able to obtain a mortgage, the effects of future interest rates and taxes need to be considered. Individuals may even consider buying and selling homes as a potential business opportunity. This can be done by flipping a house, which is the process of buying a house, improving it, and then selling it. Alternatively, people may own homes and rent them out as a form of obtaining a monthly income (Amadeo, 2020).

2.2.11 Benefits and limitations of real estate investments

There are a number of benefits to investing in property. Income property is the term given to the property that is purchased and developed with the intent to earn revenue from it (Berlin, 2020). Residential property, as well as commercial property are types of income property. In these situations, owners are able to generate income through holding and renting the property. The property appreciates in value, and then the owner is able to sell it for a profit (Berlin, 2020). The first advantage to investing in property is that as the investor, you are able to make all the decisions, such as how you will maintain the property you rent out and screening tenants. Real estate is also viewed as a relatively lower volatility asset class, as it has stable price dynamics. This is beneficial in situations where market volatility is a major concern, such as in financial crises (Cohen, 2016).

The most common advantage of property investment is the income generated through rental income. Once all the expenses are accounted for, any additional money will be in the form of income gains. If the rent that is charged is able to surpass the cash-carrying charges of the property, it will give rise to a positive cash flow (Abellera, 2019). Due to this relative stability of cash flows, it can increase the demand for purchasing real estate as a tangible asset, and it is seen as a less risky investment in comparison to publicly traded securities (Cohen, 2016). A further advantage is through help with a mortgage. This relates to the term of the loan. The longer the loan period, the more of the loan payments your tenants are paying, resulting in more significant wealth creation for yourself (Berlin, 2020). Furthermore, owning a rental property allows for substantial tax advantages, including tax deductions and are able to write off interest on the mortgage, as well as insurance, maintenance fees, and property taxes (Berlin, 2020).

The idea is to make use of the borrowing power, as there is an advantage to utilizing debt in order to increase the capability of investing in real estate. This is especially beneficial if there are multiple properties involved as one property can be utilized as leverage in order to acquire the subsequent property (Abellera, 2019). By way of more properties being obtained, an individual is able to potentially decrease the cash outlay if the value of the properties has increased enough to support the subsequent purchase. There are also certain limiting factors on commercial and residential real estate investing that decrease the consideration of real estate as a potential investment opportunity, as it is not an easily accessible platform for certain investors (Cohen, 2016). These factors include large capital requirements from investors, as well as a knowledge base that necessitates investments. There are, however, several different branches of real estate investments to consider, such as Real Estate Investment Trusts (REITs) in addition to Commercial Mortgage-Backed Securities (CMBS). Publicly traded REITs are businesses that possess income-generating property and permits individuals to make investments through the purchase of large-scale property stocks (Cohen, 2016). CMBS is a form of a fixed-income investment that is backed by several commercial loans. This type of investment is attractive because it can offer high credit quality, as well as cash flow stability (Cohen, 2016).

Apart from the prospective returns earned on property investments, there are a number of factors that need to be considered when making an investment in real estate (Luüs, 2005). Firstly, the volatility of the return needs to be established as there are unqualifiable risks involved with direct property investments. Firstly, homogeneity, as it can be difficult to compare two-property investments, as utilizing national price data directly allows for the approximation of actual historical returns attained on the investment (Luüs, 2005). Secondly, the underlying costs need to be considered, such as the transfer duties, agent's commissions, and bond registration fees. Lastly, one should consider gearing, which tends to make property investments attractive during low-interest rate economic phases. However, this can be met with high exposure to interest rate risk in volatile economies (Luüs, 2005).

Investors are constantly searching for the best portfolio allocation strategy, which starts off with the decision on how much to allocate within each broad asset category. The next decision is to select the optimal allocation strategy within each of the asset categories (Eichholtz, Hoesli, MacGregor, and Nanthakumaran, 1995). This, therefore, involves diversification within each of the asset classes in order to manage risk effectively. Historically speaking, the core assets, such as public equities and bonds, have been known to characterize a large portion of investor portfolios (Cohen, 2016). However, there has been an increased demand over the last twenty years to move beyond these traditional asset classes when constructing an investment portfolio. This is due to a number of factors, such as macroeconomic challenges, current market conditions and, increased volatility, which has created a need for allocating alternative assets in investment portfolios (Cohen, 2016). In this way, investors are further able to address exogenous factors such as interest rate volatility and inflation while being able to manage their risk and return dynamics. Real estate investments can be diversified into categories based on the type of property and the geographical region. The return earned on different types of property is driven by a series of economic factors, including retail shops, offices, and industrial properties. Therefore, there would be differential performances across various regions within each type of property (Eichholtz *et al.*, 1995).

From a theoretical point of view, it is not instantly apparent that property is a hedge against inflation. This is attributed to the value of a property, which is leased at a fixed rental amount to a tenant who is not responsible for paying taxes, maintenance, and utility costs, which are adversely affected by inflation shocks (Goetzmann and Volaitis, 2006). Nominal values of property do not necessarily increase at the same rate as inflation, as well as the fixed costs mentioned, property may only be able to act as a hedge in the long run. However, leasing a building, which is net of the taxes, maintenance, and utility costs and has contractual rent increases that are linked to CPI may represent an effective inflation-hedge. Therefore, the demand for housing is fuelled by the demand for inflation-hedging rent. Thus, whether or not the purchase of property is able to hedge against inflation is established empirically and depends on the availability of data that would be situationally dependent across countries and time periods (Goetzmann and Volaitis 2006).

2.3 Empirical review

The empirical review component is discussed in greater detail below, beginning with the introduction. This was followed by studies on inflation in South Africa and property in South Africa. Furthermore, property as a hedge against inflation was discussed with both international and local studies, as well as, studies accounting for asymmetric adjustment.

2.3.1 Introduction

The empirical section of the literature review is broken up into three sections. The first section explores inflation in South Africa and includes studies on the determinants of inflation,

inflation-targeting, and the effects inflation has on economic growth. This allows for a greater understanding on the effects of inflation in South Africa, as well as whether inflation-targeting has proven to be beneficial. The second section breaks down property in South Africa. This section explores housing price dynamics and bubbles, as well as the effects of including property in an investment portfolio. This is important because housing price dynamics have a significant effect on the financial system of a country in many ways. Housing prices affect the dependability of the financial system as it influences the profitability of financial institutions (Tsatsaronis and Zhu, 2004). A detailed understanding of the housing market is provided in this section. This will aid in the understanding of the role the housing prices play in order to determine whether investing in property is an effective hedge against inflation. The final section explores the research problem solely. This comprises of studies that examined the hedging ability of real estate. This section consists of a series of different estimation techniques that were utilized to examine the relationship amongst property and inflation. The inflation-hedging theories that were each discussed in the theoretical component of the literature review are further discussed empirically through studies that utilize these techniques with relevant datasets to draw conclusions on the hedging ability of property. It was noted that there had not been much research done in South Africa on this research topic, which therefore provided a gap for this to be researched.

2.3.2 Inflation in South Africa

Aron and Muellbauer (2007) examined the transparency, credibility, as well as predictability of South Africa's monetary policy within the inflation-targeting regime. By adopting inflation-targeting, the objective was to enhance both the effectiveness and the transparency of the monetary policy. This study included quantitative indexes between 1994 and 2004, which revealed a strong increase in the monetary policy transparency. This study utilized a wide range of data, including both interest rate and inflation expectations data. Further data incorporated was the forward interest rate data, in addition to the estimates of an interest rate policy rule. These are applied to explore the predictability and credibility of the monetary policy ever since the adoption of the inflation-targeting regime. Evidence from this study shows that the new monetary policy framework is being well-entrenched in the financial market's expectations. Furthermore, there are only slight declines in the interest rate forecast errors arising thereafter while controlling for macroeconomic volatility.

A study conducted by Akinboade, Siebrits, and Niedermei (2004) explored the determinants of inflation in South Africa. This study developed a model that looked at foreign exchange, money market, and labour market conditions and related these conditions to the domestic inflation rate. The authors mentioned that the SARB specified that the objective is to reduce inflation to a level that is more in line with other countries to prevent instability in the aforementioned markets. In this way, the bank will be able to achieve its primary objective, which is to protect the purchasing power through inflation-targeting. By assessing the determinants of inflation it provides a starting point to achieve a greater understanding of the forces that drive inflation, and therefore, helps to assess the SARB's monetary policy instruments that are put in place to control the inflation process. The datasets used in this study were sourced from the SARB database and contained quarterly data from the time period of 1970-2000. The data contained nominal values for the gross domestic product (GDP), the interest rate, broad money stock (M3), labour costs, and the consumer price index. It was noted by the authors that South Africa's inflation is fundamentally structural in form, and the authorities have restricted control of inflation's core determinants. It is for these reasons that Akinboade *et al.* (2004) concluded that a reduction in inflation would be slow to achieve and would be costly for the country. The conclusion drawn was that it would be challenging for South Africa to attain its objective of an inflation-targeting regime so as to adequately keep up with the inflation parities of their prominent trading partners. This study is an important contributor as it details South Africa's ability to control its inflation rate in comparison to other countries. This study was conducted 16 years ago, and of recent, there has been more groundwork on inflation-targeting as done by Phiri (2016), specifically on how to go about using inflation-targeting to decrease inflation.

Inflation-targeting is a concept that was detailed in a study conducted by Phiri (2016), who collected CPI inflation figures from 46 different African countries from the Federal Reserve Economic Data database. The timeframe of this study expanded over 20 years ranging from 1994 to 2014. The study compared data from countries both with and without inflation-targeting regimes. The method used in the above study was that of an autoregressive distributed lag (ARDL) model. The regression analysis was performed on the inflation rate. The results from the regression found that inflation in the chosen countries had not been persistent during the time period of the study. This, therefore, infers that with the use of inflation-targeting, the countries have the ability to stabilize their inflation rate. The central bank has the ability to improve its control over the inflation levels. This study is of importance as it details inflation as a problem faced by many countries and shows by means of a regression analysis that through inflation-targeting, there is a decrease in inflation, thereby providing a solution to the inflation problem (Phiri, 2016).

Leshoro (2012) emphasized the detrimental effects that inflation has on economic growth by focusing on determining the threshold level of inflation in South Africa. This study captured quarterly data from the years 1980-2010 from the International Monetary Fund database. The relationship between South Africa's inflation and GDP growth rates was tested. This study used an econometric method known as the Ordinary Least Squares (OLS) model. Furthermore, in order to check for robustness, the model was re-estimated by means of the Two Stages Least Squares (2SLS) model. This study was conducted to observe the economic stability of the country, which can be perceived by high levels of output growth and low levels of inflation. The results found that the inflation threshold level arises at 4%. Hence, inflation levels that are lower than and equal to 4% result in a positive but insignificant relationship between growth and inflation. Furthermore, these findings are supported by the tests of robustness. It can, therefore, be concluded that the monetary authorities should aim to keep inflation levels within their target band, preferably below 5%, in order to prevent any adverse effects on South Africa's growth (Leshoro, 2012).

2.3.3 Property in South Africa

A study conducted by Das, Gupta, and Kanda (2011) aimed to investigate the house price bubbles present in the real estate sector in South Africa. The authors' intention was to study the magnitude of the spill-over effects that housing prices have on consumption. This was the first study conducted on the residential sector of a developing country. The data used for this study breaks down each province of South Africa into rural and urban areas. Quarterly data from the time period of 1969 to 2009 was used. The unit root test that was developed by Phillips, Wu, and Yu (2010) was used in the methodology of this study. The results concluded that house price bubbles are present in the large, medium, and small-middle housing segments. However, the price bubbles are not present in the affordable and luxury segments. The authors also utilized symmetric as well as asymmetric versions of the Error Correction Model. This estimation technique was utilized in order to investigate spill-over effects from housing onto consumption. It was concluded that the results confirmed the existence of the significant and asymmetric spill-over effects. This indicated that consumption responded largely to the deceleration of the house prices. However, there was no evidence proving the impact being greater throughout the timeframe of the price bubble.

Housing price dynamics were assessed in a study that was conducted by Tsatsaronis and Zhu (2004). It is evident that housing prices have a profound effect on the financial system of a country in many ways. Housing prices affect the dependability of the financial system as it influences the profitability of financial institutions. The relationship between housing prices and mortgage finance was examined in this study. Residential property is a costly asset, and therefore, investors need to obtain a source for external financing in order to obtain the property, and hence, investors lean towards mortgage finance when purchasing property (Tsatsaronis *et al*., 2004). There are many factors that would need to be taken into account, such as supply and demand dynamics, as periods of high demand coupled with a fixed supply can drive up the prices of external financing. Real estate data was used from the years 1970 to 2003 for 17 countries. The methodology employed in this study was that of the Vector Autoregressive (VAR) model to capture the dynamic relationship between housing prices and the macroeconomic variables. The determinants of housing prices included the household's disposable income (high, middle, and low-income) as well as the population demographics (size and age of population) of the chosen countries. The investment decision to invest in real estate is also determined by the tax system as it is important to determine if it is wealth-creating, as opposed to non-housing investments. The results of the variance decomposition of the study confirmed the significance of inflation and how that in periods of high inflation, the motive for an inflation hedge was stronger among the 17 countries. It was concluded by Tsatsaronis *et al.* (2004) that when inflation increases, there is a greater need to protect against its adverse effects.

Burger and Van Rensburg (2008) examined whether the metropolitan property prices in South Africa converge. This paper, therefore, looks at whether the different metropolitan areas are constituted as a separate or a single housing market in South Africa. By the use of the theory of the Law of One Price, which implies that if geographic areas fit within the identical market, then in order for their relative prices to be stationary, their absolute prices need to converge (Burger and Van Rensburg, 2008). This study utilizes cross-sectional time-series data for five metropolitan areas in South Africa. Burger and Van Rensburg (2008) employed the Im, Pesaran, and Shin (2003) panel unit root test to examine the Law of One Price. The results indicated a stronger indication of convergence within the large middle-segment and weaker evidence of convergence in the medium middle-segment. Therefore, this proposes the presence of a national market for both the middle and large segments. On the other hand, another market for the small middle-segment homes within metropolitan areas.

The results of including real estate into a portfolio containing mixed-assets in South Africa were examined by Olaleye (2011). This study observed the way the asset classes performed within the investment market and utilized this to determine the diversification benefits of including listed property stock into a portfolio containing mixed-assets. The data that was used in the study comprised of quarterly returns on The All Share Index, property listed stock, 90-day treasury bills, and the All Bond Index. The timeframe of this study ran from 1999-2009. The risk-return performance of the above assets was compared to determine the return enhancement, as well as the risk reduction benefits of the property. The levels of risk and return were acquired using the Markowitz mean-variance analysis. The results concluded evidence of risk-adjusted performance and superior returns of the real estate stock in comparison to the other assets included. By including the property stock in these portfolios, the results produced risk-adjusted returns that were statistically significant. However, there were minimal reduction benefits, and this varied subject to the percentage allocated to real estate (Olaleye, 2011).

Marzuki (2018) examined the performance and the diversification benefits of the commercial real estate market in South Africa. This paper, similar to that of Olaleye (2011), who also looked at the diversification and risk-adjusted performance advantages of incorporating South African real estate into a mixed-asset portfolio. The study used annual data from the period 1996-2016 on the MSCI South African real estate index. The analysis of the risk-adjusted returns made use of the Sharpe Ratio, and the diversification benefits were assessed by means of correlation analysis. The results from the risk-adjusted analysis confirmed the performance of both direct as well as listed real estate, providing competitive risk-adjusted performance in comparison to bonds and stocks. Real estate contributed considerably to mixed-asset portfolios due to the highlighted portfolio diversification benefits. In order to achieve a greater understanding of housing prices, the article below looks at the house price shocks and structural breaks.

Gil-Alana, Aye, and Gupta (2012) conducted a test for persistence as well as outliers in the house prices in South Africa. Previous studies on the topic have recognized South Africa's housing sector as 29.4% of South Africa's household assets and 21.68% of South Africa's total wealth (Gil-Alana *et al.*, 2012). This study aimed to assess the influence that house price shocks have on both firms, in addition to South Africa's whole economy. There are significant features in the data, namely the structural breaks and the persistence of shocks across time. The quarterly data covered a span of three different timeframes for different house price segments. The middle income and luxury segment data covered the period of 1966-2012, the affordable segment, 1969-2012. These timeframes differ due to data limitations. The data chosen was acquired from the Amalgamated Bank of South Africa (ABSA). Aside from the persistence within the breaks, a further assessment in this study looked at the outliers which are used for the detection of shocks, which can be the result of numerous economic factors. These factors include changes in the monetary and fiscal policies in South Africa. The methodology employed is a series of unit root tests performed on the house price data, namely testing for stationarity and non-stationarity. The stationary I(0) test results concluded that the shocks are transitory and disappear in the long-run. This is the case for the affordable and luxury housing segments. However, the shocks will be permanent for the middle housing segment. Therefore, it was concluded that strong policy measures must be adopted for the middle housing segment because in the event of negative shocks, it will be necessary to recover to the original trends (Gil-Alana *et al*., 2012).

Kolisi and Phiri (2017) examined the relationship between South African interest rates and housing prices post the 2007 financial crisis. The data used for this study was quarterly time series data and was divided into two subdivisions. The data examined the pre-financial crisis from 2002-2008, as well as the post-financial crisis from the time period 2008-2016. The data chosen was that of the SARB repo rate (used to represent the interest rate), household disposable income, and the inflation rate. The housing price data was taken from ABSA and was further subdivided into three segments, subject to the households, explicitly affordable, middle, and luxury. The methodology employed in this study was that of the autoregressive distributive lag (ARDL) model. This model is used in order to determine whether the variables chosen from the study are cointegrated. Therefore, the study aims to determine whether a relationship exists between housing prices, inflation, and the interest rate in South Africa. Before the ARDL model can be utilized, each variable needs to be examined for stationarity through the use of the Augmented Dickey-Fuller (ADF) test in this article. The authors concluded that the results indicated that there exists a changing relationship between housing prices and interest rates in South Africa. This study aids in understanding whether housing prices have a relationship with other economic variables (Kolisi and Phiri, 2017).

Goodhart and Hofmann (2008) assed the linkages between credit, housing prices, money, and the economic activity in industrialized countries using data from the real gross domestic product (GDP), the consumer price index (CPI), nominal house prices, broad nominal money, nominal bank credit, and a short-term nominal interest rate. This quarterly data was obtained for the time period starting in 1970 and ending in 2006. The estimation technique utilized was a fixed-effects panel VAR. This study concluded that there is substantial evidence providing the existence of a multidirectional link among house prices, money variables, as well as the macro economy. This connection was noted to be stronger in the more recent years, dating from 1985. A further conclusion was that money and credit shock effects have proven to be significantly stronger when housing prices are thriving.

Balcilar, Beyene, Gupta, and Seleteng (2013) analysed the ripple effects of housing prices in South Africa. Previous studies done on foreign countries have revealed that housing prices are stationary, and hence that there are ripple effects that are present in housing prices. Therefore, there was a gap that the authors filled by performing the test on a South African dataset. The dataset chosen was that of five major cities, namely Durban, Cape Town, Johannesburg, Pretoria and, Port Elizabeth. Quarterly data was extracted and broken down into household segments based on small, medium, and the large-middle segment, as the luxury and affordable segments, were inaccessible at the time of the study. The timeframe chosen for the study was the years 1996-2010. The method used to conduct the analysis was unit root tests within the Bayesian modelling framework. This model employs both a series of nonlinear and linear unit root tests. The results of the tests confirmed the existence of ripple effects in the South African house prices within the three segments that were used for this study. Furthermore, evidence was found through a factor analysis that both Durban and Cape Town tend to drive the South African housing market (Balcilar *et al*., 2013).

Chang, Wu, and Gupta (2015) investigated whether South African house prices are really non-stationary. In order to examine the time-series characteristics of the South African house prices for the large, medium, and small-middle housing segments in each of the provinces. The Sequential Panel Selection Method (SPSM) was utilized for the methodology of this study. Quarterly data on each of the nine South African provinces, with regard to the various house-size categories, was collected for the timeframe of the years 1978-2012. The SPSM has the ability to determine how many, as well as which series are stationary. This is done by categorizing the entire panel into groups of both stationary and non-stationary. This study's results were obtained from both panel-based and standard time-series unit root testing and indicated whether the housing prices mentioned in this study are either stationary or non-stationary. The results concluded that stationarity is present across the nine provinces and their distinct sizes (large, medium, and small-middle).

2.3.4 Property as a hedge against inflation

This section incorporated studies from different countries, as well as South Africa, on the ability of property to act as a hedge against inflation.

2.3.4.1 International studies

The ability of residential property returns to act as a hedge against inflation was first proposed by Fama and Schwert (1977). The timeframe ran from 1953-1971. Their tests utilized the housing component of CPI and were constructed as a moving average hedonically-adjusted housing price per square foot in the United States. They found that the real housing appreciation returns were unrelated to the rate of inflation. The authors laid the foundation for this topic and their instruments were employed by authors such as Sing and Low (2011), who compared the inflation-hedging characteristics of both property and non-property assets. This study ran from 1978-1998 and also adopted the Fama and Schwert (1977) framework. These results indicated that the property offers a better inflation hedge compared to non-property assets, such as securitized property, Treasury bills, and stocks. It was noted that industrial property was proven to be the most significant inflationary hedge against both the expected and unexpected rate of inflation. Furthermore, retail shops only offered an effective hedge against the expected inflation rate. It was therefore concluded that when including industrial property and shop into an investor’s portfolio, it provided a hedge against the inflation risk, in addition to the other assets within the portfolio. This analysis was extended to examine the inflation-hedging properties of assets in situations of rising and declining inflation levels. It was found that in periods of low inflation, property was a suitable hedge against the unexpected inflation. However, during the high inflation periods, residential property proved to be an even better inflationary hedge (Sing and Low, 2011).

The inflation-hedging characteristics of residential properties in Malaysia were examined by Azmi, Hwa, Nawawi, Othman, Kaspin, Isa, Ariffin, and Hassan (2010). This study utilized the generalized Capital Asset Pricing Model (CAPM) to account for the inflation and the OLS model based on the Fama and Schwert (1977) model for the methodology. The correlation analysis revealed that real assets, such as private-equity assets (real estate and timberland) are positively correlated with the inflation rate. This was evident as the real estate coefficient was 1.2009 and the timberland coefficient was 105665, both coefficients were positive and greater than unity. However, stocks were said to have a negative correlation with inflation. There were data limitations, specifically with the real returns of the residential property in Malaysia, as it was unavailable. Therefore, the residential price index was utilized, as well as the three-month Treasury Bills rate, employed as the expected inflation rate, consistent with the Fama and Schwert (1977) study. This study further concluded that residential property proved to be partially inflation hedging, with only terrace houses providing a partial hedge against inflation. This could be attributed to its high numbers of transactions within the market, as well as the capital appreciations gained from it. However, geographically speaking, Selangor was able to hedge against both expected and unexpected inflation. This, therefore, implies that the residential property market in Selangor is the most suitable at providing an inflationary hedge (Azmi *et al*., 2010).

Stevenson and Murray (1999) observed the inflation hedging capabilities of real estate in Ireland. The timeframe utilized for this study was from the period 1985-1996. The methodology employed by the authors was that of the conventional Fama and Schwert (1977) model, coupled with the Granger causality and Engle and Granger (1987) cointegration tests. The outcomes from the regression analysis did not provide evidence that supports the tested hypothesis that real estate is an effective inflationary hedge. It was also noted that this study took place at a time of relative stability within the Irish inflation rates. The authors made the decision to rerun the regression analysis using annual data starting from 1969; however, the results remained unchanged. The cointegration tests that examined the long-run relationship also found no evidence supporting the initial hypothesis. However, the causality tests stated that real estate leads inflation. This study, therefore, provided different results in comparison to a majority of empirical research done on other real estate markets. Stevenson (2000) re-examined this relationship further. This study utilized data over a period of 30 years and utilized the conventional OLS models, as well as causality and cointegration models. The regional markets within the United Kingdom (U.K.) were used for this study. The results concluded that the OLS test provided minimal evidence of a stable and consistent relationship, as there was a large variation in the results obtained in the different regions. However, the results of the cointegration analysis, specifically the Engle-Granger technique, provided evidence that supported the hypothesis that inflation and housing are cointegrated. Furthermore, this was also supported by the causality test, which also provided evidence of this hypothesis (Stevenson, 2000).

Barber, Robertson, and Scott (1997) analysed the hedging characteristics of commercial property in the United Kingdom. This paper looks at the statistical similarities between commercial property capital, rental values, and the inflation rate in order to determine the hedging ability, as well as the type of inflation commercial property hedges against. Two estimation techniques were utilized for the purpose of this study, namely, structural vector auto-regressions and a multivariate unobserved components model. The results indicated that commercial property is an inflationary hedge. However, it is found to be a partial hedge. More precisely, the commercial property proves to be a partial hedge against the fluctuations within underlying inflation and not to the permanent price level changes. A further conclusion was that capital values are greater inflationary hedges than rental values, with retail and industrial property largely accounting for the hedging capacity. There was also no evidence indicating that property responds differently to low or high inflation rates, but the capital and rental values tend to respond greater to unexpected inflation than to anticipated price changes (Barber *et al*., 1997).

Rubens *et al*. (1989) researched investments that would protect investments against the persistent problem of inflation in the United States. These inflation-hedging assets are able to safeguard the value of the investment against the adverse effects of inflation. The dataset chosen ran from the period of 1960-1986. Although there has been research in the past stipulating that real estate is one of the best inflationary hedges, at the time of the study, there had been no current research exploring farmland or residential property as inflation hedges. Rubens *et al.* (1989) further explained that investment assets are held with the purpose of generating a positive real rate of return for the investor. However, it was noted that during periods of inflation, certain investments were not able to protect the investor and, as a result, as inflation increased, the value of the investment decreased. This is known as a perverse hedge. Portfolios were created, incorporating the three main types of real estate, namely farmland, residential, and business real estate. After testing the hedging effectiveness of this portfolio, the conclusion of the study was that farmland residential property acted as partial hedges against both expected and actual inflation rates. Furthermore, residential real estate was confirmed to be a partial hedge for actual inflation and a perfect positive hedge for the expected rate of inflation. However, business real estate was proven to be a perfect positive hedge for both the expected and the actual inflation rate (Rubens *et al.*, 1989). The ability of real assets to hedge against inflation was studied by Parajuli and Chang (2015). This is a further article that is based on inflation-hedging in the United States (U.S.). Inflation is known as a leading macroeconomic indicator and is known to produce extensive distortions within the general performance of investments within the financial market. By investing in inflation-hedging assets, an investor is able to eliminate or reduce the level of uncertainty of the future real returns of the investment. Real assets, such as real estate and farmland, have been considered as good investment assets (Parajuli and Chang, 2015). Quarterly data from 1987 was used in order to derive a reliable evaluation between the real assets. This study utilizes the generalized Capital Asset Pricing Model (CAPM) for evaluating the hedging ability of a variety of real assets in the U.S. The results were consistent with the preceding findings and concluded that real estate is able to hedge against inflation, whereas public-equity assets are less efficient at hedging an investor's portfolio against inflation.

Anari and Kolari (2002) conducted a study that observed the long-run relationship between homeowner equity and inflation. However, it was noted that previous studies were done on inflation and housing prices. Therefore, a different approach was taken. This study was conducted by determining the relationship between both house prices and non-housing prices (which are general prices that have been adjusted for the housing costs, which account for the relationship between nominal and the real interest rates), as opposed to the returns and inflation rates that were used in previous studies. The authors further detailed the reasons for their deviations were due to two reasons. Firstly, it is noted that the total return on housing cannot be accurately measured, which makes it an inaccurate representation. Secondly, by making use of return data, it can lead to the loss of valuable long-term information that is usually found in the data series. This downfall has led to house prices being more accurate as it reflects all the pertinent long-run information. The study made use of monthly data extracted from the United States, from the timeframe of 1968-2000. The methodology employed by the authors was that of an autoregressive distributive lag (ARDL) model as well as recursive regressions. The results from the tests reflected Fisher coefficients all greater than one over the time period chosen. These results, therefore, confirm that housing prices can be used as a suitable hedge against the effects of inflation in the long-run.

Hamelink and Hoesli (1996) tested the capabilities of real estate to act as an inflationary hedge on Swiss grounds. This study made use of four proxies to establish the expected inflation rate. Two of the four proxies mentioned are based on models for autoregressive conditional heteroscedasticity, namely the ARCH-M, in addition to the QTARCH. This study further utilized a proxy for the returns of the Swiss real estate, which was a transaction-based series. This is adjusted for the real estate's quality by utilizing a hedonic model. This study, therefore, makes use of both autoregressive as well as hedonic models. Coefficients such as Swiss bonds, real estate, and stocks are generally said to be positively correlated with the expected inflation rate. Furthermore, it is negatively correlated with the unexpected inflation. However, based on this testing, the results confirmed that these coefficients are not statistically significant. Hamelink and Hoesli (1996), therefore, concluded that Swiss real estate could not be used as a hedge against the effects of inflation.

The inflation-hedging capabilities of both real estate and financial assets were investigated in New Zealand by Gunasekarage, Power, and Zhou (2008). This study utilized quarterly data from the year 1979 to 2003 and employed both cointegration and causality tests. The findings revealed that the direction of causality exists from inflation to real estate, which implies that variations in the prices of property do not have the ability to cause inflation. This implies that the inflation cause is, therefore, independent of the real estate asset's movements in price. The results concluded that a strong long-run relationship exists amid the inflation rate and all forms of real estate. This includes commercial, residential, industrial, as well as the farm building. However, a long-run relationship among the financial asset's returns, such as stocks, as well as long-term bonds, and inflation was confirmed.

The shared structural time series mechanisms in residential property prices and inflation were examined by Chen and Sing (2006). This study utilized the multivariate common components model to establish the inflation-hedging properties of residential property. Data from five markets, namely, Tokyo, Hong Kong, Taipei, London, and Singapore, was taken for this study. The results were different for each of the respective markets. In Singapore, residential property was proven to be a perfect hedge against inflation for both short-term and permanent inflation values. However, for long-term inflation, Taipei residential property proved to be the most effective inflationary hedge. It was noted in this study that if an investor wants to invest in residential property within the U.K. and Asia markets, expecting their investment portfolio to provide natural inflation hedges, they will have to adopt a strategy, which the results indicate should be based on market timing. The results indicated that the best way forward would be to adopt different timing strategies. This will be utilized to reduce the exposure to the various inflation risks within the different markets (Chen and Sing, 2006).

Lee (2012) studied inflation and residential property markets and used a bounds-testing approach to investigate the short and long-term hedging ability of residential property in Hong Kong. The autoregressive distributive lag (ARDL) model was utilized over the time period 1980-2011 to determine the cointegrating relationship within the variables. This study's results concluded that the small and medium-sized Hong Kong residential properties provided a short-term hedge against the actual inflation rate. The results from the bounds test concluded that all categories of residential property, as well as common stocks, provided a long-term hedge against inflation. This was indicated by the beta coefficient for residential property as a whole being 1.386, which is positive and greater than unity. Similarly, for the small, medium and large sizes, the coefficients were 1.404, 1.451, and 1.281, respectively. Therefore, in the long-run, all residential real estate were proven to be better inflation hedges than time-deposit.

Another international article that also utilized the ARDL model to estimate the impact of consumer prices on house prices was a study done by Ma and Lui (2008). This study used data from Australia and broke it down into eight capital cities. The study ran from 1989-2001. In general, the results concluded that a long-run relationship exists between inflation and housing prices, as specified by the coefficient's t-statistics. However, when these significances were compared, it was noted that the influence of inflation on housing prices depends on the inherent characteristics of each city. Furthermore, Zhou and Clements (2010) examined the capability of Chinese real estate to hedge against inflation. This study was conducted due to the current rising of the expected inflation in the People's Republic of China. The timeframe of this study ran from 2000-2008, which was the period post-privatization of Chinese real estate. The cointegration technique utilized to examine this relationship is that of the ARDL model to investigate the existence of a long-run relationship between Chinese inflation and house prices. This study's results confirmed no long-run cointegration present among the inflation rate and real estate price changes. Therefore, it was concluded that real estate in China is not able to hedge against inflation (Zhou and Clements, 2010). Although the same methodology was employed by the authors above, the studies were taken from different countries and timeframes, which are contributing factors that would explain the differences in results. Although there are not many studies that have shown property as being unable to hedge against inflation, it is important to incorporate this, as it allows for significant comparisons to be drawn. Further studies that have led to that conclusion are examined below.

The inflation-hedging ability of housing properties was examined in Shanghai by Li and Ge (2008). This study assessed the short-term and long-term hedging properties of residential property against expected, unexpected, as well as actual inflation. The OLS model was utilized for the timeframe of 1997-2005. The expected inflation was estimated using both the Hedrick-Prescott Filter and the Autoregressive Integrated Moving Average (AIMA) methods. The results obtained illustrate that the Shanghai property was not able to hedge against all forms of inflation. On the other hand, positive real returns were obtained for all situations. Fang, Wang, and Nguyen (2008) explored the ability of housing to hedge against both expected and unexpected inflation in Taiwan. This was done to determine if the rise in housing prices is able to compensate for any additional costs due to the decrease in purchasing power. Over the time period of 1991-2006, the exponential generalized autoregressive conditional heteroscedasticity approach within the mean model framework was utilized. The results confirmed a negative relationship between the housing returns and both the expected as well as unexpected inflation rate. Therefore, this concludes that Taiwan's housing investment is an ineffective inflation hedge.

2.3.4.2 South African studies

Inglesi-lotz and Gupta (2013) assessed whether a long-run relationship between inflation and house prices, as well as non-housing goods and services, is present. This assessment was done in order to determine if residential property can be used as an effective hedge against inflation. This study based its evidence on South African data, which made it an excellent practical example and choice to include in the literature review. The data chosen was quarterly data from the ABSA database for the luxury, middle and affordable house segments. The inflation data chosen was the consumer price index that excluded housing costs and was obtained from Statistics South Africa. The timeframe chosen for the study was from the years 1970-2011. The methodology employed by the authors for the study was that of the autoregressive distributive lag (ARDL) model as it is able to determine whether the above variables are cointegrated. The results from the study confirmed that there is long-run cointegration between the house segments and inflation. This was done by rejecting the null of no cointegration, which, therefore, establishes the existence of a long-run relationship, which was one of the two conclusions made by the authors. The second conclusion was done by examining the long-run elasticities, which confirms the strength of the relationship. This is determined by a coefficient of either negative, positive, or greater than one. The results confirmed that the coefficients for all housing was 0.952, and the luxury and small segments were greater than unity at 1.111 and 1.006, respectively. These results are positive and signified that in the long-run, housing prices are a suitable hedge against inflation in South Africa (Inglesi-lotz and Gupta 2013).

Asset price's predictive ability to forecast South Africa's inflation was assessed by Gupta and Hartley (2013). This study also made use of the GDP growth in South Africa, as it further evaluated the ability that asset prices have to forecast output growth. It is evident that financial markets play a pertinent role in influencing South Africa's economic activity, namely through the influence of household expenditure. Quarterly data were collected for the time period of 1980-2010 from three primary sources, namely, the South African Reserve Bank, Bloomberg and, the International Financial Statistics databases. The methodology section was computed using an autoregressive distributive lag (ARDL) model, as well as the Bayesian method for both univariate and multivariate factor models. The results from the ARDL model confirmed that asset prices are a suitable variable used to forecast inflation, specifically during the short-run. There is also enough evidence to prove that there is significant variability between output growth and inflation in South Africa.

Taderera and Akinsomi (2020) investigated the ability of commercial real estate to act as an inflationary hedge in South Africa. This study proved to be a recent, as well as a relevant study, as it examined the hedging ability of property in a South African context. The time period chosen ran from 1995-2016. The vector error correction model (VECM) utilized for cointegrated time series, and this model is the estimation model for the purpose of this study. This model was employed to examine if a long-run relationship is present between inflation and the property returns. Furthermore, the degree that inflation drives the returns of property is also examined. The results indicated that commercial real estate provided a pervasive hedge against the effects of inflation in the short-run. Alternatively, within the long-run, both retail, as well as industrial property are inflation hedges. However, retail property is the superior hedge in comparison to industrial property. Therefore, for investors in search of a long-term inflationary hedge, commercial real estate is a suitable investment option. However, in the short run, it would be more beneficial to invest in the listed properties market.

It can be noted that although the above studies on the topic have proven to be useful in estimating the regressions to obtain adequate conclusions on the relationship between property and inflation, there have also been limitations that need to be accounted for. It was noted in the inflation-hedging theories that cointegration techniques such as the VECM and the ARDL model are utilized for estimating linear relationships. Yeap and Lean (2017) examined asymmetric adjustment in the context of the house price and inflation relationship. This article is discussed in detail below. This is relatively new to econometric analysis, and the inclusion of nonlinearity is explored by a limited number of authors. There have been recent studies that have been done that incorporate asymmetric and nonlinear relationships when formulating the housing price models. However, these studies are not based on South African studies but rather on other parts of the world. The contribution of this study fills the gap of limited existing literature on residential property in South Africa from an asymmetric perspective. The articles above looked at both residential property from an ARDL perspective, and commercial property in South Africa. This highlights the contribution to literature of this study containing both a nonlinear perspective, as well as an analysis of residential property in South Africa.

2.3.4.3 Asymmetry in housing prices

This section of the literature review incorporated studies that have examined asymmetry and nonlinearity within housing prices internationally. Balcilar, Gupta and Miller (2015) examined the out-of-sample forecasting performance of nonlinear models of the U.S. regional housing prices. The forecasts utilized were that of the traditional point forecasts, as well as density and interval forecasts of the housing price distributions. It was noted that in the long-run, the nonlinear smooth-transition autoregressive model outperforms the linear models, and in short-horizons, the models perform equally. The results indicated that for both interval and density forecasts, there was no major differences in the performance of the linear and nonlinear models. This study concluded that when forecasting regional house prices in the US, the additional costs of nonlinear forecasts tended to outweigh the benefits for the forecasts within a few months.

Changes in hose prices have an effect on government and individuals as they have a significant influence on a country's socio-economic conditions. It is necessary to value houses for the purpose of assessing the benefits and limitations in the property sector. Azadeh, Sheikhalishahi and Boostani (2014) presented a flexible meta-modelling approach in order to improve house price estimation in complex environments. The methodology comprises of fuzzy linear regression (FLR) and artificial neural network. The FLR employed seven models in order to cover the latest viewpoints. For the purpose of selecting the preferred FLR model, the mean absolute percentage of error is chosen for further examination. This study examined and forecasted the housing prices in Iran, which is mostly based on eight economic indices. These indices include general index, currency, house service pricing index, oil income, and gross domestic production, rate of informal market, construction material price and added value of oil group. The results indicated that the FLR was the preferred model, as it had the lowest mean absolute percentage of error for forecasting house prices in Iran. This revealed that Iran's housing markets are associated with extreme market "fuzziness". Below are some studies that have utilized the Nonlinear Autoregressive Distributive Lag (NARDL) model for the purpose of explaining the nonlinearities in the relationship between house prices and different variables.

Urbanisation is a term that is linked with the continuous degeneration of a natural habitat. In the majority of cases, when the demand for housing starts to increase, natural habitats such as forestry, water bodies and agricultural land are lost through the building of structures. Uzuner and Adewale (2019) investigated the asymmetric nexus of house prices and agricultural land. This study utilized annual data from Sweden for the years 1976 to 2015. Economic Policy Uncertanty (EPU) was used as the control variable for this study, and the methodology employed was that of the NARDL model. The results concluded that there was a significant and positive short and long-run relationship that existed between agricultural land and housing prices. This was more evident in cases where there was a negative shock present on agricultural land. However, when there existed a negative shock on EPU, the impact on housing prices was negative and significant for the short and long-run. This study concluded that there is an asymmetric long-run relationship that is significant and positive between housing prices and EPU. This significant relationship, however, did not exist for the agricultural land. This implied that in order to meet the demand for housing and mitigate an increased growth in housing prices, implementing an effective land use policy is strongly encouraged (Uzuner and Adewale, 2019).

Another study that utilized the NARDL model was by Rehman, Ali and Shahzad (2020). This study examined the nonlinear impact of both inflation and oil prices on residential property. The quarterly data chosen for this study was taken from the U.K, U.S and Canada for the years 1975 to 2017. The NARDL model was chosen for this study due to its ability to account for the possible asymmetric effects in the short and long-run. The results indicated that interest, oil prices and inflation rates have an asymmetric relationship with the property prices in all the mentioned countries. However, the magnitude of this relationship varies between the countries. The long-run coefficients of the inflation rates were significant for all three residential prices. Conversely, for oil prices, the U.S had more significant asymmetric effects, in comparison to the U.K and Canada. Interest rates also tended to influence the property prices of the U.K and Canada. This paper, therefore, has implications both the government authorities that regulate the housing sectors, as well as the investors that invest in the housing markets. A similar study that utilized the NARDL model examined the effects of the interest rate on the Malaysian house prices (Tan, Lee, Tan and Keh (2018). This model was utilized for two time periods, namely quarterly data from 1980-1998, and 1998-2017. The purpose of this was to examine both the short and long-run effects that the interest rate had on the house price index. For the period of 1980-1998, the results indicated a significant and positive long-run relationship between interest rate increases and the housing price index. In addition to this, a negative and insignificant relationship was established between interest rate decreases and the housing price index. Furthermore, for the period of 1998-2017, both the interest rate increases and decreases were insignificant with the house price index. This, therefore, indicated the role that is played by the interest rate in order to justify the movement towards the Malaysian house price index was getting less influence than in the past.

In Turkey, the housing sector plays an important role in the economic activity. This sector has the ability to absorb a significant size of both the unskilled and skilled unemployed individuals. Additionally, through the process of decreasing rent, this would lead to an increase in household savings due to a decrease in basic expenditures. This is a reason why having the adequate insights and knowledge about house price dynamics is important for economic policymakers. Karamelikli (2016) examined the linear and nonlinear house price dynamics in a study between house prices and inflation, unemployment, real gross domestic product and the interest rate. This study utilized the NARDL model in order to examine the asymmetric relationships in the long-run. The results indicated a negative relationship with the interest rate and inflation on housing prices. The impact of inflation was greater than that of the nominal interest rate, which would lead to the long-run real interest rate having a positive coefficient. Hence, the results indicated that there was a positive relationship between housing prices and unemployment.

The next section of the literature review details the research problem with a number of asymmetric studies. This section looks at the ability of property to hedge against inflation, with the use of many different econometric techniques. This section comprises of multiple views on the topic, which incorporates studies that have concluded that property both can and cannot hedge against inflation.

2.3.4.4 Studies accounting for asymmetric adjustment

Evidence from Malaysia on the hedging capabilities of residential property against inflation was examined by Aqsha and Masih (2018). This article is beneficial in that it extends current literature by using an advanced technique of the nonlinear autoregressive distributive lag model (Shin *et al*., 2014) to study the asymmetric relationship among the two variables. The author's results indicated that in the long-run, housing prices responded asymmetrically to the inflation rate. Although there has been a rise in the cost of housing in Malaysia, investors have still actively invested in property. This study used quarterly Malaysian data for the timeframe of 1986:Q1-2018:Q2 and focused on the HPI and CPI variables. The conclusion from the above study was that in the long run, residential property is a suitable inflationary hedge. However, an increase in house prices can be counterproductive in that it is beneficial for current homeowners but more expensive for first-time buyers. The younger generations find it difficult to purchase a home. Therefore, the way forward is to bring house prices in line with inflation so as to make houses affordable for all income levels. This study further looked at the hedging abilities of stocks and gold and concluded that residential property and stocks are effective hedges against inflation in the long run, compared to gold prices. The authors emphasized that residential property is the best investment option due to the possible capital appreciation as, with time, property gets more expensive in comparison to the other two investments.

Yeap and Lean (2017) also studied the asymmetric relationship between house prices and inflation in Malaysia. The analysis divides consumer and energy inflation into both positive and negative compositions. Both the long-run, as well as the short-run analysis of housing’s inflation hedging properties are tested by means of a NARDL approach. The results are established on the aggregate, in addition to four key categories of households in Malaysia. It was, therefore, found that in the long-run, house prices have a symmetric relationship with both energy and consumer prices. In the long-run, investing in all categories of households is unable to hedge against energy inflation, with only terraced households hedging against consumer inflation. However, housing prices respond to consumer and energy inflation asymmetrically in the short-run. Therefore, it can be concluded that housing asset investments are unable to protect against inflation.

Kuan, Yuan-Ming, and Binh (2008) utilized a Nonlinear Vector Error Correction method to examine the asymmetric inflation hedge of housing returns. Taiwanese monthly data on inflation and the housing returns were used to perform this analysis. This study established inflation as the threshold variable in order to generate the nonlinear vector correction model that splits inflation into the high as well as the low regime. This is done as it tends to have a large influence on the empirical results. The results from this study found robust evidence that when the inflation rate is greater than 0.83% of its threshold value, housing is able to act as a hedge against inflation if not, they are unable to do so (Kuan *et al.,* 2008). The methodology of this paper differs from others, which made use of the linear VECM and VAR model. These models focus on the symmetric relationship between these variables and tend to overlook the possible asymmetric effects. This study by Kuan *et al.* (2008), therefore, provides a new set of discoveries by utilizing a methodology that is different from that in the existing literature.

A recent study conducted by Christou, Gupta, Nyakabawo, and Wohar (2018) explored whether U.S. house prices hedge against inflation. This study assesses the long-run relationship of the non-housing CPI, as well as the U.S house prices. Monthly data was taken from the time period of 1953-2016. The methodology employed was that of a quantile cointegration analysis. The results of the standard cointegration models presented evidence of instability within the model. This suggests possible structural breaks being present within the relationship, as well as nonlinearity. This was a key motivation for the utilization of a time-varying approach, such as a quantile cointegration analysis. This analysis permits for the coefficient of cointegration to differ over the distribution of the housing prices. This approach also examines each quantile for the presence of cointegration (Christou *et al.,* 2018). The results from the regression analysis suggest that house prices and non-housing CPI are only cointegrated in the low quantiles. This is due to housing prices tending to over-hedge inflation in the lower quantiles. Furthermore, the results hold for cases where the price levels are higher only. This, therefore, implies that house prices are inflation hedges in situations where inflation is greater and housing prices are relatively lower.

The inflation-hedging abilities of real estate, stocks, and gold were investigated in a comparative investigation by Salisu, Raheem, and Ndako (2020). This was a study conducted using data from the United States. It was noted that each investment has a varying market characteristic and ought to react in a different way to a high inflation rate. This study utilized Fisher's hypothesis for the inflation hedging of the assets in both the bivariate and multivariate modelling contexts. This study also incorporated asymmetry, structural breaks, and time-variation into this estimation procedure. The results were found to be sensitive when the dataset was decomposed into periods before and after the financial crisis. This, therefore, implies that the inflation-hedging relationship between the assets is time-varying. This study's results expressed heterogeneous tendencies across the asset classes. Stocks and real estate investments were established as good inflation hedges, whereas gold defied Fisher's hypothesis. The outcomes were further valid when structural breaks and asymmetric adjustment were accounted for.

Since the topic of asymmetric adjustment is fairly new to econometric analysis, there is limited existing literature on inflation-hedging and property. However, there are a few studies that have looked at other hedging mechanisms in an asymmetric setting. A South African study by Phiri (2017) examined the long run equilibrium adjustment between the stock market returns and inflation. This study was the first study to examine the asymmetric cointegration between inflation and the stock market returns in South Africa. This study used monthly data on the total change in CPI and the percentage change in the total stock prices for the Johannesburg Stock Exchange (JSE) for the years 2003 to 2014. The model utilized for the purpose of this study was the momentum threshold autoregressive (MTAR) model. The results indicated a negative coefficient of -0.16, and found evidence of asymmetric adjustment. This implies that there is a negative and nonlinear cointegrating relationship between stock returns and inflation. The results of this study suggests that investors are unable to hedge against inflation by investing in the equity listed in South Africa.

Aside from the inflation-hedging ability of property and stocks mentioned above, the hedging ability of gold is also looked at in an asymmetric setting. Van Hoang *et al.* (2016) examined the ability of gold to act as a hedge against inflation. This article used data from many countries, including China, Japan, India, France, the U.K., and the U.S. for the timeframe of 1955 to 2015. This study utilized the NARDL model for its advantage of capturing the positive and negative changes independently. The results from this study indicated that gold is unable to hedge against inflation in the long run for each of the countries. However, gold is able to hedge against inflation in India, the U.S., and the U.K. in the short run. This study is considered in greater detail in the methodology chapter, for the purpose of the NARDL model.

Due to the studies on nonlinearity and asymmetric adjustment being relatively new, recent and limited studies were presented in this subsection. With regard to property, the studies have conflicting results. The study by Yeap and Lean (2017) suggested a symmetric relationship between house prices and consumer prices. However, the other studies, such as by Aqsha and Masih (2018) found evidence of asymmetric adjustment when considering the inflation-hedging ability of residential property. This highlights the contribution of asymmetric adjustment to econometric analysis and the benefits of incorporating this extension to new studies.

2.4 Chapter summary and conclusion

The purpose of this chapter was to discuss, in detail, previous studies on the inflation-hedging ability of residential property. It can be concluded that even though each component of the literature that was reviewed is unique, the detrimental effects of inflation are highlighted, and the need for investment opportunities that hedge against inflation is emphasized. A variety of different techniques were developed over the years to test inflation-hedging. It was evident that this is a problem that has been present around the world since the first tests were conducted in this field of research. The research problem is set out to determine whether residential property is an effective hedge against inflation in South Africa. Although there have not been many tests on South African data, the requirement of an inflationary hedge is emphasized. The majority of existing literature concluded that residential property is a suitable hedge against inflation, with a few studies proving otherwise. From the body of literature that was reviewed, it is probable that residential property will be confirmed to be an effective hedge against inflation, as the majority of existing literature had positive results.

It is important to note that the significance, as well as the magnitude of the relationship between residential property and inflation, differ, subject to a variety of reasons. The results from the tests may vary depending on the author's choice of countries, market conditions, timeframes, as well as the chosen variables to include in the model to perform the various tests (Hoesli, Lizieri, and MacGregor, 2008). It can also be noted that there is limited existing literature on this topic with regard to nonlinearity, which emphasizes the importance of this contribution to literature. The study of nonlinearity is relatively new to econometric analysis and is presented in more recent studies (Aqsha and Masih, 2018). This topic has only been examined internationally, as noted above by Christou *et al.* (2018) and Salisu *et al.* (2020). The topic of real estate as an inflationary hedge has only been examined in a symmetrical setting in South Africa. This was evident in the studies proposed by Inglesi-lotz and Gupta (2013), as well as Taderera and Akinsomi (2020). These studies indicated positive results that confirmed that property in South Africa had the ability to hedge against the effects of inflation. Judging by these results, which utilized South African data that is similar to the data used for the purpose of this study, it is possible to predict that similar results are expected. Furthermore, the asymmetric adjustment for residential property and inflation has not been looked at in a South African context. However, the benefit of accounting for nonlinearity has been shown to be prevalent in South Africa when considering equity as a hedge against inflation (Phiri, 2017) and it is expected that the analysis of property in the same context will be a substantial contribution to the literature. This, therefore, provides the foundation for the nonlinear autoregressive distributive lag model, which will be discussed in detail in comparison to the linear autoregressive distributive lag model in the methodology section of this study.

CHAPTER 3: DATA AND METHODOLOGY

3.1 Introduction

In the preceding chapter, a detailed review of the theoretical background of inflation, property and inflation-hedging methods were presented. Empirical literature was also examined the capacity of property to act as an inflationary hedge. The empirical review was further characterized by international and (although limited) local studies. This section also included various authors' views on whether or not residential property is an effective hedge against inflation. Therefore, there was conflicting views within the body of the existing literature on the nature of the relationship between property and inflation, and by extension, the capabilities of residential property to hedge against inflation. However, the South African studies mentioned confirmed positive results, which indicated that property was able to act as an effective hedge against inflation. It is, therefore, possible to assume similar results from this analysis. The literature in the empirical subdivision detailed a variety of econometric tools utilized to determine the results.

This study aims to utilize recent methodology that incorporates the various limitations that were discussed in the different methods of inflation-hedging. The data and methodology section of this study details the procedures necessary in order to examine whether residential property is able to hedge against the adverse effects of inflation. It is necessary to utilize data that is reliable and recent to ensure the most accurate results (Soffer, 2019). Furthermore, the use of up-to-date methodology allows for a more accurate representation of the ever-changing world of econometrics. Since drawbacks to certain estimation techniques are accounted for in the more recent models, all of this information will therefore, need to be taken into consideration.

3.2 Data

The data chosen to be used in the NARDL model is locally sourced data. This data is consistent with existing South African literature as examined by Inglesi-Lotz and Gupta (2013). Data for two variables, inflation and housing prices, was collected proxied by CPI and HPI, respectively. Therefore, this data is utilized to examine whether a long-run relationship is present between these variables. Although control variables can be added to the chosen data, the majority of existing literature on this topic, such as the article by Inglesi-lotz and Gupta (2013), conducted a bivariate study using CPI and HPI in South Africa. Therefore, keeping in line with previous studies, a bivariate study using only the focus variables was conducted. A reason for the decision to not include multiple variables was established in the Inglesi-Lotz and Gupta (2013) study. The authors found that by including variables such as real GDP and population, the result was that the null of no cointegration was rejected. This inclusion also affected the long-run elasticity, which differed from unity.

Quarterly data from January 1989 to December 2019, which covers a span of 30 years, was used. This is consistent with Kim and Ryoo (2011), which is discussed further in this section. Quarterly data was chosen as this type of data is relatively straight-forward for identifying trends; therefore, changes in the variables are easier to identify (Reilly, 2013). This type of data is taken every three months and thus, allows for the adjustment for seasonality. Furthermore, quarterly data is also advantageous for data extracted for more extended time periods (Reilly, 2013). Quarterly data was used in many articles, such as Gunasekarage *et al.* (2008) and Aqsha and Masih (2018), who each tested housing prices as a hedge against inflation. Although CPI data is published monthly, a further motivation for the use of quarterly data was due to the HPI figures from DallasFed being quarterly, as well as the ABSA housing price segments that were used in this study.

Quarterly data for a 30 year period represents 120 observations for the sample size of the study. The central limit theorem (CLT) defines the distribution of a sample mean approximates a normal distribution as the distribution's sample gets greater. There is a simple rule of thumb based on the CLT, that states that sample sizes that are equal to or greater than 30 are considered adequate for this theorem to hold (Chang, Huang, and Wu, 2006). Therefore, 120 observations is a relatively large sample size. The main advantage to choosing a larger sample size is due to the accuracy and reliability of the results. A greater sample allows for more accurate values of the mean and makes it simpler to recognise outliers that are able to skew the data in smaller sample sizes (Zamboni, 2018).

The adequacy of the sample size has been established in literature by Kim and Ryoo (2011), as well as Moores-Pitt and Strydom (2017). They conducted similar studies on the use of common stocks as a hedge against inflation. These authors found that the 30-year period provided optimal power properties in the tests utilized. In addition to those articles, the adequacy of the chosen sample size is also present in the literature review section. In the empirical review of inflation in South Africa, Akinboade *et al.* (2004), who looked at the determinants of inflation, and Leshoro (2012), who examined the detrimental effects of inflation on economic growth, also utilized the 30-year sample period. Gupta and Hartley (2013) also used the 30-year period to observe the ability of asset prices to forecast inflation. Keeping in line with the current research topic, Stevenson (2000) used the 30-year sample period to examine the relationship between residential property and inflation. It can therefore be concluded that the chosen sample size has proven to be relevant by multiple authors. Furthermore, the data chosen will be the most recent and hence, will aid in the reliability of the results.

This study is especially important in the context of South Africa because it examines a time period that proves to be extremely relevant in the context of South African history, in that it covers a period of key political, social, and economic volatility. Events such as the ending of the Apartheid-era (which was from 1948-1994) as well as the transition period from the Apartheid-era to the post-Apartheid period are included in the data (Nittle, 2018). Another event that occurred during the timeframe specified is the 2007-2008 financial crisis. This was a global economic crisis that had an impact on a variety of macroeconomic factors (Singh, 2019). This is known as contagion, which can be described as an event whereby a disturbance in one specific area has a knock-on effect on other areas. This can be either at a local or international level and entails spreading a financial crisis from one area to another, leading in other countries being affected by the spill-over effects of the crisis, in a domino effect (Ganti, 2019).

Other factors, such as political instabilities and uncertainties in the country, also affect the inflation rate. These factors link to the structural changes that occur during the sample period, which is assessed by the structural breaks test. These further include the 1997 Asian financial crisis, which affected inflation and housing prices in the 1997-1998 timeframe. By the year 2000, South Africa adopted the inflation-targeting regime, in order to stabilize the inflation rate, at the target of 3-6%, which remains today. The above events are discussed further in the structural breaks section of the results and discussions chapter. All these events need to be taken into account as they play a pertinent role in South African history and have had significant impacts on the variables studied.

3.2.1 Inflation data

The Consumer Price Index (CPI) was used as a proxy for the inflation rate in South Africa and is available for public use on the Statistics South Africa website (STASSA, 2020). Authors such as Kim and Ryoo (2011) and Aqsha and Masih (2018) used CPI as a proxy for inflation. The Consumer Price Index can be defined as an index that measures the price of the average basket of goods or services that is purchased by a consumer. Changes in the CPI value are known to record the rate of inflation in South Africa (STASSA, 2020). CPI is made up of eight categories. These include food and drinks, housing, transport, appeal, medical care, communication, education, and recreation (Perez, 2020).

The use of the CPI as a proxy for inflation is common in the literature (Taderera and Akinsomi, 2020), but does have potential drawbacks. According to Hamel (2018), these include that CPI fails to account for individual buying habits, new products, and substitute products. Therefore, CPI may tend to either overestimate or underestimate inflation (Hamel, 2018). Although CPI does the job of representing a measure for the overall inflation rate, it may not be as effective in measuring a specific individual's inflation rate because this differs from person to person, which is linked to their individual buying habits. Furthermore, when a new product enters the market, it does not form part of the basket of goods for CPI until it becomes a common consumer good (Hamel, 2028). Product substitutes relate to the situation that arises when the product's price increases, causing consumers to buy less of it and more of a cheaper substitute product. The CPI is, therefore, unable to accurately account for these shifts in consumer preferences.

Aside from the disadvantages of using the CPI as a measure for inflation, there are also a few advantages. Two significant strengths of CPI are that of its consistency and flexibility (Gresham, 2017). Consistency is a term used to describe how it measures the cost of a group of goods that remain consistent in its representation of the costs faced by an average consumer. As the goods evolve in the marketplace, these changes are included in the CPI. The flexibility component refers to the variations of the CPI that are created to include external factors, which include consumer choice and seasonal adjustments (Gresham, 2017). A further advantage of the CPI lies in its influence. It is known as one of the most highly regarded economic indicators and its calculations can have an impact on both fixed-income and equity markets. It is able to shape the public's opinions on the state of the economy as it is a measure that is utilized globally and analysts use CPI to generate predictions about future trends (Gresham, 2017).

CPI can be calculated by taking the changes in price for each prearranged basket of goods or services and averaging this value. Furthermore, CPI can be used as an index representing the cost-of-living (STASSA, 2020). For this reason, CPI is known as the most common index for identifying inflation in a country. CPI, therefore, acts as an accurate proxy for the inflation rate in South Africa and is reliable data for the purpose of this study (Inglesi-lotz and Gupta, 2013).

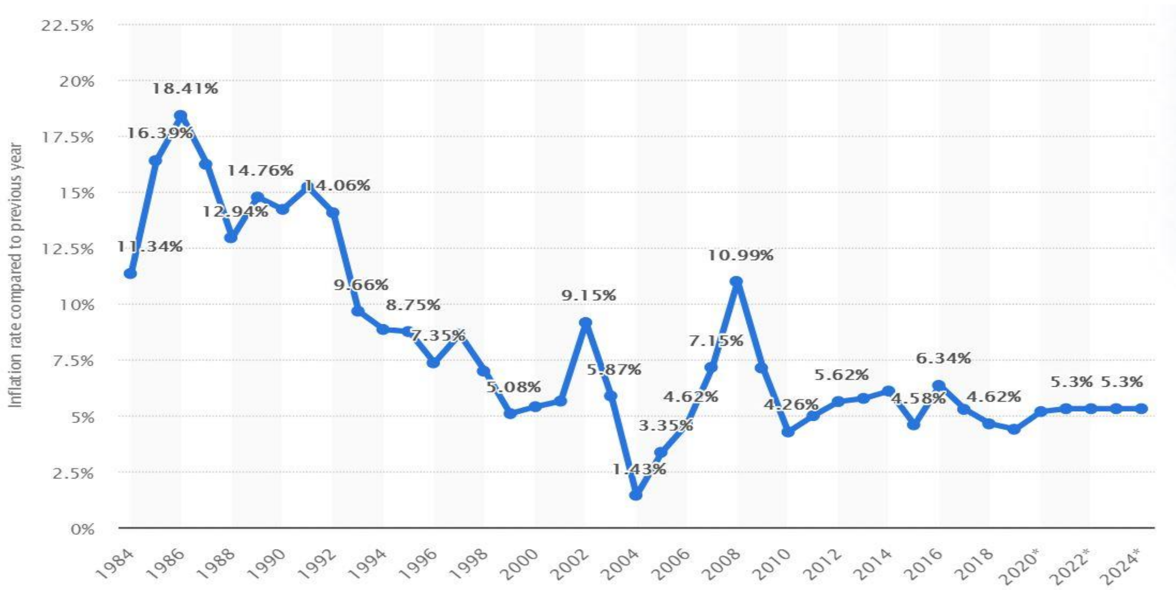


Figure 1 above shows a line graph of the annual Inflation rates for South Africa for the years used in this study.

The above graph was taken from Statista (2020), and provides an accurate representation of South Africa’s inflation over the study’s timeframe. The figures for 2020-2024 are forecasted figures for the inflation rate. This graph is provided for illustrative purposes, but for the purpose of this study, year-on-year adjusted headline data was used. South Africa represents a perfect natural experiment for this type of analysis due to the exceptionally high historical volatility, which has an inflation rate ranged from almost 0% to just under 20% over the proposed sample period of 30 years (Plecher, 2019). It is evident that during the Apartheid era, inflation was at its highest at the time, reaching 18.41% in 1986. However, from that point, inflation started to decrease to 8.75% in 1994 at the end of the Apartheid era. Inflation then began to decline steadily until its highest since the end of Apartheid, which was 10.99% in 2008. This high inflation followed the 2007-08 financial crisis. Inflation decreased from this point onwards until a spike in 2016 to 6.34%.

This spike affected the GDP, which further affected the economic growth in South Africa. Plecher (2019) stated that this low growth was attributed to weak demand in addition to the uncertainty in the country's political future. This caused a crisis, which was aided by President Jacob Zuma's allegations on the mismanagement of South Africa's funds and led to the downgrading of the economy's outlook by rating agencies. However, since the change in the country's political stance in 2018, when President Zuma was relieved of his office, inflation in South Africa seemed to have stabilized. It can be noted that in the most recent years, inflation has been relatively stable between 4.58%-6.3%. Inflation in South Africa is expected to remain steady at around 5% in the near future (Plecher, 2019). South Africa has adopted inflation targeting since the early 2000s, and the objective of the South African Reserve Bank (SARB) is to keep the CPI within the target band of between 3 to 6% (Bishop, 2018).

3.2.2 Residential property data

Regarding the data for residential property, the housing price index (HPI) is used to track the movement of house prices over time and analyse the market's performance, which is beneficial for investors (Garg, 2016). The HPI was utilized by various authors such as Inglesi-lotz and Gupta (2013), Aqsha and Masih (2018), and Anari and Kolari (2002). This measure enables investors to decide whether to invest in residential property, as it indicates whether the value of a property is currently increasing or decreasing. Therefore, due to this index providing all the relevant information an investor will need on the housing market, it is a suitable measure for the context of this study (Garg, 2016).

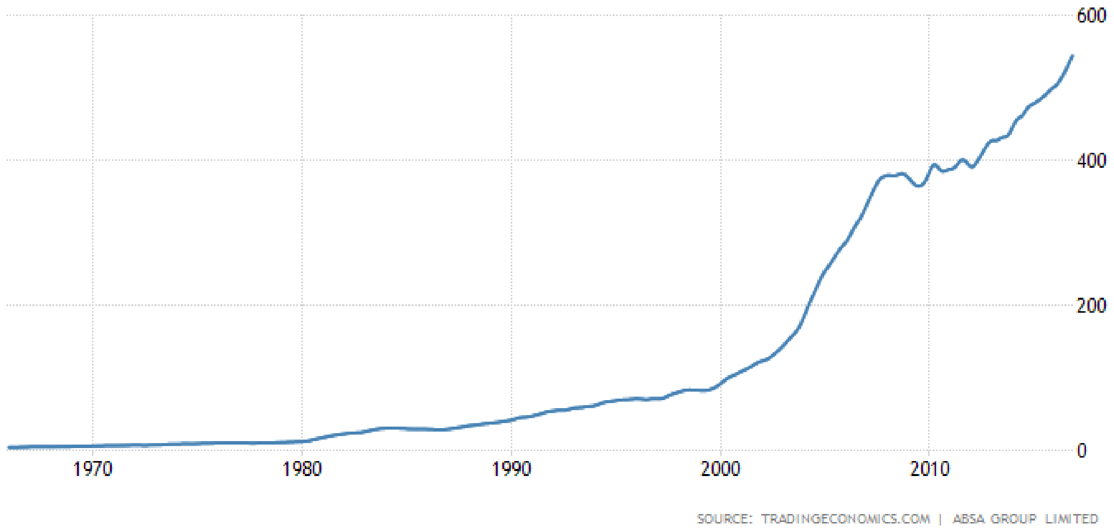


Figure 2 above shows a line graph of the annual House Price Indices for South Africa for the years used in the study.

The above graph was taken from ABSA bank and accurately depicts the HPI of South Africa over the study's timeframe (Tradingeconomics.com, 2020). It can be noted from the graph that from the beginning of the timeframe, HPI has gradually been increasing, with slight fluctuations. A fairly large increase took place from the time period of the years 2000-2007, this period was the post-apartheid era. Liberto (2019) stated that the rise in house prices has positive impacts on the economy as it stimulates investor confidence and can, hence, increase consumer spending. This, therefore, increases aggregate demand, improvements in GDP, as well as overall economic growth (Liberto, 2019). There was a slight dip in 2007-2009, which was recovered by 2010. It can be noted that this was the period of the 2007-08 financial crisis. It was evident that this crisis affected the real economy of South Africa, and hence, house prices had declined (Zini, 2008). When there is a decline in house prices, it erodes investor confidence, and companies that rely on profits from the demand for real estate tend to lay off their staff. This is due to the loss of profits, which creates a financial strain on companies. A further effect on the economy is that a recession can be triggered (Liberto, 2019). When there is a rapid fall in house prices, it can be characterized as a negative wealth effect. This is due to a decline in the consumer's wealth as it is a decline in the investment asset. This, therefore, causes consumers to lower their spending and increase their saving (Pettinger, 2016). This can lead to households being trapped in a 'negative equity', which occurs when the value of the house is lower than the price that was paid for it. This knowledge of negative equity discourages investors from borrowing and encourages saving. However, first-time home buyers benefit from a fall in house prices because it reduces the cost of the house (Pettinger, 2016). In the most recent years, it can be seen that even though there were a small number of fluctuations in the HPI, the index has been increasing, which has a positive impact on the South African economy.

It was noted by Luüs (2005) that from the year 1986 till the end of 1991, changes in house prices were at a similar pace as inflation. However, in the 1992-1993 period, there was a decrease in confidence, which was attributed to uncertainty about the country's political future. Shortly after, in 1994, house prices started to recover. In 1998, lower inflation and interest rates, with higher economic growth and an improvement in the fiscal situation in South Africa, caused the market to recover (Luüs, 2005). Due to the contagion effects after the Asian crisis, there was a substantial drop in value of the rand. This led to an increase in interest rates by seven percentage points by the end of 1998. The situation had somewhat stabilized by late

1999, and the boom in housing prices continued. By the year 2003, house prices had just about doubled value nominally, in comparison to the house prices in 1998 (Luüs, 2005).

House prices are reflected in nominal and real terms. The decision on whether to conduct the test using nominal or real values is based on the Fisher's (1930) hypothesis. This hypothesis essentially states that there is a positive relationship between the interest rates and the inflation rates. The basic form of this equation is represented as follows:

$$real_i \approx nom_i - \pi \qquad (1)$$

Where: $real_i$ denotes the real interest rate, nom_i denotes the nominal interest rate, and π denotes the inflation rate. This equation led to Fishers hypothesis. This hypothesis states that the nominal interest rate contains a real interest rate, as well as a premium, which follows the inflation rate (Howells and Bain, 2008). Therefore, it can be noted that the effects of inflation are accounted for at the nominal rate. Hence, for the purpose of this study, the nominal HPI was utilized.

As an extension of the data, it can be noted that the prices of residential property differ in accordance with their quality. This varies depending on the location of the housing, as well as other factors such as biases in consumer preferences (Inglesi-lotz and Gupta, 2013). Although the HPI enables investors to make decisions regarding their property investments as it provides an average for the entire housing market, it can also be limiting (Garg, 2016). The problem with the HPI is that it is unable to adjust for quality. There are both internal and external factors that influence the prices of property, as well as location, which all contribute to their quality. The housing market in South Africa can be segmented into three subdivisions depending on their prices, specifically the affordable, middle, and luxury housing segments (Simo-Kengne, Balcilar, Gupta, Reid, and Aye, 2013).

Furthermore, the middle housing segment can be subdivided in relation to the household's specific sizes, namely, small, medium, and large segments. This, therefore, divides the South African housing market into different income categories of the households, which enables individuals to determine whether there are differences present within the various segments in relation to the different households (Simo-Kengne *et al.*, 2013). The Amalgamated Bank of South Africa (ABSA) uses price segmentation to assess the value of each housing price segment. The affordable segment is categorized by households that are below R480 000 in value. By increasing in value, the middle segment is households that are valued between R480 000 and R3 500 000. As noted above, this segment is further divided according to the size of the household. The small segment comprises of 80 – 140 square meters, the medium between 141 – 220 squared meters, and large between 221 – 400 square meters. Lastly, the luxury segment is made up of households between R3 500 000 – R12 800 000. This is, therefore, a numerical picture of the housing market in South Africa (Simo-Kengne *et al.*, 2013). ABSA follows a process in order to compile these indices. The first part of the process involves extracting data from the applications that were approved by the bank of individuals who wish to obtain mortgage finance. Figures included in this data are the purchase price of the property, the land, and building area, as well as the land and building value of others filtered based on the different size categories (Inglesi-Lotz and Gupta, 2013). Quarterly as well as monthly data for each of the above segments are available for public use. However, there are data limitations, as the most recent data available till the final quarter is 2015. This study therefore, utilized the available segmented data available and this section of the analysis ends in 2015. This study utilized the ABSA house price segments as it is consistent with the South African literature mentioned in the literature review (Inglesi-lotz and Gupta, 2013; Kolisi and Phiri, 2017; Simo-Kengne *et al.*, 2013), which is beneficial for comparison purposes, as other banks segment their housing data differently.

This study, therefore, incorporated data from the South African housing market as a whole, represented by the HPI values, which were tested with the CPI data values. This allowed a conclusion to be drawn on if housing prices on average were able to hedge against inflation. As a separate section, the data for the housing market was divided into the different segments for a more accurate conclusion to be drawn. This will, therefore, enable an investor to determine which segments provide the best hedging ability and to make their investment decisions accordingly.

3.3 Methodology introduction

The methodology section of the study examines the estimation techniques necessary to examine the relationship between inflation and residential property, in addition to whether residential property is an effective hedge against inflation. As noted by the literature, a wide variety of studies use cointegration techniques to examine whether a long-run relationship exists between the chosen variables. For this study, the nonlinear autoregressive distributive lag (NARDL) model is employed. This technique is employed as this model improves on the conventional linear models because it can account for asymmetric adjustment. The NARDL model allows for the estimation of both long and short-run asymmetries, and differentiates between the negative and positive partial sum decompositions (Shin *et al.*, 2014). It is for this reason that by employing this model, it represents a novel contribution to the literature.

According to Shin *et al.* (2014) standard pre-tests need to be conducted to examine whether the variables are cointegrated, before the model can be estimated. This can be done by utilizing the Augmented Dickey-Fuller (ADF) test, Phillips-Perron (PP) test, and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test, which are employed to test for stationarity among the variables (Brooks, 2014). However, these tests do not account for structural breaks, and hence it would be beneficial to utilize unit root tests that account for structural breaks in the individual series. A relatively simple one is the Zivot-Andrews (1992) test, but it will only show the single most significant break. The Bai-Perron (1998) test is an alternative test that can account for five breaks. This will therefore, be an additional contribution to the study. Furthermore, the optimal lag length needs to be determined by selecting the number of lags that minimizes the information criteria. Through the use of Eviews, the vector autoregressive (VAR) model is able to endogenously select the optimal lag length that minimizes the criteria (Emerson, 2007).

Within more recent econometric development, time series have been identified as non-stationary. This gave rise to the possibility that some time series may display features of divergence away from their mean over time, whereas others may tend to converge to their mean (Nkoro and Uko, 2016). Non-stationary time series can be defined as time series that tend to diverge away from their mean over time (Hamilton, 1989). In order to overcome the problem of non-stationary, econometric analysis has become more inclined towards the issue of cointegration. This is due to cointegration techniques being a powerful tool to detect the presence of a steady-state equilibrium between variables (Nkoro and Uko, 2016). This then can lead to two conclusions being drawn. If there is no cointegration present within the variables, this results in the problem of a spurious regression, and this results in the regression being almost meaningless. However, if cointegration is confirmed, there is a long-run relationship present between the variables (Nkoro and Uko, 2016).

Cointegration takes place due to economic data sharing common stochastic trends. These are eliminated through cointegrating linear combinations (Granger and Yoon, 2002). Common stochastic trends usually occur in the form of a linear combination of the shock of a system. Economic data responds to shocks together, and because of this, they are cointegrated. Similarly, if they reacted separately to shocks, there would be no cointegration present in the data (Granger and Yoon, 2002). However, there can be situations where the economic data respond together to a specific kind of shock. Such that, they move together with positive shocks and react differently to situations with adverse shocks. The data series may, therefore, have hidden cointegration. This is an example of nonlinear cointegration (Granger and Yoon, 2002).

The literature review section of his study showed a variety of different cointegration techniques that can be applied in order to examine whether housing prices can be utilized as a hedge against inflation. Subsequent to the pretesting section, the ARDL model was employed as a cointegration technique for comparative purposes. This was accompanied by both the existing literature and the subsequent NARDL, employed in order to address the issues of nonlinearity and asymmetric adjustment identified in the existing literature. These issues are relatively new to econometric analysis, and the application of nonlinear models in this context, such as the NARDL, is likely to lead to a novel contribution to the methodology of the study (Shin *et al.,* 2014). Due to the NARDL model being superior to the conventional linear models it has gained popularity in recent studies. Authors such as Ahmad, Khan, Rahman and Khan (2018), and Rezitis (2019) have utilized the NARDL model for their respective studies. It is evident that this model is backed by researchers, which further reinforces its contribution to existing literature.

3.4 Unit root testing

An extensive range of econometric time series is characterised by trending behaviour. Models such as the trend stationary (TS) model states that the long-run part of a series follows a time polynomial (Wolters and Hassler, 2006). This is presumed to be linear in nature and is included in a stationary autoregressive moving average (ARMA) process. Another model, called the difference stationary (DS) model, states that in order to achieve stationarity, differencing is necessary (Wolters and Hassler, 2006). This implies that first differencing follows both a stationary and an invertible ARMA process. This infers that the level of the time series has a unit root present within its autoregressive component. Unit root tests are also known as integrated of order one, or I(1). Unit root tests are performed to test for the order of integration, which is done to ensure that the regression is not spurious in nature (Wolters and Hassler, 2006). A spurious regression occurs when regressions give a good fit and are able to predict a statistically significant relationship in situations where this relationship does not really exist (Mahadeva and Robinson, 2004). Therefore, these unit root tests are pertinent tests that are conducted before cointegration tests can be performed (Gujarati and Porter, 2009). For the purpose of the ARDL model, linear unit root testing was applied, such as the ADF, PP and KPSS test.

3.4.1 Augmented Dickey-Fuller (ADF) test

The ADF test is an econometric test that is utilized to examine if a specified series is stationary or not (Prabhakaran, 2019). The first step is determining the number of differences that is required in order to make the series stationary. The ADF test is known as a fundamentally statistically significant test. This implies the use of hypothesis testing, which involves a null and alternative hypothesis that results in a test statistic being computed (Prabhakaran, 2019). If a unit root is present, it can be confirmed that the series is non-stationary. The amount of unit roots that are present is similar to that of the amount of differencing operations that are necessary for the series to be stationary (Prabhakaran, 2019). The ADF test is basically an 'augmented' form of the traditional Dicky-Fuller test. The critical dissimilarity between the tests is that the ADF test is used for greater and more advanced models (Moffatt, 2019). The ADF test can be utilized in order to overcome the impact of the problem of serial correlation. This is done through the error term by the addition of the lagged dependent variable to the model (Hamzah and Masih, 2018). The null and alternative hypothesis are as follows:

H_0: Unit root present (Series is non-stationary)

H_1: No unit root present (Series is stationary)

The null hypothesis suggests the presence of a unit root, and in order to reject it, the p-value needs to be less than the level of significance (taking 5% or 0.05 as the conventional significance level). Therefore, concluding that the time series is stationary (Prabhakaran, 2019). The test statistic is negative, which implies the more negative, the greater the rejection of the null that there is a unit root. Hence, if there is a positive ADF test statistic, the decision would be to not reject the null hypothesis (Moffatt, 2019).

The ADF test can be specified in three different forms (Sun and Xu, 2010):

1. Testing for a unit root:

$$\Delta y_t = \delta y_{t-1} + \sum_{i=1}^{m} \alpha_1 \Delta y_{t-i} + \mu_t$$

2. Testing for a unit root with a drift:

$$\Delta y_t = \beta_1 + \delta y_{t-1} + \sum_{i=1}^{m} \alpha_1 \Delta y_{t-i} + \mu_t$$

3. Testing for a unit root with a drift around the deterministic time trend:

$$\Delta y_t = \beta_1 + \beta_2 t + \delta y_{t-1} + \sum_{i=1}^{m} \alpha_1 \Delta y_{t-i} + \mu_t$$

Where: β_1 represents a constant term, β_2 and α_1 represent parameter estimates and μ_t represents a pure white noise error term. The trend variable is represented by t. This test, therefore, examines if the estimates of the δ term are zero (Akmal, 2007).

However, a problem with unit root tests is that they suffer from both distorted size and low power (Mahadeva and Robinson, 2004). This can be seen when running unit root tests; as noted above, the null is that the chosen variable contains a unit root. The low power problem refers to the inability to reject the null, which leads to a wrongful conclusion that the variable contains a unit root (Mahadeva and Robinson, 2004). A further limitation of unit root tests is that it is difficult to differentiate between a highly autoregressive series from a difference-stationary one. Due to this low power limitation of the ADF test as a unit root test, a further unit root test should be used to improve the robustness. The Phillips-Perron (PP) test and the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test will also be examined in the unit root testing of the variables.

3.4.2 Phillips-Perron (PP) test

Phillips and Perron (1998) established a unit root test that is similar to that of the ADF test. The key difference is that the PP test utilizes non-parametric adjustment aspects for the serial correlations in order to handle the errors in heteroscedasticity and serial correlation. The advantage that the PP test has over the ADF test is that no lag length is required for examining heteroscedasticity and the regression analysis (Del Barrio Castro, Rodrigues, and Taylor, 2015). The null and alternative hypothesis is similar to that of the ADF test:

H_0: Unit root present (Series is non-stationary)

H_1: No unit root present (Series is stationary)

By rejecting the null hypothesis of the presence of a unit root, it is confirmed that the series is stationary. This occurs for both the ADF and PP test when the tests are statistically significant at the conventional level of significance (5%). If this is not the case, which is in situations where the tests are not statistically significant, the null will be accepted. The series will then be non-stationary and the order of integration will change from I(0) to I(1). This process will continue until rejection of the null hypothesis, implying that the variables are stationary (Phillips and Perron, 2018).

3.4.3 The Kwiatkowski-Phillips-Schmidt-Shin (KPSS)

The KPSS is an additional test that is utilized to determine if a variable is stationary around a linear trend or if the variable is non-stationary, which is the presence of a unit root (Glen, 2016). The KPSS test differs from the ADF test in the way in which its null and alternative hypothesis is presented:

H_0: No unit root present (Series is stationary)

H_1: Unit root present (Series is non-stationary)

The KPSS test is derived as one-sided LM statistics that are generated for the purpose of this test. The conclusion that can be drawn from this is that if the LM statistic is larger than the critical value (which is given at the level of significance), then the null is rejected, implying that the series is non-stationary (Glen, 2016). This, therefore, represents the presence of a unit root. However, there is also a major limitation to the KPSS test, in that it has a high rate of indicating Type 1 errors. This suggests that it may reject the null of a stationary series too often. Furthermore, if an attempt is made to control these errors, such as by having greater p-values, then this can have a negative impact on the test's power (Glen, 2016). A possible approach to handle the high Type 1 errors is to utilize the KPSS test with the alternative unit root tests discussed. This way, if all the test's results suggest that the series is stationary, then this is a reliable conclusion (Glen, 2016). Therefore, it can be seen that by using the unit root tests in conjunction with each other, the limitations of each can be combated.

3.5 Structural breaks testing

Many models are under the assumption that the relationship between the macroeconomic variables remains constant throughout the entire time period (Perron, 1989). However, it is important to note that there are situations in which changes in external factors can cause changes in the relationship between the variables within the model. Structural breaks are able to capture these situations by integrating sudden and permanent changes in the model (Perron, 1989). Testing for the presence of structural breaks has become a relevant issue in econometrics due to the numerous economic, as well as political influences that can cause a change in economic variables over time.

Structural breaks can occur due to a number of different reasons (Arnold and Auer, 2015). It could be due to an economic or financial crisis, regime shifts, institutional changes, or policy changes. A problem that occurs with structural variations is the analysis of the null, which is of structural stability, against that of a structural break, which is the alternative hypothesis (Verma, 2007). There are situations in which the presence of structural change is confirmed in the data set, however it is not accommodated within the specifications of the model. This could lead to the results being biased towards the non-rejection of the hypothesis of non-stationarity (Verma, 2007). It can be noted that conventional cointegration tests can tend to yield spurious regressions as a result of structural breaks. This is because structural breaks make it harder to reject the null, which is of no cointegration (Arnold and Auer, 2015). With the purpose of avoiding these situations of bias, it is pertinent to observe the role that structural breaks play in the testing of cointegration.

There are multiple tests for structural breaks that have been put forward over the years. The Chow (1960) test set the foundation for structural breaks and represents one of the first structural breaks tests. This theory is built on the idea that if the parameters are constant, it implies that the out-of-sample forecasts should then be unbiased (Chow, 1960). It examines the null hypothesis of no structural breaks present, against the alternative, that there is a structural break present (Dufour, 1982). This test splits the linear model into samples at a single predetermined break-point. This is tested by computing an F-statistic to compare the stability of the estimated coefficients from the two periods (Chow, 1960). One significant drawback of the Chow test is that the break-point is required to be predetermined before the test can be implemented. In addition to this, the break-point must be exogenous or, it would result in the standard distribution of the statistic being invalid (Dufour, 1982).

A structural break test that builds on the Chow test is the Quandt Likelihood Ratio (1960) test. This test attempted to eliminate the need for choosing a break-point, by calculating the Chow test for all likely break-points. Therefore, the most likely break-point is indicated by using the largest Chow test statistic across the potential break-points (Quandt, 1960). This is chosen as the Quandt statistic. The drawback to this test that caused it to be unusable was due to the non-standard distribution that depended on the number of variables, as well as series trimming. The Quandt (1972) test was, therefore, put forward as a more accepted model for testing for structural breaks.

An alternative test explores the idea of a series being cointegrated, but the cointegrating vector has shifted at a point that is unknown within the sample. In this situation, a standard cointegration test would not be appropriate due to these tests presuming that the cointegrating vector is time-invariant, under the null hypothesis. Gregory and Hansen (1996), therefore, proposed residual-based tests to examine cointegration within models that include regime shifts. Furthermore, this demonstrated that structural breaks have the ability to reduce the power of conventional cointegration tests. In addition to this, the standard cointegration tests are biased in nature, as it tends to accept the null of no long-run relationship present when there is a structural break (Gregory and Hansen, 1996).

Perron (1989) proposed that macroeconomic data persistence could be due to structural breaks present within the underlying process. Testing for stationarity about a trend may yield inconsistent results if there is a break present within the trend during the time period under examination. If the possibility of a structural break is ignored, it may lead to an over-acceptance of the null. The null hypothesis of the presence of a unit root would be accepted when it is essentially stationary (Perron, 1989). This suggests that a series that performs well modelled as an I(1) process may be known as a stationary process containing one or more structural breaks. The tests conducted by Perron (1989) are that of the standard tests for unit root hypothesis against the alternative hypothesis of trend-stationary with structural breaks within the trend. These hypothesizes allow for the presence of a once-off change within the level of the trend function. The most significant implication of the unit root insurgency is seen under the hypothesis that random shocks have a permeant effect on the financial system. This is based on fluctuations being non-transitory (Perron, 1989). This contradicts business cycle theories that view business cycle fluctuations as transitory and around a relatively stable trend path.

Zivot and Andrews (1992) suggested a variation of the original Perron test, in which they make the assumption that the exact time in which the break-point occurs is unknown. Rather, the use of a data-dependent algorithm to proxy Perron's technique, in order to examine the break-point (Zivot and Andrews, 1992). Hence, this procedure examines the presence of a unit root against the alternative, a one-time structural break. This process notes each point as a possible break-date. Therefore, this test runs a regression for each potential break-date successively (Zivot and Andrews, 1992).

An important assumption by Perron (1989) was that a structural break was determined exogenously. However, over time, literature moved away from the premise of exogenous determination of break dates and moved towards the endogenous determination (Glynn, Perera, and Verma, 2007). However, these tests included a maximum number of structural breaks that can exist within a series as two structural breaks. Therefore, the approach proposed by Bai and Perron (2003) does not set such a low number for the maximum structural breaks. It is for this reason that this approach is more appropriate for the examination of a series that is more volatile in nature, as there is no reason to anticipate a maximum of two structural breaks. During the sample period of this study, the South African economy had experienced events such as the apartheid-era, the transition phase to the post-apartheid era, as well as the 2007/2008 financial crisis. These macroeconomic events may have resulted in structural breaks.

Bai and Perron (1998) estimated the model by least squares regression analysis for time series data that comprise of more than a single structural break. This approach is not a unit root test but is known as a modelling approach within the presence of structural breaks. The goal of this approach is to determine the break dates endogenously (Bai and Perron, 2003). They consider the issues related to multiple structural changes within a linear regression model. For the purpose of this study, the Bai and Perron test will be utilized for the structural breaks testing and will be discussed in greater detail below. This approach can be broken down into two independent parts. The first part allows for the identification of any number of structural breaks within the series, regardless of their statistical significance (Antoshin, Berg, and Souto, 2008). Once the number of structural breaks has been identified, the second part of the test identifies statistics in order to examine the statistical significance of these breaks through the use of asymptotic critical values (Antoshin *et al*., 2008).

The Bai and Perron (1998) test has a major advantage such that it is able to account for heteroscedasticity and autocorrelation within the time series, in contrast to other tests such as the Bayesian Information Criteria, that is unable to accommodate these features (Antoshin *et al*., 2008). The Bai and Perron (1998) approach essentially estimates whether there has been a structural change within the manner that two or more time series are related. This, therefore, makes it advantageous for this study. For the purpose of testing for multiple structural breaks, the null and alternative hypothesis are as follows:

H_0: No changes/breaks present

H_1: An arbitrary number, m, changes/breaks present

The standard model for estimating structural breaks, as presented by Bai and Perron (1998) states that the model parameters are permitted to break in some models, represented by m possible breakpoints.

$$y_t = x'_t\beta + z'_t\Upsilon_j + \mu_t \tag{3}$$

t = T_{j-1} + 1, …, T,

Where: y_t represents the dependent variable that will be modelled as a linear combination of regressors using x_t as the time-invariant coefficient and z_t as the time-variant coefficient. Additionally, $j = 1, \ldots, m + 1$.

The features of this equation can be understood by breaking down each part of the equation. Through the use of the $x'_t\beta$ term, it, therefore, allows for the joint estimation of the regression coefficients. The $z'_t\Upsilon_j$ captures and allows for the identification of structural changes, which can be utilized for several applications. The final term, μ_t, represents the disturbance present at time t. The equation above illustrates what is known as a partial structural model, as the parameter vector β is estimated by making use of the entire sample and is also not subject to shifts (Antoshin *et al*., 2008).

The underlying determination is to evaluation the unknown regression coefficients along with the breakpoints present when T observations on the variables y_t, x'_t and z'_t are presented. The results of the regression will specify the number of structural breaks caused by a number of both political and economic events during the sample period. This model was utilized by Canarella and Miller (2016), who explored inflation persistence and structural breaks.

3.6 Optimal lag length selection

Lag length selection of an autoregressive process is an important part of econometric studies (Liew, 2004). The optimal lag length needs to be determined by selecting the number of lags that minimizes the information criteria. There are multiple lag length selection criteria to determine the autoregressive lag length. Akaike (1974) proposed the first set of information criteria, which is known as the Akaike Information Criteria (AIC). This type of information criteria is ‘efficient’, which implies that it will select the best model when the model is of an infinite dimension. The dimensionality of a model refers to the number of parameters that are estimated as a part of the model (Akaike, 1974). In contrast to the AIC, the Schwarz (1978) information criteria, or SIC, and the Hannan and Quinn (1979) information criteria, or HQIC, refers to information criteria that are ‘consistent.’ This implies that as the sample size increases, these two sets of criteria will select a model that is of finite dimension, depending on if it is contained within the set of candidate models. Emerson (2007) noted that different lag length selection criteria could often lead to differences regarding the conclusion on exactly which lag order is optimal. Therefore, the lag length choice can have a drastic effect on the cointegration analysis results (Emerson, 2007).

The AIC is most commonly utilized in cases that are not easy to examine the model's performance on a test set in standard machine learning practices, specifically small datasets (Zajic, 2019). The objective is to achieve the lowest possible AIC. This implies the best balance model fit by means of generalizability. This, therefore, helps achieve the objective of maximizing the fit on out-of-sample data (Zajic, 2019). A drawback of using AIC is that it only tends to measure the relative quality of the models. As a result, all models tested could fit poorly. Furthermore, AIC does not work well with larger samples, which makes it limited to samples that are smaller in size (Zajic, 2019). Schwarz (1978) derived the SIC to aid as an asymptotic approximation of the Bayesian posterior probability of a model. SIC is favoured in large-sample settings and is based on the empirical log-likelihood. SIC also does not necessitate the specification of priors (Cavanaugh and Neath, 1999). Aside from the sample size, another notable difference that the SIC has over the AIC is that it tends to asymptotically recognize the true model with probability one. In theory, this optimality property is shown by the inclination of SIC to choose models that are attractively simple (Cavanaugh and Neath, 1999).

Vector autoregressive (VAR) models have the ability to determine the optimal lag length. Determining the true lag length is important because overfitting, which is a term referring to higher-order lag lengths being selected over their true length, which leads to increases in the mean-square-forecast errors of the VAR model (Ozcicek and Douglas Mcmillin, 1999). Furthermore, underfitting the optimal lag length can often generate autocorrelated errors. Therefore, the accuracy of the forecasts from these VAR models vary substantially depending on the different lag lengths (Ozcicek and Douglas Mcmillin, 1999). The majority of VAR models have been estimated utilizing lags that are the same length for all the variables in the model, known as symmetric lag lengths.

However, Ozcicek and Douglas Mcmillin (1999) stated that there is no explicit economic theory for the reasoning that the lag lengths should be identical for all variables in the equation. The lag lengths may differ for the purpose of this study, for inflation and housing prices, defined by p and q, respectively. This corresponds to the model represented as ARDL (p,q). The VAR model is a useful model to use for the purpose of lag determination if the above information criteria conclude conflicting results by selecting different lag orders (Hatemi-J. and Hacker, 2009). Therefore, in this case, the Likelihood Ratio (LR) from the VAR model can be utilized for determining the lag length. This is highlighted for comparative purposes as the ARDL model is able to endogenously determine lag lengths. With the aim of choosing the optimal lag length within the VAR model, there is a generalized form of this model for the purpose of an information criterion, specified as (Hatemi-J. and Hacker, 2009):

$$\text{IC} = ln(det\Omega_j) + j\frac{f(T)}{T} \qquad j = 0, \ldots, \text{K}, \qquad (4)$$

Where: Ω_j represents the maximum likelihood estimate, which is of the variance-covariance matrix Ω when the lag order that is utilized in the estimation is *j*. The natural logarithm is represented by the *ln*, and the *det* denotes the determinant of the corresponding matrix.

3.7 Autoregressive Distributive Lag model

This study's first objective is to conduct a two-variable (bivariate) Autoregressive distributive lag (ARDL) model as a benchmark model for comparative purposes. This model was employed by a variety of researchers who studied the topic extensively. This was evident in the research papers by Gupta and Hartley (2013), who explored the predictive ability of asset prices to forecast inflation in South Africa. However, keeping in line with the current topic, researchers such as Inglesi-lotz and Gupta (2013), Aqsha and Masih (2018), and Anari and Kolari (2002) all utilized the ARDL model for testing the long-run relationship between inflation and housing prices. Consistent with predictions, the ARDL results show that property is an effective hedge against inflation, and hence, the results from this study is expected to also yield positive results. The ARDL bounds test was originally developed by Pesaran and Shin (1999) and was then extended by Pesaran, Shin, and Smith (2001). This model's method focused on the estimation of an Unrestricted Error Correction Model (UECM). The ARDL bounds test is utilized to study the long-run relationship between variables. Economic analysts suggest that the long-run properties between variables are intact, implying that their variances and means are constant and, therefore, are not dependent on time (Nkoro and Uko, 2016). This approach examines the relationship between a dependent variable (in this case, housing prices) and a set of regressors when it is not known if these regressors are either trend or stationary for first differences (Pesaran *et al.*, 2001). This type of test uses an F-statistic and T-statistic, which are the standard statistics used for testing for the significance of the variables.

Additionally, it was noted by Pesaran *et al.* (2001) that the ARDL model can be estimated with stationary variables, represented by I(0). Furthermore, it could be estimated for variables that are integrated of order one or stationary, for first differences, represented by I(1), as well as mutually cointegrated variables. However, not estimated for I(2) or greater. Consistent with existing literature such as Anari and Kolari (2002), the variable applied as a proxy for inflation is the CPI and the housing price index (HPI) for South Africa, using inflation as the explanatory variable. The explanatory variable is also known as the independent variable; this is due to it comprising of a value that is independent of the other chosen variables in the study (Thomas, 2020). The chosen variables to include in the study are said to have a cause-and-effect type of relationship. Inflation, being the independent variable, is known as the cause. Housing prices, however, is the effect and is known as the dependent variable (Thomas, 2020). This is due to housing price values being dependent on the changes in the inflation values. If there is a change in inflation (independent variable), the effect of this change is seen in housing prices (dependent variable).

The ADF, PP and KPSS tests are conducted for levels and then for first differences on the chosen variables to determine whether they are stationary or not. It is crucial to determine whether variables are stationary, as many econometric models rely on it (Palachy, 2019). This is done to ensure that the regression is not spurious preceding the cointegration testing (Gujarati and Porter, 2009). The ARDL approach to cointegration is valid irrespective of whether the chosen variables are I(0) or I(1). However, it is still essential to conduct the necessary unit root tests to confirm that there are no I(2) variables involved (Ibrahim, 2015). This is crucial because an I(2) variable present in the model will render the F-statistic, which is computed for the purpose of testing cointegration, invalid. Therefore, the application of the unit root tests is significant for establishing the integration orders (Ibrahim, 2015).

When examining the ARDL model, the optimal lag length has to be selected. This lag length selection process is an essential part of this process because it entails estimates that feed into the long-run test for cointegration. The model is of the form ARDL (p,q) where p and q represent the lag lengths for housing prices and inflation, respectively. This, therefore, permits the first difference of the housing prices and inflation rate to have different lag lengths. With the purpose of obtaining the optimal lag lengths for each of the variables, the ARDL model estimates $(p+1)^k$ as the number of regressions (Akmal, 2007). The p-value denotes the maximum number of lags, and the k value represents the number of variables that are in the equation. The automatic lag length selection done by the ARDL model was utilized by authors such as Anari and Kolari (2002).

The equation for the ARDL model will be represented as follows:

$$\Delta HP = C + \sum_{i=0}^{p} \alpha_i \Delta HP_{t-i} + \sum_{i=0}^{q} \beta_i \Delta CPI_{t-i} + \delta_1 HP_{t-1} + \delta_2 CPI_{t-1} + \mu_t \quad (5)$$

Where: Δ represents the difference operator or change in the variable, C represents a constant, HP represents housing prices in South Africa, CPI represents Inflation in South Africa, α and β represents the short-run coefficients, δ_1 and δ_2 represent the long-run coefficients for housing prices and inflation, respectively, and μ_t represents the error term or disturbance term. The above equation was estimated by using an Ordinary Least Squares (OLS) regression.

The null and alternative hypothesis will need to be specified and are as follows:

H_0: No cointegration or $\delta_1 = \delta_2 = 0$

H_1: Cointegration or $\delta_1 \neq 0$ and $\delta_2 \neq 0$

The above equation can be rewritten and extended to incorporate the different housing segments and will be represented as:

$$\Delta HP\_Aff = C + \sum_{i=0}^{p} \alpha_i \, \Delta HP\_Aff_{t-i} + \sum_{i=0}^{q} \beta_i \, \Delta CPI_{t-i} + \delta_1 \, HP\_Aff_{t-1} + \delta_2 CPI_{t-1} + \mu_t \quad (6)$$

$$\Delta HP\_Mid = C + \sum_{i=0}^{p} \alpha_i \, \Delta HP\_Mid_{t-i} + \sum_{i=0}^{q} \beta_i \, \Delta CPI_{t-i} + \delta_1 \, HP\_Mid_{t-1} + \delta_2 CPI_{t-1} + \mu_t \quad (7)$$

$$\Delta HP\_Lux = C + \sum_{i=0}^{p} \alpha_i \, \Delta HP\_Lux_{t-i} + \sum_{i=0}^{q} \beta_i \, \Delta CPI_{t-i} + \delta_1 \, HP\_Lux_{t-1} + \delta_2 CPI_{t-1} + \mu_t \quad (8)$$

Where: HP_Aff represents the housing prices for the affordable housing segment, HP_Mid represents the housing prices for the middle housing segment, and HP_Lux represents the housing prices for the luxury housing segment. By separating the regression and running it on the different housing price segments it allows for a more accurate conclusion to be drawn to determine exactly which housing segment represents the most effective hedge against inflation.

Granger (1988) establishes that the casual relationship between the variables can be studied by use of the Error Correction Model (ECM) framework, using variables that are cointegrated. The short-run dynamics are represented by the use of the individual coefficients of the lagged terms. However, the Error Correction Term (ECT) comprises of the long-run causality information. In order to signify long-run causality, there needs to be a negative and statistically significant ECT. Furthermore, the significance of lagged explanatory variables is utilized to signify short-run causality (Alimi, 2014). If it has been confirmed that there is cointegration present between the variables in the equation above, Equation (9) represents the long-run model, and Equation (10) represents the short-run dynamics:

$$HP = C + \sum_{i=0}^{m} \alpha_i \, \Delta HP_{t-1} + \sum_{i=0}^{n} \beta_i \, \Delta CPI_{t-1} + \mu_t \quad (9)$$

$$\Delta HP = C + \sum_{i=0}^{p} \alpha_i \, \Delta HP_{t-1} + \sum_{i=0}^{q} \beta_i \, \Delta CPI_{t-1} + \Phi ECT_{t-1} + \nu_t \quad (10)$$

Where: ϕ represents the coefficient of the ECT. This shows how fast variables converge to equilibrium. This ECT is estimated in order to determine whether a variable is endogenous or exogenous. There can be two conclusions drawn from the ECT. Firstly, if the ECT is determined to be significant, it indicates that the dependent variable essentially depends on the ECT; therefore, it is known as an endogenous variable (Hamzah and Masih, 2018). Alternatively, if the ECT is found to be insignificant, the dependent variable is, therefore, interpreted as being exogenous. The interpretation of the speed of adjustment to equilibrium can be due to a greater absolute value implying a faster adjustment. Therefore, a positive ECT coefficient suggests that in the long-run, the variable will move away from the equilibrium. Furthermore, a negative ECT coefficient implies that the variable will, therefore, return to the equilibrium level (Hamzah and Masih, 2018).

The ARDL bounds test is a significant part of this analysis, as it examines whether a long-run relationship exists between variables. The bounds test is based on the Wald test, which results in an F-statistic, which is compared to the asymptotic critical values, as confirmed by Pesaran *et al.* (2001). By examining the F-statistic in the bounds test, three conclusions can be drawn depending on the location of the statistic. There are two sets of critical values present, which represent the two bounds, the upper and the lower bound (Ahmad, 2010). With the aim of determining whether a long-run relationship exists, it is pertinent that the F-statistic exceeds the upper critical bound (Aqsha and Masih, 2018). Furthermore, the statistic could be in-between the lower and upper bounds, which will result in an inconclusive test. On the other hand, if all the selected variables are I(1), the conclusion will be established on the upper bound. Similarly, if the chosen variables are all I(0), the conclusion is drawn based on the lower bound (Ahmad, 2010). Alternatively, the final conclusion is drawn if the generated F-statistic is below the lower bound, resulting in no cointegration present between the variables (Habanabakize and Muzindutsi, 2017). Furthermore, this test has a distribution that is non-standard, which implies that it relies on the integration order, the intercept choice, a time trend, and the number of regressors (Ahmad, 2010). The asymptotic critical values are calculated for situations where the series is both I(0) and I(1). These critical values are interpreted at the 90, 95, 97.5, and 99.5% confidence intervals by Pesaran *et al.* (2001).

The ARDL test basically requires two steps (Pahlavani, Wilson, and Worthington, 2005). Initially, the examination of a long-run relationship, which is determined through the use of an F-statistic. Secondly, an estimation of the coefficients of the long-run relationship. This is done by determining their values and estimating their short-run elasticity, which is noted in the error correction representation. As seen above in the ARDL model, the ECT determines the speed of adjustment to the equilibrium level. In order to fully understand the magnitude of this relationship, a VECM was constructed for each of the lag lengths. This is utilized to provide an interpretation of the beta coefficient. This, therefore, describes the nature and magnitude of the relationship between housing prices and inflation. In terms of the Fisher hypothesis, this relationship can be specified as (Moores-Pitt and Strydom, 2017):

$$\text{Log}HP_t = \text{C} + \beta \text{ Log}CPI_t + \mu_t \tag{11}$$

Where: $\text{Log}HP_t$ represents the log of the housing prices variable, C represents the constant term, $\text{Log}CPI_t$ is the log of the inflation variable. The μ_t term represents a white noise disturbance term. The magnitude of the relationship between inflation and residential property is represented by the beta coefficient, which is calculated during the regression analysis of the ARDL model.

This step involves estimating the long-run elasticities. The beta coefficient for inflation could mean one of three things (Pesaran *et al.*, 2001). Firstly, if the beta coefficient generated is negative, it suggests that there exists no relationship between the variables, and therefore, residential property is not an effective hedge against inflation. Secondly, if the beta coefficient is a positive number between zero and one, it implies that residential property can be used as a partial inflationary hedge. This, therefore, means that inflation effects cannot be fully removed by the purchase of property, but rather that the effects are partially removed. Thirdly, if the beta coefficient is equal to or greater than one, it implies that property is an adequate inflationary hedge. The interpretation of the magnitude of this relationship is taken from the results of the ARDL model proposed by Pesaran *et al.* (2001). Essentially, the Fisher (1930) form of the relationship between inflation and housing prices is testing if the long-run elasticity is equal to unity (Inglesi-Lotz and Gupta, 2013). This relationship, therefore, specifies the landlord's attempt at maintaining the purchasing power of the rental income's real value. This is done through the incorporation of expected inflation on the CPI in rental agreements. Therefore, if the Fisher (1930) hypothesis holds true, the long-run elasticity for housing prices with regard to the inflation rate, should be equal to unity. Since data for this study is taken on the HPI, as well as the different housing segments, each segment is tested to determine its long-run elasticity.

One significant advantage of the ARDL lies within its ability to identify the cointegrating vectors in situations of multiple cointegrating vectors present (Nkoro and Uko, 2016). This can be explained through the use of the F-statistic calculated in the model. This statistic has a non-standard distribution under its null hypothesis. The hypothesis is of a no-cointegrating relationship, regardless of whether the chosen variables are I(0) or I(1) (Srinivasan, Kumar, and Ganesh, 2012). On the other hand, this technique will tend to crash when an integrated stochastic trend of I(2) is present. This highlights the importance of the pre-tests, as it determines the order of integration. Another advantage is that the ARDL model has the ability to differentiate between the dependent and explanatory variables in the situation of a single long-run relationship (Nkoro and Uko, 2016). Other cointegration techniques, such as Johansen's cointegration, require a relatively large data sample in order to prove valid. However, the ARDL model is a more statistically significant method for examining cointegrating relationships within small samples (Ozturk and Acaravci, 2010). Furthermore, and while this is not possible with conventional cointegration techniques, the ARDL model makes allowance for variables that may have different optimal lag lengths (Ozturk and Acaravci, 2010). The ARDL bounds test is able to estimate both the long- and short-run components simultaneously. This is advantageous because it is able to remove the problems that occur due to autocorrelation and omitted variables (Srinivasan *et al*., 2012).

Further advantages include that this technique generally tends to provide unbiased estimates of the long-run model and t-statistics that are valid, even in situations where certain regressors in the model are exogenous. Additionally, by including the dynamics into the model, the endogeneity bias may be corrected (Srinivasan *et al*., 2012). The ARDL procedure is also beneficial if there is uncertainty regarding the unit root properties of the data. The primary step within any cointegration analysis is determining the integration order of each variable (Pahlavani *et al.*, 2005). However, this is dependent on the unit root tests, as using different tests could conclude contradictory results. An example of this would be using a conventional unit root test, such as the ADF test, which may result in a unit root being present. But, the series may actually be stationary around a one-time structural break (Perron, 1989). The ARDL approach, therefore, proves to be useful because it avoids these situations. Although there have traditional cointegration techniques utilized to determine the relationship between housing prices and inflation, such as Engle-Granger, and Johansen's cointegration approaches.

However, due to the numerous advantages specified above, the recent and advanced ARDL model proves to be an advantageous model for the purpose of this study.

While the ARDL procedure has been used in prior studies, limitations to the model have been identified. A weakness of the ARDL bounds test relates to the positioning of the F-statistic. If this statistic lies between the upper and lower bound, it will not be possible to judge whether there is cointegration present within the variables (Lin, Liang, and Tsai, 2019). Furthermore, a major drawback to using the ARDL model is that it can only be used to estimate a linear relationship. Linearity can be defined as a proportionate change, which can be explained further as a 1% change in the independent variable will, therefore, at all times, lead to a 1% change in the dependent variable (Hamzah and Masih, 2018). The ARDL model measures the long-run relationship by examining cointegration and utilizes the error correction mechanism (ECM). This mechanism is utilized for a short-run relationship and considers the relationship symmetric (Khan, Sisi, and Siqun, 2019). A symmetric relationship can be defined as having a constant speed of adjustment from the equilibrium level. This implies that the variable, therefore, increases and decreases at an identical rate (Hamzah and Masih, 2018). Due to there being no implicit reason why the relationship should be symmetric, it represents a limitation to the model (Aqsha and Masih, 2018). The assumptions of symmetry and linearity are seen as too restrictive and unrealistic, particularly for the economic variables which have become more erratic. This is especially evident nowadays within the view of globalisation as economies are becoming more interrelated (Hamzah and Masih, 2018). With the intention of capturing asymmetries within the variables, the conventional ARDL model was therefore expanded to incorporate nonlinearities (Khan *et al.,* 2019). This is the reason why applying the NARDL is necessary, as it is used to estimate the model while accounting for potential asymmetric adjustment.

3.8 Nonlinear Autoregressive distributive lag model

The nonlinear ARDL model was established by Shin *et al.* (2014) with the belief that the information contained within the linear models may be insufficient to yield reliable forecasts and restrictive in many economic situations. This model has the ability to split the linear model into positive and negative components. This is the main contribution that this model has over the previous studies that have utilized the ARDL model. It was noted in the literature that the large majority of studies maintained the assumption that long-run relationships may be represented as a symmetric and linear regression. However, the cointegrating relationship may also be conditioned to both asymmetry and nonlinearity (Shin *et al.*, 2014). If the relationship is proven to be symmetric, then the ARDL model is sufficient. However, if there is an asymmetric relationship, the NARDL model would be necessary to proceed with (Khan *et al.*, 2018).

Constructing a NARDL model entails a few steps. The first step is an essential prerequisite, which is to confirm that none of the model's variables are integrated at order I(2) or higher. This is because having a variable in the model that is of order I(2) would render the results meaningless (Çıtak, Uslu, Batmaz, and Hoş, 2020). Secondly, the model is estimated by utilizing the standard OLS approach. Thirdly, after all the insignificant lags have been eliminated, the presence of long-run cointegration within the variables needs to be examined. This is examined by analysing the null hypothesis of no long-run cointegration against the alternative, which confirms the presence of a long-run relationship. Fourthly, the objective is to accurately explain the asymmetric nature of which CPI affects the hedging capabilities of housing. Fifthly, the magnitude of the long-run coefficients, specifically with regard to asymmetry, is examined. Lastly, an analysis of the short-run dynamics is performed.

There are four major advantages of the NARDL model (Masih, 2018). Firstly, it allows for the testing of cointegration; therefore, it is able to model the cointegrating relationship that may exist between inflation and housing prices. Secondly, this model has the ability to estimate both the long and short-run asymmetries from the independent to the dependent variable. It is able to do this simultaneously in a simple and flexible manner (Masih, 2018). Thirdly, this model has the ability to examine both linear and nonlinear cointegration. It can be noted that these three advantages are presented in the nonlinear threshold Vector Error Correction Model (VECM), as well as a smooth transition model. However, due to the issue of the proliferation of the number of parameters, these models may suffer from this problem, which is present in convergence (Masih, 2018). This representations a limitation of these models and the NARDL model does not suffer from this. Fourthly, a further advantage is that it permits the combination of data series that employ different integration orders. This flexibility separates this model from other models that require a time series to be identical (Van Hoang *et al.*, 2016).

The standard ARDL model mentioned above is able to determine the possible long-run relationship between the time series variables. However, it assumes that there is a symmetric or linear relationship between the variables (Cheah, Yiew, and Ng, 2017). Thus, the ARDL and other cointegration techniques, such as the Engle-Granger cointegration technique, are unable to capture any possible asymmetry or nonlinearity between inflation and housing prices. Therefore, by using the NARDL model, it provides an asymmetric extension for the ARDL model (Cheah *et al*., 2017). The relationship is known as nonlinear when the positive and negative partial sum compositions are different in absolute terms. This difference highlights the extension of the NARDL model. The NARDL model employed in this study was utilized by Katrakilidis and Trachanas (2012), who conducted a study based on the macroeconomic drivers of housing price dynamics in Greece, as well as by Aqsha and Masih (2018), and Yeap and Lean (2017) to determine the inflation hedge properties of housing in Malaysia. This study, therefore, follows similar prior methodologies, such as the studies mentioned above. Consistent with predictions, the NARDL model from this study is expected to also yield positive results, indicating the presence of asymmetry.

The view behind utilizing the NARDL model is questioning the standard assumption of estimates being linear. The exception to this is the assumption that time-series data are integrated with a maximum integration order of one. This is verified by utilizing unit root testing. Furthermore, if it is confirmed that cointegration exists in the positive and negative compositions, this indicates nonlinearity is present between the variables (Latheef and Masih, 2017). The possible causes of nonlinearity include extreme volatility within the market and asymmetrical adjustment. This model, therefore, analyses the issues of nonlinearity and non-stationarity in the setting of an unrestricted error correction model (Latheef and Masih, 2017). Further reasons that an asymmetrical relationship can occur is due to nonlinear transaction costs, as well as inter alia, which occurs as a result of noise traders. The asymmetries within a time series become highly probable in situations where the sample comprises of highly volatile regimes, for instance, a financial crisis (Raza, Shahzad, Shahbaz, and Tiwari, 2017).

The NARDL model has the ability to distinguish between all forms of asymmetry, which goes beyond only long- and short-run asymmetries (Shin *et al*., 2014). There are three forms of asymmetry. Firstly, the long-run asymmetry, which is associated with $\beta_2 \neq \beta_3$. Secondly, a term known as 'impact asymmetry,' which is in relation to the inequality of the coefficients that are on the contemporaneous first differences ΔCPI_t^+ and ΔCPI_t^-. Lastly, asymmetry, which is noted by the adjustment patterns that are formed from the initial equilibrium level to the new level of equilibrium. This can take place following an economic perturbation, such as the dynamic multipliers mentioned above (Shin *et al*., 2014).

The NARDL bounds test utilizes both negative and positive partial sum decompositions, which are used to differentiate the possible asymmetric effects for the short-run and long-run. This model enforces an exogenous zero threshold and examines the impact of shocks. These shocks are different in terms of the signs (positive or negative); however, they are of the same magnitude or size (Bouri, Gupta, Lahiani, and Shahbaz, 2018). A further benefit of the NARDL model is its ability to solve the convergence issues, which are due to over-parameterization in the model (Aqsha and Masih, 2018). Furthermore, the dynamic multipliers within this model examines the adjustment patterns of fast-paced economic changes. This, therefore, aids in analysing the asymmetry and nonlinear patterns between residential property and the inflation rate (Aqsha and Masih, 2018). The null and alternative hypothesis is specified and will be as follows:

H_0: No cointegration

H_1: Cointegration

The main purpose of this paper is to assess the effect that changes in inflation have on the housing price index in South Africa from 1989 to 2019. The first equation to consider is the linear specification below:

$$HP_t = \alpha_0 + \alpha_1 CPI_t + e_t \quad (12)$$

Where: HP represents the housing price index, CPI is the consumer price index, α_i is a vector of long-run coefficients, and e_t is the error term. Given that the above equation is a linear specification, it will not be possible to capture the asymmetric effects of changes in inflation.

The NARDL model makes accommodation for both the potential short- and long-run asymmetries. Furthermore, this model decomposes the exogenous variable, CPI, into its positive and negative partial sums (Van Hoang *et al.*, 2016). This equation is used for the purpose of modelling asymmetric cointegration, which is based on partial sum decomposition (Shin *et al.*, 2014). This essentially looks at the percentage change increases or decreases in inflation, such that:

$$CPI_t{}^{+} = \sum_{i=1}^{t} \Delta CPI_t{}^{+} = \sum_{i=1}^{t} \max(\Delta CPI_i, 0) \text{ and } CPI_t{}^{-} = \sum_{i=1}^{t} \Delta CPI_t{}^{-} = \sum_{i=1}^{t} \min(\Delta CPI_i, 0)$$

The NARDL model (p, q) derived from equation (14) can be further rewritten as follows:

$$HP_t = \sum_{i=1}^{p} \Upsilon i \Delta HP_{t-i} + \sum_{i=0}^{q} (\varphi_i{}^{+} \Delta CPI_{t-i}{}^{+} + \varphi_i{}^{-} \Delta CPI_{t-i}{}^{-}) + \mu_t \quad (13)$$

Where: Υi is the autoregressive parameter, the φ_i terms represent the delays asymmetrically distributed and μ_t represents a homoscedastic process i.i.d. with zero mean (Chikri, Moghar, Kassou, Hamza, Essaâdi-Morocco, and Bourekkadi, 2020).

Based on the above equations, the positive, as well as the negative partial sums, are outlined in the long-run equation, which is based on the standard ARDL framework above. The impact of both the short and long-run asymmetries are expressed in the NARDL framework:

$$\Delta HP_t = \beta_0 + \beta_1 HP_{t-1} + \beta_2 CPI_{t-1}^{+} + \beta_3 CPI_{t-1}^{-} + \sum_{i=1}^{p} \Upsilon i \Delta HP_{t-i} + \sum_{i=0}^{q} (\varphi_i{}^{+} \Delta CPI_{t-i}{}^{+} + \varphi_i{}^{-} \Delta CPI_{t-i}{}^{-}) + \mu_t \quad (14)$$

Where: the subscripts (+) and (-) above are referred to as the positive and negative partial sum decompositions, respectively. β_0 Represents the constant term, which contains all the exogenous factors, such as a linear trend and any dummy variables, which account for possible structural breaks (Cheah *et al*., 2017). The variables β_2 and β_3 are used to capture long-run asymmetry. Furthermore, $\varphi_i{}^{+}$ *and* $\varphi_i{}^{-}$ represent the short-run effects of both the positive and negative changes of CPI_t. Based on the above equation, the long-run relation between housing prices and inflation increases is β_2, which is anticipated to be a positive value. Furthermore, β_3 contains the long-run relation between housing prices and inflation decline. The μ_t term is known as the error term and is a stationary zero-mean error process. This term denotes the deviations from the long-run equilibrium level.

The above equation can be rewritten and extended to incorporate the different housing price segments below:

$$\Delta HP\_Aff_t = \beta_0 + \beta_1 HP\_Aff_{t-1} + \beta_2 CPI_{t-1}^{+} + \beta_3 CPI_{t-1}^{-} + \sum_{i=1}^{p} \Upsilon i \Delta HP\_Aff_{t-i} + \sum_{i=0}^{q} (\varphi_i{}^{+} \Delta CPI_{t-i}{}^{+} + \varphi_i{}^{-} \Delta CPI_{t-i}{}^{-}) + \mu_t \quad (15)$$

$$\Delta HP\_Mid_t = \beta_0 + \beta_1 HP\_Mid_{t-1} + \beta_2 CPI_{t-1}^{+} + \beta_3 CPI_{t-1}^{-} + \sum_{i=1}^{p} \Upsilon i \Delta HP\_Mid_{t-i} + \sum_{i=0}^{q} (\varphi_i{}^{+} \Delta CPI_{t-i}{}^{+} + \varphi_i{}^{-} \Delta CPI_{t-i}{}^{-}) + \mu_t \quad (16)$$

$$\Delta HP\_Lux_t = \beta_0 + \beta_1 HP\_Lux_{t-1} + \beta_2 CPI_{t-1}^{+} + \beta_3 CPI_{t-1}^{-} + \sum_{i=1}^{p} \Upsilon i \Delta HP\_Lux_{t-i} + \sum_{i=0}^{q} (\varphi_i{}^{+} \Delta CPI_{t-i}{}^{+} + \varphi_i{}^{-} \Delta CPI_{t-i}{}^{-}) + \mu_t \quad (17)$$

Where: HP_Aff, HP_Mid, and HP_Lux refer to the housing price indices for the affordable, middle and luxury segment respectively.

As mentioned in the ARDL section, the Error Correction Model (ECM) is derived after it is confirmed that there is cointegration present (Granger, 1988). If it has been confirmed that cointegration is present between the variables, Equation (18) represents the long-run model, and Equation (19) represents the short-run dynamics:

$$\text{HP} = \beta_0 + \sum_{i=1}^{m} \beta_1 \Delta HP_{t-i} + \sum_{i=0}^{n} (\beta_2 \Delta CPI_{t-i}{}^{+} + \beta_3 \Delta CPI_{t-i}{}^{-}) + \mu_t \tag{18}$$

$$\Delta\text{HP} = \beta_0 + \sum_{i=1}^{p} \beta_1 \Delta HP_{t-i} + \sum_{i=0}^{q} (\beta_2 \Delta CPI_{t-i}{}^{+} + \beta_3 \Delta CPI_{t-i}{}^{-}) + \Phi ECT_{t-1} + v_t \tag{19}$$

The intent of the short-run analysis is to evaluate the instantaneous fluctuations of the independent (CPI) variable on the dependent (HP) variable. In comparison, the long-run analysis is used to measure the response of both time and speed of the adjustment to the equilibrium level (Van Hoang *et al*. 2016). However, if the null hypothesizes for both the short-run and long-run asymmetry are not rejected, the model returns to the traditional Error Correction Model (ECM) without asymmetry (Van Hoang *et al*. 2016). Therefore, in the situation of $\beta_2 = \beta_3$, this indicates that there is no asymmetry present between housing prices and inflation. If $\beta_2 \neq \beta_3$, then the presence of a nonlinear relationship is, therefore, concluded (Cheah *et al*., 2017).

The model specification of the above equation is finalized when it is exempted from any form of misspecification biases. This is seen in the problems of serial correlation as well as parameter instability (Cheah *et al*., 2017). This can be reached once the above equation has passed the many diagnostic tests. As explained by Shin, *et al.* (2014), the bounds test approach (Pesaran *et al*., 2001) can be utilized for the above equation in order to detect the presence of the short-run and long-run relationship between housing prices and inflation. Therefore, once the positive and negative asymmetric relationship results have been obtained, the bounds testing approach is then utilized with the purpose of verifying the long-run relationship (Shin *et al.*, 2014). If a long-run relationship is present between housing prices and inflation, then the dynamic multiplier effect needs to be checked (Khan *et al.*, 2019).

According to Shin *et al*. (2014), the Wald test can be utilized in order to test the long-run asymmetry. This test is used in order to examine whether the null hypothesis of symmetric adjustment is rejected. The findings of this test will challenge the assumption of linearity in previous cointegration techniques, and hence, in the context of the housing returns and inflation relationship, the adjustment for nonlinearity must be considered. Modelling asymmetric cointegration that is based on partial sum decomposition was explored by Granger and Yoon

(2002). They explored the concept of 'hidden cointegration', which implies that the cointegrating relationships between the underlying variables may be defined by positive and negative components. The asymmetric adjustments of HP to both the positive and negative changes of the CPI are summarised in the positive and negative cumulative dynamic multipliers. These are related to the unit changes in ${CPI_t}^+$ and ${CPI_t}^-$ variables shown below.

$${m_h}^+ = \sum_{j=0}^{h} \frac{\partial HP_{i+j}}{\partial CPI_t}, \; {m_h}^- = \sum_{j=0}^{h} \frac{\partial HP_{i+j}}{\partial CPI_t}, \; h = 0,1,2, \ldots$$

It can be noted that as $h \rightarrow \infty, m_h^+ \rightarrow \alpha_1$ and ${m_h}^- \rightarrow \alpha_2$

Where: ${m_h}^+$ and ${m_h}^-$ represent the asymmetric long-run coefficients. These coefficients achieve consistency as $h \rightarrow \infty$, such that $m_h^+ \rightarrow \alpha_1$ and ${m_h}^- \rightarrow \alpha_2$. Therefore, m_h is crucial because it enshrines the important information that is responsible for the volatilities. By considering these estimated multipliers, observations can be drawn following the differences affecting the system. Furthermore, the dynamic adjustments from the initial equilibrium level to the new equilibrium level in the system is observed (Van Hoang *et al*., 2016). The model is regressed based on the natural logarithms of house prices and inflation, as this ensures superior distributional properties, as done by Aqsha and Masih (2018).

The results of the regression analysis enables a conclusion to be drawn on the relationship between residential property and inflation. The concept of an inflation hedge is explored by Van Hoang *et al*. (2016) and accounts for the possible nonlinearity between the variables. The magnitude of the relationship between inflation and residential property is represented by the beta coefficients, which are calculated during the regression analysis of the NARDL model (Shin *et al.*, 2014). The variables are known as "inflation betas" and are used to measure the hedging ability of assets such as housing prices. It was noted by Bekaert and Wang (2010) that a standard linear regression between the variables would produce a single inflation beta. This would be used to measure the inflation hedge ability of different assets. However, instead of using the linear inflation beta, by using the NARDL model of Shin *et al*. (2014), it allows the possible nonlinearity between inflation and housing prices to be accounted for. It can be noted that an investment may not be a perfect inflation-hedge and still be of value, such that in cases where the correlation between the variables are positive and lower than one. However, when the correlation between the variables is equal to one, the asset is known a perfect inflation-hedge. This is due to the increases in inflation being perfectly compensated by the increase in the price of the asset (Arnold and Auer, 2015). By considering nonlinearity, the NARDL model is found to have positive and negative components to the beta coefficient. In this way, both the positive and negative partial sum decompositions are accounted for as well as adjustment asymmetry. This is a critical difference between the NARDL model and a simple ARDL model. This can be illustrated as:

$$\text{Log}HP_t = \text{C} + \beta\ \text{Log}CPI_t^{+} + \beta\ \text{Log}CPI_t^{-} + \mu_t \tag{20}$$

Where: $\text{Log}HP_t$ represents the log of the housing prices variable, C represents the constant term, $\text{Log}CPI_t^{+}$ is the log of the inflation variable for the positive changes in inflation and $\text{Log}CPI_t^{-}$ represents the log of the negative changes. The μ_t term represents a white noise disturbance term. This equation is the long-run cointegrating equation, as only the long-run components are expressed. The magnitude of the relationship between inflation and residential property is represented by the two beta coefficients above. This result is used to determine whether residential property can be used as a hedge against the effects of inflation, for both positive and negative inflationary adjustment.

3.9 Parameter stability testing

Stability testing is an important part of econometrics as they measure any type of disruption in a dataset, such as structural breakpoints, which could potentially have an effect on the results (Talas, Kaplan, and Celik, 2013). This forms part of the NARDL testing and will be performed after the NARDL analysis. The CUSUM stability test was introduced by Brown, Durbin and Evans (1975), who studied the determination of structural change through the use of cumulated sums of recursive residuals. The CUSUM test detects any systematic movements by coefficients that possibly highlight a structural instability. This test has the ability to detect any deviations in the process mean can have a possible effect on the direction of the drift (Xiao and Phillips, 2002). The equation for this test is expressed as:

$$W_t = \sum_{t=K+1}^{m} \frac{W_t}{\sigma_w^2}$$

Where: W_t represents the recursive residual, σ_w^2 represents the standard deviation, and *t* represents the time that it takes for the constant to diverge. The CUSUM test plots the two critical lines around the 5% level of significance. If the cumulative sums are recognised out of the critical lines, the parameters are concluded to be unstable. However, if the cumulative sums are within the critical lines, the parameters are said to be stable (Brown *et al.*, 1975).

3.10 Chapter summary and conclusion

To sum up everything that has been stated so far, Chapter 4 entailed an explanation of the methodology employed within this study's framework to examine the relationship between inflation and housing prices. The main focus of this chapter was to provide the data sources, data selection and econometric techniques in detail for the purpose of this study. Prior to the methodology section, a description of the sample data used for the analysis was discussed. This comprised of a description of both the CPI and HPI variables, as well as the housing price segments. The methodology of this study can be summarised into four subsections, namely the tests for unit roots and stationarity, the structural breaks test, the test for linear cointegration, and the test for nonlinear cointegration. Each of these subsections included a theoretical background of the respective tests, as well as the advantages and disadvantages of each.

The first subsection of the methodology section, which was discussed following the data section, included the unit root tests for stationarity. These unit root tests included the Augmented-Dickey Fuller (ADF) test, the Phillips-Perron (PP) test, and the Kwiatkowski, Phillips, Schmidt and Shin (KPSS) test. These tests are all utilized, in order to prevent the limitations of using a single unit root test.

In the second subsection, the test for structural breaks, the Bai-Perron test, was discussed in detail. This was preceded by a theoretical background on the history of structural breaks testing, as well as the various tests utilized to account for structural breaks. This led up to the decision to utilize the Bai-Perron test for the purpose of this study, as it accounts for multiple structural breaks in the series.

The third subsection includes the test for linear cointegration, the Autoregressive Distributive Lag (ARDL) model was extensively covered in this section. This model was selected as it is a single equation model that has the ability to account for the casual, long-run and short-run relationships between inflation and housing prices. This section includes a broader understanding of the test and incorporates the long-run cointegration equation for this analysis. This is further broken down to incorporate the house price segments in the analysis. Moreover, the Error Correction Model is also estimated as it is utilized to account for the short-run adjustments. Furthermore, the equation for the beta coefficient that is utilized to describe the magnitude of this relationship is included. The advantages and disadvantages of this test is discussed in detail, leading up to the limitations of this model to support the reasoning behind incorporating a nonlinear cointegration test into this study.

The final subsection of the methodology section includes the test for nonlinear cointegration, the Nonlinear Autoregressive Distributive Lag (NARDL) model was discussed further. This section includes the extensions of this model, in the way that it improves the model by accounting for possible nonlinearity and asymmetric adjustment. Furthermore, the long-run cointegration equation is explained in detail and extends to the housing price segments. The equation for the magnitude of the positive and negative compositions is also incorporated in this analysis. This section concludes by incorporating stability testing, the CUSUM test into this analysis.

The use of both the ARDL and NARDL approaches assist in detecting the possible linear and nonlinear relationship between the variables. This is due to these models allowing for the estimation of both symmetric and asymmetric effects. This is a result of the short-run statistical effects of inflation (independent variable) on housing prices (dependent variable) being determined by the use of partial sum components. As each of these econometric models possess their own strengths and weaknesses, these two models were selected in order to compare their results to determine whether they arrive at the same conclusion.

The next chapter of this paper is the results and discussion section. The results from the above methodology were constructed. This section examines the hedging ability of housing prices in South Africa in two ways. Firstly, the average index HPI is utilized to provide a result for the overall housing market in South Africa. Secondly, this housing market is broken down into different segments, namely, the affordable, middle and luxury segments. This allows for the different segments to be examined individually to further determine which of the segments provide the best hedge against inflation. This will, therefore, provide investors with all the information necessary on each section of the housing market. In this way, an investor will be better equipped when making their investment decisions. Furthermore, to provide a greater comparison, the conventional ARDL model results are compared to the more recent NARDL model results. This allows a conclusions to be drawn on whether the relationship between inflation and housing prices is symmetric or asymmetric in nature.

CHAPTER 4: RESULTS AND DISCUSSION

4.1 Introduction

In the preceding chapter, the approaches and methodology that were utilized in the regression analysis were discussed in detail. Chapter 3 represented the sample and the sources of the series that will be analysed in this chapter. The standard ARDL model, as well as the NARDL model, were illustrated and were utilized as the models for the purpose of this study. This chapter focused on estimating and analysing the short and long-run relationships between the variables in this study. This chapter begins by determining the order of integration using a variety of unit root tests. After these tests for stationarity were conducted, the short and long-run relationships were examined. This was determined by the cointegration tests used to test the long-run relationship between the consumer price index (CPI) and the house price index (HPI), as well as the various house price segments.

Due to the conventional ARDL model assuming linearity, the NARDL provided for both the positive and negative relationships among the chosen variables. Therefore, by utilizing both of the above models, a linear and nonlinear relationship between the variables were examined. Furthermore, the application of these models allowed for the determination of the way in which changes in one variable had an effect on the behaviour of the other variable. The short-run relationship between the variables were examined through the Error Correction Model (ECM), and the findings of this model were reported with the error correction terms. This model is utilized due to its ability to examine whether the models revert back to equilibrium after being exposed to short-run shocks.

The final part of the analysis is the stability testing, namely the CUSUM squares stability test, which was utilized to examine the stability of the parameters within the model. In order to sum up everything that has been stated in this chapter, a summary paragraph is used to conclude the chapter.

4.2 Unit root testing

The starting point for the regression analysis was testing whether the variables in the study were stationary or non-stationary. The unit root tests were discussed in detail in the previous chapter. It was emphasized that in order to estimate a model, it was essential to determine the order of integration for the variables. Unit root testing plays a key role in the estimation of any econometric model. This is the first step for testing whether the variables were cointegrated.

The first step involves transforming the variables into logarithms in order to make the variance stationary. If the variables were non-stationary, the first difference was then taken in order to make the series stationary (Aqsha and Masih, 2018). Therefore, each of the tests is conducted for both levels and first differences. It was noted in the previous chapter that the ARDL model was viable for any time-series despite the order of integration. However, it is pertinent to conduct the unit root tests in order to confirm that none of the chosen variables were I(2). The unit root tests that were utilized for the purpose of this study included the ADF test, the PP test, and the KPSS test. All of the above tests were conducted in order to reduce the weaknesses associated with each of the individual tests.

4.2.1 Augmented Dickey-Fuller (ADF) test

The ADF test was utilized to test the stationarity of the variables. This was done to ensure that the results of the regression analysis were not spurious, which ensured that the relationship between inflation and housing prices was not inaccurate. As mentioned in the previous chapter, the null hypothesis indicates that there is a unit root present, implying that the series is non-stationary. Therefore, the alternative allows for the rejection of a unit root, indicating that the variable is stationary. The results of the regression were compared to the Mackinnon critical values at each significance level. If the test statistic was confirmed to be greater (in absolute terms) than the critical values, it led to a rejection of the null hypothesis, and the series was concluded as stationary. However, if the test statistic was less (in absolute terms) than the critical values, the null hypothesis cannot be rejected, which concluded that the variable was non-stationary. A further interpretation was when the p-value (at all levels of confidence) was less than the 5% level of significance, the null hypothesis was rejected, and the series was concluded to be stationary (Prabhakaran, 2019). However, if this was not the case, and the p-value was greater than the 5% level of significance, the null hypothesis cannot be rejected, and the series was non-stationary. In this situation, the test may be re-examined for first differences and possibly second differences. All of the variables were examined in log terms as specified in the methodology section, and the test is performed at intercept and trend terms.

Table 4.2.1.1: ADF test for the log of CPI in levels

Level of significance	t-Statistic	p-value
ADF test statistic	-3.793492	0.0039
1% level	-3.485115	
5% level	-2.885450	
10% level	-2.579598	

Table 4.2.1.1 above indicated that the log of CPI is stationary in level terms, as the ADF test statistic of 3.793492 was greater than the 5% and 10% levels of significance. This implied that the null hypothesis of a unit root was rejected, and the log of CPI was concluded to be stationary.

Table 4.2.1.2: ADF test for the log of CPI in first differences

Level of significance	t-Statistic	p-value
ADF test statistic	-5.702920	0.0000
1% level	-3.484653	
5% level	-2.885249	
10% level	-2.579491	

Table 4.2.1.2 above indicated that the log of CPI was stationary in first difference terms, as the ADF test statistic of 5.702920 was greater than all levels of significance. Furthermore, the log of CPI resulted in p-values that were less than 0.05 for both levels and the first difference. This implied that the null hypothesis can be rejected, and the variable does not contain a unit root. This confirmed that the log of CPI was concluded to be stationary.

Table 4.2.1.3: ADF test for the log of HPI in levels

Level of significance	t-Statistic	p-value
ADF test statistic	-1.016440	0.7459
1% level	-3.486064	
5% level	-2.885863	
10% level	-2.579818	

Table 4.2.1.3 above indicated that the log of HPI was non-stationary in level terms, as the ADF test statistic of 1.016440 was less than all levels of significance. This implied that the null hypothesis of a unit root cannot be rejected, and it can be concluded that the log of HPI contained a unit root and was, therefore, non-stationary in levels.

Table 4.2.1.4: ADF test for the log of HPI in first differences

Level of significance	t-Statistic	p-value
ADF test statistic	-3.309616	0.0166
1% level	-3.486064	
5% level	-2.885863	
10% level	-2.579818	

Table 4.2.1.4 above indicated that the log of HPI was stationary in first differences, as the test statistic of 3.309616 was greater than the 5% and 10% levels of significance. Therefore, the null hypothesis that a unit root is present can be rejected, and it was concluded that HPI was stationary in first difference terms. This was also confirmed by the p-value.

Table 4.2.1.5: ADF test for the log of Affordable HP in levels

Level of significance	t-Statistic	p-value
ADF test statistic	-0.605763	0.8636
1% level	-3.495677	
5% level	-2.890037	
10% level	-2.582041	

Table 4.2.1.5 above looked at the first housing price segment, the log of affordable HP, which was non-stationary in levels, as the test statistic of 0.605763 was less than all the levels of significance. Therefore, the null hypothesis cannot be rejected and it was concluded that affordable housing prices were non-stationary in level terms.

Table 4.2.1.6: ADF test for the log of Affordable HP in first differences

Level of significance	t-Statistic	p-value
ADF test statistic	-2.472273	0.1252
1% level	-3.495677	
5% level	-2.890037	
10% level	-2.582041	

Table 4.2.1.6 above confirmed that in first difference terms, the log of affordable HP was also non-stationary, as the test statistic of 2.472273 was lower than all levels of significance. This required the variable to be re-examined for second differences.

Table 4.2.1.7: ADF test for the log of Affordable HP in second differences

Level of significance	t-Statistic	p-value
ADF test statistic	-10.24979	0.0000
1% level	-3.495677	
5% level	-2.890037	
10% level	-2.582041	

Table 4.2.1.7 above indicated that for second differences, the log of affordable HP was stationary, as the test statistic of 10.24979 was far greater than the critical values at all levels of significance. This implied that the null hypothesis of a unit root can be rejected, and the variable was confirmed to be stationary at second difference terms. This was further confirmed by the p-value.

Table 4.2.1.8: ADF test for the log of Middle HP in levels

Level of significance	t-Statistic	p-value
ADF test statistic	-0.433459	0.8981
1% level	-3.498439	
5% level	-2.891234	
10% level	-2.582678	

Table 4.2.1.8 above indicated the log of middle HP, which was non-stationary in levels, as the test statistic of 0.433459 was less than all the levels of significance. Therefore, the null hypothesis cannot be rejected and it was concluded that middle housing prices are non-stationary in level terms.

Table 4.2.1.9: ADF test for the log of Middle HP in first differences

Level of significance	t-Statistic	p-value
ADF test statistic	-1.654768	0.4510
1% level	-3.498439	
5% level	-2.891234	
10% level	-2.582678	

Table 4.2.1.9 above confirmed that in first difference terms, the log of middle HP was also non-stationary, as the test statistic of 1.654768 was lower than all levels of significance. This required the variable to be re-examined for second differences.

Table 4.2.1.10: ADF test for the log of Middle HP in second differences

Level of significance	t-Statistic	p-value
ADF test statistic	-6.539739	0.0000
1% level	-3.498439	
5% level	-2.891234	
10% level	-2.582678	

Table 4.2.1.10 above indicated that for second differences, the log of middle HP was stationary, as the test statistic of 6.539739 was far greater than the critical values at all levels of significance. This implied that the null hypothesis of a unit root can be rejected, and the variable was confirmed to be stationary at second difference terms. This was further confirmed by the p-value.

Table 4.2.1.11 ADF test for the log of Luxury HP in levels

Level of significance	t-Statistic	p-value
ADF test statistic	-1.391965	0.5835
1% level	-3.496346	
5% level	-2.890327	
10% level	-2.582196	

Table 4.2.1.11 above indicated that the log of luxury HP was non-stationary in levels, as the test statistic of 1.391965 was less than the critical values at all the levels of significance. This

implied that the null hypothesis of a unit root cannot be rejected, and it was concluded that the log of luxury HP is non-stationary in level terms.

Table 4.2.1.12 ADF test for the log of Luxury HP in first differences

Level of significance	t-Statistic	p-value
ADF test statistic	-3.337604	0.0157
1% level	-3.496346	
5% level	-2.890327	
10% level	-2.582196	

Table 4.2.1.12 above indicated that the log of luxury HP was stationary in first differences, as the test statistic of 3.337604 was greater than the 5% and 10% levels of significance. This implied that the null hypothesis of a unit root was rejected, indicating that the log of luxury prices was stationary in first difference terms. This was confirmed by the p-value.

However, since the ADF test was only able to correct the autocorrelation problem, a second unit root test was performed for the robustness checks. Therefore, further unit root testing was required. This was the reason the PP unit root test was performed along with the ADF test.

4.2.2 Phillips-Perron (PP) test

As mentioned in the methodology chapter, the PP test is similar to the ADF test, as it has the same null and alternative hypothesises. The null indicates the presence of a unit root, which indicates that the series is non-stationary. The alternative hypothesis is that the series does not contain a unit root, which indicates that the series is stationary. The PP test is favoured over the ADF due to the non-parametric adjustment factors for the serial correlations in order to deal with errors in heteroscedasticity and serial correlation (Del Barrio Castro *et al.,* 2015). The PP test works the same way as the ADF test with regard to the critical values. If the PP test statistic is greater (in absolute values) than the Mackinnon critical values, the null is rejected, and the series is concluded to be stationary. However, if the test statistic is less than the critical values, the null cannot be rejected, implying that the variable is non-stationary. Similarly, if the p-value is greater than 0.05, it implies that the series contains a unit root. However, if the p-value is lower than 0.05, the series is confirmed to be stationary. As with the ADF test, the PP test was examined using both intercept and deterministic trends.

Table 4.2.2.1 PP test for the log of CPI in levels

Level of significance	t-Statistic	p-value
PP test statistic	-4.749100	0.0001
1% level	-3.484198	
5% level	-2.885051	
10% level	-2.579386	

Table 4.2.2.1 above showed the log of CPI was stationary in levels, as indicated by the PP test statistic of 4.749100 being greater than the critical values at all levels of significance. This implied that the null hypothesis of a unit root was rejected, indicating that CPI was stationary in level terms.

Table 4.2.2.2: PP test for the log of CPI in first differences

Level of significance	t-Statistic	p-value
PP test statistic	-5.637447	0.0000
1% level	-3.484653	
5% level	-2.885249	
10% level	-2.579491	

Table 4.2.2.2 above indicated that the log of CPI was stationary in first differences, as indicated by the test statistic of 5.637447 being far greater than the critical values at all levels of significance. Furthermore, the p-value was less than 0.05 for both the levels and first difference. This indicated that the null that the series contained a unit root can be rejected in favour of the alternative, that the series is stationary. This confirmed that the log of CPI was stationary at levels and first difference.

Table 4.2.2.3: PP test for the log of HPI in levels

Level of significance	t-Statistic	p-value
PP test statistic	-1.413335	0.5738
1% level	-3.484198	
5% level	-2.885051	
10% level	-2.579386	

Table 4.2.2.3 above indicated that the log of HPI was non-stationary in levels, as the test statistic of 1.413335 was less than the critical values at all the levels of significance. This implied that the null hypothesis of a unit root cannot be rejected, indicating that HPI was non-stationary in level terms.

Table 4.2.2.4: PP test for the log of HPI in first differences

Level of significance	t-Statistic	p-value
PP test statistic	-3.469952	0.0104
1% level	-3.484653	
5% level	-2.885249	
10% level	-2.579491	

Table 4.2.2.4 indicated that the log of HPI was stationary in first differences, as the test statistic of 3.469952 was greater than the critical values at the 5% and 10% levels of significance. This implied that the null hypothesis of a unit root can be rejected, indicating that HPI was stationary in first difference terms. Furthermore, for the log of HPI, the p-value was greater than the 5% significance level, which implied that at levels, the null cannot be rejected, and the series contained a unit root. However, in the first difference, the log of HPI had a p-value less than 0.05, which indicated that the null can be rejected, in favour of the alternative, that HPI was stationary at first difference.

Table 4.2.2.5 PP test for the log of Affordable HP in levels

Level of significance	t-Statistic	p-value
PP test statistic	-0.083803	0.9476
1% level	-3.492523	
5% level	-2.888669	
10% level	-2.581313	

Table 4.2.2.5 indicated that the log of affordable HP was non-stationary in levels, as the PP test statistic of 0.083803 was less than the critical values at all levels of significance. This implied that the null hypothesis of a unit root cannot be rejected, and affordable HP was non-stationary in level terms.

Table 4.2.2.6 PP test for the log of Affordable HP in first differences

Level of significance	**t-Statistic**	**p-value**
PP test statistic	-5.886166	0.0000
1% level	-3.493129	
5% level	-2.888932	
10% level	-2.581453	

Table 4.2.2.6 above indicated that the log of affordable HP was stationary in first differences, as the PP test statistic of 5.886166 was far greater than the critical values at all the levels of significance. This implied that the null hypothesis of a unit root was rejected, concluding that affordable HP was stationary in first difference terms.

Table 4.2.2.7: PP test for the log of Middle HP in levels

Level of significance	**t-Statistic**	**p-value**
PP test statistic	-0.849415	0.8005
1% level	-3.492523	
5% level	-2.888669	
10% level	-2.581313	

Table 4.2.2.7 indicated that the log of middle HP was non-stationary in levels, as the PP test statistic of 0.849415 was less than the critical values at all levels of significance. This implied that the null hypothesis of a unit root cannot be rejected, and middle HP was non-stationary in level terms.

Table 4.2.2.8: PP test for the log of Middle HP in first differences

Level of significance	**t-Statistic**	**p-value**
PP test statistic	-3.794878	0.0040
1% level	-3.493129	
5% level	-2.888932	
10% level	-2.581453	

Table 4.2.2.8 above indicated that the log of middle HP is stationary in first differences, as the PP test statistic of 3.794878 was greater than the critical values at all the levels of significance.

This implied that the null hypothesis of a unit root was rejected, concluding that middle HP was stationary in first difference terms.

Table 4.2.2.9: PP test for the log of Luxury HP in levels

Level of significance	t-Statistic	p-value
PP test statistic	-2.737762	0.0711
1% level	-3.492523	
5% level	-2.888669	
10% level	-2.581313	

Table 4.2.2.9 indicated that the log of luxury HP was non-stationary in levels, as the PP test statistic of 2.737762 was less than the critical values at the 1% and 5% levels of significance. This implied that the null hypothesis of a unit root cannot be rejected, and luxury HP was non-stationary in level terms. However, luxury HP was stationary for the 10% significance level, as the test statistic was greater than the critical value.

Table 4.2.2.10: PP test for the log of Luxury HP in first differences

Level of significance	t-Statistic	p-value
PP test statistic	-8.579006	0.0000
1% level	-3.493129	
5% level	-2.888932	
10% level	-2.581453	

Table 4.2.2.10 above indicated that the log of luxury HP was stationary in first differences, as the PP test statistic of 8.579006 was far greater than the critical values at all the levels of significance. This implied that the null hypothesis of a unit root was rejected, concluding that luxury HP was stationary in first difference terms.

4.2.3 (KPSS) test

The KPSS test was used to test for the stationarity of the variables. The KPSS test was derived as one-sided LM statistics that was generated for the purpose of this test. The conclusion that can be drawn from this was that if the LM statistic is greater than the critical values (which was given at the significance level), then the null hypothesis can be rejected, implying that the series was non-stationary (Glen, 2016). Therefore, the KPSS test stated that the null hypothesis confirmed the existence of stationarity. Hence, if the LM statistic was less than the critical values (in absolute terms), this would result in the null being accepted, and the series will be concluded as being stationary. Similar to the ADF and PP tests, the variables were examined in log terms for the intercept and deterministic trend.

Table 4.2.3.1: KPSS test for the log of CPI in levels

Level of significance	LM-Statistic
KPSS test statistic	1.331919
1% level	0.739000
5% level	0.463000
10% level	0.347000

Table 4.2.3.1 indicated that for the log of CPI in levels, the LM statistic of 1.331919 was greater than the 1%, 5%, and 10% values. This implied that the null hypothesis of stationarity can be rejected at all levels of significance, indicating that CPI was non-stationary at level terms.

Table 4.2.3.2: KPSS test for the log of CPI in first differences

Level of significance	LM-Statistic
KPSS test statistic	0.316400
1% level	0.739000
5% level	0.463000
10% level	0.347000

Table 4.2.3.2 above indicated that the log of CPI was stationary in first differences, as indicated by the LM statistic of 0.316400, which was less than the critical values at all levels of significance. This implied that the null hypothesis of stationarity cannot be rejected, concluding that CPI was stationary in first difference terms.

Table 4.2.3.3: KPSS test for the log of HPI in levels

Level of significance	LM-Statistic
KPSS test statistic	1.317538
1% level	0.739000
5% level	0.463000
10% level	0.347000

Table 4.2.3.3 indicated that for the log of HPI in levels, the LM statistic of 1.317538 was greater than the 1%, 5%, and 10% critical values. This implied that the null hypothesis of stationarity can be rejected at all levels of significance, indicating that HPI was non-stationary in level terms.

Table: 4.2.3.4: KPSS test for the log of HPI in first differences

Level of significance	**LM-Statistic**
KPSS test statistic	0.285256
1% level	0.739000
5% level	0.463000
10% level	0.347000

Table 4.2.3.4 above indicated that the log of HPI was stationary in first differences, as indicated by the LM statistic of 0.285256, which was less than the critical values at all levels of significance. This implied that the null hypothesis of stationarity cannot be rejected, concluding that HPI was stationary in first difference terms.

Table 4.2.3.5: KPSS test for the log of Affordable HP in levels

Level of significance	**LM-Statistic**
KPSS test statistic	1.166869
1% level	0.739000
5% level	0.463000
10% level	0.347000

Table 4.2.3.5 indicated that for the log of affordable HP in levels, the LM statistic of 1.66869 was greater than the 1%, 5%, and 10% critical values. This implied that the null hypothesis of stationarity can be rejected at all levels of significance, indicating that affordable HP was non-stationary in level terms.

Table 4.2.3.6: KPSS test for the log of Affordable HP in first differences

Level of significance	LM-Statistic
KPSS test statistic	0.143760
1% level	0.739000
5% level	0.463000
10% level	0.347000

Table 4.2.3.6 above indicated that the log of affordable HP was stationary in first differences, as indicated by the LM statistic of 0.143760, which was less than the critical values at all levels of significance. This implied that the null hypothesis of stationarity cannot be rejected, concluding that affordable HP was stationary in first difference terms.

Table 4.2.3.7: KPSS test for the log of Middle HP in levels

Level of significance	LM-Statistic
KPSS test statistic	1.171051
1% level	0.739000
5% level	0.463000
10% level	0.347000

Table 4.2.3.7 indicated that for the log of middle HP in levels, the LM statistic of 1.171051 was greater than the 1%, 5%, and 10% critical values. This implied that the null hypothesis of stationarity can be rejected at all levels of significance, indicating that middle HP was non-stationary in level terms.

Table 4.2.3.8: KPSS test for the log of Middle HP in first differences

Level of significance	LM-Statistic
KPSS test statistic	0.195862
1% level	0.739000
5% level	0.463000
10% level	0.347000

Table 4.2.3.8 above indicated that the log of middle HP was stationary in first differences, as indicated by the LM statistic of 0.195862, which was less than the critical values at all levels

of significance. This implied that the null hypothesis of stationarity cannot be rejected, concluding that middle HP was stationary in first difference terms.

Table 4.2.3.9: KPSS test for the log of Luxury HP in levels

Level of significance	LM-Statistic
KPSS test statistic	1.179913
1% level	0.739000
5% level	0.463000
10% level	0.347000

Table 4.2.3.9 indicated that for the log of luxury HP in levels, the LM statistic of 1.179913 was greater than the 1%, 5%, and 10% critical values. This implied that the null hypothesis of stationarity can be rejected at all levels of significance, indicating that luxury HP was non-stationary in level terms.

Table 4.2.3.10: KPSS test for the log of Luxury HP in first differences

Level of significance	LM-Statistic
KPSS test statistic	0.396499
1% level	0.739000
5% level	0.463000
10% level	0.347000

Table 4.2.3.10 above indicated that the log of luxury HP was stationary in first differences, as indicated by the LM statistic of 0.396499, which was less than the critical values at the 1% and 5% levels of significance. This indicated that the null hypothesis of stationarity cannot be rejected at the 5% significance level, concluding that middle HP was stationary in first difference terms.

4.2.4 Summary of unit root tests

The unit root tests examined in this study comprised of the ADF, PP, and KPSS unit root tests. The results from the ADF test showed conflicting results to some of the PP tests, but the conclusion was that both tests showed a mixture of both I(0) and I(1) variables. The I(2) variables from the ADF test were confirmed to be I(1) in both the PP and KPSS tests. The unit root tests on the log of CPI were a mixture of I(0) and I(1), whereas with HPI, all tests confirmed that the variable was integrated of the first order, I(1). With regard to the housing price segments, all tests confirmed that the segments also were integrated of the first order. These results produced conclusions that are relatively consistent, implying that the variables were non-stationary in levels, but when re-examined for first differences, became stationary. This is consistent with existing literature such as the study by Chang, Wu and Gupta (2015). A possible reason for this may be due to the low power of these conventional unit root tests when housing prices are highly persistent. A further reason for this finding is that housing prices have been recently argued as being nonlinear due to the presence of transaction costs. Therefore, the power of the unit root tests applied may be poor in these situations. Furthermore, it is known that these unit root tests have low power when they are utilized for a finite sample period (Chang *et al*., 2015). It was evident that the unit root tests would express conflicting results due to certain limitations, which is why it was necessary to conduct all of the above unit root tests. This was necessary as the stationarity of the variables needed to be determined before the model could be estimated. However, the ARDL methodology accommodated I(0) and I(1) variables, as well as a mixture of both I(0) and I(1) variables. Therefore, with the above results, it was possible to continue to the estimation stage of the study.

4.3 Structural breaks testing

Bai and Perron (1998) estimated the model by least squares regression analysis for time series data that comprised of more than a single structural break. The goal of this approach was to determine the break dates endogenously (Bai and Perron, 2003). They considered the issues related to multiple structural changes within a linear regression model. The Bai and Perron test was utilized for this study's structural breaks testing. The underlying purpose was to estimate the unknown regression coefficients along with the breakpoints present when T observations on the variables y_t, x'_t, and z'_t were available. The results of the regression specified the number of structural breaks caused by a number of both political and economic events during the sample period. A maximum of five structural breaks was represented in each table for the respective variables. Therefore, five structural breaks were accounted for in the null hypothesis, with an alternative of no more than five being present in the data. All structural breaks were confirmed at the 5% significance level. The specific break dates and relevant information is discussed below.

Table 4.3.1: Structural breaks for each variable

Variable	Break Dates	LWZ* Statistic
CPI	1993Q3, 1998Q1, 2002Q3, 2008Q2, 2014Q1	-3.770728
HPI	1994Q2, 2000Q1, 2004Q3, 2009Q1, 2014Q1	-3.174815
Affordable HP	1993Q1, 1997Q3, 2003Q2, 2007Q2, 2012Q1	-3.540683
Middle HP	1994Q2, 2000Q1, 2004Q1, 2008Q1, 2012Q1	-3.089017
Luxury HP	1993Q2, 1998Q1, 2003Q1, 2007Q1, 2012Q1	-3.3414726

4.3.1 Structural breaks between the years 1993-1994

During the years 1993-1994, South Africa had undergone major structural change due to the ending of the Apartheid era. This had an impact on the macroeconomic variables in South Africa as it impacted both the Log of CPI and the Log of the housing prices. It was evident that during the Apartheid era, inflation was at its highest at the time, reaching 18.41% in 1986. However, from that point, inflation started to decrease to 8.75% in 1994 at the end of the Apartheid era (Plecher, 2019). With regard to housing prices, in the 1992-1993 period, there was a decrease in confidence, which was attributed to uncertainty about the country's political future. Shortly after, in 1994, house prices started to recover (Luüs, 2005).

4.3.2 Structural breaks between the years 1997-1998

The structural breaks affecting inflation and the housing prices during the 1997-1998 timeframe was likely attributed to the Asian financial crisis, which occurred in 1997. This led to a decrease in investor confidence due to sudden changes in market expectations with China, one of South Africa's key trading partners (Corsetti, Pesenti, and Roubini, 1999). In 1998 South Africa's economy was adjusting to being reintegrated within the world economy, which included substantial structural adjustments. South Africa's inflation rate continued at a high rate partially due to a weaker monetary policy in the early 1990s and the anti-apartheid sanctions. The United States led a massive disinvestment campaign to move foreign capital out of South Africa (Ricci, 2006). This put further upward pressure on the South African inflation rate. As a result of the contagion effects from the Asian crisis, there was a massive drop in the rand value, which led to an increase in interest rates by seven percentage points by the end of 1998. The situation had somewhat stabilized by late 1999, and the house price boom resumed.

4.3.3 Structural breaks between the years 2000-2002

South Africa adopted a formal inflation-targeting regime in early 2000 in an attempt to stabilize and maintain the inflation rate. In the late 1980s, the consumer price index (CPI) fluctuated around 15% and, by 1999, it declined to 5.2% (Van der Merwe, 2004). The inflation target was initially 3-6%, which remains today. With the exception of the 1998 Asian crisis, the transformation of the monetary policy conduct has been consistent with adopting inflation targets (Woglom, 2003). The lower inflation and interest rates, with higher economic growth and an improvement in the fiscal situation in South Africa, caused the market to recover (Luüs, 2005).

4.3.4 Structural breaks between the years 2003-2004

By the year 2003, house prices had nearly doubled in value in nominal terms, in comparison to their 1998 values (Luüs, 2005). The structural breaks for this timeframe were likely attributed to the large increase in the value of the housing prices starting in 2003. This impacted the Log of HPI as a whole, as well as the affordable, middle, and luxury housing segments.

4.3.5 Structural breaks between the years 2007-2009

The next structural break for the Log of CPI was at the beginning of 2008. The previous structural break possibly occurred due to the introduction of the inflation targeting regime. From that point onwards, inflation then began to decline steadily until its highest since the end of Apartheid, which was 10.99% in 2008. This high inflation followed the 2007-08 financial crisis, which impacted South Africa, and similarly, each of the macroeconomic variables in this study. Furthermore, there was a slight dip in the housing prices between the years 2007-2009. It can be noted that this was the period of the 2007-08 financial crisis, and by 2010, house prices started to recover. It was evident that this crisis affected the real economy of South Africa, and hence, house prices had declined (Zini, 2008).

4.3.6 Structural breaks between the years 2012-2014

The starting of 2012 for the house price segments structural break could be attributed to the average middle segment prices being nearly 14% lower at the end of 2011 than it was in 2007

(Property24.com, 2012). The reasons for this decline could be due to a number of factors, such as the unchanged interest rates for the year 2011, the moderately high debt levels, the rising inflation, and the damaged credit records. All of the above factors play a part in dampening the demand for housing, as well as the house price growth (Property24.com, 2012). In 2014 South Africa held its elections, which creates political uncertainty about the country's future. This has an impact on South Africa's macroeconomic variables and could be the reason behind the break in 2014 for the variables being studied.

Although it was confirmed that structural breaks were present in the data, it was not accounted for in the ARDL or NARDL model. Since the results above indicated the presence of structural breaks, the results should be treated with caution, and a natural extension to this study would be to apply a cointegration model that can account for structural breaks, such as the Gregory-Hansen model. However, this falls outside the parameters of this study. The consideration of a trend after identifying the structural breaks is noted as an extension for further research in the final chapter of this study.

4.4 Autoregressive distributive lag (ARDL) model results

Before proceeding with the analysis, the appropriate lag lengths needed to be determined. The optimal lag length was selected based on the lag length that minimized the information criteria. AIC is utilized for a relatively small dataset (Zajic, 2019). In contrast, the SIC is favoured in large-sample settings and is based on the empirical log-likelihood (Cavanaugh and Neath, 1999). Each information criterion had its own strengths and weaknesses, which were discussed in greater detail in the methodology chapter. The SIC was utilized for the purpose of this study due to quarterly observations over a 30-year sample period being a relatively large sample. To ensure that the results of the model are not sensitive to lag length, the best ARDL model was determined using multiple lag lengths to determine the optimal number of lags that minimised the SIC. Figure 1 below showed that the optimal model for the data of the CPI and HPI values was an ARDL(10,2) model. This implied that this model resulted in the best model outcome. Similarly, when each house price segment was tested, the optimal model for the CPI and respective house price segments was an ARDL (10,1) model, as shown in figures 2-4.

Figure 1: The top 20 ARDL models according to the SIC for HPI

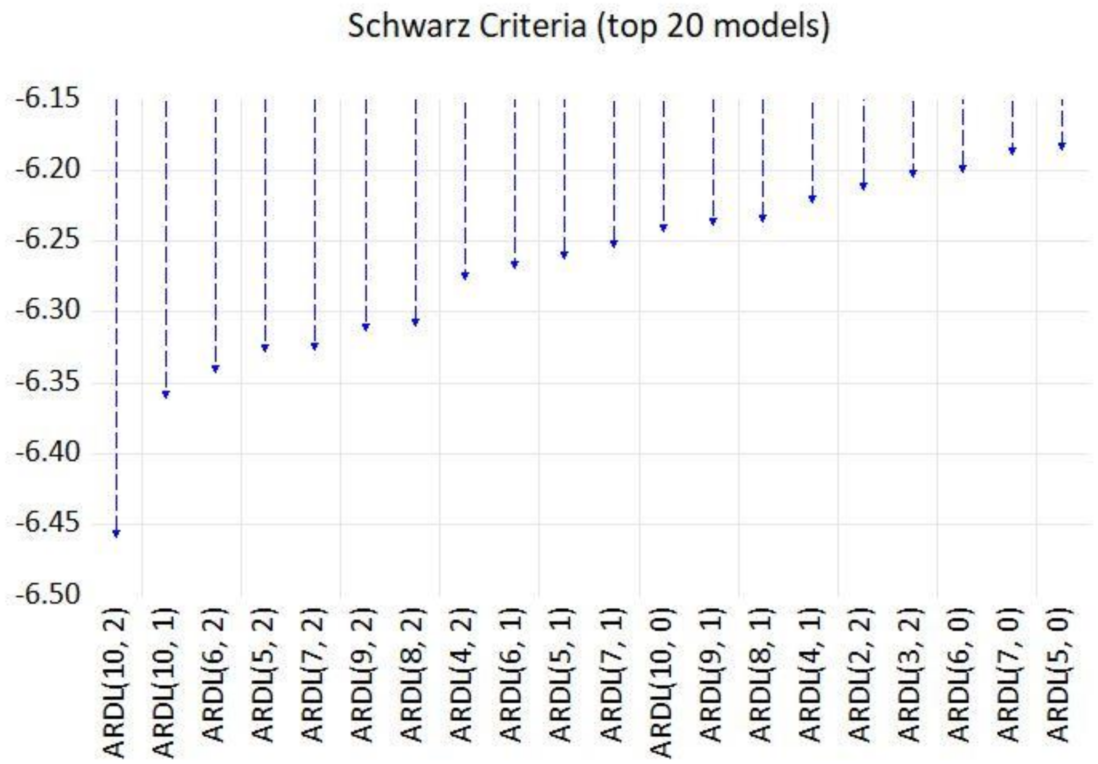


Figure 2: The top 20 ARDL models according to the SIC for Affordable HP

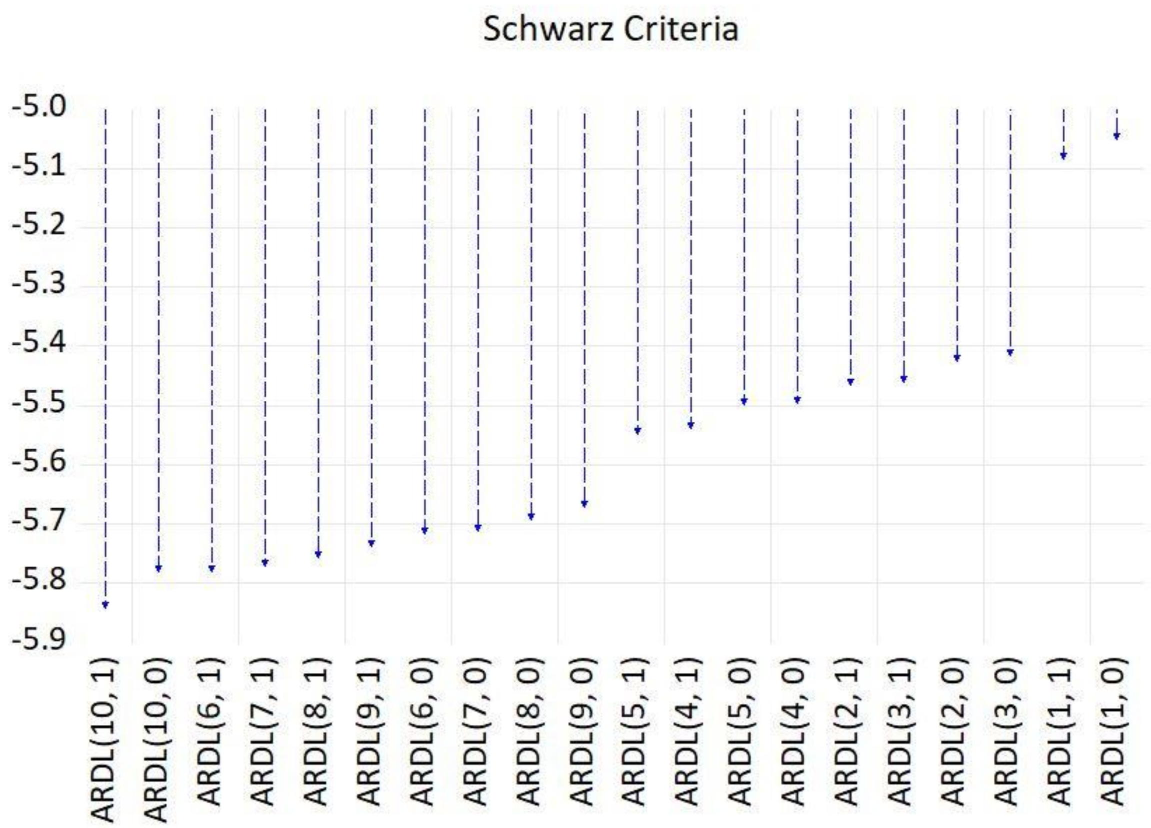


Figure 3: The top 20 ARDL models according to the SIC for Middle HP

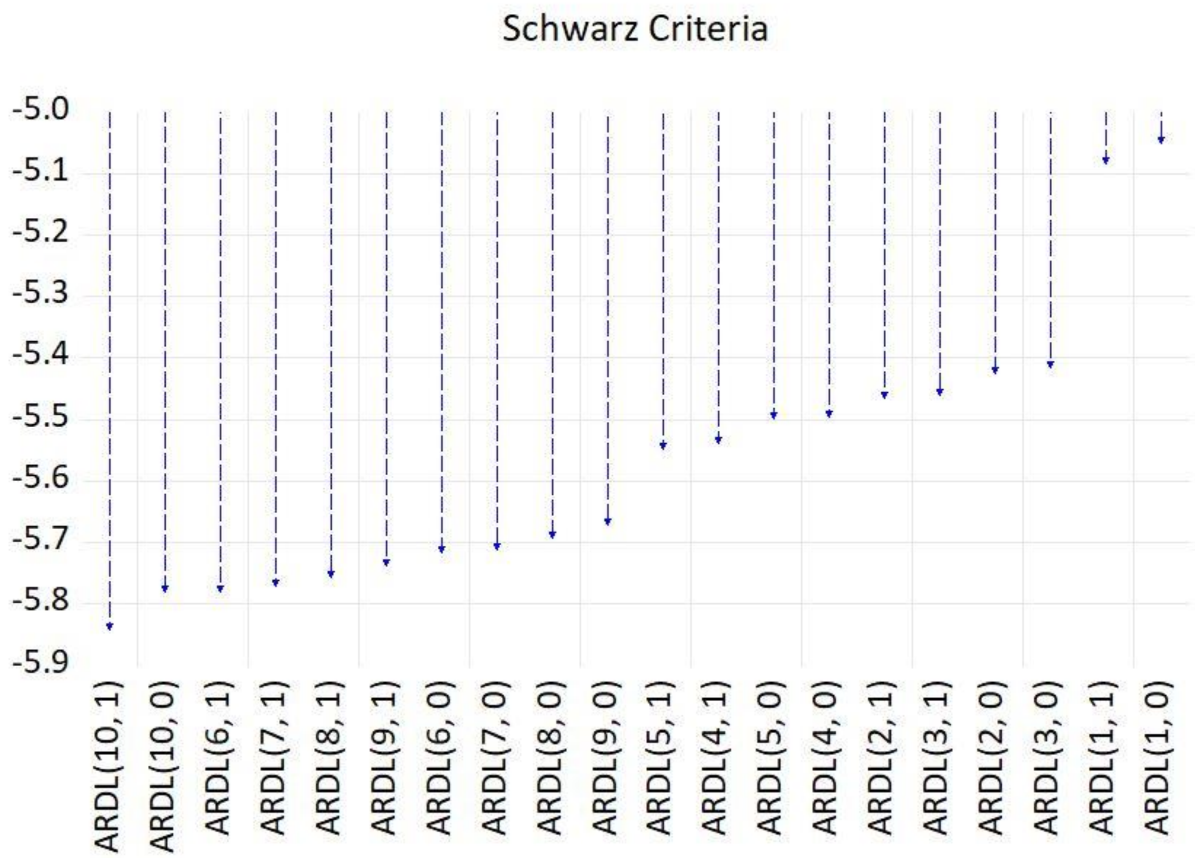
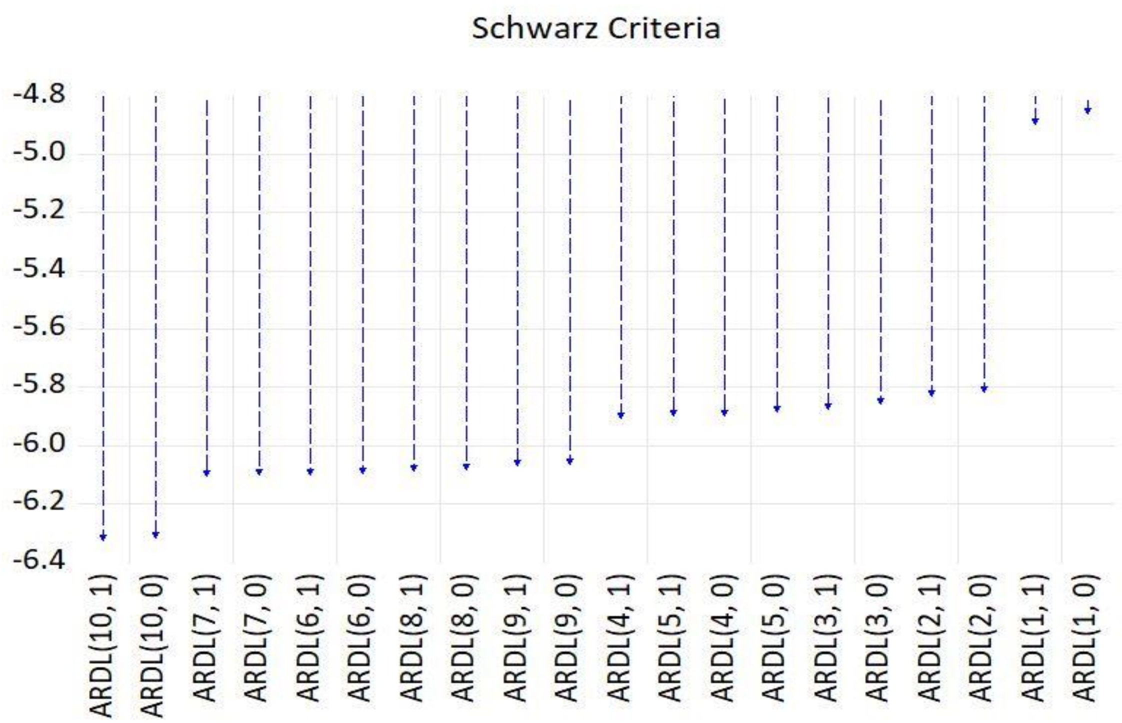


Figure 4: The top 20 ARDL models according to the SIC for luxury HP



The ARDL model was utilized to determine the long-run relationship between the variables (Pesaran *et al.,* 2001). This estimation was done in two stages. The first stage included testing for the presence of a long-run relationship between the variables through computing the F-statistic through the Wald test (Pahlavani *et al.,* 2005). This process tested whether the null hypothesis of no cointegration between the joint lagged levels of the right side of the ARDL model was either significant or not. Therefore, in order to confirm the presence of a long-run relationship between the variables, the F-statistic was required to exceed the upper critical bound (Pesaran *et al.,* 2001).

The second stage involved estimating the long-run coefficient (Pahlavani *et al.,* 2005). This indicated how much housing prices changed due to a 1 percent increase in the inflation rate. However, the ARDL model assumed a symmetric and linear relationship between housing prices and the inflation rate. Therefore, there was a need to apply the more advanced non-linear model (Khan *et al.,* 2019).

Table 4.4.1: ARDL Bounds test for CPI and HPI

F-statistic	**11.98381**		**F-statistic result**
Critical Value Bounds	**I(0) Bound**	**I(1) Bound**	
10%	3.02	3.51	Above bounds
5%	3.62	4.16	Above bounds
2.5%	4.18	4.79	Above bounds
1%	4.94	5.58	Above bounds

Table 4.4.1 indicated the results of the ARDL bounds test for the CPI and HPI variables. The F-statistic value of 11.98381 exceeded all the critical values of both the I(0) and I(1) bounds. Therefore, using the conventional level of significance of 5%, as well as all above levels of significance, the null hypothesis that no long-run relationship exists between the variables can be rejected. Hence, concluding that there is a long-run relationship present between CPI and HPI. Therefore, a cointegrating relationship is present between the variables. This concluded the first stage of the ARDL estimation for CPI and HPI.

Table 4.4.2: ARDL cointegration and long-run form (CPI and HPI)

Conditional Error Correction Regression				
Variable	**Coefficient**	**Standard error**	**T-statistic**	**Prob.**
C	0.000700	0.018378	0.038085	0.9697
LogCPI(-1)	0.016523	0.009400	1.757757	0.0818
ECM(-1)	-0.012781	0.005130	-2.491579	0.0144
Long-run coefficient Variable	**Coefficient**	**Standard error**	**T-statistic**	**Prob.**
LogCPI	1.292752	0.256325	5.043419	0.0000
C	0.054762	1.456509	0.037598	0.9701

Table 4.4.2 presented the short-run and long-run form of the model. The variable ECM(-1) represented the short-run adjustment coefficient ECT, which indicated about a 1% adjustment of the variable towards the equilibrium level within a period following a disequilibrium. The negative ECT indicated that the variable will return to the equilibrium level. Since the existence of a long-run relationship between the variables was confirmed, the next step was to estimate the long-run elasticities. Table 4.4.2 presented the ARDL cointegration equation and shows a coefficient for LogCPI of 1.292752. This value essentially represented the beta coefficient in the Fisher equation. This value was both positive and greater than unity, which implied that based on the results of the ARDL model, housing prices were able to act as a hedge against inflation. This result can be further explained as, for every percentage change in inflation, the increase in housing prices was greater than one. This can be represented by the Fishers equation for the ARDL model, which is:

$$LogHPI = 0.054762 + 1.292752 LogCPI$$

This procedure of the ARDL model presented above is further re-examined for each of the house price segments in order to determine whether there was a long-run relationship present between each segment and inflation. Furthermore, the ability of each segment to hedge against the effects of inflation was also examined to determine which segment was the best inflationary hedge. This bounds test was further extended as the housing prices in South Africa are broken down into different segments of the households, as shown below. The first segment examined was the affordable house price segment.

Table 4.4.3.: ARDL bounds test for CPI and the Affordable housing segment

F-statistic	4.343054		F-statistic result
Critical Value Bounds	**I(0) Bound**	**I(1) Bound**	
10%	3.02	3.51	Above bounds
5%	3.62	4.16	Above bounds
2.5%	4.18	4.79	Between bounds
1%	4.94	4.58	No cointegration

Table 4.4.3 represented the results of the ARDL bounds test for the CPI and Affordable housing price variables. The F-statistic value of 4.343054 exceeded the critical values of both the I(0) and I(1) bounds for both the 10% and 5% levels of significance. Therefore, using the conventional level of significance of 5%, the null hypothesis that no long-run relationship exists between the variables can be rejected. Hence, it can be concluded that there is a long-run relationship present between CPI and affordable housing prices. Therefore, a cointegrating relationship is present between the variables. This concluded the first stage of the ARDL estimation for CPI and the affordable housing segment.

Table 4.4.4: ARDL cointegration and long-run form (CPI and Affordable housing prices)

Conditional Error Correction Regression				
Variable	**Coefficient**	**Standard error**	**T-statistic**	**Prob.**
C	0.106661	0.059605	1.789454	0.0771
LogCPI(-1)	0.016772	0.015116	1.109570	0.2703
ECM(-1)	-0.013662	0.009815	-1.392046	0.1675
Long-run coefficient Variable	**Coefficient**	**Standard error**	**T-statistic**	**Prob.**
LogCPI	1.227611	0.304106	4.036789	0.0001
C	7.806970	1.660085	4.702714	0.0000

Table 4.4.4 represents the ARDL cointegration equation when the affordable house price segment is taken into consideration. The variable ECM(-1) represented the short-run adjustment coefficient, ECT, which indicated about a 1% adjustment of the variable towards the equilibrium level within a period following a disequilibrium. The negative ECT indicated

that the variable will return to the equilibrium level. Since the existence of a long-run relationship between the variables was confirmed, the next step was to estimate the long-run elasticities. The coefficient of LogCPI was 1.227611. The coefficient was both positive and greater than unity. This is in line with the ARDL model that utilized the housing price values. Therefore, by accounting for the affordable housing prices, it can be concluded that for every percentage change in inflation, the increase in affordable housing prices was greater than one. This can be represented by the Fishers equation for the ARDL model, which is:

LogAFF = 7.806970 + 1.227611LogCPI

Hence, the conclusion drawn was that affordable housing prices are an effective hedge against inflation. The next housing price segment is the middle segment, which was examined below.

Table 4.4.5: ARDL bounds test for CPI and the Middle housing segment

F-statistic	**5.373199**		**F-statistic result**
Critical Value Bounds	**I(0) Bound**	**I(1) Bound**	
10%	3.02	3.51	Above bounds
5%	3.62	4.16	Above bounds
2.5%	4.18	4.79	Above bounds
1%	4.94	5.58	Between bounds

Table 4.4.5 represented the results of the ARDL bounds test for the CPI and middle housing price variable. The F-statistic value of 5.373199 exceeded the critical values of both the I(0) and I(1) bounds for the 10%, 5%, and 2.5% levels of significance. Therefore, using the conventional level of significance of 5%, the null hypothesis that no long-run relationship exists between the variables can be rejected. Hence, it can be concluded that there is a long-run relationship present between CPI and middle housing prices. Therefore, cointegration is present between the variables.

Table 4.4.6: ARDL cointegration and long-run form (CPI and Middle housing prices)

Conditional Error Correction Regression				
Variable	**Coefficient**	**Standard error**	**T-statistic**	**Prob.**
C	0.116052	0.035000	3.315741	0.0013
LogCPI(-1)	0.034243	0.011829	2.894794	0.0048
ECM(-1)	-0.018842	0.006089	-3.094267	0.0027
Long-run coefficient Variable	**Coefficient**	**Standard error**	**T-statistic**	**Prob.**
LogCPI	1.817431	0.133991	13.56382	0.0000
C	6.159312	0.611989	10.06442	0.0000

Table 4.4.6 represented the ARDL cointegration equation when the middle house price segment was taken into consideration. The variable ECM(-1) represented the short-run adjustment coefficient, the ECT, which indicated a 1.88% adjustment of the variable towards the equilibrium level within a period following a disequilibrium. The negative ECT indicates that the variable will return to the equilibrium level. Since the existence of a long-run relationship between the variables was confirmed, the next step was to estimate the long-run elasticities. The coefficient of LogCPI was 1.817431. The coefficient was both positive and greater than unity. Therefore, by accounting for the middle housing prices, it can be concluded that for every percentage change in inflation, the increase in middle housing prices was greater than one. This can be represented by the Fishers equation for the ARDL model, which is:

$$LogMID = 6.159312 + 1.817431 LogCPI$$

Hence, the conclusion drawn was that the middle housing prices are an effective hedge against inflation. The final housing price segment is the luxury segment, which is examined below.

Table 4.4.7: ARDL bounds test for CPI and the Luxury housing segment

F-statistic	**11.13431**		**F-statistic result**
Critical Value Bounds	**I(0) Bound**	**I(1) Bound**	
10%	3.02	3.51	Above bounds
5%	3.62	4.16	Above bounds
2.5%	4.18	4.79	Above bounds
1%	4.94	5.58	Above bounds

Table 4.4.7 represented the results of the ARDL bounds test for the CPI and luxury house price variables. The F-statistic value of 11.13431 exceeded all the critical values of both the I(0) and I(1) bounds. Therefore, using the conventional level of significance of 5%, the null hypothesis that no long-run relationship exists between the variables can be rejected. Hence, it can be concluded that there is a long-run relationship present between CPI and luxury house prices. Therefore, a cointegrating relationship is present between the variables.

Table 4.4.8: ARDL cointegration and long-run form (CPI and Luxury housing prices)

Conditional Error Correction Regression				
Variable	**Coefficient**	**Standard error**	**T-statistic**	**Prob.**
C	0.472429	0.307303	1.537341	0.1274
LogCPI	0.042507	0.043596	0.975036	0.3319
ECM(-1)	-0.041640	0.032019	-1.300474	0.1964
Long-run coefficient Variable	**Coefficient**	**Standard error**	**T-statistic**	**Prob.**
LogCPI	1.020831	0.301396	3.387006	0.0010
C	11.34557	1.531440	7.408431	0.0000

Table 4.4.8 represented the ARDL cointegration equation when the luxury house price segment was taken into consideration. The variable ECM(-1) represented the short-run adjustment coefficient, the ECT, which indicated a 4% adjustment of the variable towards the equilibrium level within a period following a disequilibrium. The negative ECT indicated that the variable will return to the equilibrium level. Since the existence of a long-run relationship between the variables was confirmed, the next step was to estimate the long-run elasticities. The coefficient

of LogCPI was 1.020831 and was the beta coefficient. The coefficient was both positive and greater than unity. Therefore, by accounting for the luxury housing prices, it can be concluded that for every percentage change in inflation, the increase in luxury housing prices was greater than one. This can be represented by the Fishers equation for the ARDL model, which is:

LogLUX = 11.34557 +1.020831 LogCPI

Similarly, the conclusion drawn was that the luxury housing prices are an effective hedge against inflation. Therefore, it can be concluded that both the HPI and all the above house price segments have the ability to hedge against the effects of inflation.

Table 4.4.9: Summary table of the above results

Variable	**Long-run elasticity**
Housing Price Index (HPI)	1.292752
Affordable housing prices	1.227611
Middle housing prices	1.817431
Luxury housing prices	1.020831

Table 4.4.9 indicated the long-run elasticities of each of the variables used in this study. The results showed that HPI and the respective house price segments were all able to act as an effective hedge against inflation, as all coefficients were greater than unity. The lowest beta coefficient was that for the luxury house price segment, at 1.020831. This implied that although an effective hedge, the luxury segment had the lowest hedging capabilities in comparison to the other segments. This implied that investors would not gain the highest wealth-creating benefits from investing in luxury housing. Similarly, the affordable housing segment provided effective hedging benefits, which were greater than the luxury but lower than the middle segment. The middle house price segment was the most sensitive to inflation. This was due to its long-run elasticity of 1.817431 being greater than the other segments.

4.5 Nonlinear autoregressive distributive lag (NARDL) model results

The conventional cointegration approach, such as the ARDL estimation model, assumes that housing prices move proportionately, as well as at the same speed when inflation increases and decreases (Hamzah and Masih, 2018). However, there may be asymmetric and nonlinear cointegration present between these variables. Therefore, the NARDL bounds testing approach was utilized to accommodate the possible positive and negative partial sum decompositions. In this way, it was possible to differentiate between the asymmetric effects in both the short-run and long-run. The Wald test represented the NARDL with long-run asymmetry and short-run asymmetry (Shin *et al.*, 2014). This was done to determine whether there was an imbalanced reaction of the housing price dynamics to the fluctuations of the inflation rate. Furthermore, the bounds cointegration test was performed to verify the existence of a long-run relationship among the examined variables. This was examined using an F-test, which was done on the joint hypothesis that the lagged level variables are equal to zero (Shin *et al.*, 2014).

The optimal lag lengths were determined before the NARDL analysis and were carried out similar to the ARDL model, with SIC being the chosen information criteria. The best model for the HPI analysis, as well as the housing price segments, are shown in the figures below.

Figure 5: The top 20 NARDL models according to the SIC for HPI

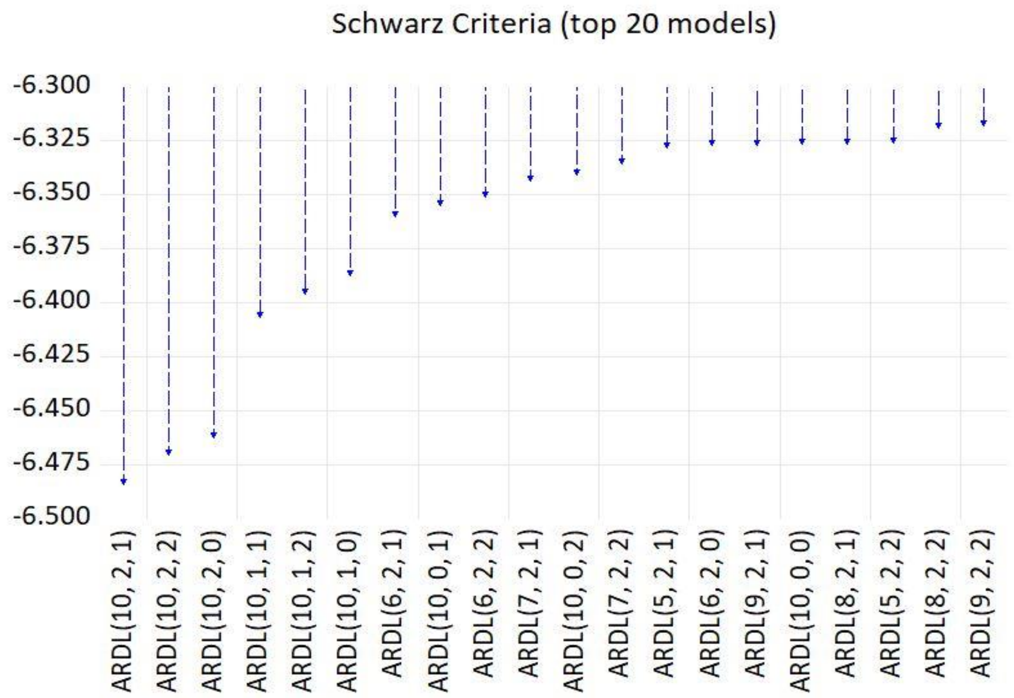


Figure 6: The top 20 NARDL models according to the SIC for Affordable HP

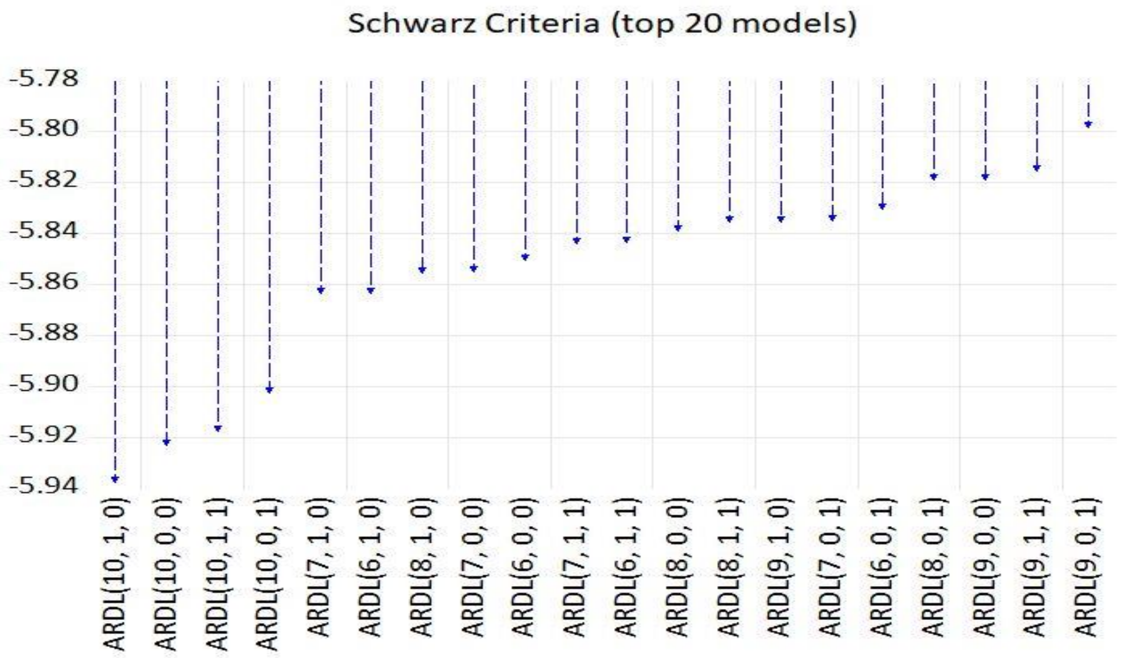


Figure 7: The top 20 NARDL models according to the SIC for Middle HP

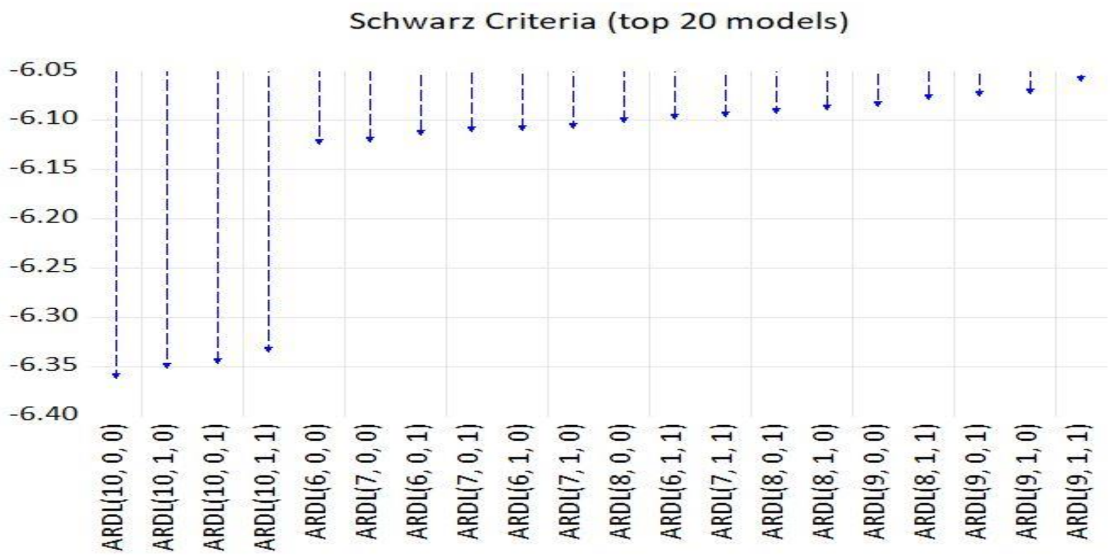
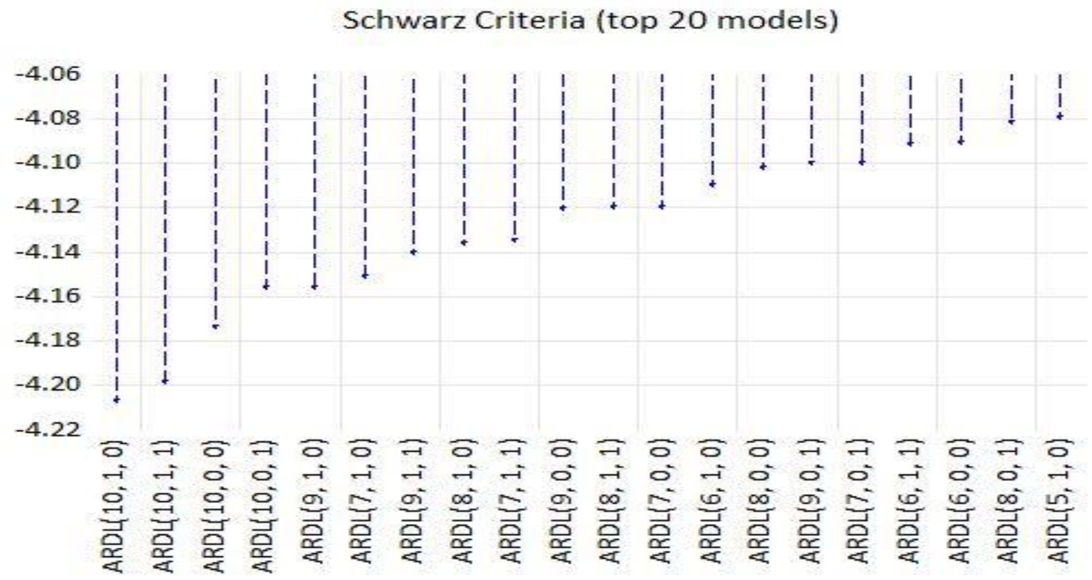


Figure 8: The top 20 NARDL models according to the SIC for Luxury HP



As seen in figure 5, the chosen NARDL model is NARDL (10,2,1), which was for the analysis using CPI and HPI. This indicated that for CPI, two lags were appropriate for positive adjustments and one lag for negative adjustments. Similarly, for the housing price segments in figures 6-8, the chosen model was NARDL (10,1,0), which indicated a single lag for positive adjustments and zero lags for negative adjustments. The first part of this analysis focused on the two main variables of this study, namely HPI as the regressand and CPI as the regressor. The objective of this study was to test for asymmetric adjustment in the long run relationship, and to estimate the positive and negative long run coefficients to determine if the relationship is confirmed to be nonlinear.

Table 4.5.1: NARDL Bounds test for CPI and HPI

F-statistic	**8.701308**		**F-statistic result**
Critical Value Bounds	**I(0) Bound**	**I(1) Bound**	
10%	2.63	3.35	Above bounds
5%	3.1	3.87	Above bounds
2.5%	3.55	4.38	Above bounds
1%	4.13	5	Above bounds

The results from table 4.5.1 represented the bounds cointegration test, which used the F-test. This confirmed the existence of a long-run relationship between the variables when the results are statistically significant. The null hypothesis for the NARDL is similar to that of the standard ARDL model, which states that there is no cointegrating relationship present. Since the F-statistic of 8.701308 exceeded the critical values at all the levels of significance, the null hypothesis of no cointegration can be rejected. It is, therefore, confirmed that when nonlinearity was accounted for in the dataset, there was still evidence that there is cointegration present between HPI and CPI.

Table 4.5.2: The NARDL Cointegration and Long-run form for CPI and HPI

Conditional Error Correction Regression				
Variable	**Coefficient**	**Standard error**	**T-statistic**	**Prob.**
C	0.029764	0.031778	0.936616	0.3514
LogCPI_POS	0.012966	0.016427	0.789280	0.4320
LogCPI_NEG	0.409833	0.748537	0.547512	0.5853
ECM (-1)	-0.007728	0.013938	-0.554463	0.5806
Long-run coefficient Variable	**Coefficient**	**Standard error**	**T-statistic**	**Prob.**
LogCPI_POS	1.677703	1.090629	1.538290	0.1274
LogCPI_NEG	53.03011	189.0999	0.280434	0.7798
C	3.851276	2.979163	1.292738	0.1993

The results in table 4.5.2 are represented in a similar manner to that of the standard ARDL model. The key difference between this table and the ARDL version above is the split of the beta coefficient of the LogCPI variable into positive and negative components. The variable ECM(-1) represents the short-run adjustment coefficient, the ECT, which indicated a 0.77% adjustment of the variable towards the equilibrium level within a period following a disequilibrium. The negative ECT indicated that the variable will return to the equilibrium level. The LogCPI_POS represents the positive adjustment coefficient, which is 1.677703, and the negative adjustment coefficient LogCPI_NEG value is 53.03011. Both of these coefficients are statistically significant and can be explained in greater detail. Since the LogCPI_POS value was positive and greater than unity, it implied that increases in inflation had a positive effect on the HPI of a magnitude that was greater than one. Therefore, there is a positive relationship between CPI and HPI. Similarly, the LogCPI_NEG value was also positive and implied that decreases in inflation had an even greater effect on HPI with regard to the magnitude. This coefficient essentially showed that for each negative percentage change in CPI, LOGHPI exhibited a positive change of 53.03%. Therefore, in situations of decreasing inflation, the housing market returns increase. Since the results above entail response coefficients in absolute values that are greater than unity and statistically significant, it can be concluded that housing prices are an effective hedge against inflation. This can be seen for both positive and negative effects of inflation, as housing returns still confirm a positive response to negative changes in inflation. Therefore, any inflationary changes will be corresponded with a percentage change in housing returns that is positive and of at least a similar magnitude.

It is important to note that both the positive and negative values differ significantly, which indicates that although cointegration is present between inflation and housing prices, the relationship between these variables is asymmetric. This highlights the important contribution of the NARDL model, as this relationship would not have been confirmed as asymmetric using the standard ARDL model.

Table 4.5.3: Wald test for the NARDL results of CPI and HPI

Equation type: NARDL		**Null Hypothesis: Symmetry**	
Test Statistic	**Value**	**Df**	**Probability**
T-statistic	-5.332656	93	0.0000
F-statistic	28.43722	(1.93)	0.0000
Chi-Square	28.43722	1	0.0000
Null Hypothesis: c(2) = c(3)			
Normalized restriction = (=0)		**Value**	**Std. Error**
C(2) – C(3)		-2.246628	0.421296

Table 4.5.3 represented the Wald test results. This test was utilized in order to determine whether or not the null hypothesis of a symmetric adjustment was rejected. As seen by the results, the null hypothesis is rejected. This implies that the long-run relationship is asymmetric. The findings from this test contradict the symmetric relationship assumption of the ARDL model. This implies that the positive and negative changes in the relationship are not the same, and hence, need to be examined separately to account for these changes. The significant evidence of asymmetry highlight the contribution of this study in the way that it

addresses the limitations of the ARDL model. The results of the cointegrating form can be represented in the following equation:

LogHPI = 3.851276 + 1.677703LogCPI_POS + 53.03011LogCPI_NEG

This NARDL model is re-examined for each of the house price segments below.

Table 4.5.4: NARDL Bounds test for CPI and the Affordable housing price segment

F-statistic	**7.362271**		**F-statistic result**
Critical Value Bounds	**I(0) Bound**	**I(1) Bound**	
10%	2.63	3.35	Above bounds
5%	3.1	3.87	Above bounds
2.5%	3.55	4.38	Above bounds
1%	4.13	5	Above bounds

The results from table 4.5.4 represented the bounds cointegration test, which used the F-test. This confirmed the existence of a long-run relationship between the variables when the results were statistically significant. Since the F-statistic of 7.362271 exceeded the critical values at all the levels of significance, the null hypothesis of no cointegration can be rejected. It is, therefore, confirmed that when nonlinearity is accounted for in the dataset, there is still evidence that there is cointegration present between CPI and affordable housing prices.

Table 4.5.5: The NARDL Cointegration and Long-run form for CPI and Affordable housing prices

Conditional Error Correction Regression				
Variable	**Coefficient**	**Standard error**	**T-statistic**	**Prob.**
C	0.740904	0.162112	4.570326	0.0000
LogCPI_POS	0.054994	0.019325	2.845714	0.0057
LogCPI_NEG	-3.185613	0.731369	-4.355683	0.0000
ECM(-1)	-0.068470	0.015783	-4.338082	0.0000
Long-run coefficient Variable	**Coefficient**	**Standard error**	**T-statistic**	**Prob.**
LogCPI_POS	0.803177	0.144600	5.554473	0.0000
LogCPI_NEG	-46.52564	7.970135	-5.837497	0.0000
C	10.82085	0.244730	44.21550	0.0000

Table 4.5.5 represented the short-run and long-run coefficients. The variable ECM(-1) represented the short-run adjustment coefficient, the ECT, which indicated a 6% adjustment of the variable towards the equilibrium level within a period following a disequilibrium. The negative ECT indicated that the variable will return to the equilibrium level. The LogCPI_POS represented the positive adjustment coefficient, which was 0.803177, and the negative adjustment coefficient LogCPI_NEG value was -46.52564. Since the LogCPI_POS value was positive but less than unity, it implied that increases in inflation will have a positive effect on the affordable housing prices of a magnitude that is less than one. Therefore, there is a positive relationship between the variables. Similarly, the LogCPI_NEG value is negative and implies that decreases in inflation will have an even greater effect on affordable housing prices with regard to the magnitude. This coefficient essentially shows that for each negative percentage change in CPI, LOGAFF exhibited a positive change of 46.53%. The negative coefficient value infers an inverse relationship, which implies that inflation decreases are linked to increasing housing returns, which are of a greater magnitude than that of the positive inflationary adjustments. This conclusion implies that investors should invest in the property market when inflation exhibits negative inflationary adjustments.

Therefore, by using the interpretation above, this implies that a continuous decrease in inflation brings about an increase in housing prices in the long run. In this situation, investors are able to still profit from housing returns during the period of decreasing inflation. Since the results above entail a negative response coefficient in absolute value is greater than unity and statistically significant, it can be concluded that affordable housing prices are an effective hedge against inflation for negative inflationary adjustments. However, for positive changes in inflation, affordable housing prices are a partial hedge against inflation, as the value is positive but not greater than one. This interpretation is supported by South African literature that has utilized the NARDL model, such as by Mazorodze and Siddiq (2018), who examined the relationship between output and the employment rate. The results indicated a decrease in the output led to an increase in the unemployment.

Table 4.5.6: Wald test for the NARDL results of CPI and Affordable housing prices

Equation type: NARDL		**Null Hypothesis: Symmetry**	
Test Statistic	**Value**	**Df**	**Probability**
T-statistic	-5.098987	73	0.0000
F-statistic	25.99967	(1.73)	0.0000
Chi-square	25.99967	1	0.0000
Null Hypothesis: c(2) = c(3)			
Normalized restriction = (=0)		**Value**	**Std. Error**
C(2) – C(3)		-2.358297	0.462503

Table 4.5.6 represented the Wald test results. As seen by the results, the null hypothesis of a symmetric adjustment was rejected. This implied that the long-run relationship between CPI and affordable housing prices was asymmetric. The results of the cointegrating form can be represented in the following equation:

LogAFF = 10.82085+ 0.803177LogCPI_POS – 46.52564LogCPI_NEG

Table 4.5.7: NARDL Bounds test for CPI and the Middle housing price segment

F-statistic	5.261596		F-statistic result
Critical Value Bounds	**I(0) Bound**	**I(1) Bound**	
10%	2.63	3.35	Above bounds
5%	3.1	3.87	Above bounds
2.5%	3.55	4.38	Above bounds
1%	4.13	5	Above bounds

The results from table 4.5.7 represented the bounds cointegration test, which used the F-test. This confirmed the existence of a long-run relationship between the variables when the results are statistically significant. Since the F-statistic of 5.261596 exceeded the critical values at all the levels of significance, the null hypothesis of no cointegration can be rejected. It is, therefore, confirmed that when nonlinearity is accounted for in the dataset, there is still evidence that there is cointegration present between CPI and middle housing prices.

Table 4.5.8: The NARDL Cointegration and Long-run form for CPI and Middle housing prices

Conditional Error Correction Regression				
Variable	**Coefficient**	**Standard error**	**T-statistic**	**Prob.**
C	0.553040	0.134736	4.104605	0.0001
LogCPI_POS	0.073932	0.017090	4.326104	0.0000
LogCPI_NEG	-1.432506	0.538997	-2.657725	0.0094
ECM(-1)	-0.050388	0.012204	-4.128738	0.0001
Long-run coefficient Variable	**Coefficient**	**Standard error**	**T-statistic**	**Prob.**
LogCPI_POS	1.467262	0.097717	15.01542	0.0000
LogCPI_NEG	-28.42962	6.170953	-4.607006	0.0000
C	10.97567	0.102657	106.9156	0.0000

Table 4.5.8 represented the short-run and long-run coefficients. The variable ECM(-1) represented the short-run adjustment coefficient, the ECT, which indicated a 5% adjustment of

the variable towards the equilibrium level within a period following a disequilibrium. The negative ECT indicates that the variable will return to the equilibrium level. The LogCPI_POS represents the positive adjustment coefficient, which was 1.467262, and the negative adjustment coefficient LogCPI_NEG value was -28.42942. Since the LogCPI_POS value was positive and greater than unity, it implied that increases in inflation had a positive effect on the middle housing prices of a magnitude that was greater than one. Therefore, there is a positive relationship between the variables. Similarly, the LogCPI_NEG value is negative and implied that decreases in inflation had an even greater effect on middle housing prices with regard to the magnitude. This coefficient essentially showed that for each negative percentage change in CPI, LOGMID exhibited a positive change of 28.43%. This suggests that a continuous decrease in inflation brings about an increase in housing prices in the long run. In this situation, investors are able to still profit from housing returns during the period of deflation. Since the results above entail response coefficients in absolute values that are greater than unity and statistically significant, it can be concluded that middle housing prices are an effective hedge against inflation. This can be seen for both positive and negative effects of inflation, as housing returns still confirm a positive response to negative changes in inflation.

Table 4.5.9: Wald test for the NARDL results of CPI and Middle housing prices

Equation type: NARDL		**Null Hypothesis: Symmetry**	
Test Statistic	**Value**	**Df**	**Probability**
T-statistic	-5.445093	83	0.0000
F-statistic	29.64904	(1.83)	0.0000
Chi-square	29.64904	1	0.0000
Null Hypothesis: c(2) = c(3)			
Normalized restriction = (=0)		**Value**	**Std. Error**
C(2) – C(3)		-2.820004	0.517898

Table 4.5.9 represented the Wald test results. As seen by the results, the null hypothesis of a symmetric adjustment was rejected. This implied that the long-run relationship between CPI and middle house prices was asymmetric. The results of the cointegrating form can be represented in the following equation:

LogMID = 10.97567 + 1.467262LogCPI_POS – 28.42962LogCPI_NEG

Table 4.5.10: NARDL bounds test for CPI and the Luxury housing price segment

F-statistic	4.081410		F-statistic result
Critical Value Bounds	**I(0) Bound**	**I(1) Bound**	
10%	2.63	3.35	Above bounds
5%	3.1	3.87	Above bounds
2.5%	3.55	4.38	Between bounds
1%	4.13	5	No cointegration

The results from table 4.5.10 represented the bounds cointegration test, which used the F-test. This confirmed the existence of a long-run relationship between the variables when the results were statistically significant. Since the F-statistic of 4.081410 exceeded the 10% and 5% levels of significance, the null hypothesis of no cointegration can be rejected. It is, therefore, confirmed that when nonlinearity is accounted for in the dataset, there is still evidence that there is cointegration present between CPI and luxury housing prices.

Table 4.5.11: The NARDL Cointegration and Long-run form for CPI and Luxury housing prices

Conditional Error Correction Regression				
Variable	**Coefficient**	**Standard error**	**T-statistic**	**Prob.**
C	2.712291	0.685265	3.958019	0.0002
LogCPI_POS	0.210841	0.058199	3.622754	0.0005
LogCPI_NEG	-4.433450	1.459378	-3.037905	0.0032
ECM(-1)	-0.203305	0.051645	-3.936607	0.0002
Long-run coefficient Variable	**Coefficient**	**Standard error**	**T-statistic**	**Prob.**
LogCPI_POS	1.037071	0.088568	11.70927	0.0000
LogCPI_NEG	-21.80694	4.697849	-4.641899	0.0000
C	13.34103	0.120921	110.3285	0.0000

Table 4.5.11 represented the short-run and long-run coefficients. The variable ECM(-1) represented the short-run adjustment coefficient, the ECT, which indicated a 20% adjustment

of the variable towards the equilibrium level within a period following a disequilibrium. The negative ECT indicated that the variable will return to the equilibrium level. The LogCPI_POS represented the positive adjustment coefficient, which was 1.037071, and the negative adjustment coefficient LogCPI_NEG value was -21.80694. Since the LogCPI_POS value was positive and greater than unity, it implied that increases in inflation had a positive effect on the luxury housing prices of a magnitude that was greater than one. Therefore, there is a positive relationship between the variables. Similarly, the LogCPI_NEG value is negative and implies that decreases in inflation will have an even greater effect on luxury housing prices with regard to the magnitude. This coefficient essentially showed that for each negative percentage change in CPI, LOGLUX exhibited a positive change of 21.81%. This implies that a continuous decrease in inflation brings about an increase in housing prices in the long run. In this situation, investors are able to still profit from housing returns during the period of deflation. Since the results above entail response coefficients in absolute values that are greater than unity and statistically significant, it can be concluded that luxury housing prices are an effective hedge against inflation. This can be seen for both positive and negative effects of inflation, as housing returns still confirm a positive response to negative changes in inflation.

Table 4.5.12: Wald test for the NARDL results of CPI and Luxury housing prices

Equation type: NARDL		**Null Hypothesis: Symmetry**	
Test Statistic	**Value**	**Df**	**Probability**
T-statistic	-3.642037	83	0.0005
F-statistic	13.26444	(1.83)	0.0005
Chi-square	13.26444	1	0.0003
Null Hypothesis: c(2) = c(3)			
Normalized restriction = (=0)		**Value**	**Std. Error**
C(2) – C(3)		-1.026902	0.281958

Table 4.5.12 represented the Wald test results. As seen by the results, the null hypothesis of a symmetric adjustment was rejected. This implied that the long-run relationship between CPI and luxury house prices was asymmetric. The results of the cointegrating form can be represented in the following equation:

LogLUX = 13.34103+ 1.037071LogCPI_POS – 21.80694LogCPI_NEG

Table 4.5.13: Summary table of the above results

Variable	Long-run elasticity (Positive and negative)	
Housing Price Index (HPI)	1.677703	53.03011
Affordable housing prices	0.803177	-46.52564
Middle housing prices	1.467262	-28.42962
Luxury housing prices	1.037071	-21.80694

Table 4.5.13 represented the long-run elasticities for the NARDL model. These are the positive and negative betas, respectively. The affordable housing segment provides the lowest hedging ability and is a partial hedge against inflation, as the positive beta coefficient is less than one. This differs from the ARDL result, in which the beta coefficient was both positive and greater than unity. However, the negative beta provides a high sensitivity to inflation as its percentage in absolute terms is 46.53%. It is noted that the middle housing prices provides the greatest sensitivity to inflation for positive changes in inflation with a coefficient of 1.467262. This is similar to the conclusion drawn from the ARDL model, which also stated that the middle segment provided the greatest sensitivity, in comparison to the other segments. It can be concluded that for negative inflationary adjustments, housing prices are able to hedge against inflation. Furthermore, for positive inflationary adjustments, housing prices also provide an effective hedge, with only the affordable housing segment providing a partial hedge.

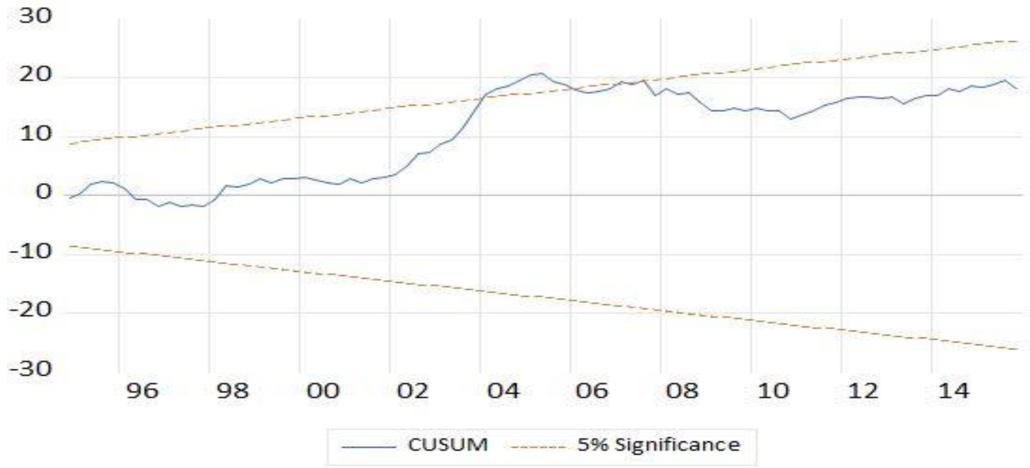
4.6 Parameter stability testing

Stability testing is an important part of econometrics as they measure any type of disruption in a dataset, such as structural breakpoints, which could potentially have an effect on the results (Talas, Kaplan, and Celik, 2013). The Cumulative Sum of Recursive Residuals (CUSUM) test was utilized in order to determine whether the parameters of the model are stable or not. The model can be confirmed to be stable if the trend lines lie within the boundaries. As shown in figure 9, the CUSUM test displays the stability of each of the chosen models.

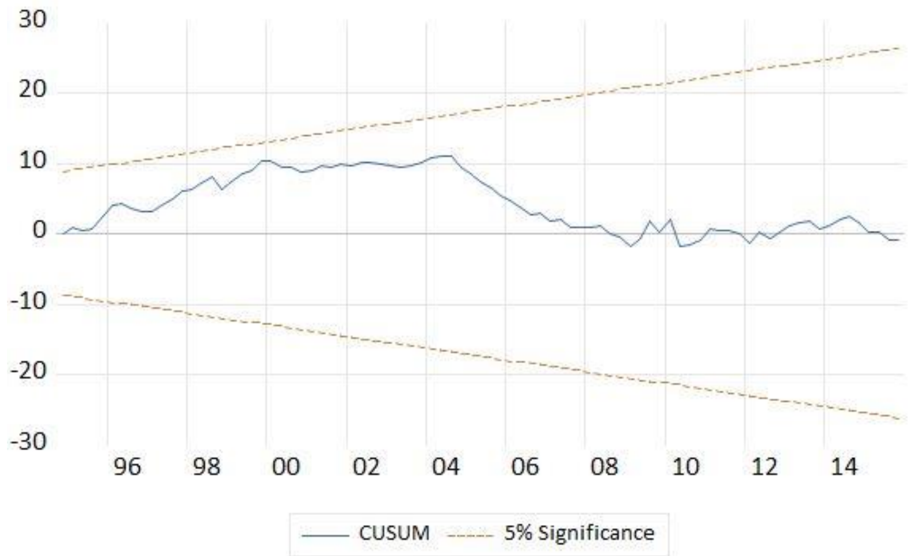
Figure 9: Parameter stability graphs

- CPI and HPI

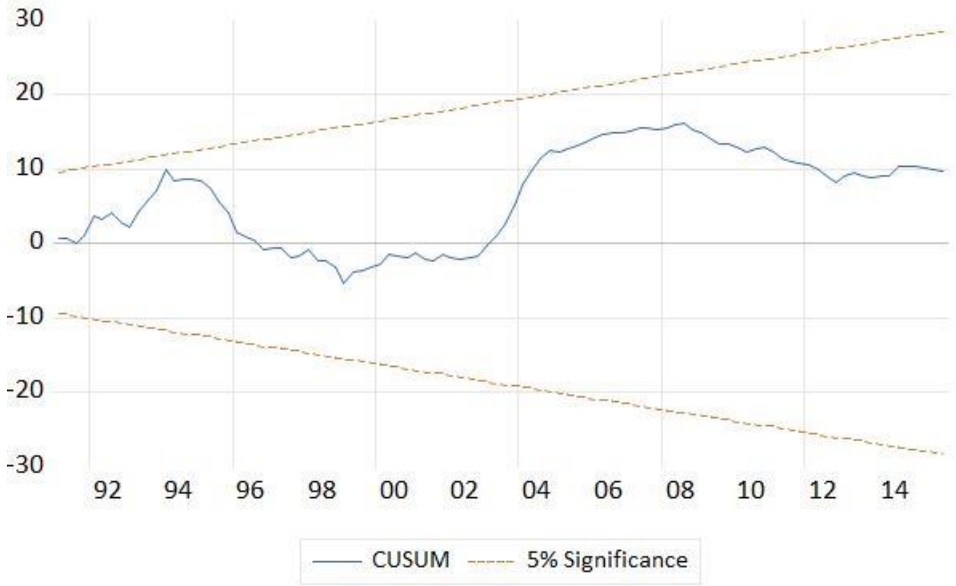
- CPI and Affordable housing prices



- CPI and Middle housing prices



- CPI and Luxury housing prices



The CUSUM parameter stability graphs above show that for HPI, the trend line stays within the boundary lines. However, for the affordable housing prices, the trend line starts off within the boundaries, then moves slightly out of the upper boundary line before returning back within the boundaries. This shows that that there is some weak evidence of parameter instability for this housing segment. The trend lines for both the middle and luxury housing prices stay within the boundary lines. It can be concluded that each of the above models is stable.

4.7 Discussion of findings

This study's primary objective was to determine whether South African residential property was able to hedge against inflation in the long-run. In order to achieve this objective, the ARDL, as well as the NARDL model was examined. The results from the ARDL model indicated that there was a long-run relationship present between the variables. The initial analysis examined whether residential property as a whole, indicated by HPI, was able to hedge against inflation. The results revealed a long-run elasticity of 1.292752, which was positive and greater than one, which implied that residential property had the ability to act as a hedge against inflation. The implication of this result indicates that investors would benefit from investing in property, as this type of investment has the ability to protect itself against the adverse effects of inflation. Furthermore, this ARDL analysis was extended to incorporate the house price segments in South Africa. This was done in order to achieve a greater understanding of the housing market through the use of analysing the different segments separately. The affordable, middle and luxury house price segments were each examined individually. The results from each of the segments were also positive and greater than unity, as the long-run elasticities were 1.22761, 1.81743, and 1.020831, for the affordable, middle, and luxury segments respectively. This indicated that investors were able to benefit from the wealth-creating benefits of property investments in any house price segment. However, the middle housing segment provided the greatest sensitivity to the changes in inflation as the value of 1.81743 was the highest in terms of the individual segments.

Essentially, the primary objective of whether residential property was able to hedge against inflation was answered by the ARDL examination. Furthermore, the final objective of exactly which of the South African house price segments provided the most effective inflation-hedging capabilities, in part, was also answered by the ARDL examination, and was revealed to be the middle house price segment. The second objective, which determined whether the relationship between the variables exhibited evidence of asymmetry. This objective was achieved through the use of the NARDL model, as it was able to examine asymmetry, which was a limitation of the ARDL model. This difference between the models implied that the NARDL model had the ability to test whether there were differences between the positive and negative changes in inflation. This examination proved to be beneficial, as there was evidence that indicated the presence of asymmetry.

Similar to the ARDL examination, the NARDL model was utilized and determined the presence of a long-run relationship between the variables. The initial analysis also examined CPI and HPI, and revealed a positive long-run elasticity of 1.677703, and a negative long-run elasticity of 53.03011. The implication of this analysis proved to be beneficial for investors, as it indicated that wealth can be created by investing in property in periods of both positive and negative inflation changes. Furthermore, when each of the segments were examined, the results also indicated significant asymmetry between the variables. The affordable house price segment had a positive long-run elasticity of 0.803177 and a negative long-run elasticity of 46.52564 (in absolute value). This indicated that in periods of positive changes in inflation, the affordable house price segment was unable to provide an effective hedge against inflation, as the value is lower than one. However, since the value is still positive, the affordable house price segment is known as a partial hedge against inflation. This implied that investors can still benefit from investing in affordable housing, but the benefit may not be as high as during periods of negative changes in inflation, as indicated by the greater value.

With regard to the middle and luxury segments, both provided an effective hedge against inflation, with values greater than one. The positive long-run elasticity was 1.467262 and 1.037071 for the middle and luxury segments respectively. Similarly, the negative long-run elasticity was 28.42962 and 21.80694 for the middle and luxury segments. This implied that for these two segments, investors can profit from the wealth-creating benefits by investing in periods of both positive and negative changes in inflation. However, in all of the above cases, the benefits from investing during periods of negative inflation were greater than periods of positive inflation changes. In this way, the objective of whether the relationship between the variables exhibited asymmetry was achieved, as well as the final objective about the house price segments. It was noted that in both the ARDL and NARDL examinations, the segment that had the greatest sensitivity to changes in inflation was the middle house price segment. These results were consistent with the results of previous authors such as Inglesi-Lotz and Gupta (2013), who also found that the middle house price segment had the greatest inflation-hedging benefits. Through the use of both these models, all three research objectives were achieved in a way that created accurate results of the inflation-hedging ability of residential property in South Africa as a whole, as well as, the different house price segments.

4.8 Chapter summary and conclusion

There has been much literature that has considered the inflation hedging ability of assets, dating back to Fisher (1930). However, the existing literature has posed conflicting results as to the nature of the relationship between inflation and housing prices. The results varied based on the methodologies employed and the chosen dataset, which was time and country-dependent. The ARDL model has been used as a conventional model to analyse the relationship between the variables, as noted by the several advantages in the methodology section. One key advantage that was highlighted was that the ARDL model accommodated I(0) and I(1) variables, as well as a mixture of both I(0) and I(1) variables. This advantage was beneficial in the unit root testing due to the results being a mix of both I(0) and I(1) for each of the unit root tests, respectively. However, this model also had limitations, such that it doesn’t account for nonlinearity and asymmetric adjustment. In the more recent literature, the issue of asymmetric adjustment has become a novel contribution and has challenged the views of the conventional assumption that the relationship is linear in nature.

This study utilized the NARDL model for the purpose of accounting for the possibly asymmetric adjustment in the relationship. Therefore, by using both the ARDL and NARDL, it enabled a comparison to be drawn on the accuracy of the results. The ARDL model confirmed the existence of a long-run relationship, as well as that residential property is able to hedge against inflation. However, when the NARDL model was examined, it was confirmed that there was substantial evidence of asymmetry within the model. Hence, making use of the NARDL was beneficial for this analysis. The issue of structural breaks was also addressed, and it was confirmed that multiple structural breaks were present within the models. A description of the possible causes of the structural breaks was included in the structural break analysis. This included the transition phase from the apartheid era, as well as major global financial crises that occurred during the timeframe of this study. Furthermore, the CUSUM stability test was conducted in order to test the model's stability and confirmed that the models are stable.

By incorporating the house price segments, it allowed for a more in-depth analysis of the data. This allowed the average indicator, as well as the various segments to be tested in order to determine the existence of a long-run relationship. This enabled a conclusion to be drawn on the hedging abilities of each of the segments, respectively. These segments were tested using both the ARDL and NARDL models. The results from the ARDL model confirmed that all segments are able to hedge, as proven by the coefficients, each being greater than unity. This result is consistent with existing South African literature, as Taderera and Akinsomi (2020) confirmed that real estate is a suitable long-term inflationary hedge. Furthermore, Inglesi-Lotz and Gupta (2013) also conducted a similar analysis on the house price segments and found that housing prices have the ability to hedge against inflation. Anari and Kolari (2002) also studied the long-run relationship between housing prices and inflation. Although this is an international study, the results reflected Fisher coefficients that were positive and greater than unity. These results confirmed that housing prices are a suitable hedge against inflation. The two studies mentioned above utilized the conventional ARDL model to examine the relationship between the variables, which makes it an effective comparison for the first half of the analysis. However, the results differed substantially with the NARDL model, as there was substantial evidence of asymmetry. The main difference occurred with the affordable housing price segment, as the NARDL model concluded this segment to be a partial inflation hedge, as indicated by the coefficient being positive but lower than one. Both models confirmed that the middle house price segment provided the greatest inflation hedging benefits for positive changes in inflation, as in both cases, the coefficient for positive changes was the highest.

The key contribution of this study was seen by the significant difference in results when the NARDL model was examined. Although the NARDL model found the affordable housing segment to be a partial hedge, when negative changes in inflation were accounted for, this segment provided the greatest hedging benefits. This is an important deduction, as it informs investors that during periods of decreased inflation, investments into the affordable housing segment can prove to be extremely beneficial for wealth creation. There is limited existing literature with regards to the issues of nonlinearity and asymmetric adjustment in South Africa. However, authors such as Aqsha and Masih (2018) confirmed that by incorporating asymmetry, residential property is the ultimate inflationary hedge in Malaysia. This study also compared the ARDL model with the NARDL model and found significant evidence of asymmetric adjustment. This further highlights the importance of this model in terms of its contribution to recent literature, as opposed to the conventional ARDL model.

CHAPTER 5: CONCLUSION, EXTENSIONS, AND LIMITATIONS

5.1 Conclusion and summary of findings

The objective of this paper was to determine the magnitude of the relationship between residential property and inflation in South Africa. Inflation has been known to have a negative impact on the value of assets in real terms as it decreases the purchasing power of the asset over time. Hence, there was an incentive to determine whether there are assets that are able to act as an effective hedge against the loss in value that resulted from an increase in inflation. Property is considered to be one of the potential inflation-hedging assets, as its ability to act as an inflationary hedge has been revealed in previous literature. However, although there was limited existing literature on this topic on South African grounds, especially with regard to the issue of asymmetric adjustment, the international studies have had mixed results. The results from the existing literature may vary depending on the author's choice of countries, market conditions, timeframes, as well as the chosen variables to include in the model to perform the various tests (Hoesli *et al*., 2008).

The first chapter of this paper looked at the background behind the issue of inflation-hedging, specifically property investment's capacity to act as an inflationary hedge. As a result of the negative effects that inflation has on the purchasing power of the majority of economic agents, most agents attempt to protect their future wealth stream through investing in assets that yield a nominal return. The investment's return should be higher than the inflation rate (Demary and Voigtländer, 2009). This enables an investor to generate wealth from the initial investment. Furthermore, this will classify the asset as an inflation-hedging asset, as it is able to protect the investor from the effects of inflation (Fama and Schwert, 1977). This research paper set out to determine whether residential property is an effective hedge against inflation, and this was the primary research question. The ARDL model was constructed and examined to test the long-run relationship between inflation and housing prices. The results from this analysis confirmed the relationship and hedging ability of housing prices. The second research question examined the relationship in order to determine if the relationship showed evidence of asymmetric adjustment. By use of the NARDL model, it was confirmed that there is evidence of asymmetric adjustment, which highlighted the importance of this model as a recent contribution to econometric analysis.

Property as an inflationary hedge has been a topic of discussion by multiple authors, which was presented in the vast body of literature in the second chapter. The theory behind the research topic was explained in great detail dating back to Fisher's (1930) hypothesis. Although this theory laid the foundation for inflation-hedging, over the years, there has been multiple econometric techniques utilized to examine this relationship. The theoretical review looked at inflation and property as a whole and went on to further build on the theory behind each of the techniques that are used for inflation hedging purposes. The empirical review section presented actual studies that have utilized the various methodologies as ways of drawing conclusions on this research topic. This section was made up of a majority of international studies and some local studies, which have confirmed that property is an inflation-hedging asset. This was further broken down into linear models, which were the conventional techniques used to explain this relationship, and in more recent studies, asymmetric models. Although these studies have had positive results, it was also essential to incorporate studies that have found different conclusions based on similar studies. There has not been much literature that has proven that property cannot be used as a hedge against inflation. However, some international studies have proven this. This has, therefore, led to conflicting results within existing literature on the inflation-hedging ability of residential property.

Over the almost century that this topic has been examined, limitations have been identified in the existing literature, which have led to the development of models that have found ways to combat these limitations. This was what made the NARDL a novel contribution to this study, as it had taken into consideration the limitations of the conventional ARDL model. Chapter 3 discussed, in detail, the data and methodologies utilized for the purpose of this study. The data employed were quarterly data that ran from 1989 to 2019 for CPI and HPI, respectively. Furthermore, the house price indices were also employed for the affordable, middle, and luxury segments. This, therefore, split the cointegration analysis into two separate parts, one for the HPI and the other for the house price segments. Before testing for cointegration, a series of unit root tests were performed with the intention of analysing the stationarity of the mentioned variables. However, the unit root tests examined in this study do not take into consideration the possible structural breaks within the data. Structural breaks were able to capture changes in the relationship by integrating sudden and permanent changes in the model. Therefore, accounting for structural breaks in the unit root testing had proved to be a novel contribution.

Once it was confirmed that the variables were stationary, it was possible to then continue with testing for cointegration. This study's first objective was to conduct a two-variable (bivariate) ARDL model as a benchmark model for comparative purposes. The ARDL bounds test was utilized to investigate the long-run relationship between variables. When conducting the ARDL model, the optimal lag length had to be selected. This lag length selection process was an essential part of this process because it provided estimates that fed into the long-run cointegration test. The bounds test was based on the Wald test, which resulted in an F-statistic, which was compared to the asymptotic critical values, as confirmed by Pesaran *et al.* (2001). In order to confirm whether cointegration was present, the F-statistic had to exceed the upper critical bound. It can, therefore, be concluded that the variables are cointegrated, and there was a long-run relationship present between them. The methodology section of this paper detailed the various advantages of the ARDL model, and similarly, the limitations of this model. Although this model was confirmed to be a solid econometric model for the purpose of this analysis, a major drawback to using the ARDL model is that it can only be used to estimate a linear relationship. In order to capture the asymmetries within the variables, the conventional ARDL model was therefore expanded to incorporate nonlinearities (Khan *et al.,* 2019). This was the reason why applying the NARDL was necessary, as it was used to estimate the model while accounting for potential asymmetric adjustment.

The main contribution that the NARDL model has over the previous studies that have utilized the ARDL model was that it had the ability to split the linear model into positive and negative components. It was noted in the literature that previous studies maintained the assumption that long-run relationships may be represented as a symmetric and linear regression. However, the cointegrating relationship may also be conditioned to both asymmetry and nonlinearity (Shin *et al.*, 2014). These are some of the advantages, which are discussed in the methodology chapter that the NARDL model has over the standard ARDL model. The NARDL bounds test utilized both negative and positive partial sum decompositions, which were used to differentiate the possible asymmetric effects for the short run and long run. Therefore, in the context of this study, CPI was decomposed to determine whether the positive and negative changes are different and not symmetric. The final part of Chapter 3 detailed parameter stability. Stability testing is an important part of econometrics as they measure any type of disruption in a dataset, such as structural breakpoints, which could potentially have an effect on the results (Talas *et al*., 2013). The CUSUM test was utilized in this study as it detects any systematic movements through coefficients that potentially highlight a structural instability.

All the above models were examined, and the results were discussed in detail in Chapter 4. There were three unit root tests conducted with the intent of including any limitations of the tests. Although the ADF test confirmed some variables to be I(2), both the PP and KPSS test confirmed that the variables were a mixture of I(0) and I(1). This allowed the variables to be examined further for cointegration. Before testing for cointegration, the final pre-test was the Bai-Perron structural breaks test. Five structural breaks were illustrated for each of the tested variables, which was followed by a discussion on the possible reasons for the breakpoints. The dataset chosen was during a time that proves to be extremely relevant in the context of South African history, in that it covers a period of key political, social, and economic volatility. Events such as the ending of the Apartheid-era (which was from 1948-1994) as well as the transition period from the Apartheid-era to the post-Apartheid period are included in the data (Nittle, 2018). Another event that occurred during the timeframe specified is the 2007-2008 financial crisis. This was a global economic crisis that had an impact on a variety of macroeconomic factors (Singh, 2019). These are examples of events that have possibly led to structural breaks in the dataset.

The results of the ARDL bounds test confirmed the presence of cointegration. This inferred that there was a long-run relationship between inflation and housing prices, as suggested by both the HPI and the housing price segments. The next part of the ARDL analysis was examining the magnitude of the relationship by the use of the long-run elasticities or beta coefficients. In order to examine whether property is an effective hedge against inflation, the beta coefficient needed to be greater than unity. The results confirmed that when tested with HPI, as well as each of the housing segments, the long-run elasticities were all greater than one. Therefore, by using the ARDL model, results confirmed that that residential property is an effective hedge against inflation. However, as mentioned above, due to the limitations of the ARDL model, to keep up-to-date with recent methodology, this entire analysis was re-examined using the NARDL model.

The NARDL bounds test also confirmed the presence of cointegration between the variables. This concluded that there was a long-run relationship between inflation and housing prices for both the HPI and housing price segments. However, there was a difference in the way the magnitude of the relationship is examined with regard to the beta coefficients, as the standard linear regression between the variables produced a single inflation beta. Relaxing the linearity assumption inherent in most of the prior literature, the NARDL model allowed for the decomposition. Therefore, this model was found to have positive and negative components to the beta coefficient. In this way, both the positive and negative partial sum decompositions were accounted for. This is a critical difference between the NARDL model and a simple ARDL model. The positive coefficient needed to be greater than unity, and the negative coefficient represented a negative value, which would have to be greater than unity in absolute terms. The results confirmed that HPI, the middle, and the luxury housing segments were an effective hedge against inflation. The negative coefficients can be interpreted as in situations of decreasing inflation; the housing market returns increase. The negative coefficient value inferred an inverse relationship, which implied that inflation decreases are linked to increasing housing returns, which were of a greater magnitude than that of the positive inflationary adjustments. This conclusion implied that investors should invest in the property market when inflation exhibits negative inflationary adjustments.

It was noted that an asset may not be a perfect hedge and still be of value, such that in cases where the correlation between the variables were positive and lower than one. This was the case for the affordable housing prices in the NARDL model. Since the positive coefficient's value was positive but less than unity, it implied that increases in inflation will have a positive effect on the affordable housing prices of a magnitude that is less than one. Therefore, affordable housing prices were known as a partial inflation-hedge for positive changes. The negative coefficient was greater than one in absolute terms and was the highest coefficient. This coefficient essentially showed that for each negative percentage change in CPI, affordable housing prices will exhibit a positive change of 46.53%. This implied that a continuous decrease in inflation brings about an increase in housing prices in the long-run. Therefore, in periods of decreases in inflation, investors will benefit from investing in affordable housing.

The final part of the analysis looked at whether the different housing segments behave differently with regard to their inflation-hedging properties. The ARDL model confirmed each segment as effective inflation hedges. Similarly, the NARDL model confirmed the segments as effective, with only affordable housing being a partial hedge. However, for both the ARDL and NARDL models, the middle housing segment was the most sensitive, as in both cases, the long-run elasticities (positive betas) were the largest. For ARDL, the long-run elasticity was 1.82, and for NARDL, it was 1.47. Therefore, although it was confirmed that residential property was an effective hedge against inflation when considering the segments, both models found that the middle housing segment provided the greatest inflation hedging benefits. It can be concluded that a continuous increase in inflation brings about an increase in housing prices in the long-run. Therefore, in periods of increasing inflation, investors would benefit from investing in the middle housing segment. This was consistent with the results of existing South African literature, as the article by Inglesi-Lotz and Gupta (2013) stated that the middle housing segment was the most attractive with regard to hedging, as relatively richer investors would benefit from investing in these properties for renting purposes. This housing segment would, therefore, also provide investment opportunities for middle-income earners, as they would be able to afford investing in these properties. In this way, the middle housing segment represented an attractive investment option for both the middle-income earners, as well as the richer investors. In this way, the middle segment targets a majority of different investors, compared to the affordable and luxury segments, which target the low and high income earners respectively. Furthermore, during economic shocks, as is the current case with Covid-19, individuals have been forced to downscale from luxury housing, putting increased demand pressure on this middle segment. At the same time, with low interest rates, there has been upward pressure from low-medium income earners aiming to take advantage of the "buyer's market".

It is evident that running the NARDL model with the ARDL model was largely beneficial due to the differences in the results. Although both models confirmed that property was able to act as an inflationary hedge, by considering nonlinearity, the results varied significantly. It was noted that the ARDL model assumed that housing prices will behave the same in periods of increased and decreased inflation. It was confirmed by the results of this study that positive variations in inflation would lead to increased investment in property in order to maintain the investment's real value. This was based on a form of the Fisher (1930) equation, which confirmed the unitary relationship between housing prices and inflation. The implication was that any negative changes in inflation would lead to a decrease in housing prices, at the same magnitude as the positive changes in inflation. This symmetry assumption has been challenged by the NARDL model, and the results confirmed that the relationship between the variables were not symmetrical. When the NARDL model was re-examined for each segment, it was apparent that the positive and negative partial sum decompositions varied considerably. Although the results were positive for the positive changes in inflation, the negative changes in inflation had a far greater positive effect on housing prices.

As seen in the literature, in the context of South African studies, the magnitude of the beta coefficient does not contradict these studies. It was noted in both local and international studies that historically, property has acted as an effective hedge against inflation. This study considered asymmetric adjustment, which allowed the positive and negative coefficients to be individually quantified. By doing this, it enables the investor to adjust the investment portfolio accordingly, based on the expectations of both positive and negative changes in inflation. This was more beneficial than the investor being under the assumption that the adjustment coefficient remained constant for both situations. This contribution was the most important section of this research paper, as by decomposing the long-run coefficient into positive and negative components, it became evident that these two adjustment coefficients differed significantly.

The findings of this study contrast the assumption that the positive and negative adjustments are equal. Therefore, it can be a novel contribution for future studies to account for the possibility of nonlinearity. The issue with relying on a single adjustment coefficient for both positive and negative changes is that it implies a degree of constancy. This assumption can be limiting due to exogenous shocks, such as financial crises, that may imply that a single long-run coefficient does not allocate the degree necessary for the long-term expression. By splitting the coefficients for positive and negative changes, it was confirmed that investing in property to hedge against positive inflationary changes is effective. However, it is even more pertinent to make these property investments when the inflation rate is expected to decrease, as there is a greater profitable opportunity from the expected increases in housing prices. It was identified that the results of the cointegration test that considered a single adjustment coefficient was misleading through the comparison of the linear ARDL model and the NARDL model. Therefore, the results were more accurate and reliable using the NARDL model, and it was proven to be a novel contribution to this study.

5.2 Extensions and contributions of this study

The extensions of this study highlighted the key contributions that this study contains. This essentially detailed the reasons why this study adds value to existing literature. There were four major extensions in this study, namely structural breaks, data, methodology, and literature. These key takeaways were discussed further below. This analysis was extended to allow for the most accurate results to be presented in order for investors to make the best decisions regarding their investment portfolios.

There has been a number of structural changes in South Africa over this study's sample period of 30 years. Testing for the presence of structural breaks has become a significant matter in econometrics due to the numerous political and economic impacts that can cause a change in the inflation and housing price variables over time. By accounting for these structural breaks in the unit root testing, it provided an extension for this study. Furthermore, the Bai and Perron (1998) structural breaks test accounts for multiple structural breaks within the series. This is the reason why this structural break test was utilized for the purpose of this study, as it has the ability to test for more than a single structural break. The transition period from the apartheid era to the post-apartheid era were times of significant structural changes in South Africa. Further examples include the Asian financial crisis, as well as the 2007/2008 financial crisis. These changes have a significant impact on the macroeconomic conditions within South Africa. This, therefore, had an effect on the relationship between inflation and housing prices. This was relevant because although the long-run relationship was examined, if this relationship was analysed for a specific short-run period, the magnitudes were likely to differ.

This research paper initially examined the relationship between inflation and housing prices by using two focus variables, namely CPI and HPI. The HPI represented the South African housing market as a whole. As an extension of this data, the South African housing market was further divided into different segments. This included the affordable, middle, and luxury housing segments. This enabled a more accurate conclusion to be drawn as the ability of residential property to act as a hedge against inflation was examined as an average and as segmented values. Therefore, this enables an investor to determine exactly which property investments provided the best inflation-hedging benefits.

This study initially utilized the Autoregressive Distributive Lag (ARDL) model to determine whether a long-run relationship existed between inflation and housing prices. However, this estimation technique assumed a symmetric and linear relationship between the variables within the model. In order to account for these limitations, this study extended this model and also examined the relationship by using the Nonlinear Autoregressive Distributive Lag (NARDL) model. This model allowed for the examination of both asymmetry and nonlinearity. The NARDL model decomposed the exogenous variable, CPI, into its positive and negative partial sums. A further extension of this model was that it made accommodation for both the potential short- and long-run asymmetries. Therefore, by examining the relationship between inflation and housing prices with the ARDL model, it allowed a comparison to be drawn between these results and the results of the NARDL model.

It was noted in the literature review chapter of this paper that inflation-hedging has been an issue that has been discussed by multiple authors since it was first proposed by the Fisher (1930) hypothesis. Furthermore, there was extensive literature on all asset classes with regard to their inflation-hedging abilities, which included residential property. However, the majority of existing literature on this topic has been done on international grounds, and there is a limited amount of existing literature within South African studies. Although there has been literature on this topic in South Africa, these studies have assumed a symmetrical setting and considers the relationship between the variables to be linear. Internationally, this is evident in the studies that have utilized the ARDL model, such as by as Anari and Kolari (2002) and Lee (2012). These studies are limiting and may be subject to inconsistent estimation due to the assumption of symmetry. Therefore, due to the issues of asymmetry and nonlinearity being new to econometric analysis, there has not been many studies that have explored these extensions. This study took the above into consideration and provided a gap for research on South African grounds, making it a novel contribution to literature. This article was, therefore, up-to-date and an in-depth analysis of the relationship between inflation and housing prices in South Africa while accounting for potential asymmetry and nonlinearity.

5.3 Limitations of this study and areas for future research

The limitations section of this paper highlights the possible opportunities for further research as well as any limiting data factors. There are four limitations of this study, namely, inflation, variables, model limitations and geographic focus. These are all possible ways in which this study could include further avenues for research in a way that will add value to the topic. These limitations are discussed further below. Firstly, the policy recommendations for investors and policy-makers are also discussed.

The outcome of this study provides beneficial implications to both policy-makers and property investor who deal with the South African property markets. This study concluded that residential property was able to act as an effective hedge against inflation in the long-run. The findings of this study imply that the South African property market is an attractive investment option, as investors would realize a greater rate of return on their investments in comparison to the rate of inflation. Investors are, therefore, able to profit from making property investments and should pay careful attention to the property markets during periods of decreased inflation. This essentially implies that investors would be able to hedge fully against inflation by investing in the property markets. Furthermore, investors would realize an even greater nominal return than the increases in the price level. This implies that in the long-run, investors that invest in the South African property markets during inflationary periods are able to increase their real wealth level. A rise in house prices can prove to be beneficial for homeowners, although it can make it more difficult for first time buyers to purchase. The capital appreciation that occurs with property investment is also a contributing factor to property being an attractive investment opportunity.

This analysis made use of the currently published CPI values as a proxy for the inflation rate in South Africa. However, this could be further extended if values such as the expected rate of inflation were incorporated into the analysis. This would enable more robust results with regard to the inflation-hedging effectiveness of residential property. This study used the focus variables to conduct a bivariate analysis on the relationship between inflation and housing prices. This allowed for the focus to be on the main variables in the study and allowed a conclusion to be drawn on them. However, further macroeconomic variables can be incorporated for control purposes, such as the interest rate, GDP, and the exchange rate. Furthermore, this study focused on residential property as a hedge against inflation. Due to there being alternative inflation-hedges, the focus on housing prices is a limitation. A further extension could be examining how housing prices perform against the other forms of inflation-hedges, such as equities and minerals. The inflation-hedging ability of alternative asset classes can be examined in an asymmetric setting to identify which asset classes are most responsive to changes in inflation.

By utilizing both the ARDL and NARDL model, this study has allowed for the limitations of the ARDL model to be accounted for. However, there are other models that are able to account for asymmetric adjustment, which represents a limitation, as this study has only utilized the NARDL for this purpose. Other models, such as the Nonlinear Vector Error Correction model have been mentioned in the studies that account for asymmetric adjustment subsection of the literature review. These are models that are also able to provide insight on the relationship between the variables. Furthermore, this study did not account for the switching behaviour in the estimation after establishing the structural breaks. Therefore, switching to a model that is able to account for structural breaks, or a cointegration technique, such as the Gregory-Hansen model, would allow for the most significant structural break in the relationship to be presented. This represented an area for further research, and is a possible extension to the study.

This study is based on South African data and examined the inflation-hedging ability of residential property within South Africa. The results of this study were time and country specific and may differ between countries. This analysis could be further extended to incorporate different countries and assess the inflation-hedging abilities. This would enable comparisons to be drawn to determine which country's property investments would be the most effective inflationary hedges. By applying the NARDL to different countries, it would take into consideration the determination of asymmetric adjustment effects on an international level. Furthermore, it would also account for greater insight into the housing markets in certain countries and how these markets are affected by changes in inflation. This may have significant implications with regard to the international component in an investment portfolio for hedging in situations of global financial crises.

5.4 Chapter summary and conclusion

Chapter 5 of this study concluded and summarized this body of research. This study aimed to investigate the nature of the relationship between property and inflation in South Africa, to examine whether property is an effective hedge against inflation. This was the primary research question, which was extended to reflect nonlinearity and asymmetric adjustment. The key motivation for this research paper was drawn from the conflicting results in previous literature, as well as the ever-changing econometric techniques, which allowed for this to be an up-to-date and in-depth analysis of the topic. This study is important in the context of South Africa, as there have not been many recent studies that incorporate nonlinearity within this topic.

The issues of nonlinearity and asymmetric adjustment are relatively new and provided a gap for a study of this nature to be conducted. South Africa has undergone many changes within the timeframe of this study, such as the transition period from the apartheid regime and major financial crises, which have had an impact on macroeconomic variables such as inflation. These structural changes were accounted for by testing for structural breaks for each variable independently, which is a further contribution of this study. In order to test for the long-run relationship between the variables, the conventional ARDL model was utilized for comparative purposes, as well as the more up-to-date NARDL model. The conclusion drawn from this analysis was that the linearity assumption was flawed, as it was seen that the relationship exhibited evidence of asymmetric adjustment.

Since the relationship was confirmed to be significantly affected by asymmetric adjustment, it was an important point of consideration for future research in order to capture the relationship more accurately. It was accounting for asymmetric adjustment in the analysis of this relationship that allowed for a more accurate assessment of the nature and magnitude of this relationship. This allowed for a more efficient determination of how property is employed as a hedge against inflation. It was concluded that even by incorporating asymmetric adjustment, property maintained the capacity to act as an effective hedge against inflation in South Africa.

REFERENCE LIST

Abellera, J.M. (2019). Five Advantages to Investing In Residential Real Estate. [Online]. Available: https://www.withum.com/resources/five-advantages-to-investing-in-residential-real-estate/ Accessed: 20 August 2020.

Ahmad, M., Khan, Z., Ur Rahman, Z. and Khan, S. (2018). Does financial development asymmetrically affect CO2 emissions in China? An application of the nonlinear autoregressive distributed lag (NARDL) model. *Carbon Management*, *9*(6), pp.631-644.

Ahmad, S. (2010). The long-run Fisher effect in developing economies. *Studies in Economics and Finance*, 27(4), pp. 268-275.

Akaike, H. (1974). A new look at the statistical model identification. *IEEE Transactions on Automatic Control*, 19(6), pp. 716-723.

Akinboade, O.A., Siebrits, F.K. and Niedermei, E.W. (2004). The determinants of inflation in South Africa: An econometric analysis. *Research Papers* 143, Department of Economics, University of South Africa, revised September 2004.

Akmal, M.S. (2007). Stock returns and inflation: An ARDL econometric investigation utilizing Pakistani data. *Pakistan economic and social review*, pp.89-105.

Alagidede, P. and Panagiotidis, T. (2010). Can common stocks provide a hedge against inflation? Evidence from African countries. *Review of financial economics*, *19*(3), pp.91-100.

Alimi, S.R. (2014). ARDL bounds testing approach to Cointegration: A re-examination of augmented fisher hypothesis in an open economy. *Asian Journal of Economic Modelling*, *2*(2), pp.103-114.

Alimi, S.R. and Ofonyelu, C.C. (2013). Toda-Yamamoto causality test between money market interest rate and expected inflation: the Fisher hypothesis revisited. *European Scientific Journal*, 9(7).

Amadeo, K. (2020). Real Estate, What It Is and How It Works. [Online]. Available: https://www.thebalance.com/real-estate-what-it-is-and-how-it-works-3305882 Accessed: 20 August 2020.

Anari, A. and Kolari, J. (2002). House prices and inflation. *Real Estate Economics*, 30(1), pp. 67-84.

Antoshin, S., Berg, A. and Souto, M. (2008). *Testing for structural breaks in small samples* (No. 8-75). International Monetary Fund.

Aqsha, N.S. and Masih, M. (2018). Is residential property the ultimate hedge against inflation? New evidence from Malaysia based on ARDL and nonlinear ARDL. [Online]. Available: https://mpra.ub.uni-muenchen.de/91508/ Accessed: 2 March 2020.

Arnold, B. (2016). How to prepare your portfolio for inflation. [Online]. Available: https://www.schroders.com/en/ch/wealth-management/insights/markte/how-to-prepare-your-portfolio-for-inflation/z Accessed: 8 August 2020.

Arnold, S. and Auer, B.R. (2015). What do scientists know about inflation hedging? *The North American Journal of Economics and Finance*, *34*, pp. 187-214.

Aron, J. and Muellbauer, J. (2007). Transparency, Credibility and Predictability of Monetary Policy under Inflation Targeting in South Africa.

Azadeh, A., Sheikhalishahi, M. and Boostani, A. (2014). A Flexible Neuro-Fuzzy Approach for Improvement of Seasonal Housing Price Estimation in Uncertain and Non-Linear Environments. *South African Journal of Economics*, *82*(4), pp.567-582.

Azmi, A.S.M., Hwa, T.K., Nawawi, A.H., Othman, A., Kaspin, M., Isa, M., Ariffin, S.M. and Hassan, H. (2010). INFLATION HEDGING CHARACTERISTICS OF MALAYSIAN RESIDENTIAL PROPERTIES. [Online]. Available: https://www.researchgate.net/profile/Ahmad_shazrin_Mohamed_azmi/publication/281277772_Inflation_Hedging_Characteristics_of_Malaysian_Residential_Properties/links/55dea77c08ae7983897d190d/Inflation-Hedging-Characteristics-of-Malaysian-Residential-Properties.pdf Accessed: 22 August 2020.

Bai, J. and Perron, P. (1998). Estimating and Testing Liner Models with Multiple Structural Changes. *Econometrica,* (66), pp. 47-78.

Balcilar, M., Beyene, A., Gupta, R., and Seleteng, M. (2013). Ripple Effects in South African House Prices. *Urban studies,* 50(5), pp. 876-894.

Balcilar, M., Gupta, R. and Miller, S.M. (2015). The out-of-sample forecasting performance of nonlinear models of regional housing prices in the US. *Applied Economics*, *47*(22), pp.2259-2277.

Bampinas, G. and Panagiotidis, T. (2015). Are gold and silver a hedge against inflation? A two century perspective. *International Review of Financial Analysis*, *41*, pp.267-276.

Barber, C., Robertson, D. and Scott, A. (1997). Property and inflation: The hedging characteristics of UK commercial property, 1967–1994. *The Journal of Real Estate Finance and Economics*, *15*(1), pp.59-76.

Barsky, R.B. (1987). The Fisher hypothesis and the forecastability and persistence of inflation. *Journal of monetary Economics*, 19(1), pp. 3-24.

Bekaert, G. and Wang, X. (2010). Inflation risk and the inflation risk premium. *Economic Policy*, *25*(64), pp.755-806.

Berlin, E. (2020). 5 Reasons to Invest in an Income Property. [Online]. Available: https://www.thebalancesmb.com/investing-in-income-property-2124810 Accessed: 20 August 2020.

Berument, H. and Jelassi, M.M. (2002). The Fisher hypothesis: a multi-country analysis. *Applied Economics*, 34(13), pp. 1645-1655.

Bahmani-Oskooee, M. and Ghodsi, S.H. (2016). Do changes in the fundamentals have symmetric or asymmetric effects on house prices? Evidence from 52 states of the United States of America. *Applied Economics*, *48*(31), pp.2912-2936.

Bishop, A. (2018). Inflation targeting in South Africa. [Online]. Available: https://www.investec.com/en_za/focus/economy/inflation-targeting-in-south-africa.html Accessed: 1 April 2020.

Bouri, E., Gupta, R., Lahiani, A. and Shahbaz, M. (2018). Testing for asymmetric nonlinear short-and long-run relationships between bitcoin, aggregate commodity and gold prices. *Resources Policy*, *57*, pp.224-235.

Brooks, C. (2014*). Modelling long-run relationships in finance.* 3rd ed. Cambridge: Cambridge University Press.

Brown, R.L., Durbin, J. and Evans, J. (1975). Techniques for testing the constancy of regression relationship over time. *Journal of Royal Statistical Society*, 2(37), pp. 149-163.

Burger, P. and Van Rensburg, L.J. (2008). Metropolitan house prices in South Africa: Do they converge? *South African Journal of Economics*, *76*(2), pp.291-297.

Canarella, G. and Miller, S.M. (2016). Inflation persistence and structural breaks. *Journal of Economic Studies*, 43(6), pp. 980-1005.

Cavanaugh, J.E. and Neath, A.A. (1999). Generalizing the derivation of the Schwarz information criterion. *Communications in Statistics-Theory and Methods*, *28*(1), pp.49-66.

Chang, H., Huang, K. and Wu, C., (2006). Determination of sample size in using central limit theorem for weibull distribution. *International journal of information and management sciences*, *17*(3), pp.31-46.

Cheah, S.P., Yiew, T.H. and Ng, C.F. (2017). A nonlinear ARDL analysis on the relation between stock price and exchange rate in Malaysia. *Economics Bulletin*, *37*(1), pp.336-346.

Chen, J. (2019). Inflation. [Online] Available: https://www.investopedia.com/terms/i/inflation.asp Accessed: 4 February 2020.

Chen, M.C. and Foo, T. (2006). Common structural time series components in inflation and residential property prices. *Journal of Real Estate Portfolio Management*, *12*(1), pp.23-36.

Chikri, H., Moghar, A., Kassou, M., Hamza, F., Essaâdi-Morocco, A. and Bourekkadi, S. (2020). The Asymmetric Influence of COVID-19 on Financial Market: Evidence From NARDL Model. *Science*.

Chow, G.C. (1960). Tests of equality between sets of coefficients in two linear regressions. *Econometrica: Journal of the Econometric Society*, pp.591-605.

Christou, C., Gupta, R., Nyakabawo, W. and Wohar, M.E. (2018). Do house prices hedge inflation in the US? A quantile cointegration approach. *International Review of Economics & Finance*, *54*, pp.15-26.

Çıtak, F., Uslu, H., Batmaz, O. and Hoş, S. (2020). Do renewable energy and natural gas consumption mitigate CO 2 emissions in the USA? New insights from NARDL approach. *Environmental Science and Pollution Research*, pp.1-12.

Cohen, J. (2016). A Study on the History and Functionality of Real Estate Crowdfunding. [Online]. Available: https://repository.upenn.edu/joseph_wharton_scholars/19/ Accessed: 20 August 2020.

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

Corsetti, G., Pesenti, P. and Roubini, N. (1999). What caused the Asian currency and financial crisis?.*Japan and the world economy*, *11*(3), pp.305-373.

Cussen, M.P. (2019). The Top 5 Ways to Hedge against Inflation. [Online]. Available: https://www.investopedia.com/articles/investing/060916/top-5-ways-hedge-against-inflation.asp Accessed: 29 March 2020.

Dabara, D.I. (2015). The inflation-hedging performance and risk-return characteristics of residential property investments in Gombe, Nigeria. *Advances in Research*, *3*(1), pp.71-83.

Das, S., Gupta, R., & Kanda, P.T. (2011). Bubbles in South African House Prices and their impact on consumption. *Journal of Real Estate Literature*, 19(1), pp. 71-92.

Del Barrio Castro, T., Rodrigues, P.M.M. & Taylor, A.M.R. (2015). On the behaviour of Phillips-Perron tests in the presence of persistent cycles. Oxford Bulletin of Economics and Statistics, 77(4), pp. 495-511.

Demary, M. and Voigtländer, M. (2009). The inflation hedging properties of real estate: A comparison between direct investments and equity returns. In *ERES Conference 2009*.

Dornbusch, R. (1976). Expectations and exchange rate Dynamics. *The Journal of Political Economy*, 84(6), pp. 1161-1176.

Dufour, J.M. (1982). Generalized Chow tests for structural change: A coordinate-free approach. *International Economic Review*, pp.565-575.

Eichholtz, P. M. A., Hoesli, M., McGregor, B. D. and Nanthakumaran, N. (1995). Real Estate Portfolio Diversification by Property Type and Region. *Journal of Property Finance*, 6(3), pp. 39– 59.

Eita, J.H. (2012). Inflation and stock market returns in South Africa. *International Business & Economics Research Journal (IBER), 11*(6), pp.677-686.

Ely, D.P. and Robinson, K.J. (1997). Are stocks a hedge against inflation? International evidence using a long-run approach. *Journal of International Money and Finance*, *16*(1), pp.141-167.

Emerson, J., (2007). Cointegration analysis and the choice of lag length. *Applied Economics Letters*, *14*(12), pp.881-885.

Fama, E.F. (1975). Short-term interest rates as predictors of inflation. *The American Economic Review*, pp.269-282.

Fama, E.F. and Schwert, G.W. (1977). Asset returns and inflation. *Journal of financial economics*, *5*(2), pp.115-146.

Fang, W.S., Wang, K.M. and Nguyen, T.B.T. (2008). Is real estate really an inflation hedge? Evidence from Taiwan. *Asian Economic Journal*, *22*(2), pp.209-224.

Frey, G. and Manera, M. (2007). Econometric models of asymmetric price transmission. *Journal of Economic surveys*, *21*(2), pp.349-415.

Ganti, A. (2019). Contagion. [Online]. Available: https://www.investopedia.com/terms/c/contagion.asp Accessed: 23 February 2020.

Garg, A. (2016). Statistical Methods for Estimating House Price Index. *Journal of Business & Financial Affairs*, *5*(231), pp. 2167-2234.

Gil-Alana, L., Aye, G. and Gupta, R. (2012).Testing for Persistence with Breaks and Outliers in South African House Prices. *Journal of Real Estate Literature*, 21(2), pp. 293-314.

Ghazali, M.F., Lean, H.H. and Bahari, Z. (2015). Is gold a good hedge against inflation? Empirical evidence in Malaysia. *Kajian Malaysia*, *33*(1), pp.69-84.

Glen, S. (2016). KPSS Test: Definition and Interpretation. [Online]. Available: https://www.statisticshowto.com/kpss-test/ Accessed: 1 September 2020.

Glynn, J., Perera, N. and Verma, R., 2007. Unit root tests and structural breaks: A survey with applications. [Online]. Available: https://ro.uow.edu.au/commpapers/455/ Accessed: 21 September 2020.

Goetzmann, W.N. and Volaitis, E. (2006). Simulating Real Estate in the Investment Portfolio: Model Uncertainty and Inflation Hedging, Yale International Center for Finance Working Paper, No. 06–04, pp.1–39.

Goodhart, C. and Hofmann, B. (2008). House prices, money, credit, and the macroeconomy. *Oxford Review of Economic Policy*, *24*(1), pp.180-205.

Graff, R.A. and Cashdan Jr, D.M. (1990). Some new ideas in real estate finance. *Journal of Applied Corporate Finance*, *3*(1), pp.77-89.

Granger, C.W.J. (1988). Causality, cointegration and control. Journal of Economic Dynamics and Control, 12(2-3), pp. 551-559.

Granger, C.W.J. and Yoon, G. (2002). Hidden cointegration. *U of California, Economics Working Paper*, (2002-02).

Gregory, A.W. and Hansen, B.E. (1996). Residual-based tests for cointegration in models with regime shifts. *Journal of econometrics*, *70*(1), pp.99-126.

Gresham, T. (2017). Three Strengths of the Consumer Price Index & Three Weaknesses of the Consumer Price Index. [Online]. Available: https://pocketsense.com/three-strengths-consumer-price-index-three-weaknesses-consumer-price-index-1108.html Accessed: 28 August 2020.

Gujarati, D.N. and Porter, D.C. (2009). *Causality in economics: The Granger causality test*, 5th Ed. New York, NY: McGraw-Hill.

Gunasekarage, A., Power, D.M. and Zhou, T.T. (2008). The long-term inflation hedging effectiveness of real estate and financial assets. *Studies in Economics and Finance*, 25(4), pp. 267-278.

Gupta, R. and Hartley, F. (2013). The Role of Asset Prices in Forecasting Inflation and Output in South Africa. *Journal of Emerging Market Finance,* 12(3), pp. 239-291.

Habanabakize, T. and Muzindutsi, P. (2017). Analysis of Government Expenditure and Sectoral Employment in the Post-apartheid South Africa: Application of ARDL Model. *Journal of Economics and Behavioral Studies*, 9(2), pp. 224-233.

Hamel, G. (2018). Drawbacks of Using CPI As a Measure of the Rate of Inflation. [Online]. Available: https://pocketsense.com/drawbacks-using-cpi-measure-rate-inflation-8512.html Accessed: 28 August 2020.

Hamelink, F. and Hoesli, M. (1996). Swiss real estate as a hedge against inflation. *Journal of Property Finance*, 7(1), pp. 33-49.

Hamilton, J.D. (1989). A new approach to the economic analysis of nonstationary time series and the business cycle. *Econometrica: Journal of the econometric society*, pp.357-384.

Hamzah, N.H. and Masih, M. (2018). Revisiting effectiveness of interest rate as a tool to control inflation: evidence from Malaysia based on ARDL and NARDL. [Online]. Available: https://mpra.ub.uni-muenchen.de/87576/1/MPRA_paper_87576.pdf Accessed: 21 September 2020.

Hannan, E. J., and Quinn, B. G. (1979). The determination of the order of an autoregression. Journal of the Royal Statistical Society. Series B (Methodological), pp. 190-195.

Hatemi-J, A. and Hacker, S. (2009). Can the LR test be helpful in choosing the optimal lag order in the VAR model when information criteria suggest different lag orders? *Applied Economics*, *41*(9), pp.1121-1125.

Hoesli, M., Lizieri, C. and MacGregor, B. (2008). The inflation hedging characteristics of US and UK investments: A multi-factor error correction approach. *Journal of Real Estate Finance and Economics,* 36(2), pp. 183–206.

Howells, P. and Bain, K. (2008). The Economics of Money, Banking and Finance. Prentice-Hall, Harlow England.

Ibrahim, I., Sundarasen, S.D.D. and Shayuti, A.F.H.A. (2009). Property Investment and Inflation Hedging in Residential Property: The Case of District of Gombak, Selangor D. E. *IUP Journal of Applied Finance*, *15*(2), pp. 38-54.

Ibrahim, M.H. (2015). Oil and food prices in Malaysia: a nonlinear ARDL analysis. *Agricultural and Food Economics*, *3*(1), pp.1-14.

Im, K.S., Pesaran, M.H. and Shin, Y. (2003). Testing for unit roots in heterogeneous panels. *Journal of econometrics*, *115*(1), pp.53-74.

Inglesi-lotz, R and Gupta, R. (2013). The long-run relationship between house prices and inflation in South Africa: An ARDL approach. *International Journal of Strategic Property Management*, 17(2), pp. 188-198.

Jan, O. (2020). Costs of expected and unexpected inflation. [Online]. Available: https://alphabetaprep.com/cfa-level-1/economics/costs-of-expected-and-unexpected-inflation Accessed: 5 November 2020.

Jonsson, M.G. (1999). The relative merits and implications of inflation targeting for South Africa. *International Monetary Fund*, pp. 99-116.

Kantor, L.G. (1983). Inflation uncertainty and inflation hedging. *Federal Reserve Bank of Kansas City Economic Review*, 3, pp.23-37.

Karamelikli, H. (2016). Linear and nonlinear dynamics of housing price in Turkey. *Ekonomia. Rynek, Gospodarka, Społeczeństwo*, (46), pp.81-98.

Katrakilidis, C. and Trachanas, E. (2012). What drives housing price dynamics in Greece: New evidence from asymmetric ARDL cointegration. *Economic Modelling*, 29(4), pp. 1064-1069.

Katsur, T. and Spierdijk, L. (2010). Stock Returns and Inflation Risk: implications for portfolio selection. *University of Groningen* Working Paper.

Khan, Z., Sisi, Z. and Siqun, Y. (2019). Environmental regulations an option: Asymmetry effect of environmental regulations on carbon emissions using non-linear ARDL. *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects*, *41*(2), pp.137-155.

Kolisi, N. and Phiri, A. (2017). Changes in the relationship between interest rates and housing prices in South Africa around the 2007 financial crisis. *Working Papers 1704*, Department of Economics, Nelson Mandela University, revised Jul 2017.

Kim, J.H. and Ryoo, H.H. (2011). Common stocks as a hedge against inflation: Evidence from century-long US data. *Economics Letters*, 113(2), pp. 168-171.

Kuan-Min, W., Yuan-Ming, L. and Binh, N.T.T. (2008). Asymmetric inflation hedge of housing return: A non-linear vector error correction approach. *International Real Estate Review*, *11*(1), pp. 65-82.

Kumpis, A. (2019). What is inflation & what causes it? [Ultimate Guide]. [Online]. Available: https://www.realwealthnetwork.com/learn/what-is-inflation-what-causes-it/ Accessed: 7 August 2020.

Labonte, M. (2011). Inflation: Causes, Costs and Current Status. [Online]. Available: https://pdfs.semanticscholar.org/48ac/7bf4dd4a6c9bce7c05722506274307bba096.pdf Accessed: 20 August 2020.

Latheef, U.A. and Masih, M. (2017). Asymmetrical effects of macro variables on commercial bank deposits: evidence from Maldives based on NARDL. [Online]. Available: https://mpra.ub.uni-muenchen.de/86361/ Accessed: 3 October 2020.

Le Long, H., De Ceuster, M.J., Annaert, J. and Amonhaemanon, D. (2013). Gold as a hedge against inflation: the Vietnamese case. *Procedia Economics and Finance*, *5*, pp.502-511.

Lee, K.N.H. (2012). Inflation and residential property markets: A bounds testing approach. *International Journal of Trade, Economics and Finance*, *3*(3), pp. 183-186.

Leshoro, TL. (2012). Estimating the inflation threshold for South *Africa. Journal for Studies in Economics and Econometrics*, 36(20), pp. 53-65.

Leung, A. (2010). Commercial property as an inflation hedge: an Australian perspective. *Pacific Rim Property Research Journal*, *16*(1), pp.97-115.

Li, L.H. and Ge, C.L., 2008. Inflation and housing market in Shanghai. *Property Management*, 26(4), pp. 273-288.

Liberto, D. (2019). What Is The House Price Index (HPI)? [Online]. Available: https://www.investopedia.com/terms/h/house-price-index-hpi.asp Accessed: 25 February 2020.

Liew, V.K.S. (2004). Which lag length selection criteria should we employ? *Economics bulletin*, *3*(33), pp.1-9.

Lin, J.B., Liang, C.C. and Tsai, W. (2019). Nonlinear Relationships between Oil Prices and Implied Volatilities: Providing More Valuable Information. *Sustainability*, *11*(14), pp. 3906-3921.

Luüs, C., (2005). The Absa residential property market database for South Africa-key data trends and implications. *BIS Paper*, *21*, pp.149-170.

Ma, L. and Liu, C. (2008), January. Estimating impacts of consumer prices on house prices. In *ACE 2008: Proceedings of the 37th Australian Conference of Economists* (pp. 1-16). Economic Society of Australia.

Mahadeva, L. and Robinson, P. (2004). *Unit root testing to help model building*. London: Centre for Central Banking Studies, Bank of England.

Maitra, S. (2019). Time-series Analysis with VAR & VECM: Statistical approach. [Online]. Available: https://towardsdatascience.com/vector-autoregressions-vector-error-correction-multivariate-model-a69daf6ab618 Accessed: 11 August 2020.

Marzuki, J. (2018). Analysis of the Performance and Diversification Benefits of the South Africa Commercial Real Estate Market. *Journal of Real Estate Literature*, *26*(2), pp.291-311.

Masih, M. (2018). Is the relationship between financial development and income inequality symmetric or asymmetric? New evidence from South Africa based on NARDL. [Online]. Available: https://mpra.ub.uni-muenchen.de/87574/ Accessed: 21 September 2020.

Mazorodze, B.T. and Siddiq, N. (2018). On the unemployment output relation in South Africa: a non-linear ARDL approach. *Journal of Economics and Behavioral Studies*, *10*(5 (J)), pp.167-178.

McMahon, T. (2019). How does inflation affect foreign exchange rates? [Online]. Available: https://inflationdata.com/articles/2019/03/14/inflation-affect-foreign-exchange-rates/ Accessed: 10 February 2020.

Mitchell-Innes, H.A. (2006). *The relationship between interest rates and inflation in South Africa: Revisiting Fisher's hypothesis* (Doctoral dissertation, Rhodes University).

Moffatt, M (2019). What Is the Augmented Dickey-Fuller Test? [Online]. Available: https://www.thoughtco.com/the-augmented-dickey-fuller-test-1145985 Accessed: 30 August 2020.

Moores-Pitt, P. and Strydom, B.S. (2017). Equities as a hedge against inflation in South Africa. *African Review of Economics and Finance*, *9*(1), pp.156-179.

Munyeka, W. (2014). The relationship between economic growth and inflation in the South African economy. *Mediterranean Journal of Social Sciences*, 5(15), pp.2039-2117.

Ngwane, T. (2014). Understand the impact of inflation. [Online]. Available: https://www.allangray.co.za/latest-insights/personal-investing/understand-the-impact-of-inflation/ Accessed: 9 August 2020.

Nittle, N.K. (2018). A Brief History of South African Apartheid. [Online]. Available: https://www.thoughtco.com/brief-history-of-south-african-apartheid-2834606 Accessed: 23 February 2020.

Nkoro, E. and Uko, A.K. (2016). Autoregressive Distributed Lag (ARDL) cointegration technique: application and interpretation. *Journal of Statistical and Econometric Methods*, *5*(4), pp.63-91.

Okereke, R.A. (2019). Property investment: A hedge against inflation. *Journal of Science, Engineering and Technology*. 6(2), pp. 118-132.

Olaleye, A. (2011). The effects of adding real estate into mixed-asset portfolios in South Africa. *Journal of Financial Management of Property and Construction*, 16(3), pp. 272-282.

Ozcicek, O. and Douglas Mcmillin, W. (1999). Lag length selection in vector autoregressive models: symmetric and asymmetric lags. *Applied Economics*, *31*(4), pp.517-524.

Ozturk, I. and Acaravci, A. (2010). The causal relationship between energy consumption and GDP in Albania, Bulgaria, Hungary and Romania: Evidence from ARDL bound testing approach. *Applied Energy*, *87*(6), pp.1938-1943.

Pahlavani, M., Wilson, E. and Worthington, A.C. (2005). Trade-GDP nexus in Iran: An application of the autoregressive distributed lag (ARDL) model. [Online]. Available: https://ro.uow.edu.au/commpapers/144/ Accessed: 2 September 2020.

Palachy, S. (2019). Detecting stationarity in time series data. [Online]. Available: https://towardsdatascience.com/detecting-stationarity-in-time-series-data-d29e0a21e638 Accessed: 5 March 2020.

Parajuli, R. and Chang, S.J. (2015). Real Assets and Inflation: Which Real Assets Hedge Inflation, Agricultural & Applied Economics Association Annual Meeting, San Francisco.

Patti, N. (2020). The Two Main Causes of Inflation. [Online]. Available: https://medium.com/the-rebus/the-two-main-causes-of-inflation-bf47de0afe49 Accessed: 6 August 2020.

Perron, P. (1989). The Great Crash, the Oil-Price Shock, and the Unit-Root Hypothesis. *Econometrica*, (57), pp. 1361-1401.

Perez, D. (2020). The Advantages of Consumer Price Index. [Online]. Available: https://smallbusiness.chron.com/advantages-consumer-price-index-22455.html Accessed: 28 August 2020.

Pesaran, M.H., and Shin, Y. (1999). An autoregressive distributed lag modelling approach to cointegration analysis, in Strom, S. (Ed.). Paper presented at Econometrics and Economics Theory in the 20th Century: The Ragnar Frisch Centennial Symposium, Cambridge University Press, Cambridge.

Pesaran, M., Shin, Y. and Smith, R. (2001). Bounds Testing Approaches to the Analysis of Level Relationships. *Journal of Applied Econometrics*, 16(3), pp. 289-326.

Pettinger, T. (2015). Different Measures of Inflation. [Online]. Available: https://www.economicshelp.org/blog/3203/economics/measures-of-inflation/ Accessed: 1 November 2020.

Pettinger, T. (2016). Impact of falling house prices. [Online]. Available: https://www.economicshelp.org/blog/1032/housing/why-falling-house-prices-cause-a-recession/ Accessed: 7 December 2020.

Pettinger, T. (2019). Causes of Inflation. [Online]. Available: https://www.economicshelp.org/macroeconomics/inflation/causes-inflation/ Accessed: 5 August 2020.

Phillips, P.C.B. (1998). Impulse response and forecast error variance asymptotics in nonstationary VARS. *Journal of Econometrics*, 83(1-2), pp. 21-56.

Phillip, P.C.B. & Perron, P. (1988). Testing for a unit root in time series regression. *Biometrika,* 75(2), pp. 335-346.

Phiri, A. (2016). Inflation persistence in African countries: Does inflation targeting matter? *Economics and Business Letters*, 5(3), pp. 65-71.

Phiri, A. (2017). Long-run equilibrium adjustment between inflation and stock market returns in South Africa: A nonlinear perspective. *International Journal of Sustainable Economy*, *9*(1), pp.19-33.

Plecher, H. (2019). South Africa: Inflation rate from 1984-2024. [Online]. Available: https://www.statista.com/statistics/370515/inflation-rate-in-south-africa/ Accessed: 12 February 2020.

Prabhakaran, S. (2019). Augmented Dickey Fuller Test (ADF Test) – Must Read Guide. [Online]. Available: https://www.machinelearningplus.com/time-series/augmented-dickey-fuller-test/ Accessed: 29 August 2020.

Property24.com (2012). House prices to remain subdued – Absa. [Online]. Available: https://www.property24.com/articles/house-prices-to-remain-subdued-absa/14610 Accessed: 5 February 2021.

Quandt, R.E. (1960). Tests of the hypothesis that a linear regression system obeys two separate regimes. *Journal of American Statistical Association*, 55, 320-330.

Quandt, R.E. (1972). A new approach to estimating switching regressions. *Journal of the American statistical association*, *67*(338), pp.306-310.

Raza, N., Shahzad, S.J.H., Shahbaz, M. and kumar Tiwari, A. (2017). Modelling the nexus between oil shocks, inflation and commodity prices: Do Asymmetries really matter?. *Economics Bulletin*, *37*(4), pp.2374-2383.

Reed, E. (2017). 10 Effects of Inflation You Need to Know About. [Online]. Available: https://www.thestreet.com/personalfinance/effectsofinflationhtml#gid=ci02572b8ed0012687&pid=9-it-incentivizes-spending-and-deters-saving Accessed: 8 August 2020.

Rehman, M.U., Ali, S. and Shahzad, S.J.H. (2020). Asymmetric nonlinear impact of oil prices and inflation on residential property prices: a case of US, UK and Canada. *The Journal of Real Estate Finance and Economics*, *61*(1), pp.39-54.

Reilly, T. (2013). Advantages and disadvantages of using monthly, weekly and daily data. [Online]. Available: https://autobox.com/cms/index.php/blog/entry/advantages-and-disadvantages-of-using-monthly-weekly-and-daily-data Accessed: 10 February 2020.

Rezitis, A.N. (2019). Investigating price transmission in the Finnish dairy sector: an asymmetric NARDL approach. *Empirical Economics, 57*(3), pp.861-900.

Ricci, L.A. (2006). Part IV. Monetary Developments. In: Nowak, M. and L.A. Ricci, ed. Post Apartheid South Africa: The First Ten Years. Washington, D.C: International Monetary Fund, 189-210.

Rodel, M.G. (2012). Inflation Hedging. [Online]. Available: https://mediatum.ub.tum.de/doc/1110584/1110584.pdf Accessed: 10 August 2020.

Roger, S. and Stone, M. (2005). On target?: The international experience with achieving inflation targets. [Online]. Available: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=888032 Accessed: 5 March 2021.

Rohlfs, C. (2020). Hard Assets: Using Real Estate to Hedge Against Inflation. [Online]. Available: https://fundrise.com/education/real-estate-is-a-hard-asset Accessed: 1 December 2020.

Rozas, L.W. and Klein, W.C. (2010). The value and purpose of the traditional qualitative literature review. *Journal of Evidence-Based Social Work*, *7*(5), pp.387-399.

Rubens, J., Bond, M. and Webb, J. (1989). The inflation-hedging effectiveness of real estate. *Journal of Real Estate Research*, *4*(2), pp.45-55.

Salisu, A.A., Raheem, I.D. and Ndako, U.B. (2020). The inflation hedging properties of gold, stocks and real estate: A comparative analysis. *Resources Policy*, *66*, p.101605.

SARB (2007). Why is inflation bad? [Online]. Available: https://www.resbank.co.za/AboutUs/Documents/Why%20is%20Inflation%20Bad.pdf Accessed: 20 August 2020.

Schotman, P.C. and Schweitzer, M. (2000). Horizon sensitivity of the inflation hedge of stocks. *Journal of empirical Finance*, *7*(3-4), pp.301-315.

Schwarz, G. (1978). Estimating the dimension of a model. The Annals of Statistics, 6(2), pp. 461-464.

Shin, Y., Yu, B. and Greenwood-Nimmo, M. (2014). Modelling asymmetric cointegration and dynamic multipliers in a nonlinear ARDL framework. In *Festschrift in honor of Peter Schmidt*, pp. 281-314.

Simo-Kengne, B.D., Balcilar, M., Gupta, R., Reid, M. and Aye, G.C. (2013). Is the relationship between monetary policy and house prices asymmetric across bull and bear markets in South Africa? Evidence from a Markov-Switching Vector Autoregressive model. *Economic Modelling*, *32*, pp.161-171.

Srinivasan, P., Kumar, P.S. and Ganesh, L. (2012). Tourism and economic growth in Sri Lanka: An ARDL bounds testing approach. *Environment and Urbanization Asia*, *3*(2), pp.397-405.

Sing, T.F. and Low, S.H.Y. (2001). A comparative analysis of inflation-hedging characteristics of property and non-property assets in Singapore'. *Journal of real estate portfolio management*, *6*(4), pp.373-386.

Singh, M. (2019). The 2007-08 Financial Crisis in Review. [Online]. Available: https://www.investopedia.com/articles/economics/09/financial-crisis-review.asp Accessed: 24 February 2020.

Smith, L. (2019). How to Profit from Inflation. [Online]. Available: https://www.investopedia.com/articles/investing/080813/how-profit-inflation.asp Accessed: 5 February 2020.

Soffer, A. (2019). 6 Ways to Make Your Data Analysis More Reliable. [Online]. Available: https://www.leadspace.com/ways-to-make-your-data-analysis-more-reliable/ Accessed: 6 December 2020.

Spyrou, S.I. (2004). Are stocks a good hedge against inflation? Evidence from emerging markets. *Applied Economics*, *36*(1), pp.41-48.

Stevenson, S. (2000). A long-term analysis of regional housing markets and inflation. *Journal of Housing Economics*, *9*(1-2), pp.24-39.

Stevenson, S. and Murray, L. (1999). An examination of the inflation hedging ability of Irish real estate. *Journal of Real Estate Portfolio Management*, *5*(1), pp. 59-69.

Sueppel, R. (2017). Understanding negative inflation risk premia. [Online]. Available: https://www.sr-sv.com/understanding-negative-inflation-risk-premia/#:~:text=Inflation%20risks%20are%20inherent%20in,are%20subject%20to%20inflation%20risks. Accessed: 5 March 2021.

Sun, Y. and Xu, Y. (2010). Dynamic linkages between China and US equity markets under two recent financial crises. [Online]. Available: https://lup.lub.lu.se/student-papers/search/publication/1613235 Accessed: 5 January 2021.

Taderera, M. and Akinsomi, O. (2020). Is commercial real estate a good hedge against inflation? Evidence from South Africa. [Online]. Available: https://www.sciencedirect.com/science/article/abs/pii/S0275531919302533?via%3Dihub Accessed: 11 August 2020.

Talas, E., Kaplan, F. and Celik, A.K. (2013). Model stability test of money demand by monthly

time series using CUSUM and MOSUM tests: Evidence from Turkey. *Research in World Economy,* 4(2), pp. 36-42.

Tan, C.T., Lee, C.Y., Tan, Y.T. and Keh, C.G. (2018). A nonlinear ARDL analysis on the relation between housing price and interest rate: The case of Malaysia. *Journal of Islamic, Social, Economics and Development*, *3*(14), pp.109-121.

Thomas, L. (2020). Independent and dependent variables. [Online]. Available: https://www.scribbr.com/methodology/independent-and-dependent-variables/ Accessed: 5 September 2020.

Tradingeconomics.com. (2020). South Africa Housing Index. [Online]. Available: https://tradingeconomics.com/south-africa/housing-index Accessed: 24 February 2020.

Tsatsaronis, K. and Zhu, H. (2004). What drives housing price dynamics: cross-country evidence? [Online]. Available: SSRN: https://ssrn.com/abstract=1968425 Accessed: 8 February 2020.

Uzuner, G. and Adewale, A.A. (2019). Does asymmetric nexus exist between agricultural land and the housing market? Evidence from non-linear ARDL approach. *Environmental Science and Pollution Research*, *26*(8), pp.7677-7687.

Van der Merwe, E.J. (2004). Inflation targeting in South Africa. SARB Occasional Working Paper No. 19.

Van Hoang, T.H., Lahiani, A. and Heller, D. (2016). Is gold a hedge against inflation? New evidence from a nonlinear ARDL approach. *Economic Modelling*, 54, pp. 54-66.

Van Staden, G. (2016). Hedge against inflation: invest in property. [Online]. Available: https://www.property24.com/articles/hedge-against-inflation-invest-in-property/23356 Accessed: 6 February 2020.

Verma, R. (2007). Savings, investment and growth in India: an application of the ARDL bounds testing approach. *South Asia Economic Journal*, *8*(1), pp.87-98.

Woglom, G. (2003). How has inflation targeting affected monetary policy in South Africa?. *South African Journal of Economics*, *71*(2), pp.380-406.

Wolters, J. and Hassler, U. (2006). Unit root testing. *Allgemeines Statistisches Archiv*, *90*(1), pp.43-58.

Xiao, Z. and Phillips, P.C.B. (2002). A CUSUM test for cointegration using regression residuals.

Journal of Econometrics, 108(1), pp. 43-61

Yeap, G. P., and Lean, H.H. (2017). Asymmetric inflation hedge properties of housing in Malaysia: New evidence from nonlinear ARDL approach. *Habitat International,* 62, pp. 11-21.

Zajic, A. (2019). Introduction to AIC – Akaike Information Criterion. [Online]. Available: https://towardsdatascience.com/introduction-to-aic-akaike-information-criterion-9c9ba1c96ced Accessed: 1 September 2020.

Zamboni, J. (2018). The Advantages of a Large Sample Size. [Online]. Available: https://sciencing.com/calculate-tscore-5135749.html Accessed: 1 October 2020.

Zhou, X. and Clements, S. (2010). The inflation hedging ability of real estate in China. *Journal of real estate Portfolio Management*, *16*(3), pp.267-277.

Zini, M. (2008). The Impact of the Financial Crisis on South Africa. [Online]. Available: https://blogs.worldbank.org/africacan/the-impact-of-the-financial-crisis-on-south-africa Accessed: 24 February 2020.

Zivot, E. and Andrews, D.W.K. (1992). Further evidence on the great crash, the oil-price shock, and the unit-root hypothesis. *Journal of business & economic statistics*, *20*(1), pp. 25-44.

APPENDIXES

Appendix 1: Ethical Clearance

UNIVERSITY OF
KWAZULU-NATAL
INYUVESI
YAKWAZULU-NATALI

14 January 2021

Miss Nikita Ramsaran (216007988)
School Of Acc Economics&Fin
Westville

Dear Miss Nikita Ramsaran,

Protocol reference number: 00010471
Project title: Residential property as a hedge against inflation in South Africa

Exemption from Ethics Review

In response to your application received on 10 January 2021, your school has indicated that the protocol has been granted **EXEMPTION FROM ETHICS REVIEW.**

Any alteration/s to the exempted research protocol, e.g., Title of the Project, Location of the Study, Research Approach and Methods must be reviewed and approved through an amendment/modification prior to its implementation. The original exemption number must be cited.

For any changes that could result in potential risk, an ethics application including the proposed amendments must be submitted to the relevant UKZN Research Ethics Committee. The original exemption number must be cited.

In case you have further queries, please quote the above reference number.

PLEASE NOTE:
Research data should be securely stored in the discipline/department for a period of 5 years.

I take this opportunity of wishing you everything of the best with your study.

Yours sincerely,

[redacted]

Prof Josue Mbonigaba
Academic Leader Research
School Of Acc Economics&Fin

Appendix 2: Turnitin report

Final submission

ORIGINALITY REPORT

15%	11%	9%	6%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	researchspace.ukzn.ac.za Internet Source	5%
2	Submitted to University of KwaZulu-Natal Student Paper	<1%
3	Geok Peng Yeap, Hooi Hooi Lean. "Asymmetric inflation hedge properties of housing in Malaysia: New evidence from nonlinear ARDL approach", Habitat International, 2017 Publication	<1%
4	hdl.handle.net Internet Source	<1%
5	repository.nwu.ac.za Internet Source	<1%
6	Submitted to North West University Student Paper	<1%
7	Submitted to University of Liverpool Student Paper	<1%
8	Submitted to Banasthali University Student Paper	