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ANALYSING THE INFLUENCE THAT MACROECONOMIC FACTORS HAVE ON THE RETURNS OF SOUTH AFRICAN REAL ESTATE INVESTMENT TRUSTS

Research Report

by

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School of Economics and Finance

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University of the Witwatersrand, Johannesburg

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DECLARATION

I, Jane Taylor, declare that this research report is my own unaided work. It is submitted in partial fulfilment of the requirements for the degree of Master of Commerce in Finance at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at this or any other university.



Signature

28 February 2022

Date

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ABSTRACT

Real estate investment trusts (REITs) have become a popular investment vehicle for investors seeking to gain exposure to the real estate market. The South African REIT regime came into effect on 1 May 2013 and since then, the South African REIT market has been characterised by notable return volatility. This raises the question as to whether changes in key macroeconomic factors influence South African REIT returns, and if so, to what extent do changes in macroeconomic factors have on the returns of South African REITs. Notably, limited empirical research has been conducted to analyse the impact that macroeconomic factors have on South African REIT returns. As such, the aim of this study is to analyse the influence that economic growth, inflation, interest rates, and the stock market have on the returns of South African REITs. Particularly, the overall South African REIT market as well as the prominent REIT property subtypes in South Africa including the retail, office, and industrial sectors are investigated.

To estimate and evaluate the relationships between the stated macroeconomic factors and South African REIT returns, vector autoregression models and vector error correction models are employed. The results reveal that South African REIT returns are significantly positively associated with economic growth, inflation, and stock market returns whereas they are significantly negatively related to interest rates. However, changes in these macroeconomic factors only explain a small percentage of the variability in REIT returns. Importantly, the findings of this study are consistent with what has been observed in other global REIT markets except for inflation in which a negative association has generally been reported. The results of this study strengthens the field of REIT research by adding to the existing body of knowledge of what is currently known about South African REITs. From a practical standpoint, this additional insight may assist REIT asset managers, real estate collective investment scheme fund managers, and investors with portfolio construction and risk management decisions.

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DEFINITION OF KEY TERMS

Active professional management	An approach to investing in which the portfolio manager seeks to outperform a given benchmark portfolio (Maginn, Tuttle, Pinto, & McLeavey, 2007).
Confidence interval	An interval that has a given probability of containing the parameter it is intended to estimate (Maginn et al., 2007).
Diversification	The holding of various risky assets to minimise the exposure to any one of them (van Wyk, Botha, & Goodspeed, 2015).
Economic growth	The expansion of productive capacity of an economy that results from capital accumulation and technological progress (DeFusco, McLeavey, Pinto, & Runkle, 2015b).
Efficient frontier	The set of portfolios that maximise the expected return for every given level of risk (Janse van Rensburg, McConnel, & Brue, 2015).
First differencing	A transformation that subtracts the value of a time series in period $t-1$ from its value in period t (DeFusco et al., 2015b).
Inflation	A rise in the general level of prices in an economy (Janse van Rensburg et al., 2015).
Interest rates	The cost of borrowing or the price paid for the use of funds expressed as a percentage per year (van Wyk, Botha, & Goodspeed, 2015.
Level of significance	The probability of rejecting a true null hypothesis (DeFusco et al., 2015b).
Liquidity	The extent to which an instrument can be readily acquired or disposed of at prevailing market prices (van Wyk, Botha, & Goodspeed, 2015.
Mixed asset portfolio	A collection of investment securities assembled in a manner designed to provide diversification, and hence, risk reduction benefits (van Wyk, Botha, & Goodspeed, 2015.

Real estate investment trust	A company that owns and manages income-producing real estate assets (van Wyk, Botha, & Goodspeed, 2015.
Rebalancing	Adjusting the actual portfolio to the strategic asset allocation due to price changes in portfolio holdings (Maginn et al., 2007).
Stock market	A market in which shares and other financial securities of public companies are issued and traded (Jones, 2018).
Strategic asset allocation	The process of allocating money to permissible asset classes that integrates the investor's return objective, risk tolerance, and investment constraints with long-run capital market expectations (Maginn et al., 2007).
Tactical asset allocation	Asset allocation that involves making short-term adjustments to asset class weights based on short-term predictions of relative performance among asset classes (Maginn et al., 2007).
Total return	The rate of return that accounts for capital appreciation/deprecation and income (Maginn et al., 2007).

ABBREVIATIONS

ADF	Augmented Dickey Fuller
AIC	Akaike information criterion
APT	Arbitrage pricing theory
ARCH	Autoregressive conditional heteroskedasticity
CAL	Capital allocation line
CAPM	Capital asset pricing model
CRSP	Centre for Research in Security Prices
CUSUM	Cumulative sum of recursive residuals
CVAR	Cointegrating vector autoregression
DF-GLS	Dickey Fuller generalised least squares
EPRA	European Public Real Estate Association
GARCH	Generalised autoregressive conditional heteroskedasticity
GMV	Global minimum variance
HQ	Hannan-Quinn information criterion
JSE	Johannesburg Stock Exchange
LM	Lagrange multiplier
MVF	Minimum variance frontier
NAREIT	National Association of Real Estate Investment Trusts
OECD	Organisation for Economic Co-operation and Development
OLS	Ordinary least squares
PLSs	Property loan stocks
PUTs	Property unit trusts
REITs	Real estate investment trusts
SARB	South African Reserve Bank
SC	Schwarz criterion
SMA	Structural moving average
StatsSA	Statistics South Africa
VAR	Vector autoregression
VECM	Vector error correction model
VMA	Vector moving average

CHAPTER 1 – INTRODUCTION

1.1 BACKGROUND

As an investor, it is imperative to have an understanding of the differences among investment assets in order to build a properly diversified portfolio that conforms to your investment objectives and risk tolerance (Markowitz, 1952). Moreover, the ability to understand the characteristics and driving forces of these assets is essential for investment success. Historically, real estate investment trusts (REITs) were one of the most misunderstood investments and they found no natural home in diversified portfolios (Krewson-Kelly & Thomas, 2016). Over the last six decades, however, REITs have increased in popularity and have become an important feature of investment portfolios. Despite REITs becoming one of the world's fastest growing real estate investment vehicles, there are still many poorly understood aspects of this asset class (Krewson-Kelly & Thomas, 2016; Parker, 2011).

Since the introduction of the first REIT regime in the United States in 1960, many countries around the world have embraced the United States REIT approach in an effort to facilitate the growth and development of their domestic real estate markets (Paolone, O'Reilly, & Kruth, 2019). According to the European Public Real Estate Association, the global REIT market had a market capitalisation of $2 252.54 billion consisting of 974 REIT companies as at 2021-Q3 (Pekdemir, Moreno, Luiz, & Marinov, 2021). It can be said that REITs have become an accepted form of real estate investment as a result of the numerous advantages associated with investing in REITs. Several authors have highlighted that the main advantages associated with investing in REITs compared to directly investing in real estate include greater liquidity, diversification, active professional management, earnings predictability and high income payout ratios, smaller capital outlay, and access to superior quality and range of properties (Block, 2012; Francis & Ibbotson, 2001; Paolone et al., 2019; Yau, Schneeweis, Robinson, & Weiss, 2007).

Additionally, many studies have been undertaken to measure the benefits of including REITs in a mixed-asset portfolio. Although some studies have found that REITs do not

add significant performance benefits (Kuhle, 1987; Nelling & Gyourko, 1998), the overwhelming majority of studies provide evidence to suggest that including an allocation of REITs to a mixed-asset portfolio is highly advantageous to investors as it leads to both return-enhancement and risk-reduction benefits (Newell, Pham, & Ooi, 2015; Ntuli & Akinsomi, 2017; Olaleye, 2011; Oyedele, 2014; Oyedele, McGreal, Adair, & Ogedengbe, 2013).

A formalised REIT regime based on the National Association of Real Estate Investment Trusts (NAREIT) in the United States and the European Public Real Estate Association (EPRA) in Europe was introduced in South Africa on 1 April 2013 and came into effect on 1 May 2013 (SA REIT Association, 2021b). Since then, South Africa has become the largest REIT market in the Middle East and African region with a market capitalisation of $14.50 billion comprising 31 REIT companies as at 2021-Q3 (Pekdemir et al., 2021).

From an academic point of view, some literature relating to the South African REIT market has been published. This research includes, but is not limited to:

- The initial performance of the South African REIT market (Ntuli & Akinsomi, 2017).
- The impact of introducing REITs on foreign investments and liquidity in South Africa (Carstens & Freybote, 2018).
- An analysis of the performance and diversification benefits of the South African REIT market (Marzuki, 2018).
- The impact of South African REIT portfolio composition on diversification benefits for foreign REIT investors (Carstens, Freybote, & De Villiers, 2019; Marzuki, 2018).
- The impact of South African REIT legislation on firm growth and firm value (Wesson & Carstens, 2019).
- The resiliency of South African REITs to a pandemic (Akinsomi, 2020).

Despite the information that is accessible with respect to South African REITs, to the author's knowledge, limited research has been undertaken to determine the impact that macroeconomic factors have on South African REIT returns. It is necessary that research is conducted in this regard so as to enhance the understanding of the characteristics and driving forces of this asset class in a South African context.

1.2 PROBLEM STATEMENT

Since the South African REIT regime came into effect on 1 May 2013, the South African REIT market has experienced significant return volatility. According to the South African REIT Association, the South African REIT market has experienced annual returns ranging between a high of 27.7% in 2014 to a low of −37.9% in 2020 (SA REIT Association, 2021a). Given this extreme volatility in returns, the question arises as to whether changes in key macroeconomic factors influence South African REIT returns, and if so, to what extent do changes in macroeconomic factors have on the returns of South African REITs.

Internationally, many researchers have undertaken studies to examine whether macroeconomic factors impact REIT returns. The most prominent literature in this regard has been conducted in the United States, however, as the global REIT market has expanded, the association between macroeconomic factors and REIT returns has attracted the attention of numerous researchers worldwide. Therefore, in addition to the United States, research on the influence that macroeconomic factors have on REIT returns has also been conducted in Europe, the Asia-Pacific region and, to a lesser extent, Africa. Given the findings of these studies, it can be concluded that the most dominant macroeconomic drivers of REIT returns include economic growth, inflation, interest rates, and stock market returns (Cohen & Burinskas, 2020; Ewing & Payne, 2005; Fang, Chang, Lee, & Chen, 2016; Liow, Ibrahim, & Huang, 2006; Yunus, 2012). Various other macroeconomic factors such as money supply, industrial production growth, oil price fluctuations, government spending, and consumer spending may also influence REIT returns (Bilson, Brailsford, & Hooper, 2001; Fatnassi, Slim, Ftiti, & Maatoug, 2014; Loo, Anuar, & Ramakrishnan, 2016; Naranjo & Ling, 1997; Razali, Jalil, & Nguyen, 2020).

There is limited empirical research relating to the impact that the aforementioned macroeconomic factors have on the returns of South African REITs. As such, this study aims to shed light on the relationship between these macroeconomic factors and South African REIT returns.

1.3 PURPOSE STATEMENT

The purpose of this study is to analyse the influence that numerous macroeconomic factors, namely economic growth, inflation, interest rates, and the stock market, have on the returns of South African REITs. Additionally, this study determines the degree to which these macroeconomic factors impact South African REIT returns. A unique feature of this study is that it analyses the overall South African REIT market as well as the prominent REIT property subtypes in South Africa including the retail, office, and industrial sectors. To achieve this, vector autoregression (VAR) models and vector error correction models (VECMs) are employed. Subsequently, a comparison is drawn with the findings from prior international studies to establish whether the relationship between macroeconomic factors and REIT returns in international markets is also pertinent in the South African REIT market.

1.4 RESEARCH OBJECTIVES

This study is guided by the following research objectives:

- To analyse the influence that several macroeconomic factors have on South African REIT returns.
- To identify the extent of the impact that the various macroeconomic factors have on South African REIT returns.
- To compare whether the relationship between macroeconomic factors and South African REIT returns is in accordance with what has been observed in other international REIT markets.

1.5 IMPORTANCE AND BENEFITS OF THE STUDY

As mentioned previously, limited empirical research has been conducted to analyse the impact that macroeconomic factors have on South African REIT returns. Thus, the findings of this study will enhance the field of REIT research in South Africa by adding to the existing body of knowledge of what is currently known about South African REITs. Importantly, the findings of this study provide a basis for comparison between the South African REIT market and other global REIT markets to ascertain whether South African REITs are influenced by macroeconomic factors in the same manner as those internationally.

Additionally, from a practical standpoint, this study may be useful to REIT asset managers as the results could potentially assist them in making portfolio allocation decisions. The findings may also be beneficial to real estate collective investment scheme fund managers in determining an effective strategic asset allocation as well as in making tactical asset allocation adjustments to capitalise on changes in the macroeconomy. Furthermore, the results obtained from conducting this research may equip investors with enhanced knowledge regarding the relationship between macroeconomic factors and South African REIT returns which could assist them in making more informed investment decisions.

1.6 DELIMITATIONS

This study only analyses the influence that various macroeconomic factors have on South African REIT returns. Firm-specific factors such as size, leverage, dividend yield, and book-to-market ratio may also affect REIT returns, however, they will not be analysed for the purposes of this study. Moreover, this study solely investigates the impact that economic growth, inflation, interest rates, and the stock market have on South African REIT returns. Previous literature indicates that these are the most dominant macroeconomic drivers of REIT returns, hence, the author believes that it is necessary to analyse these important macroeconomic factors in this study. Other macroeconomic factors including money supply, industrial production growth, oil price fluctuations, government spending, and consumer spending will not be evaluated in this study. Furthermore, it is important to highlight that the findings of this study provide an understanding of the historical relationship between several macroeconomic factors and South African REIT returns which is no indication of the relationship that may prevail in future periods.

1.7 STRUCTURE OF THE STUDY

This research report comprises six main chapters. Chapter 2 provides an overview of REITs and critically evaluates prior literature relating to the influence that macroeconomic factors have on REIT returns. Chapter 3 outlines the methodology employed to conduct the study. An analysis of the data is conducted in Chapter 4 whereafter a discussion of the findings is conferred in Chapter 5. The conclusion and recommendations for future research are presented in Chapter 6.

CHAPTER 2 – LITERATURE REVIEW

2.1 INTRODUCTION

The main objective of this chapter is to critically evaluate prior literature relating to the influence that macroeconomic factors have on the returns of real estate investment trusts (REITs). To provide a backdrop to the subject matter, emphasis is first placed on several important characteristics of REITs in section 2.2. Thereafter, the macroeconomic factors that form the basis of this study, namely economic growth, inflation, interest rates, and the stock market, are discussed in sections 2.3 to 2.6. Particularly, these sections expand on the economic theory behind each macroeconomic factor and further reviews the empirical relationship between these macroeconomic factors and REIT returns. A summary concludes the chapter in section 2.7.

2.2 REAL ESTATE INVESTMENT TRUSTS

Before investigating the relationship between macroeconomic factors and REIT returns, it is imperative to have an understanding of the main characteristics of REITs. As such, this section provides a comprehensive overview of REITs including what they are, how they were developed, the different types of REITs, and the various REIT property subtypes. Additionally, this section explains why investors invest in REITs by analysing how they fit into a mixed-asset portfolio as well as the advantages and disadvantages associated with investing in REITs. Finally, a brief discussion on asset pricing theory and the relationship between macroeconomic factors and REIT returns is provided to serve as an introduction to sections 2.3 to 2.6.

2.2.1 What is a real estate investment trust?

A REIT is an entity that derives revenue through owning, managing, or financing income-producing real estate (Krewson-Kelly & Thomas, 2016). Globally, REITs are generally exempt from paying corporate income tax if a specified majority (usually 75% or more depending on the country) of their income and assets pertain to income-producing real estate and almost all of their potentially taxable income is distributed to their shareholders in the form of dividends (Brueggeman & Fisher, 2005). Due to this

unique feature of REITs, shareholders can expect to earn significantly higher distributions from investing in these entities compared to many other entities that are not required to distribute most of their income (Paolone et al., 2019). REITs can either be privately traded or publicly traded on an exchange. This study focuses on publicly traded REITs which allow investors to gain exposure to the real estate market without having to purchase, manage, or finance the properties directly (Krewson-Kelly & Thomas, 2016).

2.2.2 History of REITs

REITs were formed in 1960 in the United States with the introduction of the Real Estate Investment Trust Act. They were established to meet the needs of investors who were looking to gain access to income-producing real estate (Brounen & De Koning, 2012). Prior to the introduction of the REIT regime, the benefits associated with investing in commercial real estate was only available to high-net-worth individuals or accessible through financial intermediaries. Therefore, REITs brought about inclusivity by enabling regular investors to buy shares of the trust thereby allowing them to also reap the benefits of commercial real estate investments (Brounen & De Koning, 2012). Noteworthy, the Real Estate Investment Trust Act of 1960 only permitted REITs to own or finance commercial real estate investments. However, the United States REIT regime later evolved with the passing of the Tax Reform Act of 1986 which enabled REITs to also manage and operate commercial real estate properties instead of just owning or financing these investments (Brueggeman & Fisher, 2005). Important to highlight is that the United States REIT regime provided a model for REIT legislation in countries across the globe. Following the United States, the Netherlands was the second market to adopt the REIT regime in 1969. Subsequently, REITs have become increasingly popular worldwide with all G-7 nations and approximately two-thirds of Organisation for Economic Co-operation and Development (OECD) countries having embraced the United States REIT approach (Paolone et al., 2019). The global REIT market will be further expanded upon in section 2.2.8.

2.2.3 Types of REITs

There are three types of REITs namely equity, mortgage, and hybrid REITs (Yau et al., 2007). A discussion on these three types of REITs follows.

2.2.3.1 Equity REITs

Equity REITs own and manage income-producing real estate with the primary purpose of leasing these properties to tenants. Hence, equity REITs predominantly derive their revenue from rental income received from the tenants that lease their properties (Brueggeman & Fisher, 2005; Yau et al., 2007). They may also generate income from the sale of properties although this is typically a small portion of their total revenue (Krewson-Kelly & Thomas, 2016). Equity REITs are the most common type of REIT constituting the largest percentage of the global REIT market (Paolone et al., 2019).

2.2.3.2 Mortgage REITs

Mortgage REITs provide financing to investors of income-producing real estate. They do this by either lending money directly through mortgages and loans or indirectly by acquiring mortgage-backed securities (Yau et al., 2007). As such, mortgage REITs obtain a significant portion of their revenue from interest income earned from lending money through loans or their investments in residential- or commercial-backed securities. To raise capital, mortgage REITs issue debt or equity in public or private capital markets (Krewson-Kelly & Thomas, 2016). The total market value of mortgage REITs is comparatively smaller to equity REITs (Paolone et al., 2019).

2.2.3.3 Hybrid REITs

Hybrid REITs adopt the investment strategies of both equity and mortgage REITs. Thus, these types of REITs own, manage, and finance income-producing real estate (Krewson-Kelly & Thomas, 2016; Yau et al., 2007). Hybrid REITs make up a small percentage of the global REIT market (Paolone et al., 2019).

2.2.4 REIT property subtypes

To achieve operational efficiency and drive business growth, most REITs focus on investing in a specific property subtype (Paolone et al., 2019). Table 1 reports the primary property subtypes with their respective percentages held in the global REIT market.

Table 1: Global REITs by property subtype held

Property subtype	Percentage
Retail	23.3
Office	14.5
Residential	11.3
Healthcare	6.8
Industrial	4.2
Hotel	2.7
Self-storage	2.6
Industrial/Office	1.0
Diversified	33.6

Source: Paolone et al. (2019)

Evidently, the global REIT market is primarily made up of diversified REITs representing 33.6% of the global REIT market. The second most common property subtype includes retail REITs comprising 23.3% of the global REIT market. Following this, office and residential REITs constitute 14.5% and 11.3% of the global REIT market respectively. The property subtypes listed in Table 1 are expanded upon below.

2.2.4.1 Retail REITs

Retail REITs own and manage retail properties including regional malls, community shopping centres, and outlet centres (Brueggeman & Fisher, 2005; Krewson-Kelly & Thomas, 2016; Paolone et al., 2019). Regional malls are large, enclosed spaces in which higher-priced discretionary goods are typically sold. Tenants of regional malls generally have lease terms spanning three to ten years. Community shopping centres typically rent space for similar lease maturities to tenants that provide necessity goods and services such as food, homeware, furniture, and banking. Outlet stores, on the other hand, rent space to factory stores who sell products at discount prices (Paolone et al., 2019).

2.2.4.2 Office REITs

Office REITs own and manage office properties including office parks and skyscrapers in central business districts of cities or suburban areas. The office buildings are leased to specific types of tenants including multinational corporations, banks, technology firms, government agencies, and law firms that need space to accommodate their workforce. The lease terms of these properties are usually long, spanning five to twenty-five years (Brueggeman & Fisher, 2005; Krewson-Kelly & Thomas, 2016; Paolone et al., 2019).

2.2.4.3 Residential REITs

Residential REITs own and manage various residential dwelling units including single-family or multi-family structures such as apartment buildings, terraced houses, vacation homes, and student housing. These properties are solely leased for people to reside in and cannot be used for business purposes (Brueggeman & Fisher, 2005; Krewson-Kelly & Thomas, 2016). The typical lease duration for these types of properties tends to be approximately one year (Paolone et al., 2019).

2.2.4.4 Healthcare REITs

Healthcare REITs own health care-related properties including hospitals, rehabilitation centres, skilled nursing homes, assisted living and independent residential facilities for senior citizens, and medical office buildings. These properties are leased to and managed by health care providers who commonly sign long-term leases of ten or more years (Brueggeman & Fisher, 2005; Krewson-Kelly & Thomas, 2016; Paolone et al., 2019).

2.2.4.5 Industrial REITs

Industrial REITs own and manage single-tenant or multi-tenant industrial properties including distribution centres, manufacturing facilities, and warehouses. These properties are generally located outside of central business districts due to the large space that is required for these types of buildings (Brueggeman & Fisher, 2005; Krewson-Kelly & Thomas, 2016). The tenants of these properties usually enter into long-term leases spanning five to twenty-five years (Paolone et al., 2019).

2.2.4.6 Hotel REITs

Hotel REITs own hospitality-related properties including hotels and resorts. These properties are leased to and managed by hotel management companies who service a variety of guests such as vacationers and business travellers. The hotel sector is characterised by short-term leases (Brueggeman & Fisher, 2005; Krewson-Kelly & Thomas, 2016; Paolone et al., 2019).

2.2.4.7 Self-storage REITs

Self-storage REITs own and manage storage facilities comprised of different types of units with varying sizes. The units are leased to businesses or individuals for a short period of time, usually on a monthly basis (Brueggeman & Fisher, 2005; Krewson-Kelly & Thomas, 2016; Paolone et al., 2019).

2.2.4.8 Diversified REITs

Diversified REITs own and manage numerous types of properties. For instance, a diversified REIT may own a combination of retail, office, and industrial properties (Brueggeman & Fisher, 2005; Krewson-Kelly & Thomas, 2016; Paolone et al., 2019).

2.2.5 REITs in a mixed-asset portfolio

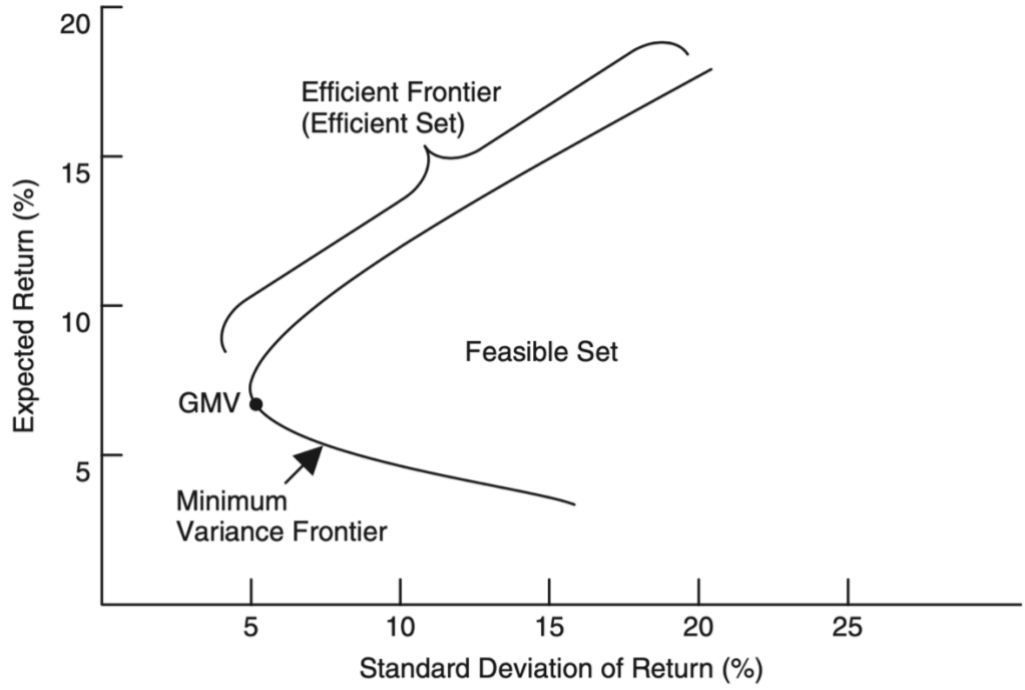
Given that REITs have become a popular real estate investment vehicle, it is essential to recognise why investors include an allocation to REITs in their investment portfolios. However, before analysing the effect that an allocation to REITs has on an investor's mixed-asset portfolio, it is important to have an understanding of efficient portfolios and how investors analyse the addition of a new asset class to an existing efficient portfolio.

2.2.5.1 Efficient portfolios

According to Markowitz (1952), an efficient portfolio offers the highest expected return $E(R_p)$ for a given level of risk represented by standard deviation of return σ_p. Graphically, efficient portfolios plot on the efficient frontier as seen in Figure 1. The efficient frontier forms part of the minimum variance frontier (MVF) which comprises the set of minimum-variance portfolios. Minimum-variance portfolios exhibit the lowest risk for a given level of expected return, hence, any feasible portfolio to the right of the

MVF would not be attractive to a risk-averse investor since these portfolios exhibit a higher level of risk for the same expected return as the portfolios on the MVF (Markowitz, 1952). The left-most point of the MVF represents the global minimum-variance (GMV) portfolio. The GMV portfolio has the lowest level of risk of all the minimum-variance portfolios. The portion of the MVF beginning and continuing above the GMV portfolio is defined as the efficient frontier which comprises the set of efficient portfolios with the highest expected return for a given level of risk. Notably, the MVF portfolios that lie below the GMV are sub-optimal portfolios because they have a lower expected return for a given level of risk compared to the efficient portfolios that lie on the efficient frontier (Markowitz, 1952).

Figure 1: The efficient frontier

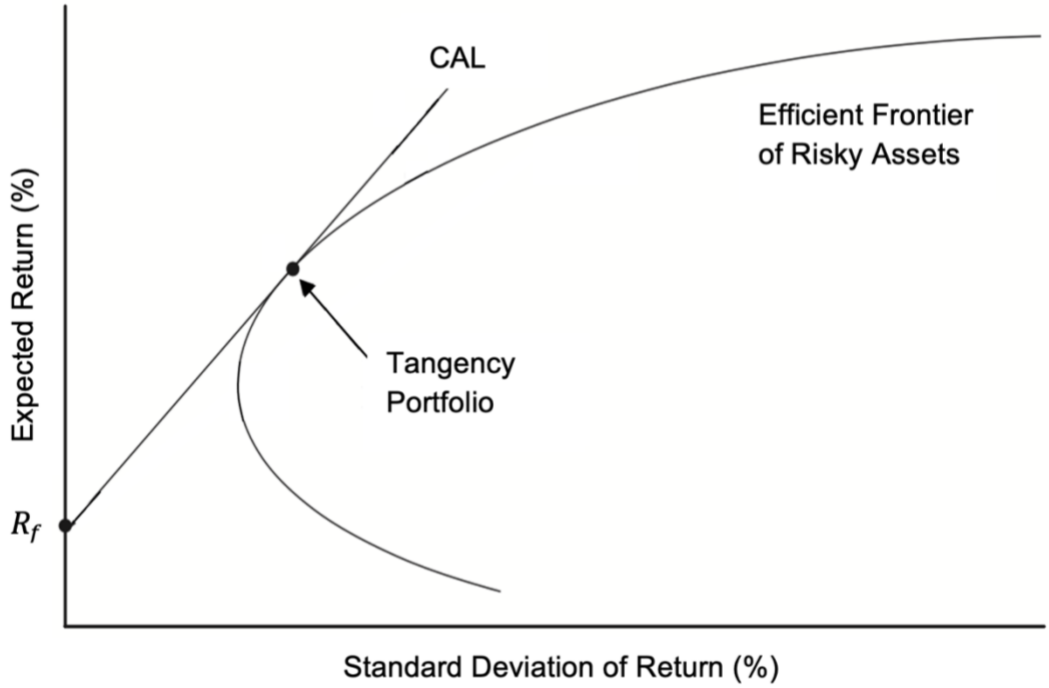


Source: Sharpe, Chen, Pinto, and McLeavey (2007)

The portfolios described above only contain risky assets, however, the majority of investors are able to include risk-free assets R_f, such as government bonds, into their portfolios. By combining a risk-free asset to a portfolio of risky assets, a straight line called the capital allocation line (CAL) is derived as depicted in Figure 2. The point where the CAL intersects the efficient frontier is defined as the tangency portfolio. The

tangency portfolio is the optimal risky portfolio as it has the highest Sharpe ratio which is a measure of return per unit of risk (Sharpe, 1964).

Figure 2: The tangency portfolio



Source: Adapted from Singal (2019)

2.2.5.2 Addition of a new asset class to an existing efficient portfolio

Assume that an investor holds a portfolio p with an expected return $E(R_p)$ and standard deviation of return σ_p. In order to determine whether an investor will realise a mean-variance improvement by adding an allocation of a new asset class to their existing portfolio, the following three inputs are required (Sharpe et al., 2007):

1) The Sharpe ratio of the new asset class that could potentially be added to the existing portfolio.
2) The Sharpe ratio of the existing portfolio.
3) The correlation between the new asset class' return and the existing portfolio p's return expressed as $Corr(R_{new}, R_p)$.

Adding an allocation to the new asset class will only be beneficial if the new asset class' Sharpe ratio is larger than the product of the existing portfolio's Sharpe ratio and the correlation between the new asset class' return and the existing portfolio's return.

This relationship can be expressed as follows (Blume, 1984; Elton, Gruber, & Rentzler, 1987):

$$\frac{E(R_{new}) - R_f}{\sigma_{new}} > \left(\frac{E(R_p) - R_f}{\sigma_p}\right) Corr(R_{new}, R_p)$$

If this relationship holds, adding an allocation of the new asset class to the existing portfolio will result in the investor achieving a superior efficient frontier with a tangency portfolio that has a higher Sharpe ratio (Sharpe et al., 2007). Important to highlight is that this expression does not indicate what percentage of the portfolio should be allocated to the new asset class. Thus, investors make use of mean-variance optimisation to determine the optimal weights of the respective asset classes that make up the efficient portfolio (Singal, 2019).

2.2.5.3 Allocation of REITs to an efficient portfolio

Many studies have been undertaken to measure the effects of including REITs in a mixed-asset portfolio. Although some studies have found that REITs do not add significant performance benefits (Kuhle, 1987; Nelling & Gyourko, 1998), the vast majority of studies provide evidence supporting the addition of REITs to a mixed-asset portfolio as it leads to both return-enhancement and risk-reduction benefits (Lee & Stevenson, 2005; Newell et al., 2015; Ntuli & Akinsomi, 2017; Olaleye, 2011; Oyedele, 2014; Oyedele et al., 2013).

A study in support of adding an allocation to REITs in a mixed-asset portfolio is that of Lee and Stevenson (2005). These authors examined the attractiveness of including United States REITs in a mixed-asset portfolio comprising United States equities, bonds, and cash as well as international equities. Using data from 1980-2000, the authors constructed efficient portfolios over 5-, 10-, 15- and 20-year time horizons. Through their analysis, it was found that, irrespective of the time horizon, including REITs in a mixed-asset portfolio resulted in both return-enhancement and risk-reduction benefits. Interestingly, these benefits tended to decline as an investor moved along the efficient frontier. For example, over the 5-year investment horizon, the efficient portfolios at the lower end of the efficient frontier achieved a return-enhancement and risk-reduction gain ranging between 3.6-7.6 basis points and 7.3-

13.4 basis points respectively. Whereas, the efficient portfolios at the upper end of the efficient frontier achieved a return-enhancement and risk-reduction gain of approximately 2 basis points and 5 basis points respectively. Evidently, the risk-reduction gain is much larger than the return-enhancement gain, hence, the authors concluded that as an investor moves along the efficient frontier, the rationale for including REITs in a mixed-asset portfolio shifts towards the risk-reduction qualities rather than the return-enhancement capabilities.

Similar findings relating to return-enhancement benefits were observed in a South African context. Ntuli and Akinsomi (2017) undertook a study to measure the effect of adding an allocation of South African REITs to a mixed-asset portfolio of South African stocks and bonds. In order to do such, the authors made use of monthly total return data for the period 2013-2015. In particular, the authors used the FTSE/JSE Real Estate Investment Trust Index (J867) as a proxy for the South African REIT market, the FTSE/JSE All Share Index (J203) as a proxy for the South African stock market, and the FTSE/JSE All Bond Index (ALBI) as a proxy for the South African bond market. It was found that the addition of REITs to a mixed-asset portfolio of stocks and bonds resulted in an improved efficient frontier. For instance, at a 3% risk level, a mixed-asset portfolio comprising stocks and bonds had an expected return of 0.79% whereas a mixed-asset portfolio comprising REITs, stocks, and bonds had an expected return of 0.88%. As such, the authors concluded that adding an allocation of South African REITs to a mixed-asset portfolio of South African stocks and bonds provides return-enhancement benefits.

Other studies conducted by Newell et al. (2015), Olaleye (2011), Oyedele (2014), and Oyedele et al. (2013) correspond with the results of the aforementioned studies. It must be noted, however, that the extent of the return-enhancement and risk-reduction benefits varied depending on the market in which the study was conducted. Nevertheless, it is apparent that including an allocation of REITs to a mixed-asset portfolio is highly beneficial to investors as it will result in the investor achieving a superior efficient frontier with a tangency portfolio that has a higher Sharpe ratio.

2.2.6 Advantages of investing in REITs

Despite the return-enhancement and risk-reduction benefits of including REITs in a mixed-asset portfolio, there are numerous other reasons as to why investors invest in REITs. Several authors have highlighted that the main advantages associated with investing in REITs include greater liquidity, diversification, active professional management, earnings predictability and high income payout ratios, smaller capital outlay, and access to superior quality and range of properties (Block, 2012; Francis & Ibbotson, 2001; Paolone et al., 2019; Yau et al., 2007). These advantages are described in more detail below.

2.2.6.1 Greater liquidity

Investing in REITs gives an investor the ability to gain exposure to the real estate market without assuming the liquidity risk that accompanies direct real estate investment (Block, 2012; Krewson-Kelly & Thomas, 2016). Investors can buy and sell the shares of publicly traded REITs timeously since they are publicly traded on stock exchanges. Contrarily, it can take several months or sometimes even years to buy or sell property directly. Therefore, investing in REITs allows investors to participate in real estate-based investments in a liquid manner by providing greater flexibility with regard to realising cash values and gains or losses (Paolone et al., 2019).

2.2.6.2 Diversification within the real estate market

REITs provide investors with important diversification benefits within the real estate market. By investing in diversified REITs or an array of specialised REITs, such as retail, office, industrial and residential REITs, investors can diversify their real estate portfolios by property subtype. Moreover, REITs generally own real estate in a variety of cities, provinces, and even countries allowing investors to achieve geographic diversification (Block, 2012; Francis & Ibbotson, 2001; Paolone et al., 2019; Yau et al., 2007).

2.2.6.3 Active professional management

Direct investment in real estate requires intensive real estate investment and management expertise. Investors, however, may lack the necessary skills required to make optimal real estate investment decisions and efficiently manage their properties.

Thus, investing in REITs provides investors with the benefit of having their property interests actively managed by highly skilled and experienced real estate managers (Paolone et al., 2019).

2.2.6.4 Earnings predictability and high income payout ratios

Due to the contractual nature of REITs' rental income, these companies earn a secure and stable stream of income over long periods, and therefore, the earnings predictability of REITs is higher than that of other companies (Paolone et al., 2019). Furthermore, as discussed previously, REITs are obliged to pay out most of their earnings to shareholders in the form of dividends. This characteristic enables these companies to be one of the most stable and highest yielding of all publicly traded equities (Block, 2012).

2.2.6.5 Smaller capital outlay

Direct investment in real estate requires a substantial capital outlay. For instance, investing in retail properties, such as regional malls, would require an investment outlay of billions of Rands. Most investors do not have access to the funds that are required to develop a well-diversified portfolio of direct real estate investments. Investing in REITs, on the other hand, requires a significantly smaller investment outlay since the shares of REITs can be bought inexpensively. Hence, REITs offer investors a more cost-effective way to gain access to the real estate market (Paolone et al., 2019).

2.2.6.6 Access to superior quality and range of properties

Investors may wish to include high quality properties with elegant architectural design and/or properties that are located in sought after areas in their real estate portfolios. However, properties with these types of characteristics rarely come on the market, and if they do, they are in high demand and typically overpriced. By investing in REITs that own such properties, investors can gain exposure to a range of superior quality properties (Paolone et al., 2019).

2.2.7 Disadvantages of investing in REITs

In spite of the numerous advantages associated with investing in REITs, there are a few disadvantages that need to be pointed out. Potential disadvantages of investing in REITs include less control, moderate income growth potential, reliance on debt, and higher correlation to other asset classes (Block, 2012; Harrison, Panasian, & Seiler, 2011; Paolone et al., 2019; Yau et al., 2007). These disadvantages are discussed below.

2.2.7.1 Less control

Shareholders of REITs with a minority interest have less control over property-level investment decisions compared to direct owners of real estate who have control over decisions related to property type, location, rental prices, and tenants, amongst others (Paolone et al., 2019).

2.2.7.2 Moderate income growth potential

As discussed previously, REITs are required to pay out a substantial portion of their earnings to their shareholders in the form of dividends, hence, they have a low rate of income retention. The high payout percentage restricts REITs in terms of reinvestment for future growth which tends to reduce income growth potential (Block, 2012).

2.2.7.3 Reliance on debt

Due to the high payout ratio, REITs generally rely on financial leverage to expand their real estate holdings. Additionally, REITs regularly turn to the debt market to refinance their maturing debt. The use of financial leverage increases the risk associated with investing in these types of entities (Harrison et al., 2011; Paolone et al., 2019).

2.2.7.4 Higher correlation to other asset classes

Historically, there has been a low correlation between direct real estate and other assets classes such as equities and fixed income. However, the correlation between REITs and other asset classes tends to be higher than that between direct property and other asset classes. Although REITs provide important diversification benefits, it can be said that investors could achieve better portfolio diversification benefits by investing directly in a variety of real estate compared to investing indirectly through

REITs due to the lower correlation between direct property and other asset classes (Block, 2012; Paolone et al., 2019; Yau et al., 2007).

Despite the aforementioned disadvantages, it is evident that the advantages associated with investing in REITs outweigh the disadvantages, and as such, they remain a popular investment vehicle amongst investors looking to gain exposure to the real estate market.

2.2.8 Global REIT Market

Since the first REIT legislation was enacted in the United States in 1960, the listed real estate market has become globalised over the last six decades. Many countries around the world have instated similar REIT regimes to the United States in an effort to facilitate the growth and development of their domestic real estate markets (NAREIT, 2021). According to the European Public Real Estate Association, the global REIT market had a market capitalisation of $2 252.54 billion made up of 974 REIT companies as at 2021-Q3 (Pekdemir et al., 2021). Table 2 reports the distribution of the global REIT market amongst the four main regions: Americas, Asia-Pacific, Europe, and Middle East and Africa. It is apparent that the Americas region has the most established REIT market with a market capitalisation of $1 576.17 billion (representing 69.97% of the global REIT market capitalisation) with 374 REIT companies (representing 38.40% of REIT companies globally).

Table 2: Global REIT market

Region	Market capitalisation ($ Billion)	Percentage of total market capitalisation (%)	Number of companies	Percentage of total number of companies (%)
Americas	1 576.17	69.97	374	38.40
Asia-Pacific	424.25	18.83	271	27.82
Europe	223.06	9.90	233	23.92
Middle East and Africa	29.06	1.29	96	9.86
Total	**2 252.54**	**100.00**	**974**	**100.00**

Source: Adapted from Pekdemir et al. (2021)

The REIT markets of the four main regions presented in Table 2 are analysed in more detail below.

2.2.8.1 Americas REIT market

When looking at the countries in the Americas region in Table 3, it is evident that the United States has the largest REIT market not only in this region but also globally. The United States has a market capitalisation of $1 472.48 billion (representing 65.37% of the global REIT market capitalisation) with 193 REIT companies (representing 19.82% of REIT companies globally). Although the Americas region has the largest REIT market worldwide, it is primarily attributable to the United States which contributes 93.42% to this region's REIT market capitalisation.

Table 3: Americas REIT market

Country	Market capitalisation ($ Billion)	Number of companies
Developed markets		
Canada	72.47	44
United States	1 472.48	193
Emerging markets		
Brazil	14.88	121
Mexico	16.34	16

Source: Adapted from Pekdemir et al. (2021)

2.2.8.2 Asia-Pacific REIT market

By analysing the Asia-Pacific REIT market in Table 4, it can be seen that Japan has the largest REIT market in this region and the second largest REIT market globally, albeit significantly smaller than that of the United States. Japan has a market capitalisation of $153.96 billion (representing 6.83% of the global REIT market capitalisation) with 64 REIT companies (representing 6.57% of REIT companies globally). Notably, Australia has the third largest REIT market capitalisation globally of $111.79 billion (representing 4.96% of the global REIT market capitalisation) with 40 REIT companies (representing 4.12% of REIT companies globally).

Table 4: Asia-Pacific REIT market

Country	Market capitalisation ($ Billion)	Number of companies
Developed markets		
Australia	111.79	40
Hong Kong	29.57	10
Japan	153.96	64
New Zealand	5.27	5
Singapore	74.35	33
South Korea	6.30	17
Emerging markets		
China	8.17	6
India	7.87	3
Indonesia	0.60	2
Malaysia	9.23	18
Pakistan	0.15	1
Philippines	3.46	5
Taiwan	3.47	7
Thailand	10.06	60

Source: Adapted from Pekdemir et al. (2021)

2.2.8.3 European REIT market

When looking at the countries in the European region in Table 5, it is clear that the United Kingdom has the largest REIT market in this region. The United Kingdom has a market capitalisation of $94.60 billion (representing 4.20% of the global REIT market capitalisation) with 54 REIT companies (representing 5.54% of REIT companies globally).

Table 5: European REIT market

Country	Market capitalisation ($ Billion)	Number of companies
Developed markets		
Belgium	26.23	17

France	50.40	27
Germany	5.63	7
Ireland	1.92	3
Italy	0.85	3
Netherlands	13.14	5
Portugal	0.07	2
Spain	26.93	77
United Kingdom	94.60	54
Emerging markets		
Bulgaria	0.70	34
Greece	2.59	4

Source: Adapted from Pekdemir et al. (2021)

2.2.8.4 Middle East and African REIT market

By analysing the Middle East and African REIT market in Table 6, one can see that South Africa has the largest REIT market in this region. South Africa's REIT market has a market capitalisation of $14.50 billion (representing 0.64% of the global REIT market capitalisation) with 31 REIT companies (representing 3.18% of REIT companies globally).

Table 6: Middle East and African REIT market

Country	**Market capitalisation ($ Billion)**	**Number of companies**
Developed markets		
Israel	2.77	6
Emerging markets		
Bahrain	0.04	1
Kenya	0.01	1
Kuwait	0.09	1
Nigeria	0.04	2
Oman	0.05	1
Saudi Arabia	5.11	17
South Africa	14.50	31

Turkey	6.30	34
United Arab Emirates	0.15	2

Source: Adapted from Pekdemir et al. (2021)

2.2.9 South African REIT market

As mentioned previously, South Africa has the largest REIT market in the Middle East and Africa region. Given that this study focuses on the South African REIT market, it is important to explore how the South African REIT regime was developed as well as review the regulation and taxation that South African REITs are subject to.

2.2.9.1 Development

A formalised REIT regime based on the National Association of Real Estate Investment Trusts (NAREIT) in the United States and the European Public Real Estate Association (EPRA) in Europe was introduced in South Africa on 1 April 2013 and came into effect on 1 May 2013 (SA REIT Association, 2021b). Prior to the introduction of the REIT regime, the South African listed real estate market comprised comparable investment vehicles known as Property Unit Trusts (PUTs) and Property Loan Stocks (PLSs) (Cloete, 2005). PUTs and PLSs were subject to different regulatory frameworks, however, as highlighted by National Treasury (2007), these regulatory frameworks were too restrictive which hindered the South African listed property market from competing on a global scale. As such, the South African REIT regime was introduced whereby PUTs were automatically considered to be REITs and PLSs were able to adopt the necessary regulatory framework to qualify as REITs. This allowed the South African listed real estate market to compete internationally. Since the REIT regime was introduced in South Africa, the South African REIT market has experienced considerable growth being supported by both local and international investors (SA REIT Association, 2021b).

2.2.9.2 Regulation

The listing requirements of South African REITs are regulated by the Johannesburg Stock Exchange (JSE). In addition to the normal listing rules for companies, South African REITs must also comply with further criteria detailed in Section 13 of the JSE

listing requirements. Specifically, a REIT must (i) own at least R300 million worth of property, (ii) ensure debt levels are kept below 60% of its gross asset value, (iii) earn at least 75% of its income from rental and/or property owned or investment income from indirect property ownership, (iv) adopt measures to monitor risk, (v) not unnecessarily enter into derivative instruments that are out of the ordinary course of business, and (vi) pay at least 75% of its taxable earnings available for distribution to its investors each year (JSE, 2015).

2.2.9.3 Taxation

After the JSE grants a listed entity REIT status, Section 25BB of the Income Tax Act becomes applicable to the entity (van der Zwan, 2019). Although REITs are taxpayers and submit tax returns, Section 25BB grants REITs a deduction from their income for all qualifying distributions made to shareholders. Nevertheless, distributions paid to shareholders are taxable at each shareholders' marginal income tax rate as the dividend received does not qualify for the ordinary dividend exemption provisions. Section 25BB also exempts a REIT from capital gains tax on any profit earned from the sale of a property. However, it must be noted that REIT investors are subject to capital gains tax when selling their shares of these entities (van der Zwan, 2019).

2.2.10 Asset pricing theory and macroeconomic factors impacting REIT returns

Before investigating the relationship between macroeconomic factors and REIT returns, it is imperative to have an understanding of asset pricing theory. Accordingly, an overview of the two primary theories that have been derived for the valuation of risky assets, namely the capital asset pricing model (CAPM) and the arbitrage pricing theory (APT), is provided below.

The development of the CAPM is attributed to Sharpe (1964), Lintner (1965), and Mossin (1966). The main insight of the CAPM is that investors assess the risk of an asset in respect of the asset's contribution to the systematic risk of their total portfolio. Noteworthy, systematic risk is defined as the portion of risk that is non-diversifiable and is measured as the covariance of an asset's return to the market portfolio.

Using the CAPM, the required return on an asset can be computed as follows (Pinto, Henry, Robinson, & Stowe, 2015):

$$r = R_f + \beta_i(Equity\ risk\ premium)$$

where r is the required return on an asset, R_f is the return on a risk-free asset, β_i is a measure of systematic risk, and $Equity\ risk\ premium$ is the incremental return that investors require for holding equities rather than a risk-free asset.

Important to note is that the CAPM is based on several unrealistic assumptions including that markets are in equilibrium, investors have homogenous expectations, and they pursue a mean-variance optimising objective, amongst others. Moreover, empirical tests of the CAPM have highlighted numerous anomalies that are inconsistent with the theory. For instance, Basu (1977) observed that stocks with low price-to-earnings ratios outperformed stocks with high price-to-earnings ratios, and Banz (1981) documented that portfolios of stocks with low market capitalisations outperformed portfolios of stocks with large capitalisations on a risk-adjusted basis. Additionally, Fama and French (1992) showed that stocks with high book-to-market ratios (value stocks) tend to produce larger risk-adjusted returns than stocks with low book-to-market ratios (growth stocks). Due to these and many other anomalies cited in empirical studies of the CAPM, scholars searched for an alternative asset pricing theory that was intuitive, required only limited assumptions, and accounted for various risk factors. This led to the development of a multi-factor asset pricing model known as the APT proposed by Ross (1976a, 1976b). Contrary to the CAPM which contends that the covariance of an asset's return to the market portfolio (β_i) is the only relevant risk measure, the APT contends that there are many risk factors that affect returns. APT models express the required return on an asset as follows (Pinto et al., 2015):

$$r = R_f + (Risk\ premium)_1 + (Risk\ premium)_2 + \cdots + (Risk\ premium)_k$$

where $(Risk\ premium)_i = (Factor\ sensitivity)_i \times (Factor\ risk\ premium)_i$ by which $Factor\ sensitivity$ is the asset's sensitivity to a particular factor and $Factor\ risk\ premium$ is the expected return in excess of the risk-free rate accruing to an asset with unit sensitivity to factor i and zero sensitivity to all other factors.

Examples of risk factors included in APT models include various macroeconomic factors such as economic growth, inflation, or interest rates. One of the first papers to study the impact that various macroeconomic factors have on the performance of stock returns by applying an APT model was that of N.-F. Chen, Roll, and Ross (1986). In this study, the authors analysed the impact that seven macroeconomic factors had on the performance of United States stock returns during the period 1953-1984. The goal of this study was to explore the pricing influence of exogenous macroeconomic factors so as to ascertain whether these factors were related to the underlying variables that explain pricing in the stock market. Through this analysis, it was found that five macroeconomic factors were significant in explaining expected stock returns. The most prominent macroeconomic factors included the change in the growth rate in industrial production, the change in risk premium, the change in the term structure of interest rates and, to a lesser extent, the unanticipated inflation rate and the change in expected inflation.

Expanding on the work of N.-F. Chen et al. (1986), many researchers have undertaken studies to examine whether macroeconomic factors are also useful in explaining REIT returns. These studies have predominantly been conducted in the United States, however, as the global REIT market has grown, a multitude of researchers in other regions have undertaken similar studies. Therefore, research on the influence that macroeconomic factors have on REIT returns has also been conducted in Europe, the Asia-Pacific region and, to a smaller degree, Africa. The findings of these studies suggest that economic growth, inflation, interest rates, and the stock market have a significant influence on REIT returns (Cohen & Burinskas, 2020; Ewing & Payne, 2005; Fang et al., 2016; Yunus, 2012). Furthermore, other macroeconomic factors such as money supply, industrial production growth, oil price fluctuations, government spending, and consumer spending may also have an impact on REIT returns (Bilson et al., 2001; Fatnassi et al., 2014; Loo et al., 2016; Naranjo & Ling, 1997; Razali et al., 2020).

For the purposes of this study, the most dominant macroeconomic factors that drive REIT returns, namely economic growth, inflation, interest rates, and the stock market,

are analysed. The influence that these factors have on REIT returns is expanded upon in sections 2.3 to 2.6.

2.3 ECONOMIC GROWTH

Economic growth refers to the continuous expansion in the productive capacity of an economy between two periods (Janse van Rensburg et al., 2015; Jones, 2018). Studies have shown that economic growth has a significant influence on REIT returns. Thus, this section reviews the association between economic growth and REIT returns from a theoretical perspective whereafter the most prominent empirical literature in this regard is evaluated.

2.3.1 Theoretical relationship between economic growth and REIT returns

Economic expansion typically translates into increased business activity and demand for real estate which in turn results in higher occupancy rates and rental charges. In addition, when the economy is growing, tenants' ability to pay rent improves, hence, less arrears are incurred by the lessors. Higher occupancy rates and rental charges coupled with reduced arrears leads to increased rental income which is the primary source of revenue for REITs (Paolone et al., 2019). Theoretically, it can be said that there should be a positive association between economic growth and REIT returns. The following subsection assesses various studies that have analysed the relationship between economic growth and REIT returns so as to ascertain whether this predicted positive relationship is empirically true.

2.3.2 Empirical relationship between economic growth and REIT returns

Several studies in various international REIT markets have been conducted to investigate the impact that economic growth has on REIT returns. Consistent with the theory, most authors have observed a positive relationship between these variables whereby higher economic growth translates into increased REIT returns (Liow et al., 2006; McCue & Kling, 1994; Naranjo & Ling, 1997; Razali et al., 2020; Yunus, 2012). On the other hand, a few studies have found that an increase in economic growth leads to a decrease in REIT returns in which case there is a negative relationship between economic growth and REIT returns (Cohen & Burinskas, 2020; Ewing & Payne, 2005). Some other authors have concluded that there is no relationship

between economic growth and REIT returns (Chang, Chen, & Leung, 2011; Kola & Kodongo, 2017; Loo et al., 2016). The most prevalent studies pertaining to the relationship between economic growth and REIT returns are evaluated in more detail below.

McCue and Kling (1994) explored the relationship between the macroeconomy and real estate returns in the United States by employing a vector autoregression (VAR) model to undertake forecast error variance decompositions and impulse response functions. To conduct their study, the authors made use of a dataset of United States equity REITs obtained from NAREIT as well as various macroeconomic factors for the period 1974-1991. The forecast error variance decompositions showed that economic growth explained a small proportion (9.3%) of the variation in REIT returns. Additionally, the impulse response functions revealed that REITs experienced a significant positive response to a one standard deviation shock to economic growth with the response peaking at approximately 1.25% ten months following the initial shock. Naranjo and Ling (1997) found similar results by making use of nonlinear multivariate regression techniques to identify macroeconomic factors that affected real estate returns in the United States over the period 1978-1994. The real estate return series used in this study comprised value weighted portfolios for five real estate related industries (including REITs) from the Centre for Research in Security Prices (CRSP). Using quarterly data from 1978-1994, the authors found that economic growth was a fundamental driver that positively affected REIT returns.

A positive relationship between economic growth and REIT returns was also observed in the Asian and United Kingdom REIT markets in a study conducted by Liow et al. (2006). In particular, the authors analysed the association between expected risk premia on property stocks and various macroeconomic factors in Singapore, Hong Kong, Japan, and the United Kingdom from 1986-2003. Using principal component analysis, it was found that economic growth was able to predict positive excess returns for listed property stocks in all of the markets studied. Yunus (2012) also investigated the interaction between REITs and macroeconomic factors in a multitude of markets from 1990-2007. Specifically, the sample for this study comprised the following REIT markets: United States, Canada, Japan, Australia, Germany, France, Italy, the

Netherlands, and the United Kingdom. The REIT data consisted of publicly traded real estate stock price indexes retrieved from EPRA and NAREIT whilst the macroeconomic data was obtained from the OECD's Main Economic Indicators Database and Thompson's DataStream International. Through Granger causality tests, Yunus (2012) identified that international REIT returns were driven by economic growth in the short run. Moreover, by conducting impulse response functions, it was observed that a one standard deviation shock to economic growth induced a temporary positive response in REIT returns for the overwhelming majority of the countries.

Similarly, Loo et al. (2016) analysed the relationship between Asian REIT markets and their respective macroeconomic factors. The REIT data used to conduct the study comprised the total return REIT indexes from Japan, Hong Kong, Singapore, Malaysia, Thailand, Taiwan, and South Korea from the date of availability of the data until December 2014. The authors discovered that only the Singaporean and Malaysian REIT markets were co-integrated with economic growth. Furthermore, Granger causality tests revealed that economic growth only had a significant influence on the Malaysian REIT market in the short run. For the other REIT markets, the relationship between economic growth and REIT returns was found to be statistically insignificant.

Chang et al. (2011) also found no evidence of a relationship existing between economic growth and REIT returns for a sample of REITs operating in the United States. Using quarterly data covering the period 1975-2008, the authors were able to employ a VAR model and conduct impulse response functions to analyse the relationship between numerous macroeconomic factors and REIT returns in the United States. The impulse response functions revealed that a shock to economic growth had an insignificant effect on REIT returns in the thirty months following the shock. As a result, Chang et al. (2011) concluded that the United States REIT market adjusted much faster and was more forward looking than the real economy over the period analysed. Likewise, Kola and Kodongo (2017) also found that economic growth had an insignificant effect on the returns of REITs in the United States, Bulgaria, and South Africa. To conduct their study, the authors made use of monthly data for the

period spanning 2005-2015 for the United States, 2007-2015 for Bulgaria, and 2009-2015 for South Africa. The following indexes were used as proxies for the respective REIT markets: S&P US REITs Index for the United States, SOFIA BG REIT Index for Bulgaria, and FTSE/JSE REITs Index for South Africa. By making use of the generalised method of moments model, Kola and Kodongo (2017) found that economic growth had no explanatory power on the conditional risk of returns and excess returns of the REITs in all of the markets analysed.

On the contrary, Ewing and Payne (2005) observed a negative relationship between economic growth and REIT returns. These authors undertook a study to analyse the response of the United States REIT market to changes in various macroeconomic factors. To conduct their study, the authors made use of the NAREIT Index as a proxy for the United States REIT market for the period 1980-2000. Ewing and Payne (2005) estimated a VAR model and undertook impulse response functions to examine how long and to what degree REIT returns reacted to unanticipated changes in several macroeconomic factors. The results indicated that the response of the REIT market to an unanticipated increase in economic growth was insignificant in the first month following the shock. Thereafter, REIT returns became negative and significant from the second to seventh month. Accordingly, the authors concluded that an unexpected increase in economic growth had no immediate effect of REIT returns. However, in the months to follow, an increase in economic growth put pressure on the economy's capacity to produce and exacerbated inflation expectations which in turn caused REIT returns to fall.

Despite the aforementioned conflicting findings, it is evident that previous studies have primarily observed a significant positive relationship between economic growth and REIT returns implying that an increase in economic growth results in higher REIT returns. This observed positive relationship is in accordance with what the theory predicts.

2.4 INFLATION

Inflation can be defined as the percentage change in an economy's overall price level. When inflation occurs, the purchasing power of an economy's currency declines

because each unit of currency will buy fewer goods and services than it did in the prior period (Janse van Rensburg et al., 2015; Jones, 2018). Many researchers have observed that inflation has a statistically significant influence on REIT returns. Therefore, this section provides a theoretical overview of this association after which the empirical relationship between inflation and REIT returns is investigated.

2.4.1 Theoretical relationship between inflation and REIT returns

Real estate prices tend to rise when the overall price level increases, however, this is not necessarily the case for rental rates. REITs that enter into short-term leases have the ability to adjust their rental rates in accordance with the prevailing inflation rate, and as such, inflationary pressure is less of a concern for these REITs (Paolone et al., 2019). On the other hand, REITs that own and manage properties that are characterised by long-term leases will be more affected by inflation. Although these long-term lease agreements include annual rental escalations to account for inflation, they are usually based on recent inflation rates. Hence, should the inflation rate be higher than what was expected, the inflation-adjusted value of the rental income may decrease overtime which will have a negative impact on the operating performance of REITs (Paolone et al., 2019). From a theoretical perspective, one could postulate that inflation could either have a positive or negative impact on REIT returns depending on the level of inflation risk that the REIT is exposed to. Numerous studies are analysed in the following subsection to determine the empirical relationship between inflation and REIT returns.

2.4.2 Empirical relationship between inflation and REIT returns

A multitude of studies have been undertaken to understand the relationship between inflation and REIT returns. The majority of these studies have found that there is a negative relationship between these variables which infers that a rise in inflation leads to a decrease in REIT returns (Adrangi, Chatrath, & Raffiee, 2004; Ewing & Payne, 2005; Fang et al., 2016; Patterson, 2009; Sukor, Sujak, & Noordin, 2020). For example, Adrangi et al. (2004) conducted a study to establish the long-run relationship between inflation and United States REIT returns. The data used to conduct the study was obtained from NAREIT and the International Monetary Fund for the 27-year period spanning 1972-1999. Regression analyses and cointegration tests revealed that there

was a negative relationship between inflation and REIT returns. Accordingly, the authors concluded that REITs do not provide an inflation hedge. Similar findings were found by Ewing and Payne (2005) who analysed the response of the United States REIT market to changes in various macroeconomic factors as discussed previously in section 2.3.2. By conducting impulse response functions, it was found that REIT returns responded negatively to a one standard deviation shock to inflation. Moreover, the negative response remained significant for two months following the initial shock. Thus, the results indicated that inflation lead to lower expected returns for REITs.

Patterson (2009) also evaluated the impact of several macroeconomic factors on the United States REIT market with specific emphasis on the retail, office, residential, and industrial REIT property subtypes. In this study, the author made use of monthly REIT return and macroeconomic data over the period 1989-2006 which was obtained from the CRSP and the Federal Reserve Bank of St. Louis Economic Database. The estimated VAR models revealed that there was a statistically significant relationship between inflation and the retail and office REITs whereas the relationship was found to be statistically insignificant for the residential and industrial REITs. By conducting impulse response functions on the statistically significant relationships, it was found that a one standard deviation change in inflation resulted in negative reactions from both the retail and office REITs. Specifically, office REITs displayed a sharp negative reaction in the first month but recovered fully within four months of the initial inflation shock. Contrarily, retail REITs displayed a small negative reaction in the first month which became increasingly more negative in the second month. These retail REITs did not fully recover within 12 months of the initial inflation shock.

There is also evidence that has been published from the Asian region showing that there is a significant negative relationship between inflation and REIT returns. For instance, Fang et al. (2016) undertook a study to examine the impact of macroeconomic factors on REIT returns in Japan, Singapore, and China. In order to do such, the authors made use of monthly return and macroeconomic data from 2008-2012 which was acquired from DataStream. By estimating an autoregressive distributed lag model and an error correction model, the authors established that a significant negative relationship existed between inflation and REIT returns in all three

countries. In addition, Granger non-causality tests demonstrated that there was a unidirectional relationship between inflation and REIT returns in which inflation movements caused REIT index changes in Japan and Singapore. Similar results were obtained in a study conducted by Sukor et al. (2020). These authors investigated the return and dividend characteristics of Malaysian REITs against various macroeconomic factors for the period 2011-2017. Using ordinary least squares regression, the authors found that for most of the REITs analysed, there was a negative relationship between their price index return and inflation although this relationship was found to be statistically insignificant. Furthermore, the authors found that there was a significant negative relationship between inflation and the dividend yield of the majority of the REITs analysed.

In spite of the aforementioned studies predominantly finding a negative relationship between inflation and REIT returns, Simpson, Ramchander, and Webb (2007) identified a positive association between REIT returns in the United States and increases in inflation. In this study, the authors analysed the relationship between 195 publicly traded REIT returns and changes in expected and unexpected inflation over the period 1981-2002. By applying pooled estimation methodology, the authors found that REIT returns exhibited a significant positive relationship with expected and unexpected increases in inflation whereas they had a significant negative relationship with expected and unexpected decreases in inflation. Therefore, the authors concluded that REIT returns rose in response to both increases and decreases in expected and unexpected inflation.

In contrast to the studies described above that report a statistically significant relationship between inflation and REIT returns, a number of authors have discovered that inflation does not have a statistically significant influence on REIT returns (Chatrath & Liang, 1998; S.-J. Chen, Hsieh, Vines, & Chiou, 1998; S.-J. Chen, Hsieh, & Jordan, 1997; Olanrele et al., 2020). One such study is that of Chatrath and Liang (1998) who investigated whether REITs provide an inflation hedge in the long-run. To conduct their study, the authors made use of monthly and quarterly data for equity, mortgage, and hybrid REITs in the United States along with inflation proxies for the period 1972-1995. By undertaking regression analyses and cointegration tests, it was

observed that there was no evident relationship between inflation and REIT returns. In an African context, Olanrele et al. (2020) examined the causal effect of various macroeconomic factors on the dividend return performance of the Nigerian REITs Index. In order to do such, the authors employed quarterly data for the period 2008-2017 and estimated an autoregressive distributed lag model as well as an error correction model. The study revealed that inflation did not have a direct causal effect on REIT returns both in the short run and long run.

Although some authors have identified that inflation does not influence REIT returns, the overwhelming majority of studies provide evidence to suggest that there is a significant negative relationship between inflation and REIT returns. This suggests that an increase in inflation results in a decrease in REIT returns.

2.5 INTEREST RATES

Interest is the payment by a borrower to a lender for the use of funds, hence, the interest rate is defined as the amount of interest payable over a certain period and is measured as a percentage of the amount borrowed (Jones, 2018; Riley & Brown, 2015). It is important to distinguish between money market and capital market interest rates. The former is associated with lending and borrowing short-term financial instruments with a maturity of six months or less whereas the latter is associated with lending and borrowing long-term financial instruments with a maturity of more than six months (Choudhry & Wilcox, 2019). Many studies published in the last few decades have reported that interest rates have a significant impact on REIT returns. Consequently, this section analyses the theoretical as well as the empirical relationship between interest rates and REIT returns.

2.5.1 Theoretical relationship between interest rates and REIT returns

As mentioned previously, it is mandatory for REITs to pay out the majority of their earnings in the form of dividends which means that they have to rely on the debt market to expand their business (Harrison et al., 2011; Paolone et al., 2019). This high reliance on borrowings implies that REITs are sensitive to interest rates. When interest rates rise, the cost of debt increases whereby REITs incur higher interest expenses which negatively affects their profitability (Paolone et al., 2019). Therefore, the theory

predicts that there should be a negative relationship between interest rates and REIT returns. The following section assesses relevant studies to determine whether the theory is supported empirically.

2.5.2 Empirical relationship between interest rates and REIT returns

Numerous studies have been conducted to examine the impact that interest rates have on REIT returns. Although these studies were conducted in different markets around the globe and used a variety of interest rate proxies, they primarily observed a negative relationship between interest rates and REIT returns (Brooks & Tsolacos, 1999; K. Chen & Tzang, 1988; Liow & Huang, 2006; Mueller & Pauley, 1995). This suggests that higher interest rates result in lower REIT returns. The most noteworthy studies are examined below.

K. Chen and Tzang (1988) undertook a study to determine whether REITs in the United States were sensitive to movements in short-term and long-term interest rates over the period 1983-1985. In order to do such, the authors collected data on all equity and mortgage REITs listed on the NYSE and AMEX over the period of analysis. As a result of the Federal Reserve changing its policy orientation in 1979 from interest rate targeting toward money supply targeting, the authors divided the sample period into two subperiods being 1973-1979 and 1980-1985. The proxy used for long-term interest rates was the twenty-year United States government bond yield and the three proxies used for short-term interest rates included the yields on the three-month, six-month, and one-year United States Treasury Bills. Using the intertemporal CAPM as a base model to conduct their study, K. Chen and Tzang (1988) found that during the first subperiod (1973-1979), REITs were only sensitive to changes in long-term interest rates, however, during the second subperiod (1980-1985), REITs were sensitive to changes in both long-term and short-term interest rates. The authors posited that the differences in the findings of the two sub-periods was attributed to the change in the Federal Reserve's policy orientation. Nevertheless, it is important to highlight that the changes in interest rates had a negative impact on the return-generating process of REITs.

Mueller and Pauley (1995) also found that interest rates were negatively related to REIT returns in the United States over the period 1972-1993. These authors analysed the correlation between changes in interest rates and changes in the NAREIT Price Index as well as the Wilshire Real Estate Index (which includes equity REITs and publicly traded real estate operating companies). The authors results indicated that the NAREIT Price Index had a low negative correlation with interest rate movements over the period analysed. This relationship was statistically significant for short-term, medium-term, and long-term interest rates. Statistically significant correlations that were low and negative was also found between the Wilshire Real Estate Index and interest rate movements. To further analyse the aforementioned association, Mueller and Pauley (1995) conducted a regression analysis in which interest rate changes were regressed on the REIT price changes. The regression analysis revealed similar results to the previous correlation analysis which led the authors to conclude that rising interest rates had a minor negative effect on REIT prices over the analysed period.

Studies analysing the relationship between interest rates and REIT returns have also been undertaken in the United Kingdom. One of these studies is that of Brooks and Tsolacos (1999) who investigated the impact of macroeconomic factors on the listed property market in the United Kingdom for the period 1985-1998. The authors employed a VAR model to undertake forecast error variance decompositions and impulse response functions. The real estate return series used to conduct the study was the FTSE Property Total Return Index. The three-month Treasury Bill rate was used as a proxy for the nominal short-term interest rate whilst the difference between the three-month Treasury Bill rate and the yield on twenty-year United Kingdom gilts was used as a proxy for the interest rate spread. The forecast error variance decompositions showed that changes in short-term interest rates and the interest rate spread explained approximately 6.3-8.2% and 36.2-38% of the variation in the real estate return series two years after the change in interest rates. Moreover, the impulse response functions revealed that a one standard deviation shock to the interest rate spread had a negative impact on the real estate market that became stronger in the twenty-four months following the increase. Likewise, a shock to the short-term interest rate had a negative impact on the real estate market in the six months following the

initial shock, however, the effect reversed and became positive, albeit weak, from the seventh to twenty-fourth month following the initial shock.

More recently, Liow and Huang (2006) employed a generalised autoregressive conditional heteroskedasticity (GARCH) in mean model to analyse whether interest rates affected the excess returns of the listed property markets in Hong Kong, Japan, Singapore, and the United Kingdom from 1987-2003. The following monthly property price indexes from DataStream were used as proxies for the respective listed property markets: Hang Seng Property Index for Hong Kong, Tokyo SE Real Estate Index for Japan, Singapore All-Equity Property Index for Singapore, and the Financial Times Real Estate Index for the United Kingdom. Through their analysis, the authors found that the effect of changes in long-term interest rates on the excess returns of the listed property markets was negative in all three countries although it was only statistically significant in the United Kingdom. Additionally, the effect of changes in short-term interest rates on the excess returns of the listed property markets was negative in Hong Kong, Japan, and Singapore whereas it was positive in the United Kingdom, however, it was only statistically significant in Japan. Given these findings, Liow and Huang (2006) concluded that property stocks were generally sensitive to changes in long-term and short-term interest rates.

Razali et al. (2020) also employed a GARCH model to consider the effect of macroeconomic factors on the return volatility of Malaysian REITs for the 8-year period spanning 2010-2017. The data used in this study included the quarterly total return index of listed REITs in Malaysia and the base lending rate was used as a proxy for interest rates. The results from the GARCH model led the authors to conclude that interest rates played a significant role in the return volatility of Malaysian REITs over the period analysed. Similar results have been observed in studies published from the Australian REIT market. For instance, West and Worthington (2006) employed a GARCH model to consider the effect of macroeconomic factors on Australian property returns over the period 1985-2002. The authors used a listed property trust index (which is equivalent to REITs) as well as a property stock index as indicators of property market performance. Short-, medium-, and long-term interest rates were proxied by the price indexes of the Reserve Bank of Australia's 90-day Bank-Accepted

Bill, 5-year Commonwealth Bond, and 10-year Commonwealth Bond. The results from the GARCH model showed that interest rates were significant risk factors in Australian commercial property returns.

Reddy and Wong (2018) also found that interest rates had a significant impact on the return generating process of Australian REITs over the period 1995-2016. The goal of this study was to explore the relationship between interest rates and different Australian REIT sectors including diversified, specialised, retail, office, and industrial REITs. The yield on the 90-day Bank Bill and the 10-year government bond yield were used as proxies for short-term and long-term interest rates respectively. Using the CAPM methodology, the authors found that diversified and retail REITs exhibited a strong relationship with interest rates whereby an increase in short-term interest rates contributed positively to returns whereas rising long-term interest rates contributed negatively to returns. A possible explanation for these results is that increasing short-term interest rates may be indicative of an economy that is in the expansionary phase of the business cycle as central banks tend to raise interest rates during these periods in order to reduce inflation. On the other hand, the performance of specialised, office, and industrial REITs was not well explained by the asset pricing model. Overall, the authors concluded that interest rates played a significant role in the return generating process of Australian REITs over the period of analysis.

In summary, the aforementioned studies provide evidence to suggest that there is a statistically significant negative relationship between interest rates and REIT returns. This negative relationship is consistent with what the theory suggests.

2.6 STOCK MARKET

The stock market comprises exchanges and over-the-counter markets where shares and other financial instruments of public companies are issued and traded (Faure, 2015). Authors have highlighted that a significant relationship exists between stock market returns and REIT returns. As such, this section evaluates the theoretical relationship between the stock market and REIT returns whereafter notable literature on the empirical relationship between these variables is reviewed.

2.6.1 Theoretical relationship between the stock market and REIT returns

The percentage of an investor's portfolio that is allocated to stocks is directly impacted by stock performance. Particularly, when stocks earn a positive return and outperform the other asset classes in an investor's portfolio, the asset allocation to stocks increases since they will represent a larger proportion of the total portfolio. To keep in line with the strategic asset allocation, the investor will have to rebalance their portfolio by reducing their allocation to stocks (Arnott, Burns, Plaxco, & Moore, 2007). This can be achieved by selling a portion of their stocks and investing the proceeds in other asset classes such as real estate. The performance of REITs may be positively impacted if investors reallocate their funds to the real estate market (Liu & Su, 2010). Therefore, from a theoretical perspective, it can be said that an increase in stock market returns may have a positive influence on REIT returns.

2.6.2 Empirical relationship between the stock market and REIT returns

A number of studies have investigated the relationship between various stock market returns and REIT returns. The results of these studies are consistent and indicate that a positive relationship exists between these variables (Allen, Madura, & Springer, 2000; Fang et al., 2016; Laopodis, 2009; Liu & Su, 2010; Okunev, Wilson, & Zurbruegg, 2000, 2002; Payne, 2003). This positive relationship implies that a rise in stock market returns results in higher REIT returns. Important studies analysing this association are assessed below.

Allen et al. (2000) conducted a study to evaluate the sensitivity of REIT returns to stock market and interest rate changes in the United States. The data used in this study comprised the monthly returns of 46 publicly traded equity and non-equity REITs as well as the return of the S&P 500 Index for the period spanning 1992-1996. Using the seemingly unrelated regression framework, the authors found that there was an insignificant relationship between changes in stock market returns and equity REIT returns. On the contrary, the authors discovered that a positive significant relationship existed between changes in stock market returns and non-equity REIT returns.

Another study that observed a positive association between the United States stock market and REIT returns is that of Payne (2003). This author examined the impact

that macroeconomic factors had on the excess returns of equity, mortgage, and hybrid REITs in the United States from 1981-2003. The excess returns of the respective REITs were computed by subtracting the one-month United States Treasury Bill rate from the REIT returns. Similarly, the excess returns of the stock market was calculated by subtracting the one-month United States Treasury Bill rate from the returns of the S&P 500 Index. The aforementioned data required to conduct this study was obtained from the NAREIT and the Federal Reserve Bank of St. Louis Economic Database. Following the estimation of VAR models, generalised impulse response functions were undertaken which revealed that a shock to the excess return of the stock market induced a positive response in excess REIT returns for the three types of REITs.

Laopodis (2009) also undertook a study to investigate the association between REITs, the stock market, and economic activity in the United States for the period spanning 1971-2007. The author employed a VAR model to conduct forecast error variance decompositions and impulse response functions. The results from the forecast error variance decompositions indicated that the stock market explained a small percentage (6%) of the variation in REIT returns. Furthermore, the impulse response functions showed that a shock to the stock market had a positive impact on REIT returns. Similar findings were found in the Asian REIT market by Fang et al. (2016) who analysed the influence that macroeconomic factors had on REIT returns in Japan, Singapore, and China as discussed previously in section 2.4.2. By estimating an autoregressive distributed lag model and an error correction model, the authors found that there was a significant positive relationship between the stock market and REIT returns in all three countries. Moreover, Granger non-causality tests revealed that there was a significant unidirectional relationship between the stock market and REIT returns in which stock market movements caused REIT index changes in Singapore.

Several other authors have also employed Granger causality tests to analyse the relationship between stock market returns and REIT returns. For example, Okunev et al. (2000) examined the association between the United States real estate market and the stock market during the period 1972-1998. In order to do such, the authors conducted linear and non-linear Granger causality tests. The linear causality tests revealed that there was a unidirectional relationship from the real estate market to the

stock market whereas the non-linear causality tests identified that there was a strong unidirectional relationship from the stock market to the real estate market. The authors suggested that a possible reason for the inconsistent results obtained from the linear causality tests is that there may have been structural breaks in the time series and that there may be a nonlinear cointegrating relationship between the real estate and stock markets. Nevertheless, Okunev et al. (2000) concluded that returns in the real estate market were influenced and determined by the stock market, however, the nonlinear relationship infers that it may be challenging to forecast REIT returns from stock market behaviour.

Okunev et al. (2002) undertook a similar study to Okunev et al. (2000) in order to explore the relationship between the Australian real estate market and the stock market from 1980-1999. Both the linear and non-linear causality tests conducted by the authors revealed that there was a strong unidirectional relationship from the stock market to the real estate market. Comparable results were reported by Liu and Su (2010) who analysed the association between the real estate market and stock market in China. In this study, the authors made use of monthly data for the period 1996-2008 which was obtained from the China National Bureau of Statistics and the Taiwan Economic Journal. The authors conducted Granger causality tests and found that there was a short-run unidirectional relationship from the stock market to the real estate market.

Evidently, the studies mentioned above observed a significant positive association between stock market returns and REIT returns whereby an increase in stock market returns translates into higher REIT returns. This positive relationship is in line with what the theory posits.

2.7 SUMMARY

REITs have become increasingly important over the past six decades with many investors including these investment vehicles in their portfolios to gain access to real estate markets around the world. As such, this chapter outlined the key features of REITs including an explanation of what they are, the historical development of REITs, the various types of REITs, and the different REIT property subtypes. This chapter

further highlighted the importance of REITs by examining how these investment vehicles fit into a mixed-asset portfolio as well as the advantages and disadvantages associated with investing in REITs. Following this, the REIT markets of the four main global regions were reviewed. Given that this study focuses on analysing South African REITs, an overview of the South African REIT market was also provided.

With the aforementioned background of REITs, asset pricing theory and the influence of macroeconomic factors on REIT returns was discussed. In particular, empirical studies on the four main macroeconomic factors that have been found to significantly influence REIT returns, namely economic growth, inflation, interest rates, and the stock market, were evaluated. This prior literature has primarily reported that REIT returns are positively related to economic growth and stock market returns. Contrarily, previous studies have predominantly observed that inflation and interest rates negatively impact REIT returns.

CHAPTER 3 – RESEARCH METHOD

3.1 INTRODUCTION

The purpose of this chapter is to explain the methodological processes used to conduct this study. In time series analysis, the two primary models used to estimate and evaluate the relationship between multiple variables over time include vector autoregression (VAR) models and vector error correction models (VECMs). Sections 3.2 and 3.3 expound on these respective time series models. Thereafter, the data required to conduct this study and the way in which it is obtained is discussed in section 3.4. Subsequently, the research method limitations are noted in section 3.5 whereafter a summary concludes the chapter in section 3.6.

3.2 VECTOR AUTOREGRESSION MODELS

As was evident in the literature review, VAR models have been a popular research method adopted by many prior researchers who examined the influence that macroeconomic factors have on real estate investment trust (REIT) returns. Amongst the authors that employed the VAR methodology include Brooks and Tsolacos (1999), Chang et al. (2011), Ewing and Payne (2005), Laopodis (2009), McCue and Kling (1994), Patterson (2009), Payne (2003), and Yunus (2012). Similar to these studies, the present study also makes use of VAR models to analyse the impact that macroeconomic factors have on the returns of South African REITs. As such, this section explores key aspects relating to VAR models including the structural form and reduced form representations of the VAR model as well the identification of VAR models using short-run restrictions. Following this, model specification and model checking tests are elaborated on. Additionally, this section explores the uses of VAR models including impulse response functions, forecast error variance decompositions, and Granger causality analysis.

3.2.1 What is a vector autoregression model?

The VAR model is a stationary multivariate linear time series model that was introduced by Sims (1980) as an alternative method to large-scale macroeconometric models such as the Keynesian model. VAR models could be employed by

macroeconomists to characterise the joint dynamic behaviour of multiple variables without having to impose strong restrictions as was the case with the econometric modelling that was done at the time (Sims, 1980). VAR models have now become a widespread method of time series modelling used in finance and econometrics (Bjørnland & Thorsrud, 2015; Enders, 2014; Kilian, 2013).

3.2.2 Structural form representation of the VAR model

A VAR model comprises a set of n stationary time series variables $(y_{1,t}, \dots, y_{n,t})$ which are each expressed as a linear function of p lags of itself and of all the other variables plus an error term (Enders, 2014; Lütkepohl, 2004). For example, consider the simplest case which is a bivariate VAR(1) model comprising two variables ($y_{1,t}$ and $y_{2,t}$) and one lag of each of the variables. This model consists of the following covariance stationary, bivariate, dynamic simultaneous equations:

$$y_{1,t} = \gamma_{10} - b_{12}y_{2,t} + \gamma_{11}y_{1,t-1} + \gamma_{12}y_{2,t-1} + \epsilon_{1,t}$$
$$y_{2,t} = \gamma_{20} - b_{21}y_{1,t} + \gamma_{21}y_{1,t-1} + \gamma_{22}y_{2,t-1} + \epsilon_{2,t}$$

where $t = 1, \dots, T$, there are fixed initial values for y_0, and $\binom{\epsilon_{1,t}}{\epsilon_{2,t}} \sim IID\left[\binom{0}{0}, \begin{pmatrix}\sigma_1^2 & 0\\ 0 & \sigma_2^2\end{pmatrix}\right]$.

Using matrix algebra, the bivariate VAR(1) model can be expressed as:

$$\begin{bmatrix}1 & b_{12}\\ b_{21} & 1\end{bmatrix}\begin{bmatrix}y_{1,t}\\ y_{2,t}\end{bmatrix} = \begin{bmatrix}\gamma_{10}\\ \gamma_{20}\end{bmatrix} + \begin{bmatrix}\gamma_{11} & \gamma_{12}\\ \gamma_{21} & \gamma_{22}\end{bmatrix}\begin{bmatrix}y_{1,t-1}\\ y_{2,t-1}\end{bmatrix} + \begin{bmatrix}\epsilon_{1,t}\\ \epsilon_{2,t}\end{bmatrix}$$

or:

$$BY_t = \Gamma_0 + \Gamma_1 Y_{t-1} + \epsilon_t$$

where $B = \begin{bmatrix}1 & b_{12}\\ b_{21} & 1\end{bmatrix}$, $Y_t = \begin{bmatrix}y_{1,t}\\ y_{2,t}\end{bmatrix}$, $\Gamma_0 = \begin{bmatrix}\gamma_{10}\\ \gamma_{20}\end{bmatrix}$, $\Gamma_1 = \begin{bmatrix}\gamma_{11} & \gamma_{12}\\ \gamma_{21} & \gamma_{22}\end{bmatrix}$, $Y_{t-1} = \begin{bmatrix}y_{1,t-1}\\ y_{2,t-1}\end{bmatrix}$, and $\epsilon_t = \begin{bmatrix}\epsilon_{1,t}\\ \epsilon_{2,t}\end{bmatrix}$.

Noteworthy features of the bivariate VAR(1) model in the structural form include (Bjørnland & Thorsrud, 2015; Enders, 2014):

- The realisations of the ϵ_t's are uncorrelated, and thus, orthogonal.

- The ϵ_t's can be interpreted as structural innovations which have economic meaning.
- There is feedback in the system since $y_{1,t}$ has a contemporaneous impact on $y_{2,t}$ and vice versa.
- Due to there being feedback in the system, the equations cannot be estimated directly by ordinary least squares (OLS) because these OLS estimates will suffer from simultaneous equation bias.
- There are ten parameters that need to be estimated in the structural form bivariate VAR(1) model (count the parameters in $B, \Gamma_0, \Gamma_1,$ and D).

3.2.3 Reduced form representation of the VAR model

Considering that the structural form VAR model cannot be estimated directly by OLS, it is necessary to estimate the reduced form VAR model (Bjørnland & Thorsrud, 2015; Enders, 2014). To derive the reduced form VAR model, the structural form VAR model is multiplied by B^{-1} as follows:

$$B^{-1}BY_t = B^{-1}\Gamma_0 + B^{-1}\Gamma_1 Y_{t-1} + B^{-1}\epsilon_t$$

so:

$$Y_t = \mathrm{A}_0 + \mathrm{A}_1 Y_{t-1} + e_t$$

where

$$\mathrm{A}_0 = B^{-1}\Gamma_0 = \frac{1}{1-b_{12}b_{21}}\begin{bmatrix}\gamma_{10} - b_{12}\gamma_{20}\\ \gamma_{20} - b_{21}\gamma_{10}\end{bmatrix} = \begin{bmatrix}a_{10}\\ a_{20}\end{bmatrix},$$

$$\mathrm{A}_1 = B^{-1}\Gamma_1 = \frac{1}{1-b_{12}b_{21}}\begin{bmatrix}\gamma_{11} - b_{12}\gamma_{21} & \gamma_{12} - b_{12}\gamma_{22}\\ \gamma_{21} - b_{21}\gamma_{11} & \gamma_{22} - b_{21}\gamma_{12}\end{bmatrix} = \begin{bmatrix}a_{11} & a_{12}\\ a_{21} & a_{22}\end{bmatrix}, \text{ and}$$

$$e_t = B^{-1}\epsilon_t = \frac{1}{1-b_{12}b_{21}}\begin{bmatrix}\epsilon_{1,t} - b_{12}\epsilon_{2,t}\\ \epsilon_{2,t} - b_{21}\epsilon_{1,t}\end{bmatrix} = \begin{bmatrix}e_{1,t}\\ e_{2,t}\end{bmatrix}.$$

Alternatively, the reduced form bivariate VAR(1) model can be expressed as a system of equations:

$$y_{1,t} = a_{10} + a_{11}y_{1,t-1} + a_{12}y_{2,t-1} + e_{1,t}$$
$$y_{2,t} = a_{20} + a_{21}y_{1,t-1} + a_{22}y_{2,t-1} + e_{2,t}$$

The covariance matrix of the reduced form errors is denoted as:

$$E[e_t e_t'] = (B^{-1})D(B^{-1})' = \Omega = \begin{bmatrix} \omega_1^2 & \omega_{12} \\ \omega_{21} & \omega_2^2 \end{bmatrix}$$

Important features of the bivariate VAR(1) model in the reduced form include (Bjørnland & Thorsrud, 2015; Enders, 2014):

- The reduced form errors e_t are linear combinations of the structural form errors ϵ_t. For example, $e_{1,t} = \frac{\epsilon_{1,t} - b_{12}\epsilon_{2,t}}{1 - b_{12}b_{21}}$ whereby $e_{1,t}$ is a linear combination of $\epsilon_{1,t}$ and $\epsilon_{2,t}$.
- The reduced form errors e_t do not have economic interpretation.
- There is no feedback effect in the reduced form VAR model because $y_{1,t}$ is impacted by $y_{2,t-1}$ (instead of $y_{2,t}$ as is the case in the structural form), and $y_{2,t}$ is impacted by $y_{1,t-1}$ (instead of $y_{1,t}$ as is the case in the structural form).
- Since there is no feedback in the system, the reduced form VAR model can be consistently and efficiently estimated by OLS.
- There are nine parameters that need to be estimated in the reduced form bivariate VAR(1) model (count the number of parameters in A_0, A_1, and Ω).

3.2.4 Identification using short-run restrictions

As highlighted in section 3.2.3, the reduced form errors e_t are likely to be correlated since they are linear combinations of the structural form errors ϵ_t. Therefore, a shock in one variable is likely to be accompanied by a shock in another variable, hence, statistical inference is unable to be undertaken on the reduced form VAR model. As such, it is necessary to undertake statistical inference on the structural form VAR model whereby the ϵ_t's are uncorrelated, and thus, orthogonal (Bjørnland & Thorsrud, 2015). However, the number of parameters that need to be estimated in the structural form VAR model differ from that in the reduced form VAR model. Consequently, it is impossible to identify the reduced form VAR model from the structural form VAR model unless restrictions are placed on the structural parameters.

As proposed by Sims (1980), the number of restrictions required and the way in which they need to be imposed can be identified using a recursive approach known as the

Cholesky decomposition. To illustrate this process, the reduced form bivariate VAR(1) model introduced previously is employed:

$$Y_t = \mathrm{A}_0 + \mathrm{A}_1 Y_{t-1} + e_t$$

This can be written more compactly as:

$$A(L)Y_t = \mathrm{A}_0 + e_t$$

where $A(L)$ is the lag polynomial and is equal to $(I - A_1 L)$.

To obtain the infinite order vector moving average VMA(∞) representation of the VAR model, the equation above is multiplied by $A(L)^{-1} = (I - A_1 L)^{-1}$ as follows:

$$\begin{aligned} Y_t &= (I - A_1 L)^{-1}\mathrm{A}_0 + (I - A_1 L)^{-1} e_t \\ &= \mu + \psi(L) e_t \\ &= \mu + \sum_{j=0}^{\infty} \psi(L)_j \, e_{t-j} \\ &= \mu + e_t + \psi_1 e_{t-1} + \psi_2 e_{t-2} + \cdots \end{aligned}$$

where $\psi(L) = A(L)^{-1}$, and since $A_0 = I$, then $\psi_0 = I$.

The easiest and most favoured way to orthogonalize the correlated reduced form errors is through the Cholesky decomposition (Bjørnland & Thorsrud, 2015). The Cholesky decomposition is derived from matrix algebra and states that any positive definite symmetric matrix can be written as the product of a lower triangular matrix and its conjugate transpose:

$$\Omega = E[e_t e_t'] = PP'$$

where P is the lower triangular matrix with positive diagonal elements and zeros above the diagonal, and P' is its conjugate transpose.

For the bivariate VAR(1) model, the matrix P can be written in expanded form:

$$P = \begin{bmatrix} p_{11} & 0 \\ p_{21} & p_{22} \end{bmatrix}$$

Therefore, according to the Cholesky decomposition, for a bivariate VAR(1) model, there is one zero above the diagonal which implies that one restriction must be imposed on the reduced form VAR model. Using this, the VMA(∞) representation of the VAR model can be multiplied by P and its inverse ($PP^{-1} = I$) to yield the following equation:

$$Y_t = \mu + \sum_{j=0}^{\infty} \psi_j \, e_{t-j}$$

$$= \mu + \sum_{j=0}^{\infty} \psi_j \, PP^{-1} e_{t-j}$$

$$= \mu + \sum_{j=0}^{\infty} C_j \, \nu_{t-j}$$

where $C_j = \psi_j P$, and $\nu_t = P^{-1} e_t$.

Important to highlight is that the components of ν_t are uncorrelated and have unit variance:

$$E[\nu_t \nu_t{}'] = E[(P^{-1}) e_t e_t{}' (P^{-1})'] = (P^{-1}) E[e_t e_t{}'] (P^{-1})'$$
$$= (P^{-1})(PP')(P^{-1})' = I$$

Accordingly, the VMA(∞) representation of the bivariate VAR model can be rewritten as follows:

$$\begin{bmatrix} y_{1,t} \\ y_{2,t} \end{bmatrix} = \begin{bmatrix} \mu_1 \\ \mu_2 \end{bmatrix} + \begin{bmatrix} c_{0,11} & 0 \\ c_{0,21} & c_{0,22} \end{bmatrix} \begin{bmatrix} \nu_{1,t} \\ \nu_{2,t} \end{bmatrix} + C_1 \nu_{t-1} + C_2 \nu_{t-2} + \cdots$$

or, since $\psi_0 = I \Rightarrow C_0 = P$, and $C_j = \psi_j P$, it can be written as:

$$\begin{bmatrix} y_{1,t} \\ y_{2,t} \end{bmatrix} = \begin{bmatrix} \mu_1 \\ \mu_2 \end{bmatrix} + \begin{bmatrix} p_{11} & 0 \\ p_{21} & p_{22} \end{bmatrix} \begin{bmatrix} \nu_{1,t} \\ \nu_{2,t} \end{bmatrix} + \psi_1 P \nu_{t-1} + \psi_2 P \nu_{t-2} + \cdots$$

The second shock $\nu_{2,t}$ does not affect the first variable $y_{1,t}$ contemporaneously, while both shocks can affect the second variable contemporaneously. However, after one period ($j \geq 1$), no further restrictions are in place, hence, both shocks are free to affect

both variables. As a result, by making use of the Cholesky decomposition, the reduced form errors have been orthogonalized so that statistical inference can be conducted.

3.2.5 Model specification and model checking

As mentioned previously, the aforementioned VAR models are structured so that each stationary time series variable in the system is a linear function of past lags of itself and of all the other variables. Thus, prior to specifying a VAR model, unit root tests need to be run on each of the time series variables to ensure stationarity. Thereafter, it is necessary to select a lag order so that an appropriate VAR(p) model can be estimated. Once a VAR model has been specified, a series of statistical tests for stability and diagnostic purposes need to be conducted to ensure that the estimated VAR model provides an accurate representation of the data generating process underlying the time series variables (Lütkepohl, 2004). These model specification and model checking tests are detailed below.

3.2.5.1 Unit root tests

A time series y_t is covariance stationary if it has a constant and finite expected value, a constant and finite variance, and the covariance of the time series with itself is constant and finite (DeFusco, McLeavey, Pinto, & Runkle, 2015a). If a time series is not covariance stationary but can be transformed into a stationary process by differencing the series, it is said to be difference stationary. A time series that is difference stationary is known as an integrated process. The number of times that the time series needs to be differenced, say d, before it is made into a stationary process is called the order of integration of the process and is written as $y_t \sim I(d)$ (Pesaran, 2015). Unit root tests can be conducted to test the stationarity of a time series. In this study, the Augmented Dickey-Fuller (ADF) and the Dickey-Fuller generalised least squares (DF-GLS) unit root tests are employed.

The ADF unit root test is an extension of the original Dickey-Fuller unit root test introduced by Dickey and Fuller (1979, 1981). The original Dickey-Fuller unit root test is unable to control for serial correlation in a time series as this test assumes that the errors of the time series are independent and have a constant variance. The ADF unit root test, on the other hand, is a parametric approach that can control for serial

correlation by adding lagged changes of the time series. The null hypothesis of the ADF unit root test states that the time series has a unit root whilst the alternative hypothesis states that the time series is stationary. Therefore, the null hypothesis should be rejected to confirm that the time series is stationary. There are three forms of the ADF unit root test namely the ADF-τ test, ADF-τ_μ test, and ADF-τ_τ test. The ADF-τ test is used to test the stationarity of a time series that has no constant and no trend term. Alternatively, the ADF-τ_μ test is used to test the stationarity of a time series that has a constant but no trend term whereas the ADF-τ_τ test is used to test the stationarity of a time series that has a constant and a trend term (Dickey & Fuller, 1979, 1981).

The DF-GLS unit root test of Elliott, Rothenberg, and Stock (1996) generally has better power characteristics than the standard ADF test. The DF-GLS unit root test takes the same form as the basic ADF test but is applied to a transformed version of the time series that has been demeaned and/or detrended using pseudo-GLS estimates. Similar to the ADF unit root test, the null hypothesis of the DF-GLS unit root test should be rejected to confirm that the time series is stationary. There are two forms of the DF-GLS unit root test namely the DF-GLS$^\mu$ test and DF-GLS$^\tau$ test. The DF-GLS$^\mu$ test is run on a time series that has been demeaned whereas the DF-GLS$^\tau$ test is run on a time series that has been demeaned and detrended (Elliott et al., 1996).

For the purposes of this study, the aforementioned unit root tests are conducted to determine the order of integration of the macroeconomic factors and REIT return series. This ensures that each of the underlying time series variables in the estimated VAR models are stationary.

3.2.5.2 Lag order selection

The lag order of a VAR model can be determined by model selection procedures. These procedures fit a VAR(p) model with order $p = 0, \dots, p_{max}$ and select the order p that minimises the criteria (Lütkepohl, 2004).

The general form of many of the lag order selection criteria is expressed as:

$$Cr(p) = \log\det\left(\widetilde{\Sigma_u}(p)\right) + c_T\varphi(p)$$

where $\log$ is the natural logarithm, $\det(\cdot)$ denotes the determinant, $\widetilde{\Sigma_u}(p) = T^{-1}\sum_{t=1}^{T}\hat{u}_t\hat{u}_t'$ is the residual covariance matrix estimator for a model of order p, c_T is a sequence that depends on the sample size T, and $\varphi(p)$ is a function that penalises large VAR orders.

Common model selection criteria tests include the Akaike information criterion (AIC), Hannan-Quinn information criterion (HQ), and the Schwarz criterion (SC). These respective information criteria are denoted mathematically as:

$$AIC(p) = \log\det\left(\widetilde{\Sigma_u}(p)\right) + \frac{2}{T}mK^2 \text{ (Akaike, 1973, 1974),}$$

$$HQ(p) = \log\det\left(\widetilde{\Sigma_u}(p)\right) + \frac{2loglogT}{T}mK^2 \text{ (Hannan \& Quinn, 1979), and}$$

$$SC(p) = \log\det\left(\widetilde{\Sigma_u}(p)\right) + \frac{logT}{T}mK^2 \text{ (Rissanen, 1978; Schwarz, 1978).}$$

In this study, the AIC, HQ, and SC lag order selection tests are used to identify the optimal lag length to ensure that appropriate VAR models are estimated.

3.2.5.3 Stability analysis

One way to test the stability of a VAR model is to calculate and analyse the eigenvalues of the companion matrix $\widetilde{\mathrm{A}}$ (Juselius, 2006). To illustrate this process, the reduced form VAR(p) model is first considered:

$$Y_t = \mathrm{A}_0 + \mathrm{A}_1 Y_{t-1} + \cdots + \mathrm{A}_p Y_{t-p} + e_t$$

In the companion form, this equation can be written as:

$$\tilde{Y}_t = \widetilde{\mathrm{A}}_0 + \widetilde{\mathrm{A}}\tilde{Y}_{t-1} + \tilde{e}_t$$

where $\tilde{Y}_t = \left(Y_t, Y_{t-1}, \ldots, Y_{t-p+1}\right)'$, $\tilde{e}_t = (e_t, 0, \ldots, 0)'$, and $\widetilde{\mathrm{A}} = \begin{bmatrix} \mathrm{A}_1 & \mathrm{A}_2 & \cdots & \mathrm{A}_{p-1} & \mathrm{A}_p \\ I & 0 & \cdots & 0 & 0 \\ 0 & I & \cdots & 0 & 0 \\ \vdots & & & & \\ 0 & 0 & \cdots & I & 0 \end{bmatrix}$.

If the eigenvalues of the companion matrix $\widetilde{A}$ have modulus less than one, the reduced form VAR(p) model is said to be stable. Notably, if the reduced form VAR(p) model is stable, the Y_t process is stationary and ergodic with time invariant means, variances, and autocovariances (Juselius, 2006). In addition to analysing the eigenvalues of the companion matrix $\widetilde{A}$, cumulative sum of recursive residuals (CUSUM) can be plotted to test for stability in a VAR model (Brown, Durbin, & Evans, 1975). Importantly, CUSUM tests are applied to the individual equations of an estimated VAR model. If the CUSUM plots remain between the critical bounds at a 5% level of significance, the estimated VAR model is stable. Contrarily, if the CUSUM plots deviate from the zero line and cross the 95% confidence intervals, there is structural instability in the underlying model (Brown et al., 1975; Lütkepohl, 2004). For the purposes of this study, the eigenvalues and CUSUM tests are used to determine whether the estimated VAR models are stable, and thus, stationary and ergodic with means, variances, and autocovariances that are independent of time.

3.2.5.4 Diagnostic tests

A series of diagnostic tests can be conducted on an estimated VAR model to test for residual autocorrelation, conditional heteroskedasticity, and nonnormality. Testing for residual autocorrelation can be achieved by making use of the Portmanteau test. The null hypothesis of this test states that there is no residual autocorrelation whilst the alternative hypothesis states that there is residual autocorrelation. Consequently, failing to reject the null hypothesis confirms that the residuals of the estimated VAR model are not autocorrelated which infers that the residuals are independent of each other (Lütkepohl, 2004). To determine whether there is autoregressive conditional heteroskedasticity (ARCH) effects in the residuals of an estimated VAR model, the Lagrange multiplier test for ARCH referred to as the ARCH-LM test can be conducted. The null hypothesis of this test specifies that there is no ARCH in the residuals whereas the alternative hypothesis specifies that there is ARCH in the residuals. As such, failing to reject the null hypothesis verifies that the estimated VAR model has no residual ARCH effects which suggests that the variance of the residuals are constant (Lütkepohl, 2004). To test for nonnormality in the residuals, the Jarque-Bera test can be employed. The null hypothesis of this test states that the residuals are normally distributed whereas the alternative hypothesis states that the residuals are not

normally distributed. Therefore, failing to reject the null hypothesis confirms that the residuals of the estimated VAR model are normally distributed (Lütkepohl, 2004). In this study, the Portmanteau autocorrelation test, ARCH-LM test, and Jarque-Bera nonnormality test are conducted to check the model assumptions and properties of the estimated VAR models.

3.2.6 Uses of VAR models

Once the necessary model specification and model checking tests have been conducted, the correctly specified VAR model can be used to estimate and evaluate the relationship between multiple variables over time. VAR models can be used for forecasting, however, in practical terms, the forecasts tend to be imprecise which makes them less informative. Thus, in practice, the statistical inference conducted by researchers to examine the dynamics that are predicted by the fitted VAR model include impulse response functions, forecast error variance decompositions, and Granger causality analysis (Bjørnland & Thorsrud, 2015; Brooks, 2008; Enders, 2014). These statistics are elaborated on below.

3.2.6.1 Impulse response functions

Impulse response functions are useful for analysing the interactions between the time series variables in a VAR model. Specifically, they trace the marginal effect of a shock in one variable through the system by applying a one-unit change to the error of that variable and analysing how the other variables in the system respond to such an impulse over time (Bjørnland & Thorsrud, 2015; Brooks, 2008; Enders, 2014). Impulse response functions are performed on the structural moving average SMA(∞) representation of the VAR model. To obtain the SMA(∞) representation, $e_t = B^{-1}\epsilon_t$ is substituted into the VMA(∞) representation of the VAR model as follows:

$$\begin{aligned} Y_t &= \mu + \psi(L)e_t \\ &= \mu + \psi(L)B^{-1}\epsilon_t \\ &= \mu + \theta(L)\epsilon_t \end{aligned}$$

where $\theta(L) = \psi(L)B^{-1} = B^{-1} + \psi_1 B^{-1}L + \cdots$.

In matrix form, the SMA(∞) representation of the bivariate VAR model can be expressed as:

$$\begin{bmatrix} y_{1,t} \\ y_{2,t} \end{bmatrix} = \begin{bmatrix} \mu_1 \\ \mu_2 \end{bmatrix} + \begin{bmatrix} \theta_{11}^0 & \theta_{12}^0 \\ \theta_{21}^0 & \theta_{22}^0 \end{bmatrix} \begin{bmatrix} \epsilon_{1,t} \\ \epsilon_{2,t} \end{bmatrix} + \begin{bmatrix} \theta_{11}^1 & \theta_{12}^1 \\ \theta_{21}^1 & \theta_{22}^1 \end{bmatrix} \begin{bmatrix} \epsilon_{1,t-1} \\ \epsilon_{2,t-1} \end{bmatrix} + \cdots$$

Moving S periods ahead, the aforementioned expression can be written as:

$$\begin{bmatrix} y_{1,t+S} \\ y_{2,t+S} \end{bmatrix} = \begin{bmatrix} \mu_1 \\ \mu_2 \end{bmatrix} + \begin{bmatrix} \theta_{11}^0 & \theta_{12}^0 \\ \theta_{21}^0 & \theta_{22}^0 \end{bmatrix} \begin{bmatrix} \epsilon_{1,t+S} \\ \epsilon_{2,t+S} \end{bmatrix} + \begin{bmatrix} \theta_{11}^1 & \theta_{12}^1 \\ \theta_{21}^1 & \theta_{22}^1 \end{bmatrix} \begin{bmatrix} \epsilon_{1,t+S-1} \\ \epsilon_{2,t+S-1} \end{bmatrix} + \cdots + \begin{bmatrix} \theta_{11}^S & \theta_{12}^S \\ \theta_{21}^S & \theta_{22}^S \end{bmatrix} \begin{bmatrix} \epsilon_{1,t} \\ \epsilon_{2,t} \end{bmatrix} + \cdots$$

Evidently, the SMA(∞) representation is able to measure the effect of a one-unit change in ϵ_1 at time t on y_1 in period $t + S$. From the SMA(∞) representation, it can be seen that $\epsilon_{1,t}$ impacts on $y_{1,t+S}$ via θ_{11}^S. Therefore, written as a partial derivative, the impulse responses can be found as follows:

$$\frac{\partial y_{1,t+S}}{\partial \epsilon_{1,t}} = \theta_{11}^S; \quad \frac{\partial y_{1,t+S}}{\partial \epsilon_{2,t}} = \theta_{12}^S; \quad \frac{\partial y_{2,t+S}}{\partial \epsilon_{1,t}} = \theta_{21}^S; \quad \frac{\partial y_{2,t+S}}{\partial \epsilon_{2,t}} = \theta_{22}^S$$

By plotting θ_{ij} against S (for $S = 1,2, \ldots$), the impulse response function of a shock to j ($\epsilon_{1,t}$ or $\epsilon_{2,t}$) on variable i ($y_{1,t+S}$ or $y_{2,t+S}$) can be generated. For the purposes of this study, impulse response functions are generated to show the impact (positive or negative) of a one-unit shock to each macroeconomic factor on South African REIT returns and for how long these impulse responses may persist.

3.2.6.2 Forecast error variance decompositions

Forecast error variance decompositions estimate the proportion of the forecast error variance of one variable that is due to the variability in a structural shock to another variable over time. Hence, forecast error variance decompositions determine the relative importance of exogenous shocks to the evolution of a variable (Bjørnland & Thorsrud, 2015; Brooks, 2008; Enders, 2014). For the bivariate VAR(1) model, to establish the proportion of the variability of y_i in period $t + S$ that is due to a shock in ϵ_j at time t, the VMA(∞) representation of the VAR model is shifted forward S periods:

$$Y_{t+S} = \mu + e_{t+S} + \psi_1 e_{t+S-1} + \cdots + \psi_S e_t + \cdots$$

The best linear forecast of Y_{t+S} based on the information that is available at time t is:

$$\hat{Y}_{t+S|t} = \mu + \psi_S e_t + \psi_{S+1} e_{t-1} + \cdots$$

As such, the forecast error is given by:

$$Y_{t+S} - \hat{Y}_{t+S|t} = e_{t+S} + \psi_1 e_{t+S-1} + \cdots + \psi_{S-1} e_{t+1}$$

Substituting $e_t = B^{-1}\epsilon_t$ into this equation, the forecast error can be written in terms of the structural shocks as follows:

$$\begin{aligned} Y_{t+S} - \hat{Y}_{t+S|t} &= B^{-1}\epsilon_{t+S} + \psi_1 B^{-1}\epsilon_{t+S-1} + \cdots + \psi_{S-1} B^{-1}\epsilon_{t+1} \\ &= \theta^0 \epsilon_{t+S} + \theta^1 \epsilon_{t+S-1} + \cdots + \theta^{S-1}\epsilon_{t+1} \end{aligned}$$

The equation above can be written in expanded form:

$$\begin{bmatrix} y_{1,t+S} - \hat{y}_{1,t+S|t} \\ y_{2,t+S} - \hat{y}_{2,t+S|t} \end{bmatrix} = \begin{bmatrix} \theta_{11}^0 & \theta_{12}^0 \\ \theta_{21}^0 & \theta_{22}^0 \end{bmatrix} \begin{bmatrix} \epsilon_{1,t+S} \\ \epsilon_{2,t+S} \end{bmatrix} + \cdots + \begin{bmatrix} \theta_{11}^{S-1} & \theta_{12}^{S-1} \\ \theta_{21}^{S-1} & \theta_{22}^{S-1} \end{bmatrix} \begin{bmatrix} \epsilon_{1,t+1} \\ \epsilon_{2,t+1} \end{bmatrix}$$

As an example, the first equation can be expressed as:

$$\begin{aligned} y_{1,t+S} - \hat{y}_{1,t+S|t} = {} & \theta_{11}^0 \epsilon_{1,t+S} + \theta_{11}^1 \epsilon_{1,t+S-1} + \cdots + \theta_{11}^{S-1}\epsilon_{1,t+1} \\ & + \theta_{12}^0 \epsilon_{2,t+S} + \theta_{12}^1 \epsilon_{2,t+S-1} + \cdots + \theta_{12}^{S-1}\epsilon_{2,t+1} \end{aligned}$$

From this equation, the S-step-ahead forecast error variance of y_1 is equal to:

$$\begin{aligned} var(y_{1,t+S} - \hat{y}_{1,t+S|t}) &= (\theta_{11}^0)^2\sigma_1^2 + \cdots + (\theta_{11}^{S-1})^2\sigma_1^2 + (\theta_{12}^0)^2\sigma_2^2 + \cdots + (\theta_{12}^{S-1})^2\sigma_2^2 \\ &= \left[\sigma_{y_1}(S)\right]^2 \end{aligned}$$

Accordingly, the proportion of this variance that is due to shocks in ϵ_1 at horizon S is:

$$\rho_{1,1}(S) = \frac{\sigma_1^2[(\theta_{11}^0)^2 + \cdots + (\theta_{11}^{S-1})^2]}{\left[\sigma_{y_1}(S)\right]^2}$$

Likewise, the proportion of this variance that is due to shocks in ϵ_2 at horizon S is:

$$\rho_{1,2}(S) = \frac{\sigma_2^2[(\theta_{12}^0)^2 + \cdots + (\theta_{12}^{S-1})^2]}{\left[\sigma_{y_1}(S)\right]^2}$$

Additionally, $\rho_{2,1}(S)$ and $\rho_{2,2}(S)$ can be derived in the same manner as $\rho_{1,1}(S)$ and $\rho_{1,2}(S)$ above. For the purposes of this study, the forecast error variance decompositions explain the proportion of the forecast error variance in South African REIT returns that is caused by the variability in structural shocks to each macroeconomic factor over time.

3.2.6.3 Granger causality analysis

Granger (1969) introduced a definition of causality that is parallel to predictability whereby a variable y_1 is Granger-causal for another series y_2 if the information in y_1 helps predict y_2. Specifically, Granger casualty analysis tests whether lagged values of y_1 are useful in predicting $y_{2,t}$ conditional on having accounted for the effects on $y_{2,t}$ of lagged values of y_2. If this is the case, then y_1 is said to Granger cause y_2 (Granger, 1969). To formalise this definition, $y_{2,t+h|\Omega_t}$ is defined as the optimal h-step-ahead forecast of y_2 at time t based on the information that is available at this time Ω_t (Lütkepohl, 2004). Then, $y_{1,t}$ is Granger-noncausal for $y_{2,t}$ if:

$$y_{2,t+h|\Omega_t} = y_{2,t+h|(\Omega_t \backslash y_{1,s}|s \leq t)}$$

where $\Omega_t \backslash A$ denotes the set that contains all the elements of Ω_t which are not contained in A.

Therefore, $y_{1,t}$ is Granger-noncausal for $y_{2,t}$ if removing the information contained in past values of $y_{1,t}$ does not alter the optimal forecast for $y_{2,t}$ at any horizon h. If including past values of $y_{1,t}$ results in an improved forecast, then $y_{1,t}$ is Granger-causal for $y_{2,t}$. To operationalise the definition, assume $y_{1,t}$ and $y_{2,t}$ are generated by the reduced form bivariate VAR(1) model as:

$$\begin{bmatrix} y_{1,t} \\ y_{2,t} \end{bmatrix} = \begin{bmatrix} a_{10} \\ a_{20} \end{bmatrix} + \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} \begin{bmatrix} y_{1,t-1} \\ y_{2,t-1} \end{bmatrix} + \begin{bmatrix} e_{1,t} \\ e_{2,t} \end{bmatrix}$$

In analysing whether $y_{1,t}$ is Granger-noncausal for $y_{2,t}$, the Granger-noncausality condition is equivalent to the null hypothesis $a_{21} = 0$. In other words, the Granger-noncausality condition is that a_{21} should be equal to zero in which case the lagged values of $y_{1,t}$ do not help to predict $y_{2,t}$. Similarly, in analysing whether $y_{2,t}$ is Granger-noncausal for $y_{1,t}$, the Granger-noncausality condition is equivalent to the null hypothesis $a_{12} = 0$. Accordingly, the Granger-noncausality condition is that a_{12} should be equal to zero implying that the lagged values of $y_{2,t}$ do not help to predict $y_{1,t}$ (Lütkepohl, 2004). The aforementioned null hypotheses can be tested using standard χ^2- or F-tests of the Wald type and can result in four possible outcomes summarised in Table 7.

Table 7: Granger causality test outcomes for a bivariate VAR (1) model

	Fail to reject H_0: $a_{21} = 0$	**Reject H_0: $a_{21} = 0$**
Fail to reject H_0: $a_{12} = 0$	$y_{1,t-1}$ is Granger-noncausal for $y_{2,t}$ $y_{2,t-1}$ is Granger-noncausal for $y_{1,t}$ (∴ no Granger causality)	$y_{1,t-1}$ is Granger-causal for $y_{2,t}$ $y_{2,t-1}$ is Granger-noncausal for $y_{1,t}$
Reject H_0: $a_{12} = 0$	$y_{1,t-1}$ is Granger-noncausal for $y_{2,t}$ $y_{2,t-1}$ is Granger-causal for $y_{1,t}$	$y_{1,t-1}$ is Granger-causal for $y_{2,t}$ $y_{2,t-1}$ is Granger-causal for $y_{1,t}$ (∴ bi-directional Granger causality)

Source: Adapted from Lütkepohl (2004).

In this study, the primary purpose of conducting Granger causality analysis is to determine whether lagged values of the macroeconomic factors may be useful in predicting South African REIT returns.

3.3 VECTOR ERROR CORRECTION MODELS

As mentioned in section 3.2, it is necessary that all the variables in a VAR model are stationary. However, in transforming a non-stationary variable into a stationary variable by differencing the series, important long-run information contained in the series may be lost. A VECM can overcome this problem by using combinations of first differenced ($y_t \sim I(1)$) and lagged levels of cointegrated variables (Johansen & Juselius, 1990). This section explains the concept of cointegration with particular emphasis on the Johansen approach used to test for cointegration. Specifically, the way in which VAR models can be reparametrized as VECMs is described whereafter the Johansen cointegration tests used to identify the number of cointegrating vectors is expanded upon. Furthermore, the cointegrating vector and loading matrix used to understand the long-run relationship between time series variables is elaborated on.

3.3.1 Cointegrated variables

A VECM is designed to estimate and evaluate the long-run relationship between non-stationary time series that are known to be cointegrated. The concept of cointegration was introduced in the econometrics literature by Granger (1981) and Engle and Granger (1987). Two time series are said to be cointegrated if a long-term financial or economic relationship exists between them such that they do not diverge from each other without bound in the long run. To illustrate this, first consider two time series $y_{1,t}$ and $y_{2,t}$ which are both $I(1)$ processes. Any linear combination of $y_{1,t}$ and $y_{2,t}$ expressed as $y_{1,t} - \beta y_{2,t} = \xi_t$ will also be $I(1)$. If, however, $y_{1,t}$ and $y_{2,t}$ are bound together over time in an equilibrium relationship governed by β, the disequilibrium error ξ_t would be a zero-mean reverting stationary process despite the fact that $y_{1,t}$ and $y_{2,t}$ are both $I(1)$ processes. Thus, from a statistical perspective, cointegration is a concept that mimics the presence of a long-run equilibrium to which the system converges (Engle & Granger, 1987; Granger, 1981).

3.3.2 Cointegration and error correction models

The relationship between cointegration and error correction models was first highlighted by Granger (1981). Thereafter, Granger and Weiss (1983) presented the Granger Representation Theorem in which it was proved that a vector of cointegrated series can be represented by an error correction model. Following the work of these

authors, Johansen (1988, 1995) and Johansen and Juselius (1990) formalised a systems approach to test for cointegration. Johansen's cointegrating VAR (CVAR) approach is based on the estimation of a p^{th} order VAR model in n variables. Hence, the $n \times 1$ vector y_t $(t = 1, \dots, T)$ can be expressed as:

$$y_t = \pi_1 y_{t-1} + \pi_2 y_{t-2} + \cdots + \pi_p y_{t-p} + \Psi D_t + \epsilon_t$$

where ΨD_t is a vector of deterministic terms, and ϵ_t is $i.i.d.(0, \Omega)$.

By recursive substitution, the VAR model can be reparametrized as a VECM:

$$\Delta y_t = \pi y_{t-1} + \Gamma_1 \Delta y_{t-1} + \Gamma_2 \Delta y_{t-2} + \cdots + \Gamma_{p-1} \Delta y_{t-(p-1)} + \Psi D_t + \epsilon_t$$

where $\pi = -(I_n - \pi_1 - \cdots - \pi_P)$, and $\Gamma_i = -\left(\pi_{i+1} + \pi_{i+2} + \cdots + \pi_p\right)$ for $i = 1, \dots, p-1$.

Noteworthy features of the VECM include (Johansen & Juselius, 1990):

- If $y_t \sim I(1)$, then $\Delta y_t \sim I(0)$ in which case the left-hand side of the VECM is $I(0)$.
- All the variables on the right-hand side except for πy_{t-1} are $I(0)$.
- Since all the variables on the left-hand side and right-hand side are $I(0)$ except for πy_{t-1}, it can be said that πy_{t-1} must also be $I(0)$ if it exists.
- Since $y_{t-1} \sim I(1)$, the π matrix gives the coefficients that result in linear combinations of $I(1)$ variables that are $I(0)$.

3.3.3 Johansen cointegration tests

When looking at the VECM transformation of the VAR model, the parameters of the various Γ_i contain information about the short-run adjustment processes. To look at the long-run equilibrium relationships, focus is placed on the π matrix. In particular, the rank of π is of importance. Likelihood ratio tests need to be constructed for the rank of π to determine the number of cointegrating vectors r by running the trace and maximum eigenvalue tests on the VECM transformation of the VAR model (Johansen & Juselius, 1990). The three possible cases to consider are:

- If the rank of π is zero $(r = 0)$, the VECM collapses to a VAR model in first differences.

- If the rank of $\pi = n$ ($r = n$), there are n cointegrating vectors amongst the n variables in which case each of these variables are $I(0)$ and the VAR model is stationary in levels.
- If $1 \leq r < n$, π is of reduced rank r and nonzero whereby the number of nonzero eigenvalues of π is its rank.

An explanation of the trace and maximum eigenvalue tests used to determine the number of cointegrating vectors r follows.

3.3.3.1 Trace test

The trace test statistic is computed as:

$$\lambda_{trace} = -T \sum_{i=r_0+1}^{n} \ln (1 - \hat{\lambda}_i)$$

where T is the number of usable observations, and $\hat{\lambda}_i$ is the *i*-th largest eigenvalue.

The null and alternative hypotheses of the trace test are represented by:

$$H_0: r = r_0$$
$$H_a: r > r_0$$

The trace test is used iteratively, therefore, r_0 is initially set to zero so the null hypothesis states that there are no cointegrating vectors and the alternative hypothesis states that there is at least one cointegrating vector. As such, the null hypothesis should be rejected to confirm that there is at least one cointegrating vector. If the null hypothesis is rejected, r_0 is then set to one which results in the null hypothesis stating that there is one cointegrating vector with the alternative hypothesis stating that there are at least two cointegrating vectors. The value of r_0 is continually increased until the null hypothesis is no longer rejected.

3.3.3.2 Maximum eigenvalue test

The maximum eigenvalue test statistic is calculated as:

$$\lambda_{max} = -T \ln (1 - \hat{\lambda}_{r_0+1})$$

The maximum eigenvalue test is similar to the trace test, however, the difference between the two tests is the alternative hypothesis as seen below:

$$H_0: r = r_0$$
$$H_a: r = r_0 + 1$$

When using the maximum eigenvalue test iteratively, r_0 is initially set to zero, and thus, the null hypothesis specifies that there are no cointegrating vectors whereas the alternative hypothesis specifies that there is one cointegrating vector. Accordingly, the null hypothesis should be rejected to confirm that there is one cointegrating vector. If the null hypothesis is rejected, r_0 is then set to one in which case the null hypothesis states that there is one cointegrating vector and the alternative hypothesis states that there are two cointegrating vectors. The value of r_0 will continue to increase until the null hypothesis is no longer rejected.

3.3.4 Cointegrating vector and loading matrix

Once the number of cointegrating vectors r has been decided, the CVAR analysis can proceed. To do this, an $n \times n$ matrix π needs to be decomposed into the product of two other $n \times r$ matrices β and α which yields the following equation:

$$\Delta y_t = \alpha\beta' y_{t-1} + \Gamma_1 \Delta y_{t-1} + \Gamma_2 \Delta y_{t-2} + \cdots + \Gamma_{p-1} \Delta y_{t-(p-1)} + \Psi D_t + \epsilon_t$$

where β is the cointegrating vector which gives the weights that result in the linear combination of the $I(1)$ variables $y_{i,t-1}$ being $I(0)$, and the α matrix is the loading matrix which contains the speed of adjustment parameters that capture the adjustment of the y's to the long-run equilibrium.

Johansen (1988, 1991) and Johansen and Juselius (1990, 1992) formulated a series of likelihood ratio tests for imposing restrictions on β and α. The likelihood ratio test statistic is calculated as:

$$LR = T \sum_{i=1}^{r} \ln\left(\frac{1 - \hat{\lambda}_{H,i}}{1 - \hat{\lambda}_i}\right)$$

where $\hat{\lambda}_{H,i}$ are the eigenvalues for the restricted model, and $\hat{\lambda}_i$ are the eigenvalues for the unrestricted model.

The null hypothesis for imposing restrictions on β is given by:

$$H_0: \beta = H\phi$$

where $H = n \times s$ matrix, $\phi = s \times r$ matrix, and the likelihood ratio test statistic follows an asymptotic χ^2 distribution with $r \times (n - s)$ degrees of freedom.

The null hypothesis for imposing restrictions on α is expressed as:

$$H_0: \alpha = A\psi$$

where $A = n \times m$ matrix, $\psi = m \times r$ matrix, and the likelihood ratio test statistic follows an asymptotic χ^2 distribution with $r \times (n - m)$ degrees of freedom.

For the purposes of this study, the cointegrating vectors of the estimated VECMs are used to identify the long-run relationship (positive or negative) that exists between each of the macroeconomic factors and South African REIT returns. Zero restrictions are imposed on the β coefficients of the macroeconomic factors to determine whether significant long-run relationships exist between the respective macroeconomic factors and South African REIT returns. Furthermore, zero restrictions are imposed on the speed of adjustment coefficients to establish whether the time series variables are weakly exogenous.

3.4 DATA

The data required to conduct this study includes macroeconomic data and REIT return data. The period of analysis spans twelve and a half years from 2009-Q1 to 2021-Q2. The following sections describe important characteristics relating to the macroeconomic and REIT return data that is used in this study.

3.4.1 Macroeconomic data

As highlighted previously, the macroeconomic factors analysed in this study include economic growth, inflation, interest rates, and the stock market. This macroeconomic data is publicly available from Statistics South Africa (StatsSA), the South African Reserve Bank (SARB), and IRESS. Table 8 reports the proxy, data source, and periodicity for each of the macroeconomic factors analysed in this study.

Table 8: Macroeconomic factors

Macroeconomic factor	Proxy	Data source	Periodicity
Economic growth	%Δ Real gross domestic product	StatsSA	Quarterly
Inflation	%Δ Consumer price index	StatsSA	Quarterly
Interest rates	Yield on South African 10-year government bond	SARB	Quarterly
Stock market	JSE All Share Total Return Index	IRESS	Quarterly

3.4.2 REIT return data

The return data for the overall South African REIT market required to conduct the present study is publicly available from the South African REIT Association. In addition to analysing the relationship between macroeconomic factors and the returns of the overall South African REIT market, this study also analyses the impact that macroeconomic factors have on the returns of various REIT property subtypes in South Africa. It is important to highlight that this detailed analysis at the property subtype level is a unique feature of this study as minimal studies have been conducted in this regard. The majority of prior studies have only analysed the influence that several macroeconomic factors have on the returns of the overall REIT markets in the respective countries in which the studies were conducted.

An advantage of this study is that the results obtained from the analysis of the South African REIT property subtypes are contrasted to that of the overall South African REIT market. Particularly, this analysis establishes whether South African REIT property subtypes are more or less affected by macroeconomic factors compared to the overall South African REIT market. This analysis also establishes whether the various South African REIT property subtypes react differently to shocks in macroeconomic factors. The prominent REIT property subtypes in South Africa include the retail, office, and industrial sectors. This REIT property subtype data is obtained from the MSCI Real Estate Analytics Portal which is accessed through Growthpoint Properties' MSCI subscription. The author obtained permission from Growthpoint Properties' finance

department in order to use the company's MSCI subscription to access the required data. Table 9 reports the proxy, data source, and periodicity for each of the REIT return series analysed in this study.

Table 9: REIT return series

REIT return series	Proxy	Data source	Periodicity
South African REIT market	South African REITs Total Return Index	South African REIT Association	Quarterly
South African retail property sector	Total return of the MSCI South Africa Biannual Property Index: Retail Market Segment	MSCI Real Estate Analytics Portal	Semi-annual
South African office property sector	Total return of the MSCI South Africa Biannual Property Index: Office Market Segment	MSCI Real Estate Analytics Portal	Semi-annual
South African industrial property sector	Total return of the MSCI South Africa Biannual Property Index: Industrial Market Segment	MSCI Real Estate Analytics Portal	Semi-annual

3.5 RESEARCH METHOD LIMITATIONS

There are a few limitations associated with the data used to conduct this study that need to be highlighted. The first limitation relates to the REIT return data obtained from the South African REIT Association. As was stated previously, REIT legislation in South Africa only came into effect on 1 May 2013 (SA REIT Association, 2021b). Prior to the introduction of the REIT regime, the South African listed real estate market comprised comparable investment vehicles known as Property Unit Trusts (PUTs) and Property Loan Stocks (PLSs). With the introduction of the REIT regime, PUTs were automatically considered to be REITs and PLSs were able to adopt the necessary regulatory framework to qualify as REITs (Cloete, 2005). Despite the REIT regime only being introduced in South Africa in 2013, the South African REIT Association has

made available relevant back-dated return data to 2009-Q1. Generally, when conducting statistical analyses, a larger sample of observations is desirable as it allows for more reliable and accurate results to be obtained. As such, this study makes use of the available back-dated return data so that more observations are included in the dataset. Therefore, it must be noted that the official REIT return data only starts from 2013-Q3. Prior to this, the return data comprises PUTs and PLSs which, as explained above, later transitioned into REITs.

The second limitation relates to the REIT property subtype return data obtained from the MSCI Real Estate Analytics Portal. Compared to the quarterly REIT return data retrieved from the South African REIT Association, the return data sourced from the MSCI Real Estate Analytics Portal is semi-annual which reduces the number of observations included in the dataset. A higher periodicity, such as quarterly data, would have been more favourable to use as this would have allowed for a larger number of observations to be included in the dataset. However, this data is not available, hence, it must be noted that a limited number of observations (twelve and a half years of semi-annual return data equating to twenty-five observations) is used to analyse the influence that macroeconomic factors have on the returns of various REIT property subtypes in South Africa.

3.6 SUMMARY

This study involves estimating and evaluating the relationship between numerous macroeconomic factors and South African REIT returns. In order to do such, two time series models, namely VAR models and VECMs, are employed. This chapter outlined important aspects relating to VAR models including the structural form and reduced form representations of VAR models as well the identification of VAR models using short-run restrictions. Furthermore, the model specification tests and model checking tests, namely the unit root tests, lag order selection tests, and statistical tests for stability and diagnostic purposes, required to be conducted on VAR models were detailed. This chapter also explained the uses of VAR models including impulse response functions, forecast error variance decompositions, and Granger causality analysis.

Following the aforementioned overview of VAR models, the chapter then discussed VECMs. Specifically, the concept of cointegration and the Johansen approach used to test for cointegration was expanded upon. This discussion included the reparameterization of a VAR model to a VECM as well as how the number of cointegrating vectors is determined using the trace test and maximum eigenvalue test so that an appropriate VECM can be estimated. Additionally, the cointegrating vector and loading matrix used to identify the long-run relationships that exist between time series variables was explained. Thereafter, key characteristics relating to the macroeconomic and REIT return data used in this study was discussed. Lastly, this chapter highlighted the research method limitations associated with conducting the present study.

CHAPTER 4 – DATA ANALYSIS

4.1 INTRODUCTION

The primary aim of this chapter is to provide a comprehensive overview of the results obtained using the methodologies discussed in Chapter 3. Section 4.2 presents the results from the unit root tests undertaken to determine the order of integration of the time series variables. Following this, sections 4.3 and 4.4 divulge on the dynamics that are predicted by the vector autoregression (VAR) models and vector error correction models (VECMs) for the overall South African real estate investment trust (REIT) market as well as the retail, office, and industrial property sectors. It must be noted that these results are discussed in more detail and compared to prior literature in Chapter 5. A summary concludes this chapter in section 4.5.

4.2 UNIT ROOT TESTS

As discussed in Chapter 3, prior to specifying a VAR model, unit root tests need to be run on each of the time series variables to ensure stationarity. To establish the order of integration of the macroeconomic factors as well as the REIT return series, the Augmented Dickey Fuller (ADF) and Dickey Fuller generalised least squares (DF-GLS) unit root tests are conducted. The results of these unit root tests are detailed in Appendices A to H. The ADF and DF-GLS unit root tests reveal that the economic growth rate, inflation rate, and interest rate series as well as the total return series of the retail, office, and industrial property sectors are $I(1)$ processes. As such, the first difference of these series are used in the estimation of the VAR models in section 4.3. Moreover, the unit root tests highlight that the total return series of the stock market and REIT market are $I(0)$ processes. Hence, these series are used in levels without any differencing when estimating the VAR models in the next section.

4.3 VECTOR AUTOGRESSION MODELS

This section estimates VAR models for the overall South African REIT market as well as the retail, office, and industrial property sectors so as to analyse the short-run relationships between various macroeconomic factors and South African REIT returns.

4.3.1 REIT market

The findings of the lag order selection tests, stability analysis, diagnostic tests, impulse response functions, forecast error variance decompositions, and Granger causality analysis pertaining to the estimated VAR model for the South African REIT market is presented below.

4.3.1.1 Lag order selection

The lag order of a VAR model depends, to some extent, on the choice of p_{max}. Accordingly, it is important to choose an appropriate value for p_{max} so that an adequate VAR model can be estimated (Lütkepohl, 2004). If the value of p_{max} is too small, an appropriate VAR model may not be in the set of possibilities, and thus, cannot be found. On the other hand, if the value of p_{max} is excessively large, an inadequate order that is too large may be selected because there is a probability of rejecting a true null hypothesis in each test. Therefore, using a moderate value for p_{max} is a sensible approach since any problems associated with an inadequate lag order selection should be detected when undertaking model checking tests (Lütkepohl, 2009). Taking this into consideration, p_{max} is set to a moderate value of three when running the lag order selection tests for the present study. As will be shown in the model checking tests to follow, this chosen value of p_{max} allows for the estimation of adequate VAR models for the overall South African REIT market as well as the retail, office, and industrial property sectors. The results of the lag order selection tests for the REIT market are summarised in Table 10.

Table 10: Lag order selection criteria for the REIT market

Lag order	AIC(p)	HQ(p)	SC(p)
$p = 1$	5.460860	5.683059	6.051333
$p = 2$	5.155048	5.510566	6.099804
$p = 3$	5.250724	5.739562	6.549764
Selected lag order	**2**	**2**	**1**

According to the Akaike information criterion (AIC) and Hannan-Quinn information criterion (HQ), the order that minimises the criteria is two lags ($p = 2$) which suggests that a VAR(2) model is appropriate. However, the Schwarz criterion (SC) identifies one

lag ($p = 1$) as the optimal lag length thereby implying a VAR(1) model. Nevertheless, the VAR(2) model is estimated for the REIT market since the majority of the lag order selection tests propose this model.

4.3.1.2 Stability analysis

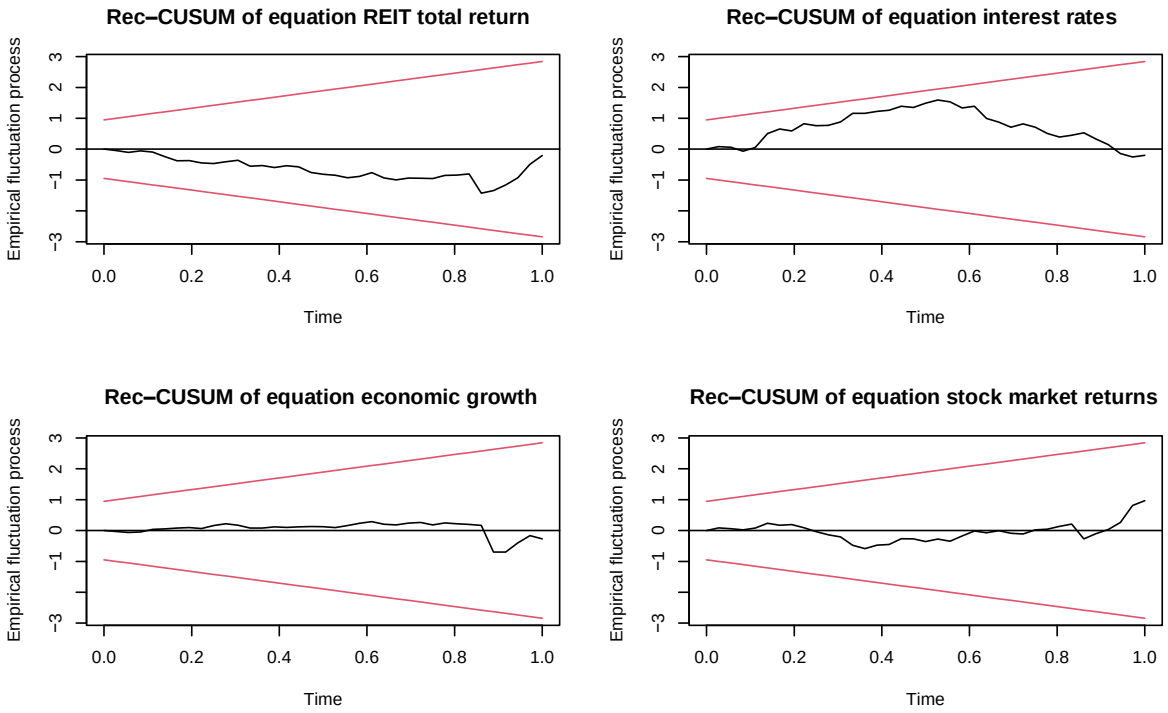
Table 11 reports the eigenvalues of the estimated VAR(2) model for the REIT market.

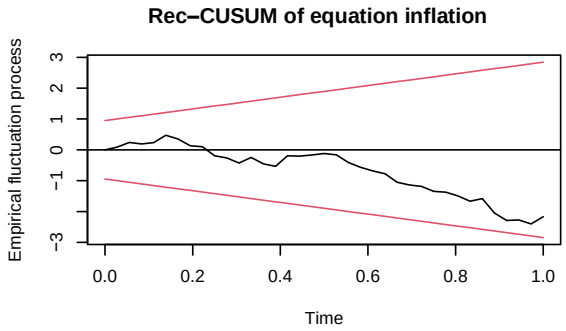
Table 11: Eigenvalues of the VAR(2) model for the REIT market

0.7511	0.7511	0.6422	0.6422	0.5245
0.4820	0.4738	0.4738	0.2578	0.1126

Evidently, all of the eigenvalues have modulus less than one, hence, the VAR(2) process is stable. Furthermore, Figure 3 emphasises that there is no indication of model instability as the cumulative sum of recursive residuals (CUSUM) plots remain between the critical bounds at a 5% level of significance.

Figure 3: CUSUM tests of the individual equations of the VAR(2) model for the REIT market





The eigenvalues and the results of the CUSUM tests reveal that the estimated VAR(2) model is stable. This indicates that the model is stationary and ergodic with time invariant means, variances, and autocovariances.

4.3.1.3 Diagnostic tests

The outcome of the diagnostic tests for autocorrelation, conditional heteroskedasticity, and nonnormality of the estimated VAR(2) model are shown in Table 12.

Table 12: Diagnostic tests of the VAR(2) model for the REIT market

	Portmanteau autocorrelation test	**ARCH-LM test**	**Jarque-Bera nonnormality test**
Chi-squared	328.54	675	316.13
P-value	0.789	0.4928	$<2.2e^{-16}$
Reject/Fail to reject null hypothesis	Fail to reject	Fail to reject	Reject

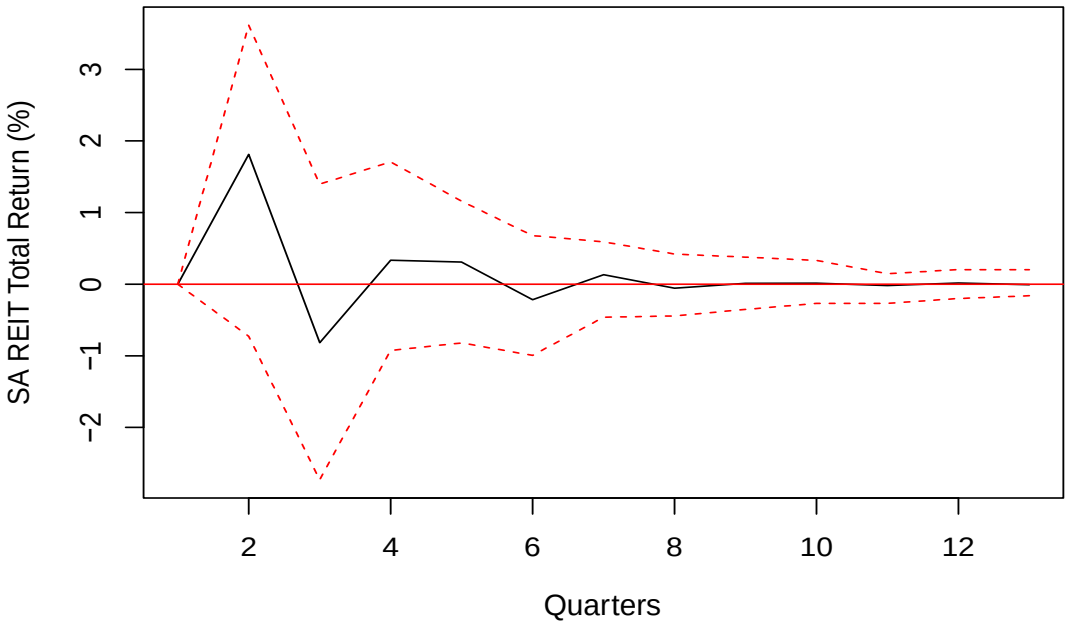
In summary, fail to reject the null hypothesis of no residual autocorrelation for the Portmanteau autocorrelation test at the 10%, 5%, and 1% levels of significance. As a result, it can be said that the residuals of the estimated VAR(2) model do not exhibit autocorrelation. Similarly, fail to reject the null hypothesis of the Lagrange multiplier test for autoregressive conditional heteroskedasticity (ARCH-LM test) at the 10%, 5%, and 1% levels of significance. This implies that there is no ARCH effects in the residuals of the estimated VAR(2) model. On the other hand, the null hypothesis that the residuals are normally distributed is rejected at the 10%, 5%, and 1% levels of significance for the Jarque-Bera nonnormality test. This demonstrates that the residuals of the estimated VAR(2) model are not normally distributed. It must be noted that a VAR model that is rejected by one of the diagnostic tests is not completely

satisfactory. However, given the results of the stability analysis as well as the other diagnostic tests, the estimated VAR(2) model for the REIT market is still sufficient to undertake statistical inference.

4.3.1.4 Impulse response functions

The impact of a one-unit change in economic growth on the total return of the REIT market is graphically illustrated in Figure 4.

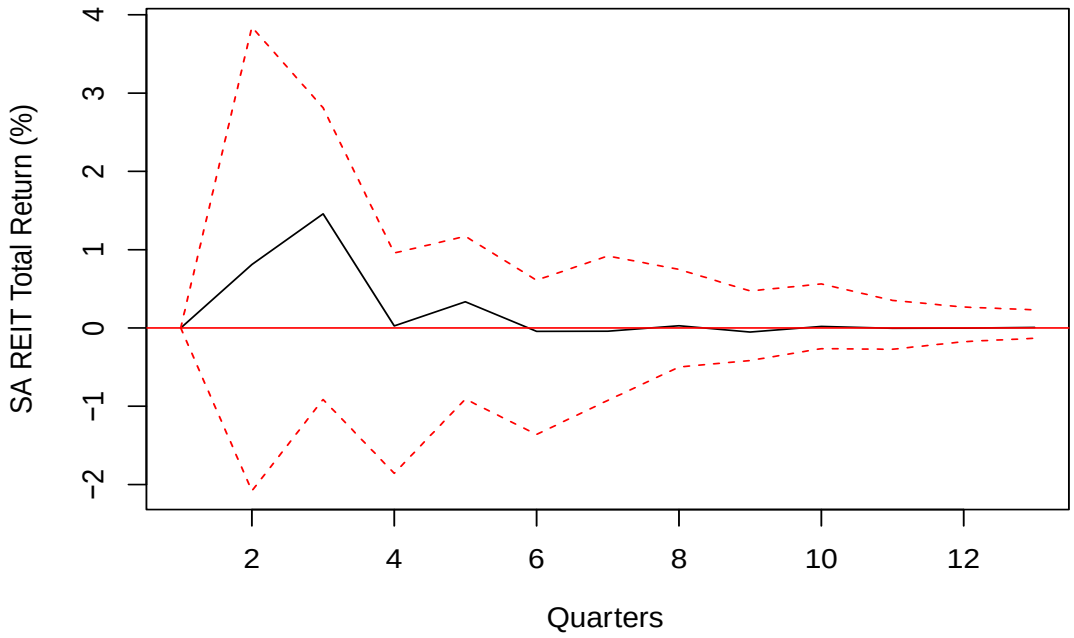
Figure 4: Orthogonal impulse response of the REIT market total return from a shock to economic growth



The impulse response of the REIT market total return to a shock to economic growth is initially zero, however, this is shortly followed by a strong increase in the total return which peaks at approximately 1.8 percentage points two quarters after the shock. Over the next quarter, the impulse response declines and reaches a trough in the third quarter at approximately −0.9 percentage points. Subsequently, the REIT market total return becomes positive again by the fourth quarter whereafter it gradually converges back to its long-run equilibrium six quarters after the initial shock. Important to highlight is that the impulse response is significantly different from zero at the 95% confidence level as the boundary lines of the 95% confidence interval do not cross over the zero line. Therefore, it can be said that a one-unit change in economic growth has a significant positive effect on the total return of the REIT market which persists for approximately three quarters.

Figure 5 displays the impact of a one-unit change in inflation on the total return of the REIT market.

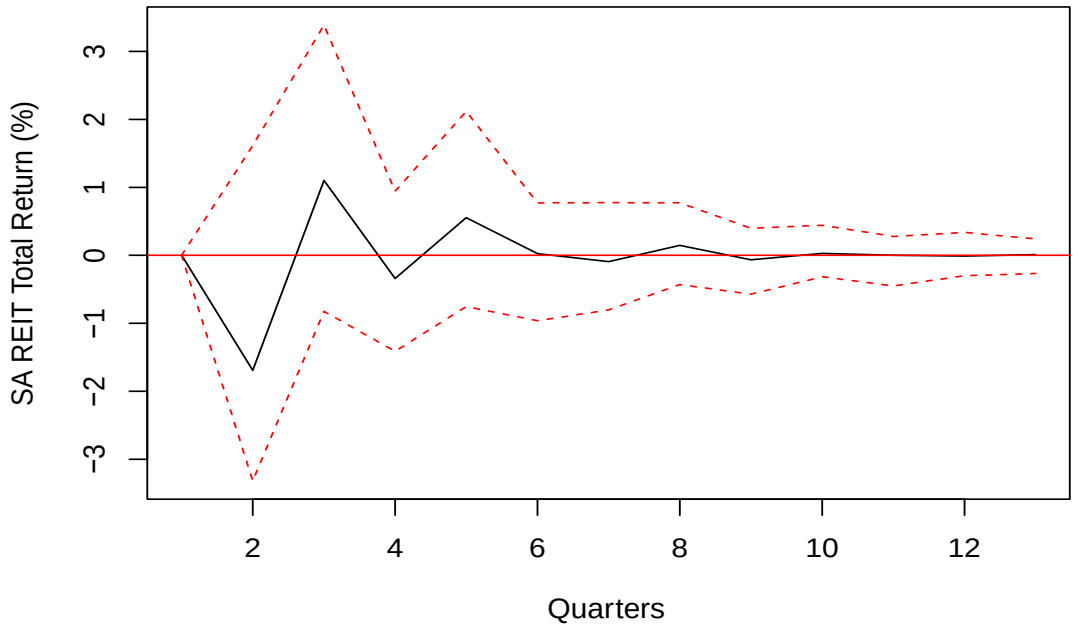
Figure 5: Orthogonal impulse response of the REIT market total return from a shock to inflation



A shock to inflation has no immediate influence on the REIT market total return. Over the next two quarters, the shock induces a sharp increase in the total return which peaks in the third quarter at approximately 1.5 percentage points. Thereafter, the positive impulse response decays and converges back to zero by the sixth quarter after the initial shock. The 95% confidence interval lines do not cross over the zero line, hence, the impulse response can be classified as statistically significant at the 95% confidence level. Overall, it can be concluded that a one-unit change in inflation has a significant positive impact on the total return of the REIT market which persists for approximately six quarters.

The effect of a one-unit change in interest rates on the total return of the REIT market is plotted in Figure 6.

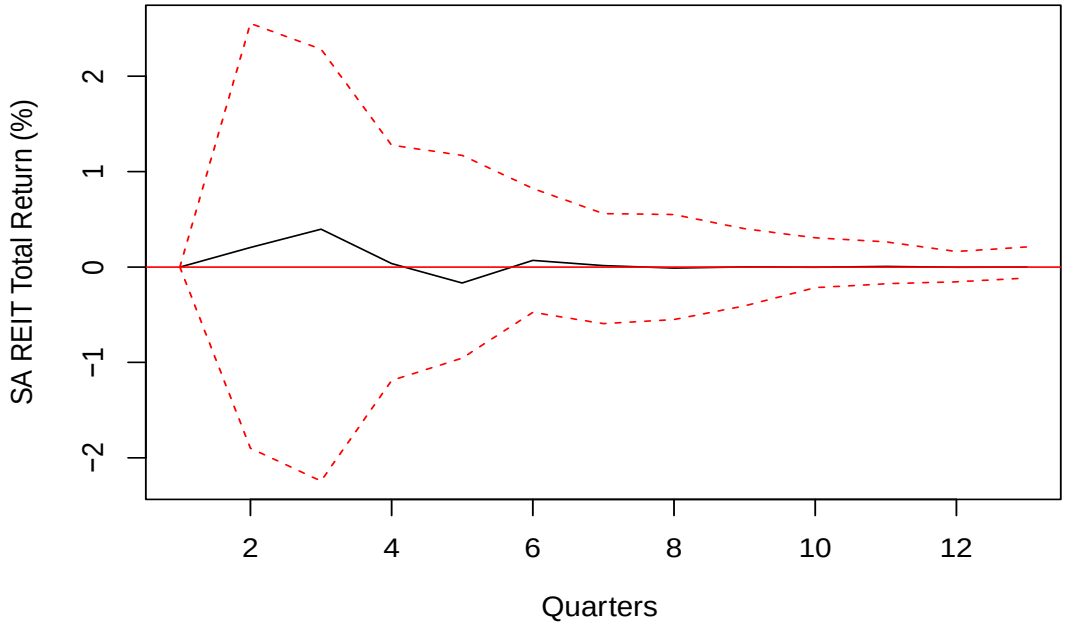
Figure 6: Orthogonal impulse response of the REIT market total return from a shock to interest rates



A shock to interest rates has no immediate effect on the REIT market total return, however, soon after the shock, the total return experiences a steep decline which troughs at approximately −1.7 percentage points in the second quarter. The impulse response then increases over the next quarter where it becomes positive and reaches a peak in the third quarter at approximately 1 percentage point. Following this peak, the impulse response decreases and becomes negative in quarter four whereafter it increases and becomes positive by the fifth quarter. In the sixth quarter after the initial shock, the REIT market total return slowly approaches its long-run equilibrium. It must be noted that the impulse response is significantly different from zero at the 95% confidence level as the upper and lower bounds of the 95% confidence interval do not cross over the zero line. As a result, a one-unit change in interest rates has a significant negative impact on the total return of the REIT market which persists for approximately three quarters.

Figure 7 depicts the influence of a one-unit change in stock market returns on the total return of the REIT market.

Figure 7: Orthogonal impulse response of the REIT market total return from a shock to stock market returns



The impulse response of the REIT market total return to a shock to stock market returns is initially zero. This is then followed by a slight increase in the total return which peaks in the third quarter at approximately 0.4 percentage points. In the ensuing quarter, the positive impulse response diminishes and converges back to zero by the fourth quarter after the initial shock. The boundary lines of the 95% confidence interval do not cross over the zero line, thus, the impulse response is statistically significant at the 95% confidence level. As such, it can be concluded that a one-unit change in stock market returns has a significant positive impact on the total return of the REIT market which persists for approximately four quarters.

4.3.1.5 Forecast error variance decompositions

An overview of the forecast error variance decompositions of the estimated VAR(2) model for the REIT market is provided in Table 13.

Table 13: Forecast error variance decompositions of the VAR(2) model for the REIT market

Quarters	REIT market total return	Economic growth	Inflation	Interest rates	Stock market returns
1	1	0	0	0	0
2	96.23251	0.7016950	1.229224	1.089595	0.7469749
3	95.19528	0.6234035	1.637487	1.826355	0.7174762

4	95.14699	0.6476525	1.665765	1.783414	0.7561782
5	94.68558	0.7060639	1.667458	2.188084	0.7528179
6	94.65292	0.7047468	1.662485	2.220171	0.7596726
7	94.57582	0.7054504	1.662746	2.296008	0.7599806
8	94.55402	0.7086510	1.665327	2.313059	0.7589462
9	94.54105	0.7086195	1.666210	2.325124	0.7589970
10	94.54098	0.7084532	1.666037	2.325759	0.7587722
11	94.54064	0.7084624	1.666017	2.326071	0.7588105
12	94.54059	0.7084514	1.665990	2.326083	0.7588881
Average	**94.83694**	**0.6937863**	**1.623159**	**2.092702**	**0.7534104**

A negligible proportion of the forecast error variance of the REIT market total return is attributable to the variability in a structural shock to economic growth and stock market returns. On average, these respective macroeconomic factors only explain 0.69% and 0.75% of the forecast error variance over the twelve-quarter time horizon. The variability in structural shocks to inflation and interest rates explain a slightly larger percentage of the forecast error variance of the REIT market total return. In particular, inflation contributes approximately 1.62% to the forecast error variance whilst interest rates have an average contribution of 2.09% over the twelve quarters. Thus, the results from the forecast error variance decompositions reveal that inflation and interest rates exert the largest impact on the variance of the REIT market total return. It must be highlighted, however, that these macroeconomic factors only explain a small percentage of the variation in the total return of the REIT market.

4.3.1.6 Granger causality analysis

The findings from the Granger causality analysis of the estimated VAR(2) model for the REIT market are summarised in Table 14.

Table 14: Granger causality analysis of the VAR(2) model for the REIT market

Null hypothesis	F-test value	P-value	Reject/Fail to reject null hypothesis
REIT market total return does not Granger cause economic growth, inflation, interest rates, and stock market returns.	6.7139	$1.095e^{-07}$	Reject
Economic growth does not Granger cause the REIT market total return, inflation, interest rates, and stock market returns.	1.6936	0.1026	Fail to reject
Inflation does not Granger cause the REIT market total return, economic growth, interest rates, and stock market returns.	2.1147	0.03656	Reject
Interest rates do not Granger cause the REIT market total return, economic growth, inflation, and stock market returns.	0.6686	0.7187	Fail to reject
Stock market returns do not Granger cause the REIT market total return, economic growth, inflation, and interest rates.	0.47529	0.8726	Fail to reject

The results of the Granger casualty analysis indicate that the REIT market total return Granger causes economic growth, inflation, interest rates, and stock market returns. In addition, inflation Granger causes the REIT market total return, economic growth, interest rates, and stock market returns. Therefore, lagged values of the inflation rate may be useful in forecasting the REIT market total return.

4.3.2 Retail property sector

The results of the lag order selection tests, stability analysis, diagnostic tests, impulse response functions, forecast error variance decompositions, and Granger causality analysis in relation to the estimated VAR model for the South African retail property sector is to follow.

4.3.2.1 Lag order selection

Table 15 presents the findings of the lag order selection tests for the retail property sector when employing a p_{max} of three as discussed previously.

Table 15: Lag order selection criteria for the retail property sector

Lag order	AIC(p)	HQ(p)	SC(p)
$p = 1$	2.828644	2.922105	3.225387
$p = 2$	3.104265	3.244456	3.699379
$p = 3$	3.263429	3.450351	4.056915
Selected lag order	**1**	**1**	**1**

The order that minimises the criteria for all of the lag order selection tests is one lag ($p = 1$). Accordingly, a VAR(1) model is estimated for the retail property sector.

4.3.2.2 Stability analysis

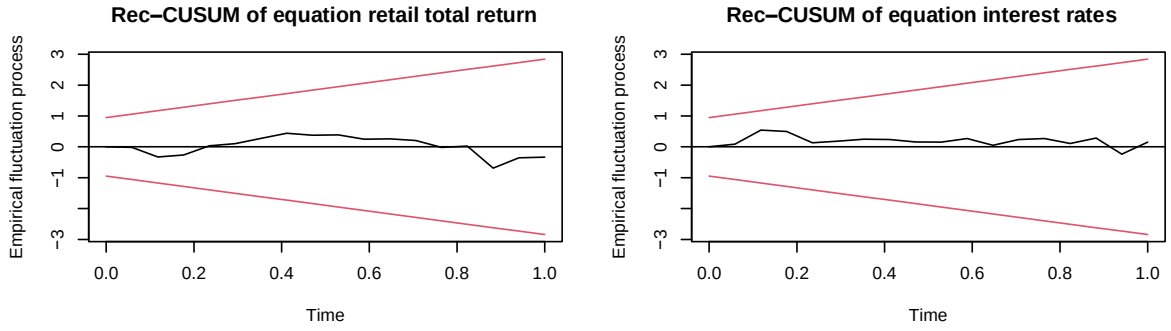
The eigenvalues of the estimated VAR(1) model are listed in Table 16.

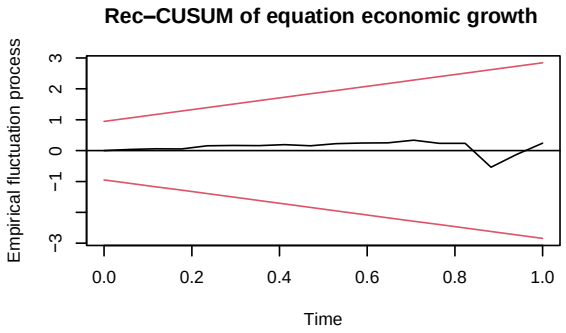
Table 16: Eigenvalues of the VAR(1) model for the retail property sector

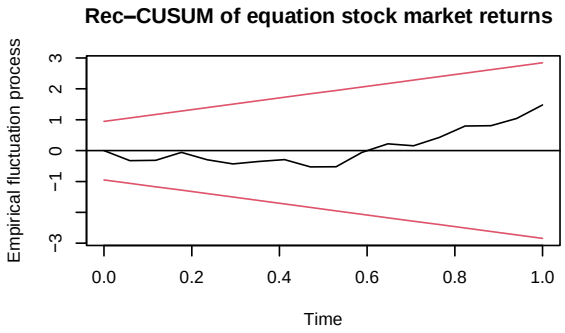
0.6525	0.6525	0.4656	0.1769	0.1769

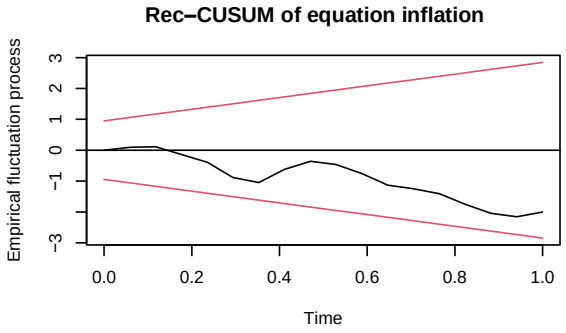
The VAR(1) process is stable since all of the eigenvalues have modulus less than one. Additionally, Figure 8 provides evidence in support of structural stability of the model as neither of the CUSUM plots deviate too far from the zero line or cross the 95% confidence intervals.

Figure 8: CUSUM tests of the individual equations of the VAR(1) model for the retail property sector









The eigenvalues and the findings of the CUSUM tests highlight that the estimated VAR(1) model for the retail property sector is stable. Therefore, the model is stationary and ergodic with means, variances, and autocovariances that are independent of time.

4.3.2.3 Diagnostic tests

The results of the diagnostic tests for autocorrelation, conditional heteroskedasticity, and nonnormality of the estimated VAR(1) model are outlined in Table 17.

Table 17: Diagnostic tests of the VAR(1) model for the retail property sector

	Portmanteau autocorrelation test	**ARCH-LM test**	**Jarque-Bera nonnormality test**
Chi-squared	215.82	220.72	34.134
P-value	0.6581	0.5682	0.0001753
Reject/Fail to reject null hypothesis	Fail to reject	Fail to reject	Reject

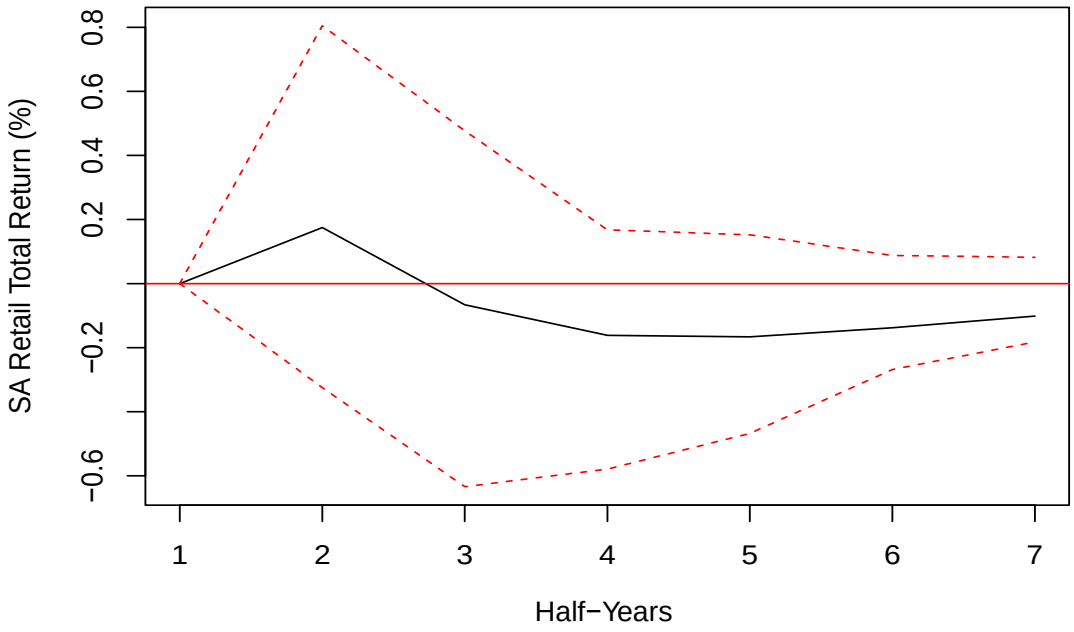
Failing to reject the null hypothesis of the Portmanteau autocorrelation test at the 10%, 5%, and 1% levels of significance indicates that there is no autocorrelation in the residuals of the estimated VAR(1) model. Likewise, fail to reject the null hypothesis that there is no ARCH effects in the residuals for the ARCH-LM test at the 10%, 5%,

and 1% levels of significance. As such, the residuals of the estimated VAR(1) model do not suffer from conditional heteroskedasticity. For the Jarque-Bera nonnormality test, the null hypothesis is rejected at the 10%, 5%, and 1% levels of significance which highlights that the residuals of the estimated VAR(1) model are not normally distributed. As mentioned previously, a model that is rejected by one of the diagnostic tests is not entirely satisfactory. However, taking the findings of the stability analysis and the other diagnostic tests into account, it can be said that the estimated VAR(1) model for the retail property sector is still adequate to perform statistical inference.

4.3.2.4 Impulse response functions

Figure 9 plots the effect of a one-unit change in economic growth on the total return of the retail property sector.

Figure 9: Orthogonal impulse response of the retail property sector total return from a shock to economic growth

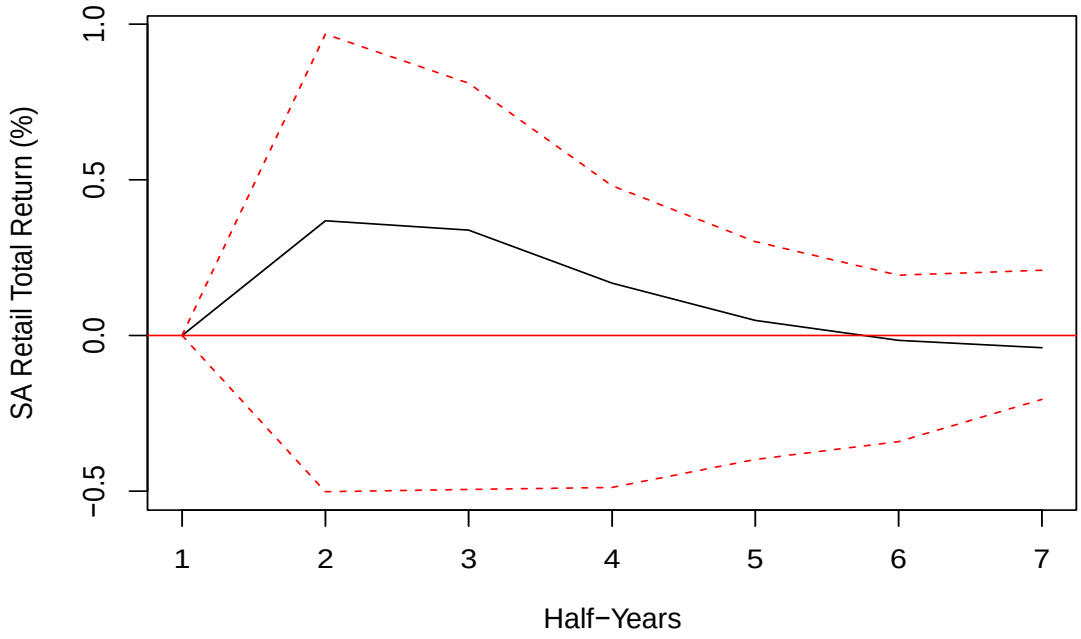


At the onset, a shock to economic growth has no impact on the retail property sector total return. Soon after the shock, there is a marginal increase in the total return which peaks two half-years after the shock at approximately 0.2 percentage points. This positive impulse response reverses and becomes negative by the third half-year whereafter it remains negative for the rest of the period reaching approximately −0.18 percentage points. By the seventh half-year after the initial shock, the retail property sector total return has not fully recovered to its long-run equilibrium. Importantly, the

impulse response is significantly different from zero at the 95% confidence level as the upper and lower bounds of the 95% confidence interval do not cross over the zero line. Consequently, a one-unit change in economic growth has a significant positive impact on the total return of the retail property sector which persists for approximately three half-years.

The influence of a one-unit change in inflation on the total return of the retail property sector is graphically illustrated in Figure 10.

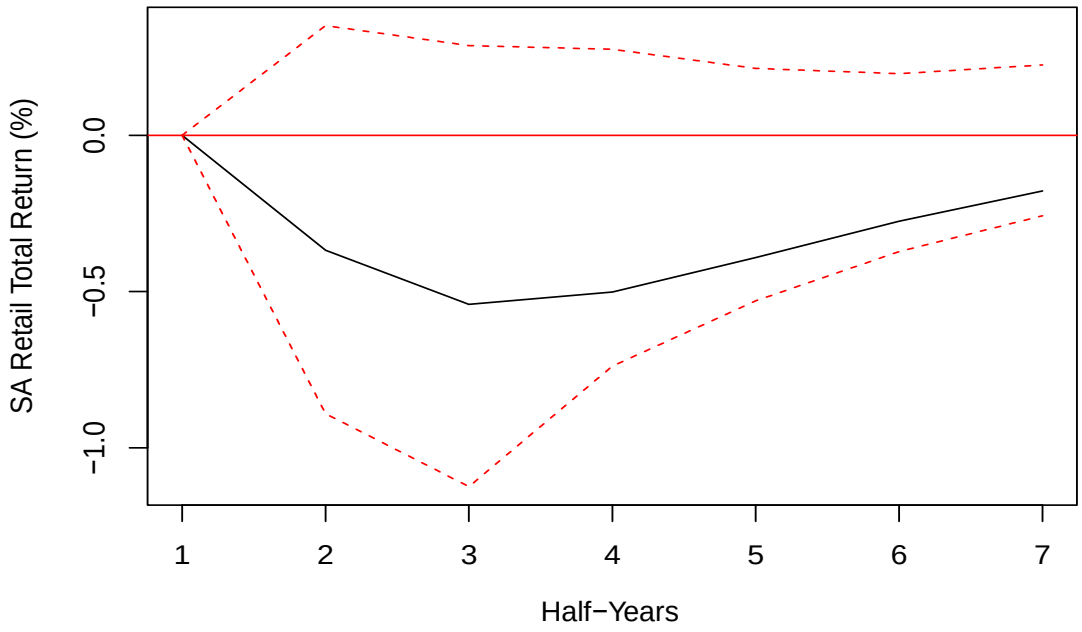
Figure 10: Orthogonal impulse response of the retail property sector total return from a shock to inflation



The impulse response of the retail property sector total return from a shock to inflation is initially zero. However, over the next half-year, the shock causes a slight increase in the total return which peaks at approximately 0.35 percentage points two half-years following the shock. The positive impulse response then gradually reduces over the next four half-years and converges back to zero by the sixth half-year after the initial shock. The 95% confidence interval lines do not cross over the zero line, hence, the impulse response is said to be statistically significant at the 95% confidence level. Therefore, it can be concluded that a one-unit change in inflation has a significant positive effect on the total return of the retail property sector which persists for approximately six half-years.

Figure 11 displays the impact of a one-unit change in interest rates on the total return of the retail property sector.

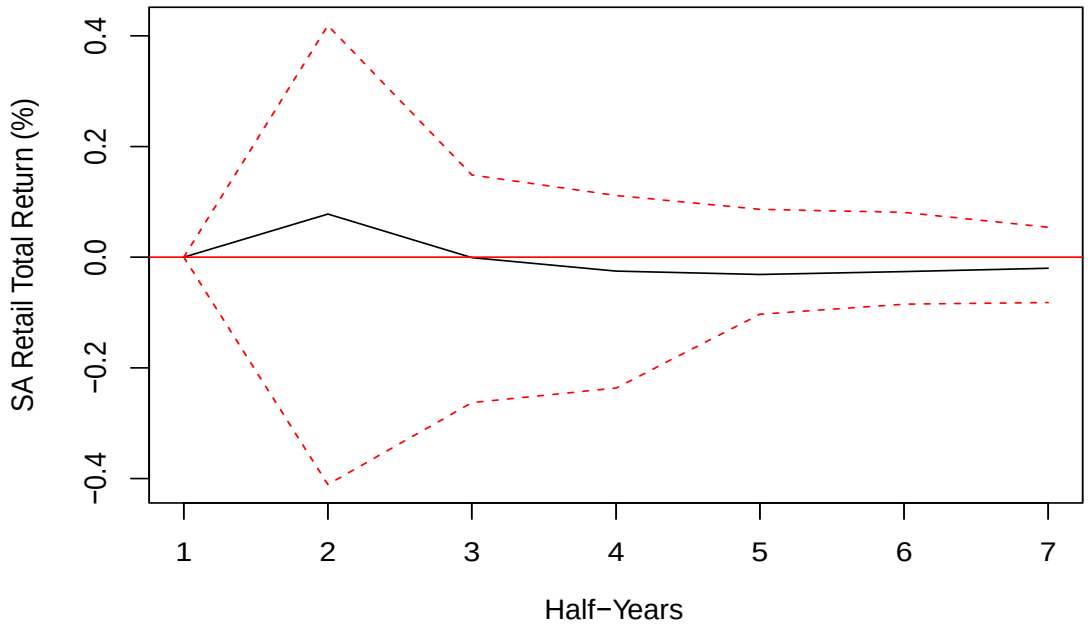
Figure 11: Orthogonal impulse response of the retail property sector total return from a shock to interest rates



A shock to interest rates has no immediate influence on the retail property sector total return. This is then followed by a gradual decline in the total return which worsens and reaches a trough of approximately −0.5 percentage points at the third half-year. This negative impulse response then decays over the next four half-years although it has not converged back to zero by the seventh half-year after the initial shock. The boundary lines of the 95% confidence interval do not cross over the zero line which suggests that the impulse response is statistically significant at the 95% confidence level. Therefore, a one-unit change in interest rates has a significant negative influence on the total return of the retail property sector which persists for more than seven half-years.

The effect of a one-unit change in stock market returns on the total return of the retail property sector is plotted in Figure 12.

Figure 12: Orthogonal impulse response of the retail property sector total return from a shock to stock market returns



The impulse response of the retail property sector total return to a shock to stock market returns is initially zero. Over the next half-year, there is a small increase in the total return which peaks in the second half-year at approximately 0.09 percentage points. In the subsequent half-year, the positive impulse response declines back to its long-run equilibrium by the third half-year following the initial shock. The impulse response is significantly different from zero at the 95% confidence level as the boundary lines of the 95% confidence interval do not cross over the zero line. Thus, it can be said that a one-unit change in stock market returns has a significant positive impact on the total return of the retail property sector which persists for approximately three half-years.

4.3.2.5 Forecast error variance decompositions

Table 18 provides a synopsis of the forecast error variance decompositions of the estimated VAR(1) model for the retail property sector.

Table 18: Forecast error variance decompositions of the VAR(1) model for the retail property sector

Half-Years	Retail total return	Economic growth	Inflation	Interest rates	Stock market returns
1	1	0	0	0	0

2	94.58372	0.5368551	2.387502	2.384705	0.10721622
3	88.73703	0.5467384	3.917216	6.703591	0.09542557
4	84.79068	0.9037682	4.128411	10.077513	0.09962891
5	82.55905	1.2785184	4.048140	12.003470	0.11081924
6	81.43762	1.5308983	3.996327	12.916216	0.11893849
Average	**86.42162**	**0.9593557**	**3.695519**	**8.817099**	**0.71064057**

The variability in structural shocks to economic growth and stock market returns explain a negligible percentage of the forecast error variance of the retail property sector total return. Specifically, over the six half-years, an average of 0.96% and 0.71% of the forecast error variance is caused by these respective macroeconomic factors. A slightly larger proportion of the forecast error variance is explained by the variability in structural shocks to inflation and interest rates. These macroeconomic factors contribute approximately 3.70% and 8.82% respectively to the forecast error variance of the retail property sector total return. As such, the findings from the forecast error variance decompositions indicate that inflation and interest rates primarily influence the variance of the retail property sector total return, however, these macroeconomic factors explain a small percentage of this variance.

4.3.2.6 Granger causality analysis

Table 19 presents the outcome from the Granger causality analysis of the estimated VAR(1) model for the retail property sector.

Table 19: Granger causality analysis of the VAR(1) model for the retail property sector

Null hypothesis	F-test value	P-value	Reject/Fail to reject null hypothesis
Retail sector total return does not Granger cause economic growth, inflation, interest rates, and stock market returns.	1.3849	0.2461	Fail to reject
Economic growth does not Granger cause the retail sector total return, inflation, interest rates, and stock market returns.	0.6349	0.639	Fail to reject

Inflation does not Granger cause the retail sector total return, economic growth, interest rates, and stock market returns.	3.4026	0.01245	Reject
Interest rates do not Granger cause the retail sector total return, economic growth, inflation, and stock market returns.	1.3331	0.2643	Fail to reject
Stock market returns do not Granger cause the retail sector total return, economic growth, inflation, and interest rates.	0.11528	0.9768	Fail to reject

The findings of the Granger causality analysis reveal that inflation Granger causes the retail property sector total return, economic growth, interest rates, and stock market returns. Therefore, lagged values of the inflation rate may be useful in predicting the retail property sector total return.

4.3.3 Office property sector

The findings of the lag order selection tests, stability analysis, diagnostic tests, impulse response functions, forecast error variance decompositions, and Granger causality analysis regarding the estimated VAR model for the South African office property sector is presented below.

4.3.3.1 Lag order selection

The results of the lag order selection tests are reported in Table 20. As mentioned previously, p_{max} is set to a moderate value of three when running these tests.

Table 20: Lag order selection criteria for the office property sector

Lag order	AIC(p)	HQ(p)	SC(p)
$p = 1$	2.302369	2.477608	3.046262
$p = 2$	1.627262	1.907664	2.817491
$p = 3$	1.984731	2.370256	3.621294
Selected lag order	**2**	**2**	**2**

The AIC, HQ, and SC tests indicate that the lag length should be two lags ($p = 2$) as this is the lag order that minimises the criteria. Given these consistent results, a VAR(2) model is estimated for the office property sector.

4.3.3.2 Stability analysis

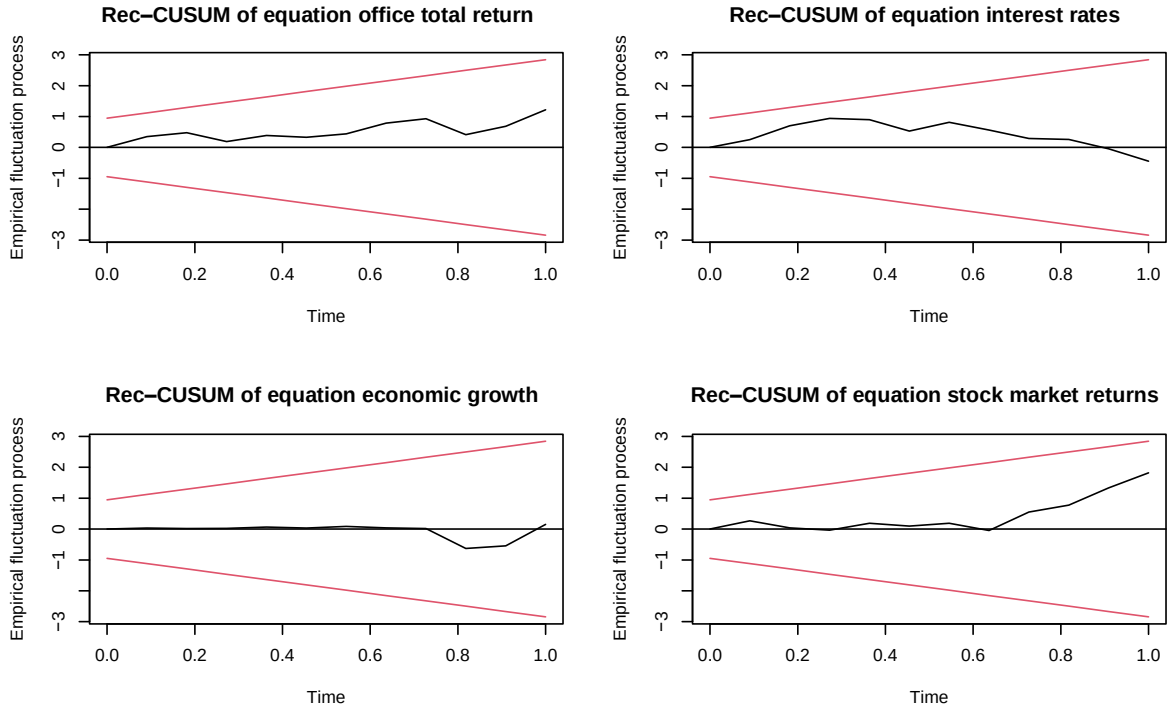
Table 21 captures the eigenvalues of the estimated VAR(2) model for the office property sector.

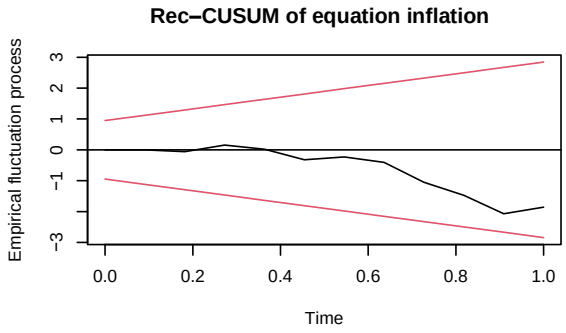
Table 21: Eigenvalues of the VAR(2) model for the office property sector

0.9624	0.9624	0.9378	0.9378	0.6630
0.6630	0.3491	0.3491	0.2692	0.2692

All of the eigenvalues have modulus less than one which infers that the VAR(2) process is stable. Furthermore, the CUSUM plots in Figure 13 remain between the critical bands at the 5% level of significance, therefore, there is no concern about the stability of the model.

Figure 13: CUSUM tests of the individual equations of the VAR(2) model for the office property sector





The analysis of the eigenvalues and the CUSUM tests show that the estimated VAR(2) model for the office property sector is stable. As such, the model is stationary and ergodic with time invariant means, variances, and autocovariances.

4.3.3.3 Diagnostic tests

Table 22 provides an overview of the diagnostic tests for autocorrelation, conditional heteroskedasticity, and nonnormality of the estimated VAR(2) model for the office property sector.

Table 22: Diagnostic tests of the VAR(2) model for the office property sector

	Portmanteau autocorrelation test	**ARCH-LM test**	**Jarque-Bera nonnormality test**
Chi-squared	191.61	222.32	7.8529
P-value	0.6524	0.5380	0.6432
Reject/Fail to reject null hypothesis	Fail to reject	Fail to reject	Fail to reject

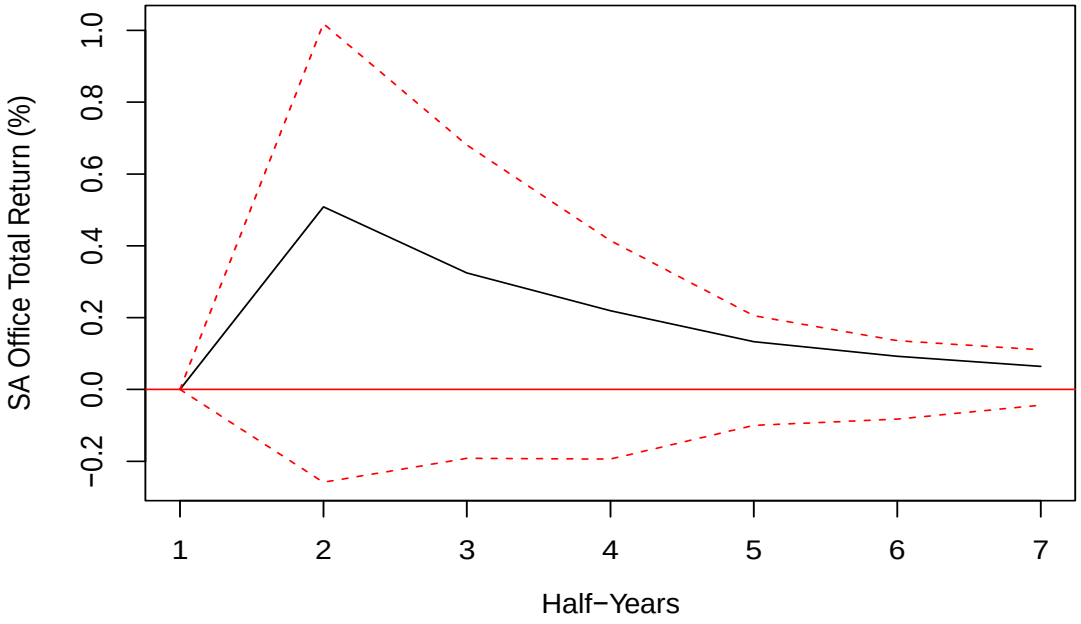
Fail to reject the null hypothesis of no residual autocorrelation for the Portmanteau autocorrelation test at the 10%, 5%, and 1% levels of significance. This finding suggests that the residuals of the estimated VAR(2) model are not autocorrelated. Similarly, fail to reject the null hypothesis of the ARCH-LM test at the 10%, 5%, and 1% levels of significance, hence, there is no ARCH effects in the residuals of the estimated VAR(2) model. Moreover, failing to reject the null hypothesis of the Jarque-Bera nonnormality test at the 10%, 5%, and 1% levels of significance implies that the residuals of the estimated VAR(2) model are normally distributed. Therefore, the results of the stability analysis and the diagnostic tests confirm that the estimated

VAR(2) model for the office property sector is sufficient to undertake statistical inference.

4.3.3.4 Impulse response functions

Figure 14 depicts the effect of a one-unit change in economic growth on the total return of the office property sector.

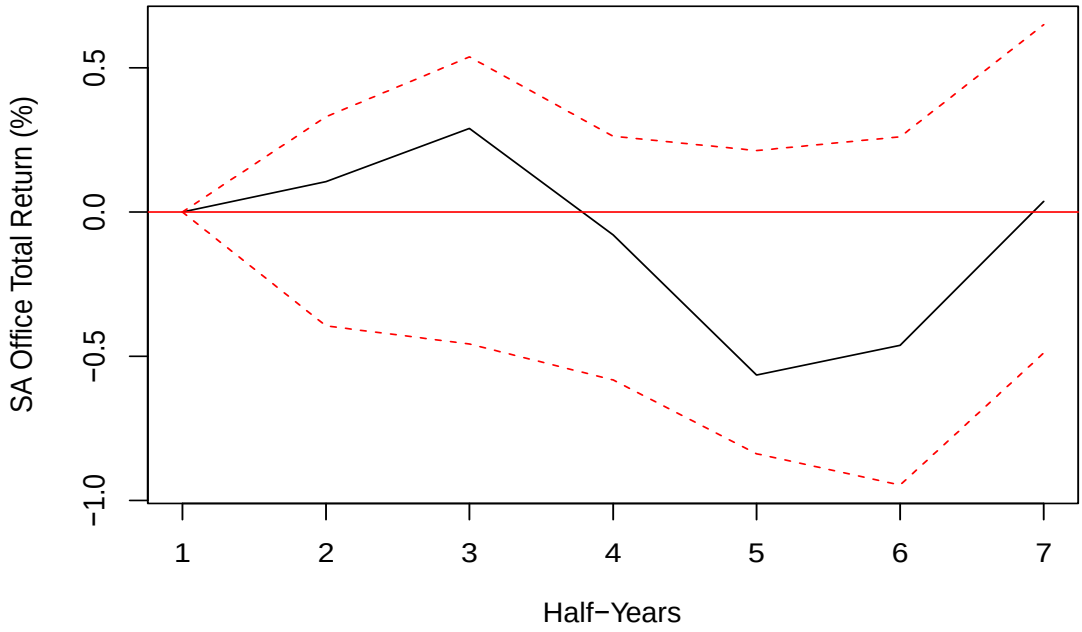
Figure 14: Orthogonal impulse response of the office property sector total return from a shock to economic growth



A shock to economic growth has no instant impact on the office property sector total return, however, soon after the shock, the total return increases and reaches a peak at approximately 0.5 percentage points two half-years following the shock. The positive impulse response then slowly diminishes over the next five half-years. It must be noted that by the seventh half-year following the initial shock, the office property sector total return has not converged to its long-run equilibrium. The upper and lower bounds of the 95% confidence interval do not cross over the zero line, thus, the impulse response is statistically significant at the 95% confidence level. Accordingly, a one-unit change in economic growth has a significant positive effect on the total return of the office property sector which persists for more than seven half-years.

The influence of a one-unit change in inflation on the total return of the office property sector is plotted in Figure 15.

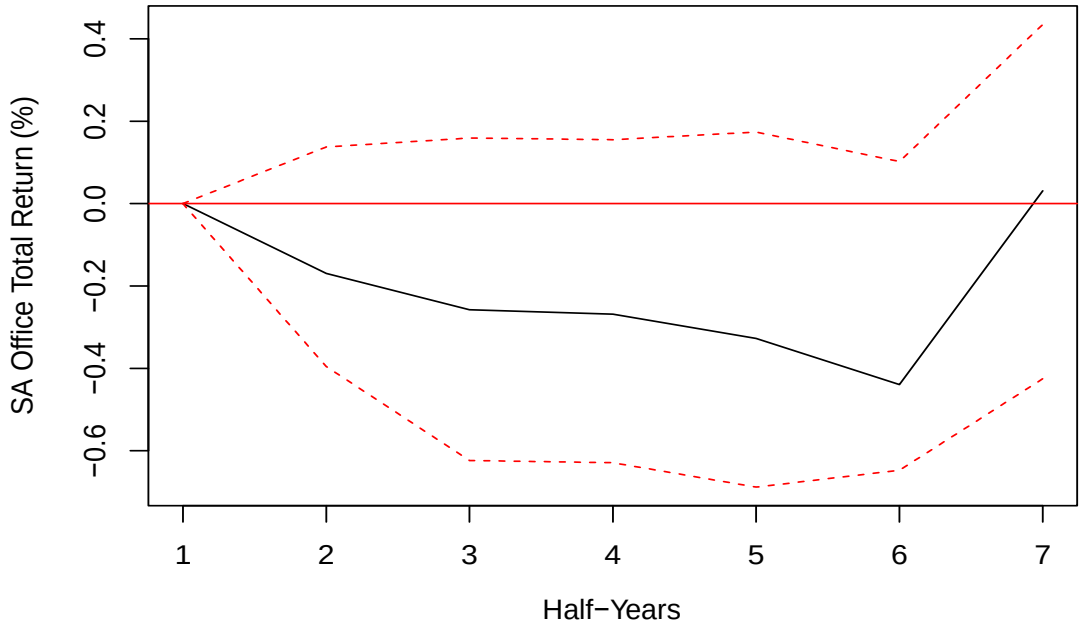
Figure 15: Orthogonal impulse response of the office property sector total return from a shock to inflation



At the onset, the impulse response of the office property sector total return to a shock to inflation is zero. This is then followed by a gradual increase in the total return which peaks three half-years after the shock at approximately 0.25 percentage points. The positive impulse response reverses and becomes negative by the fourth half-year whereafter it worsens and reaches a trough five half-years following the shock at approximately −0.5 percentage points. This negative impulse response then reduces over the next two half-years to zero, however, it cannot be determined if the shock has fully worked its way through the system by the seventh half-year after the initial shock. Since the boundary lines of the 95% confidence interval do not cross over the zero line, the impulse response is deemed to be statistically significant. As such, a one-unit change in inflation has a significant positive impact on the total return of the office property sector which persists for approximately four half-years.

Figure 16 graphically illustrates the effect of a one-unit change in interest rates on the total return of the office property sector.

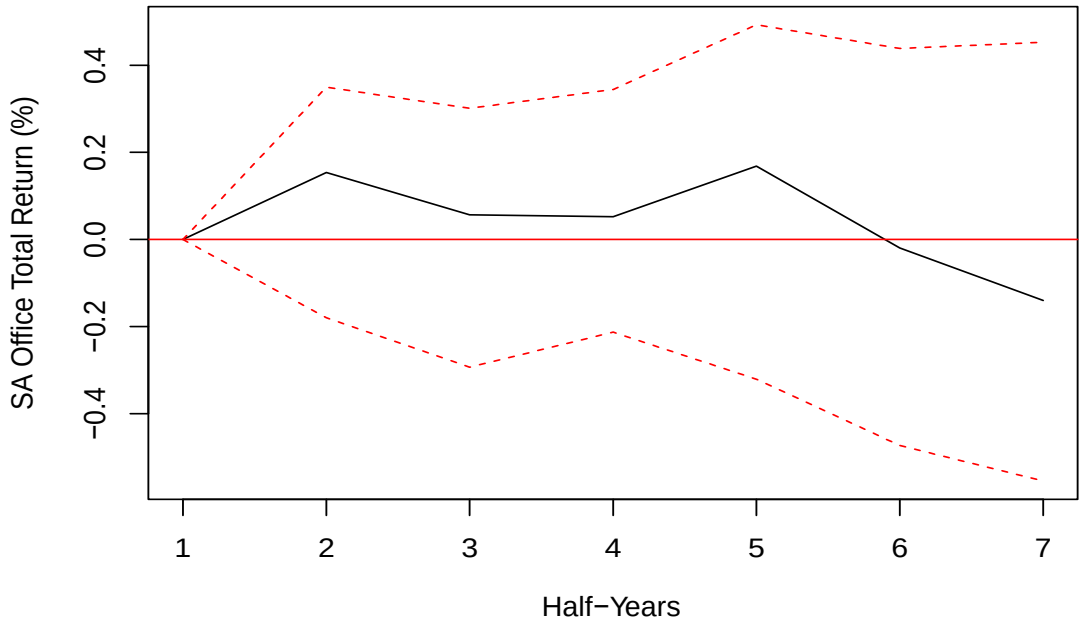
Figure 16: Orthogonal impulse response of the office property sector total return from a shock to interest rates



A shock to interest rates has no initial impact on the office property sector total return. Over the next five half-years, the total return decreases and reaches a trough of approximately −0.4 percentage points by the fifth half-year. This negative impulse response then reduces to zero by the seventh half-year. Nevertheless, it cannot be said that the office property sector total return has fully converged to its long-run equilibrium by the seventh half-year after the shock. The impulse response is significantly different from zero at the 95% confidence level as the boundary lines of the 95% confidence interval do not cross over the zero line. Therefore, a one-unit change in interest rates has a significant negative impact on the total return of the office property sector which persists for approximately seven half-years.

The impact of a one-unit change in stock market returns on the total return of the office property sector is displayed in Figure 17.

Figure 17: Orthogonal impulse response of the office property sector total return from a shock to stock market returns



The impulse response of the office property sector total return to a shock to stock market returns is initially zero. The shock then induces a positive impulse response which peaks two half-years and five half-years following the shock at approximately 0.19 and 0.2 percentage points respectively. In the ensuing half-year, the positive impulse response decreases and becomes negative during the sixth and seventh half-years. The impulse response has not converged back to zero by the seventh half-year after the initial shock. The upper and lower bounds of the 95% confidence interval do not cross over the zero line, hence, the impulse response is statistically significant at the 95% confidence level. As a consequence, it can be concluded that a one-unit change in stock market returns has a significant positive impact on the total return of the office property sector which persists for approximately six half-years.

4.3.3.5 Forecast error variance decompositions

Table 23 outlines the forecast error variance decompositions of the estimated VAR(2) model for the office property sector.

Table 23: Forecast error variance decompositions of the VAR(2) model for the office property sector

Half-Years	Office total return	Economic growth	Inflation	Interest rates	Stock market returns
1	1	0	0	0	0
2	58.16613	39.76506	0.3626861	0.9367462	0.7693755
3	57.15119	37.43633	2.3732045	2.3704589	0.6688107
4	63.58056	30.49619	2.0164659	3.3195908	0.5871920
5	60.46610	28.93715	5.9240704	3.8581456	0.8145382
6	56.10148	29.94520	7.6336853	5.6188304	0.7007989
Average	**59.09309**	**33.31599**	**3.6620224**	**3.2207544**	**0.7081431**

The results indicate that economic growth contributes approximately 33.32% to the forecast error variance of the office property sector total return. The variability in structural shocks to inflation and interest rates explain a much smaller percentage of the forecast error variance. These macroeconomic factors contribute approximately 3.66% and 3.22% respectively to the forecast error variance. On average, 0.71% of the forecast error variance of the office property sector total return is due to the variability in a structural shock to stock market returns. These results indicate that the variance of the office property sector total return is predominately impacted by economic growth and, to a much lesser extent, inflation and interest rates.

4.3.3.6 Granger causality analysis

Table 24 reports the findings from the Granger causality analysis of the estimated VAR(2) model for the office property sector.

Table 24: Granger causality analysis of the VAR(2) model for the office property sector

Null hypothesis	F-test value	P-value	Reject/Fail to reject null hypothesis
Office sector total return does not Granger cause economic growth, inflation, interest rates, and stock market returns.	1.072	0.3961	Fail to reject

Economic growth does not Granger cause the office sector total return, inflation, interest rates, and stock market returns.	1.0528	0.4092	Fail to reject
Inflation does not Granger cause the office sector total return, economic growth, interest rates, and stock market returns.	5.4845	$4.221e^{-05}$	Reject
Interest rates do not Granger cause the office sector total return, economic growth, inflation, and stock market returns.	4.9484	0.000122	Reject
Stock market returns do not Granger cause the office sector total return, economic growth, inflation, and interest rates.	2.4036	0.02662	Reject

In summary, it can be said that inflation Granger causes the office sector total return, economic growth, interest rates, and stock market returns. As a result, lagged values of the inflation rate may be useful in forecasting the office property sector total return. Additionally, interest rates Granger cause the office sector total return, economic growth, inflation, and stock market returns. This shows that lagged values of interest rates may also be useful in predicting the office property sector total return. Similarly, stock market returns Granger cause the office sector total return, economic growth, inflation, and interest rates. Hence, lagged values of stock market returns may be useful in forecasting the office property sector total return.

4.3.4 Industrial property sector

The results of the lag order selection tests, stability analysis, diagnostic tests, impulse response functions, forecast error variance decompositions, and Granger causality analysis relating to the estimated VAR model for the South African industrial property sector is provided below.

4.3.4.1 Lag order selection

Table 25 summarises the results of the lag order selection tests for the industrial property sector when employing a p_{max} of three as discussed previously.

Table 25: Lag order selection criteria for the industrial property sector

Lag order	AIC(p)	HQ(p)	SC(p)
$p = 1$	2.261273	2.436512	3.005166
$p = 2$	1.668768	1.949150	2.858996
$p = 3$	2.203715	2.589240	3.840279
Selected lag order	**2**	**2**	**2**

Evidently, the optimal lag length selected is two lags ($p = 2$) since this is the order that minimises the criteria for all of the lag order selection tests. Given these findings, a VAR(2) model is estimated for the industrial property sector.

4.3.4.2 Stability analysis

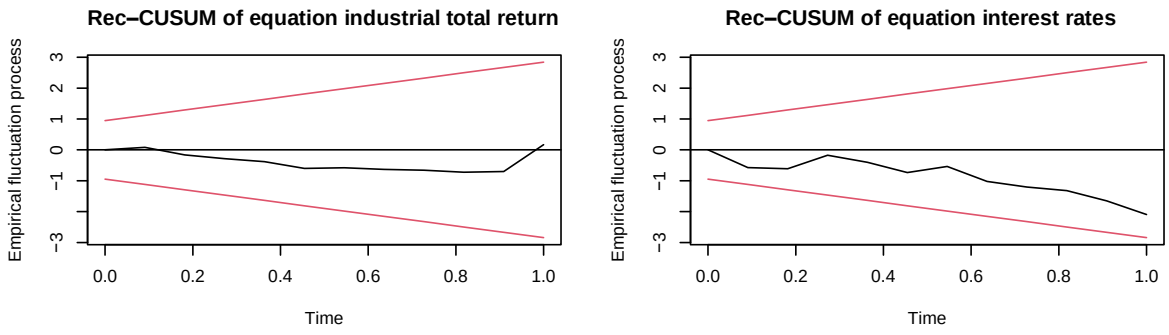
Table 26 captures the eigenvalues of the estimated VAR(2) model for the industrial property sector.

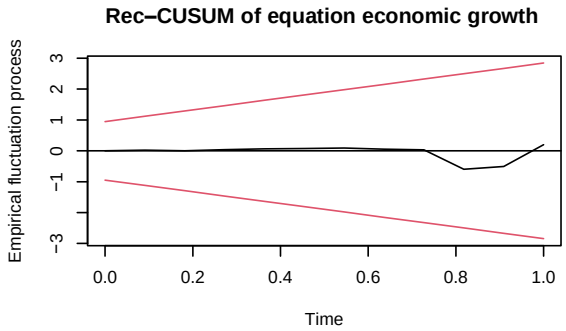
Table 26: Eigenvalues of the VAR(2) model for the industrial property sector

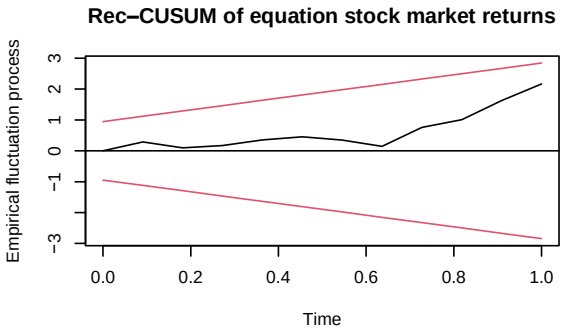
0.9997	0.9997	0.7591	0.7591	0.6522
0.6522	0.6136	0.4400	0.3687	0.004095

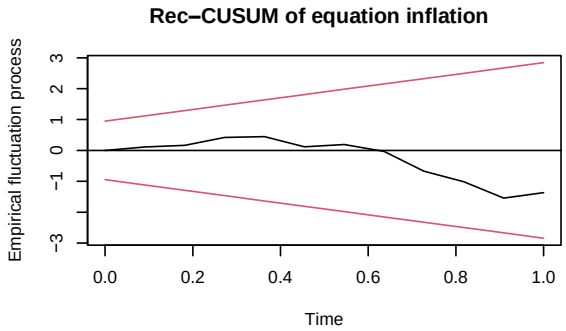
The VAR(2) process can be classified as stable since all of the eigenvalues have modulus less than one. Likewise, Figure 18 displays that the CUSUM plots do not diverge too far away from the zero line or cross the 95% confidence intervals, and thus, there is no indication of structural instability.

Figure 18: CUSUM tests of the individual equations of the VAR(2) model for the industrial property sector









The eigenvalues and the findings of the CUSUM tests reveal that the estimated VAR(2) model for the industrial property sector is stable. Accordingly, the model is stationary and ergodic with means, variances, and autocovariances that are independent of time.

4.3.4.3 Diagnostic tests

The results of the diagnostic tests for autocorrelation, conditional heteroskedasticity, and nonnormality of the estimated VAR(2) model for the industrial property sector are presented in Table 27.

Table 27: Diagnostic tests of the VAR(2) model for the industrial property sector

	Portmanteau autocorrelation test	**ARCH-LM test**	**Jarque-Bera nonnormality test**
Chi-squared	196.23	236.83	12.161
P-value	0.5621	0.2811	0.2744
Reject/Fail to reject null hypothesis	Fail to reject	Fail to reject	Fail to reject

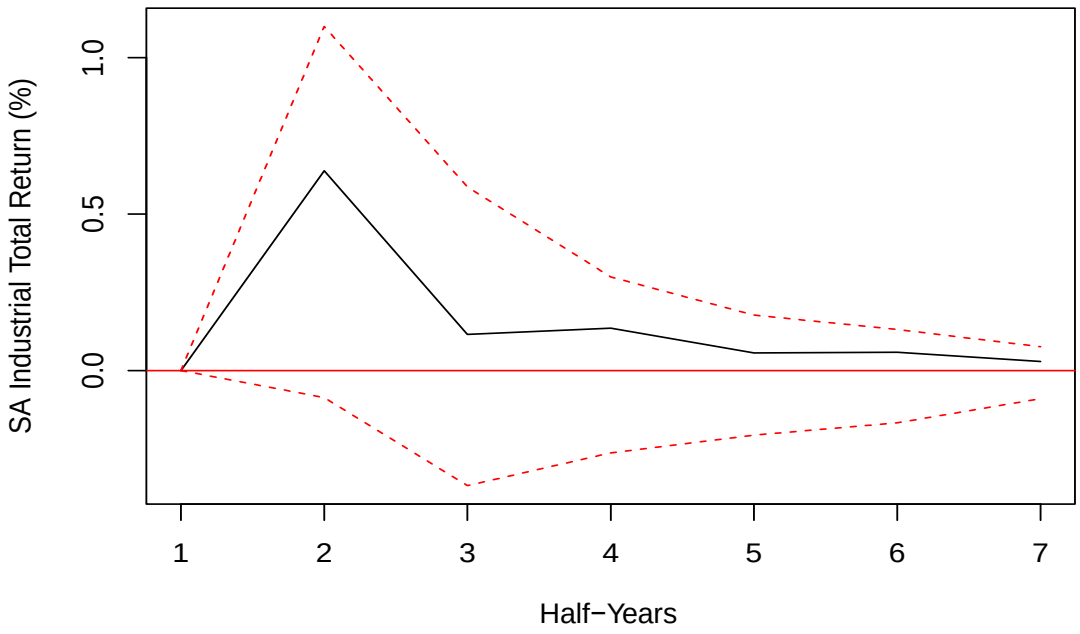
Failing to reject the null hypothesis of the Portmanteau autocorrelation test at the 10%, 5%, and 1% levels of significance indicates that the residuals of the estimated VAR(2)

model are not autocorrelated. Similarly, fail to reject the null hypothesis that there is no ARCH effects in the residuals at the 10%, 5%, and 1% levels of significance for the ARCH-LM test. Thus, the residuals of the estimated VAR(2) model do not exhibit conditional heteroskedasticity. For the Jarque-Bera nonnormality test, fail to reject the null hypothesis at the 10%, 5%, and 1% levels of significance which implies that the residuals of the estimated VAR(2) model are normally distributed. Therefore, the findings of the stability analysis and the diagnostic tests verifies that the estimated VAR(2) model for the industrial property sector is adequate to conduct statistical inference.

4.3.4.4 Impulse response functions

The impact of a one-unit change in economic growth on the total return of the industrial property sector is depicted in Figure 19.

Figure 19: Orthogonal impulse response of the industrial property sector total return from a shock to economic growth

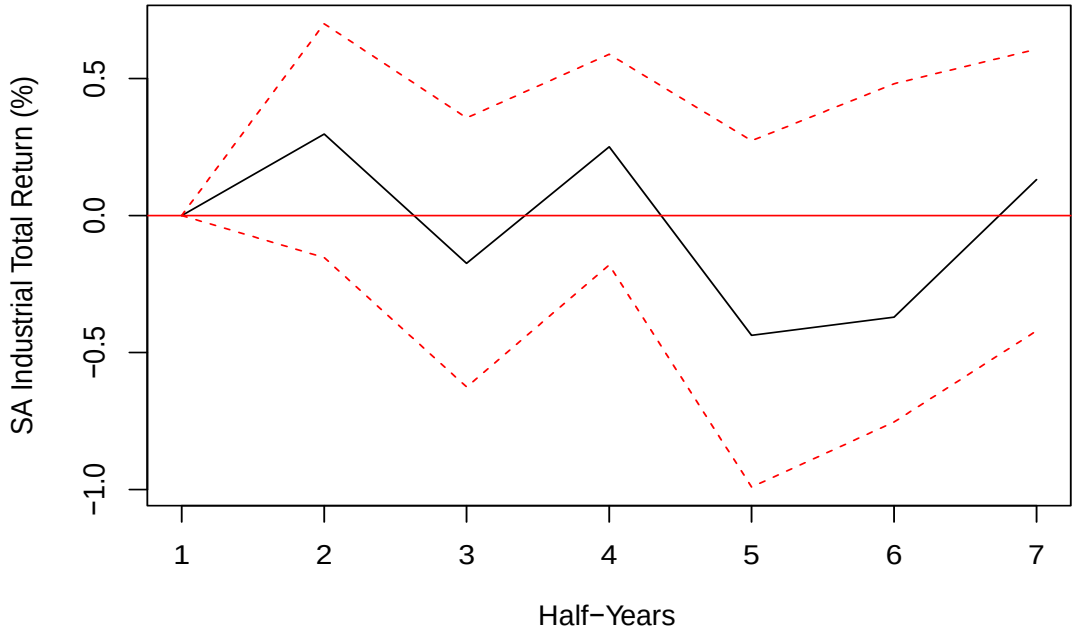


Initially, a shock to economic growth has no impact on the industrial property sector total return. Over the next half-year, the shock causes an increase in the total return which peaks in the second half-year at approximately 0.6 percentage points. This positive impulse response then declines to approximately 0.15 percentage points in the third half-year where it remains at this level for the next two half-years up until the fifth half-year. Subsequently, the impulse response converges back to zero by the

seventh half-year after the initial shock. The impulse response is significantly different from zero at the 95% confidence level as the boundary lines of the 95% confidence interval do not cross over the zero line. As such, a one-unit change in economic growth has a significant positive effect on the total return of the industrial property sector which persists for approximately seven half-years.

Figure 20 plots the influence of a one-unit change in inflation on the total return of the industrial property sector.

Figure 20: Orthogonal impulse response of the industrial property sector total return from a shock to inflation

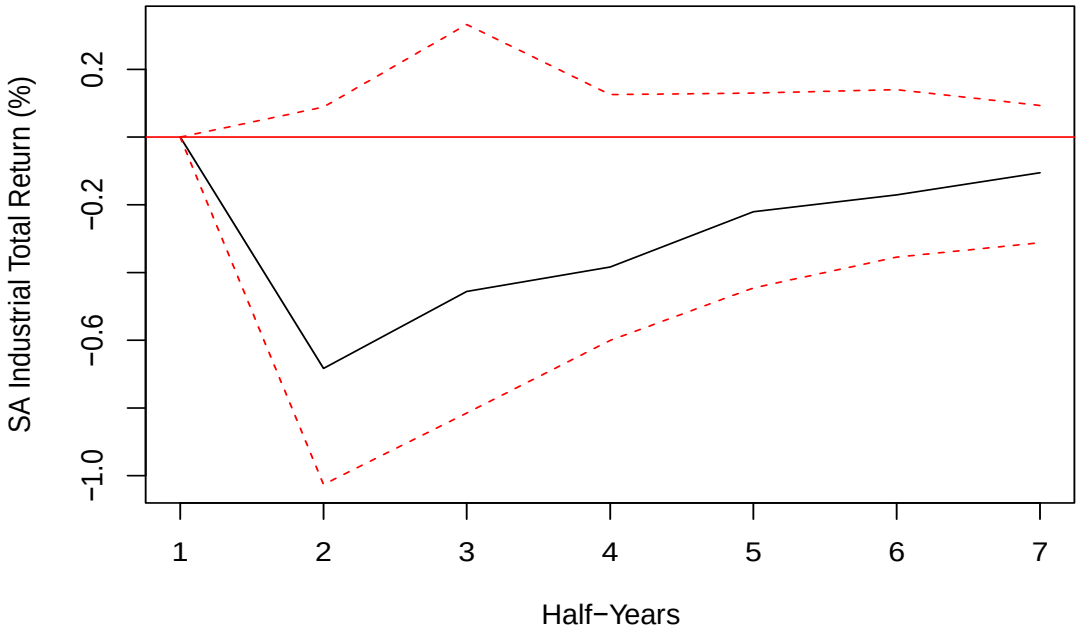


At the onset, the impulse response of the industrial property sector total return to a shock to inflation is zero. However, soon after the shock, the total return experiences a marginal increase which peaks at approximately 0.3 percentage points in the second half-year. The impulse response then decreases in the next half-year to approximately −0.15 percentage points whereafter it increases again to reach the same peak as it previously did by the fourth half-year after the shock. Following this peak, the impulse response decreases and becomes negative again where it reaches a trough of approximately −0.4 percentage points in the fifth half-year. Thereafter, the total return increases and becomes positive although it cannot be concluded that the shock has fully worked its way through the system by the seventh half-year after the initial shock. The upper and lower bounds of the 95% confidence interval do not cross over the zero

line which highlights that the impulse response is statistically significant at the 95% confidence level. As a result, a one-unit change in inflation has a significant positive impact on the total return of the industrial property sector which persists for approximately two half-years.

The impact of a one-unit change in interest rates on the total return of the industrial property sector is graphically illustrated in Figure 21.

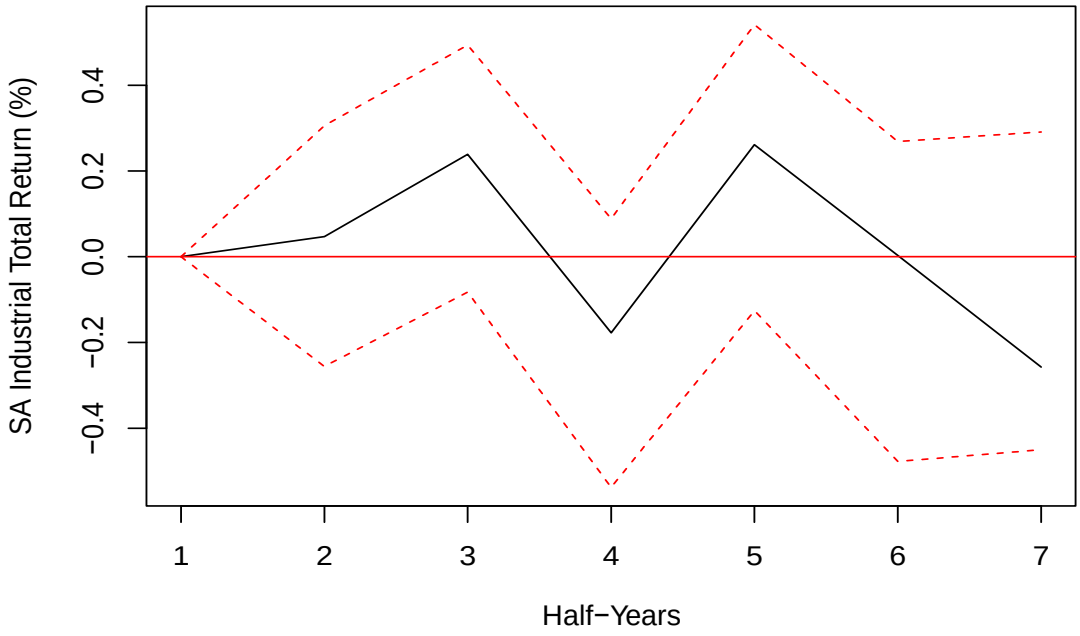
Figure 21: Orthogonal impulse response of the industrial property sector total return from a shock to interest rates



A shock to interest rates has no immediate influence on the industrial property sector total return, however, the total return then decreases over the next half-year and reaches a trough of approximately −0.65 percentage points at the second half-year. This negative impulse response then decays over the next five half-years although it has not converged back to zero by the seventh half-year after the initial shock. It must be noted than the impulse response is statistically significantly at the 95% confidence level as the boundary lines of the 95% confidence interval do not cross over the zero line. Therefore, it can be said that a one-unit change in interest rates has a significant negative impact on the total return of the industrial property sector which persists for more than seven half-years.

Figure 22 displays the effect of a one-unit change in stock market returns on the total return of the industrial property sector.

Figure 22: Orthogonal impulse response of the industrial property sector total return from a shock to stock market returns



The impulse response of the industrial property sector total return to a shock to stock market returns is initially zero. This is shortly followed by a gradual increase in the total return which peaks at approximately 0.2 percentage points three half-years after the shock. Over the next half-year, the positive impulse response reverses and becomes a negative impulse response of approximately −0.2 percentage points in the fourth half-year. Subsequently, the total return becomes positive again where it peaks at approximately 0.25 percentage points in the fifth half-year. Over the next two half-years, the impulse response decreases and becomes negative although the industrial property sector total return does not fully recover to its long-run equilibrium. Since the boundary lines of the 95% confidence interval do not cross over the zero line, the impulse response is significantly different from zero at the 95% confidence level. As such, a one-unit change in stock market returns has a significant positive influence on the total return of the industrial property sector which persists for approximately three half-years.

4.3.4.5 Forecast error variance decompositions

The forecast error variance decompositions of the estimated VAR(2) model for the industrial property sector is reported in Table 28.

Table 28: Forecast error variance decompositions of the VAR(2) model for the industrial property sector

Half-Years	Industrial total return	Economic growth	Inflation	Interest rates	Stock market returns
1	1	0	0	0	0
2	61.25726	28.25157	2.100163	8.338735	0.0522668
3	61.15644	22.79594	2.274827	12.637603	1.1351908
4	59.22886	26.84490	2.545147	10.110210	1.2708849
5	59.22262	26.44699	4.217110	8.315468	1.7978211
6	57.88276	26.24088	5.564524	8.579481	1.7323599
Average	**59.74959**	**26.11606**	**3.340354**	**9.596299**	**1.1977047**

A considerable proportion of the forecast error variance of the industrial property sector total return is attributable to the variability in a structural shock to economic growth. Particularly, economic growth explains approximately 26.12% of the forecast error variance over the six half-year time horizon. Interest rates contribute approximately 9.60% to the forecast error variance of the industrial property sector total return. The variability in structural shocks to inflation and stock market returns explain a much smaller percentage of the forecast error variance. On average, 3.34% and 1.20% of the forecast error variance is explained by these respective macroeconomic factors. Therefore, it can be said that the variance of the industrial property sector total return is primarily influenced by economic growth and, to a much smaller degree, interest rates.

4.3.4.6 Granger causality analysis

The results from the Granger causality analysis of the estimated VAR(2) model for the industrial property sector are captured in Table 29.

Table 29: Granger causality analysis of the VAR(2) model for the industrial property sector

Null hypothesis	F-test value	P-value	Reject/Fail to reject null hypothesis
Industrial sector total return does not Granger cause economic growth, inflation, interest rates, and stock market returns.	0.82275	0.5861	Fail to reject
Economic growth does not Granger cause the industrial sector total return, inflation, interest rates, and stock market returns.	1.8291	0.09113	Fail to reject
Inflation does not Granger cause the industrial sector total return, economic growth, interest rates, and stock market returns.	2.5784	0.01821	Reject
Interest rates do not Granger cause the industrial sector total return, economic growth, inflation, and stock market returns.	2.6424	0.01584	Reject
Stock market returns do not Granger cause the industrial sector total return, economic growth, inflation, and interest rates.	0.88526	0.5349	Fail to reject

It can be concluded that inflation Granger causes the industrial sector total return, economic growth, interest rates, and stock market returns. Accordingly, lagged values of the inflation rate may be useful in predicting the industrial property sector total return. Furthermore, interest rates Granger cause the industrial sector total return, economic growth, inflation, and stock market returns. This implies that lagged values of interest rates may be useful in forecasting the industrial property sector total return.

4.4 VECTOR ERROR CORRECTION MODELS

This section estimates VECMs for the overall South African REIT market as well as the retail, office, and industrial property sectors in order to examine the long-run relationships between numerous macroeconomic factors and South African REIT returns.

4.4.1 REIT market

The Johansen cointegration tests, cointegrating vector, and loading matrix of the VECM for the South African REIT market is presented below.

4.4.1.1 Johansen cointegration tests

The outcome of the trace test is summarised in Table 30.

Table 30: Trace test for the REIT market

Null hypothesis	Test statistic	Critical values		
		10%	5%	1%
$r = 0$	143.70	83.20	87.31	96.58
$r = 1$	78.99	59.14	62.99	70.05
$r = 2$	44.44	39.06	42.44	48.45
$r = 3$	19.70	22.76	25.32	30.45
$r = 4$	6.23	10.49	12.25	16.26

The null hypothesis of there being no cointegrating vectors ($r = 0$) is rejected at the 10%, 5%, and 1% levels of significance. Setting the cointegrating rank to one ($r = 1$) also results in the null hypothesis being rejected at the 10%, 5%, and 1% levels of significance. When the cointegrating rank is increased to two ($r = 2$), the null hypothesis is rejected at the 10% and 5% levels of significance. On the other hand, fail to reject the null hypothesis of there being three cointegrating vectors ($r = 3$) at the 10%, 5%, and 1% levels of significance. Hence, the trace test indicates that there are three cointegrating vectors. Table 31 captures the findings of the maximum eigenvalue test.

Table 31: Maximum eigenvalue test for the REIT market

Null hypothesis	Test statistic	Critical values		
		10%	5%	1%
$r = 0$	64.71	34.75	37.52	42.36
$r = 1$	34.55	29.12	31.46	36.65
$r = 2$	24.74	23.11	25.54	30.34
$r = 3$	13.47	16.85	18.96	23.65

$r = 4$	6.23	10.49	12.25	16.26

The null hypothesis is rejected at the 10%, 5%, and 1% levels of significance when the cointegrating rank is set to zero ($r = 0$). Increasing the cointegrating rank to one ($r = 1$) results in the null hypothesis being rejected at the 10% and 5% levels of significance. Reject the null hypothesis of there being two cointegrating vectors ($r = 2$) at the 10% level of significance, however, fail to reject the null hypothesis at the 5% and 1% levels of significance. As such, the maximum eigenvalue test reveals that there are two cointegrating vectors.

Given the results of the trace and maximum eigenvalue tests, it can be concluded that a long-run relationship exists between the time series variables. However, it is evident that the two types of tests yield conflicting results. Lütkepohl, Saikkonen, and Trenkler (2001) studied the relative performance of the two types of tests and found that the local power of the trace and maximum eigenvalue tests are very similar. However, the small-sample power of the trace test was found to be superior to that of the maximum eigenvalue test in some situations, and thus, the authors concluded that the trace test is preferred. Accordingly, as per the trace test, a VECM with three cointegrating vectors is estimated for the REIT market.

4.4.1.2 Cointegrating vector

Table 32 reports the cointegrating vector of the estimated VECM for the REIT market.

Table 32: Cointegrating vector for the REIT market

	REIT market total return	Economic growth	Inflation	Interest rates	Stock market returns	Trend
$\widehat{\boldsymbol{\beta}}^{\boldsymbol{T}}$	1.0000	−7.2358	−1.2118	2.1832	−0.8810	0.0350

By normalising the REIT market total return, the cointegrating vector can be written as follows:

$$reit_t = 7.2358grow_t + 1.2118inf_t - 2.1832int_t + 0.8810jse_t - 0.0350t + ec_t$$

where $reit_t =$ REIT market total return, $grow_t =$ economic growth, $inf_t =$ inflation, $int_t =$ interest rates, $jse_t =$ stock market returns, $t =$ trend term, and ec_t = error correction term.

To determine whether a significant long-run relationship exists between the respective macroeconomic factors and the REIT market total return, likelihood ratio tests are conducted on the beta coefficients of the macroeconomic factors. In particular, zero restrictions are imposed on the beta coefficients of the macroeconomic factors. The results of the likelihood ratio tests for imposing restrictions on the beta coefficients are presented in Table 33.

Table 33: Likelihood ratio tests for imposing restrictions on β for the REIT market

Null hypothesis	Chi-squared value	P-value	Reject/Fail to reject null hypothesis
$\hat{\beta}_{grow} = 0$	48.51	0	Reject
$\hat{\beta}_{inf} = 0$	8.14	0.02	Reject
$\hat{\beta}_{int} = 0$	7.76	0.02	Reject
$\hat{\beta}_{jse} = 0$	22.46	0	Reject

Reject the null hypotheses that the beta coefficients are equal to zero at the 5% level of significance. Therefore, it can be said that there is a significant long-run relationship between the respective macroeconomic factors and the REIT market total return.

The cointegrating vector results indicate that the following long-run relationships exist between the macroeconomic factors and the REIT market total return:

- Economic growth is significantly positively associated with the REIT market total return with a coefficient of 7.2358.
- Inflation is significantly positively associated with the REIT market total return with a coefficient of 1.2118.
- Interest rates are significantly negatively associated with the REIT market total return with a coefficient of −2.1832.
- Stock market returns are significantly positively associated with the REIT market total return with a coefficient of 0.8810.

As such, it can be said that an increase in economic growth, inflation, and stock market returns leads to an increase in the total return of the REIT market in the long run. Contrarily, a rise in interest rates results in a lower total return of the REIT market in the long run.

4.4.1.3 Loading matrix

The loading matrix containing the speed of adjustment coefficients of the estimated VECM for the REIT market is captured in Table 34.

Table 34: Loading matrix for the REIT market

	REIT market total return	Economic growth	Inflation	Interest rates	Stock market returns
$\widehat{\boldsymbol{\alpha}}^{\boldsymbol{T}}$	−0.0812	0.2247	0.0182	−0.0063	−0.3593

Likelihood ratio tests are conducted on the speed of adjustment coefficients to identify whether the time series variables are weakly exogenous. In doing so, restrictions are imposed on the speed of adjustment coefficients such that they are equal to zero. Table 35 summarises the results of the likelihood ratio tests for imposing restrictions on the speed of adjustment coefficients.

Table 35: Likelihood ratio tests for imposing restrictions on α for the REIT market

Null hypothesis	Chi-squared value	P-value	Reject/Fail to reject null hypothesis
$\hat{\alpha}_{reit} = 0$	10.2	0.02	Reject
$\hat{\alpha}_{grow} = 0$	35.15	0	Reject
$\hat{\alpha}_{inf} = 0$	13.17	0.01	Reject
$\hat{\alpha}_{int} = 0$	6.61	0.04	Reject
$\hat{\alpha}_{jse} = 0$	13.2	0	Reject

Reject the null hypotheses that the speed of adjustment coefficients are equal to zero at the 5% level of significance. Accordingly, none of the time series variables are weakly exogenous which implies that they respond to the deviation from the long-run equilibrium relationship.

4.4.2 Retail property sector

The Johansen cointegration tests, cointegrating vector, and loading matrix of the VECM for the South African retail property sector is detailed below.

4.4.2.1 Johansen cointegration tests

Table 36 provides an overview of the results obtained from the trace test.

Table 36: Trace test for the retail property sector

Null hypothesis	Test statistic	Critical values		
		10%	5%	1%
$r = 0$	136.45	83.20	87.31	96.58
$r = 1$	80.10	59.14	62.99	70.05
$r = 2$	42.96	39.06	42.44	48.45
$r = 3$	15.71	22.76	25.32	30.45
$r = 4$	4.21	10.49	12.25	16.26

When the cointegrating rank is set to zero ($r = 0$), the null hypothesis is rejected at the 10%, 5%, and 1% levels of significance. Similarly, the null hypothesis is rejected at the 10%, 5%, and 1% levels of significance when the cointegrating rank is set to one ($r = 1$). Increasing the cointegrating rank to two ($r = 2$) results in the null hypothesis being rejected at the 10% and 5% levels of significance. Fail to reject the null hypothesis of there being three cointegrating vectors ($r = 3$) at the 10%, 5%, and 1% levels of significance. Consequently, the trace test shows that there are three cointegrating vectors. The results of the maximum eigenvalue test are recorded in Table 37.

Table 37: Maximum eigenvalue test for the retail property sector

Null hypothesis	Test statistic	Critical values		
		10%	5%	1%
$r = 0$	56.35	34.75	37.52	42.36
$r = 1$	37.15	29.12	31.46	36.65
$r = 2$	27.24	23.11	25.54	30.34
$r = 3$	11.50	16.85	18.96	23.65

$r = 4$	4.21	10.49	12.25	16.26

The null hypothesis of there being no cointegrating vectors ($r = 0$) is rejected at the 10%, 5%, and 1% levels of significance. Additionally, when the cointegrating rank is increased to one ($r = 1$), the null hypothesis is rejected at the 10%, 5%, and 1% levels of significance. Setting the cointegrating rank to two ($r = 2$) leads to the null hypothesis being rejected at the 10% and 5% levels of significance. However, fail to reject the null hypothesis of there being three cointegrating vectors at the 10%, 5%, and 1% levels of significance. Thus, the findings of the maximum eigenvalue test demonstrate that there are three cointegrating vectors.

Taking the results of the trace and maximum eigenvalue tests into account, it can be said that there is a long-run relationship between the time series variables. Therefore, a VECM with three cointegrating vectors is estimated for the retail property sector.

4.4.2.2 Cointegrating vector

The cointegrating vector of the estimated VECM for the retail property sector is presented in Table 38.

Table 38: Cointegrating vector for the retail property sector

	Retail sector total return	**Economic growth**	**Inflation**	**Interest rates**	**Stock market returns**	**Trend**
$\widehat{\boldsymbol{\beta}}^{\boldsymbol{T}}$	1.0000	−1.1396	−1.7092	0.3234	−0.0621	−0.0679

By normalising the retail property sector total return, the cointegrating vector can be written as follows:

$$retail_t = 1.1396grow_t + 1.7092inf_t - 0.3234int_t + 0.0621jse_t + 0.0679t + ec_t$$

where $retail_t =$ retail property sector total return.

Likelihood ratio tests are conducted on the beta coefficients of the macroeconomic factors to establish whether there is a significant long-run relationship between the respective macroeconomic factors and the retail property sector total return. In order

to do such, zero restrictions are imposed on the beta coefficients of the macroeconomic factors. Table 39 reports the findings from the likelihood ratio tests for imposing restrictions on the beta coefficients.

Table 39: Likelihood ratio tests for imposing restrictions on β for the retail property sector

Null hypothesis	Chi-squared value	P-value	Reject/Fail to reject null hypothesis
$\hat{\beta}_{grow} = 0$	10.78	0	Reject
$\hat{\beta}_{inf} = 0$	26.35	0	Reject
$\hat{\beta}_{int} = 0$	14.63	0	Reject
$\hat{\beta}_{jse} = 0$	9.1	0.01	Reject

In summary, reject the null hypotheses that the beta coefficients are equal to zero at the 5% level of significance. As such, a significant long-run relationship exists between the respective macroeconomic factors and the retail property sector total return.

The aforementioned cointegrating vector findings suggest that the following long-run relationships exist between the macroeconomic factors and the retail property sector total return:

- Economic growth is significantly positively related to the retail property sector total return with a coefficient of 1.1396.
- Inflation is significantly positively related to the retail property sector total return with a coefficient of 1.7092.
- Interest rates are significantly negatively related to the retail property sector total return with a coefficient of -0.3234.
- Stock market returns are significantly positively related to the retail property sector total return with a coefficient of 0.0621.

In the long run, the total return of the retail property sector rises when there is an increase in economic growth, inflation, and stock market returns. In contrast, an increase in interest rates causes the total return of the retail property sector to decline in the long run.

4.4.2.3 Loading matrix

Table 40 outlines the loading matrix containing the speed of adjustment coefficients of the estimated VECM for the retail property sector.

Table 40: Loading matrix for the retail property sector

	Retail sector total return	Economic growth	Inflation	Interest rates	Stock market returns
$\widehat{\boldsymbol{\alpha}}^{\boldsymbol{T}}$	−0.1473	−0.1072	−0.0468	0.0011	0.4045

To determine whether the time series variables are weakly exogenous, likelihood ratio tests are conducted on the speed of adjustment coefficients. Particularly, zero restrictions are imposed on the speed of adjustment coefficients. The outcome of the likelihood ratio tests for imposing restrictions on the speed of adjustment coefficients is recorded in Table 41.

Table 41: Likelihood ratio tests for imposing restrictions on α for the retail property sector

Null hypothesis	Chi-squared value	P-value	Reject/Fail to reject null hypothesis
$\hat{\alpha}_{retail} = 0$	4.86	0.03	Reject
$\hat{\alpha}_{grow} = 0$	6.92	0.03	Reject
$\hat{\alpha}_{inf} = 0$	20.83	0	Reject
$\hat{\alpha}_{int} = 0$	16.75	0	Reject
$\hat{\alpha}_{jse} = 0$	12.53	0.01	Reject

Reject the null hypotheses that the speed of adjustment coefficients are equal to zero at the 5% level of significance. As a result, it can be said that none of the time series variables are weakly exogenous. Hence, these variables respond to the deviation from the long-run equilibrium relationship.

4.4.3 Office property sector

The Johansen cointegration tests, cointegrating vector, and loading matrix of the VECM for the South African office property sector follows.

4.4.3.1 Johansen cointegration tests

Table 42 summarises the findings of the trace test.

Table 42: Trace test for the office property sector

Null hypothesis	Test statistic	Critical values		
		10%	5%	1%
$r = 0$	145.08	83.20	87.31	96.58
$r = 1$	83.53	59.14	62.99	70.05
$r = 2$	42.29	39.06	42.44	48.45
$r = 3$	19.30	22.76	25.32	30.45
$r = 4$	7.24	10.49	12.25	16.26

The null hypothesis is rejected at the 10%, 5%, and 1% levels of significance when the cointegrating rank is set to zero ($r = 0$). Moreover, setting the cointegrating rank to one ($r = 1$) also leads to the null hypothesis being rejected at the 10%, 5%, and 1% levels of significance. Reject the null hypothesis of there being two cointegrating vectors ($r = 2$) at the 10% level of significance, however, fail to reject the null hypothesis at the 5% and 1% levels of significance. Therefore, the trace test highlights that there are two cointegrating vectors. The results of the maximum eigenvalue test are reported in Table 43.

Table 43: Maximum eigenvalue test for the office property sector

Null hypothesis	Test statistic	Critical values		
		10%	5%	1%
$r = 0$	61.55	34.75	37.52	42.36
$r = 1$	41.24	29.12	31.46	36.65
$r = 2$	22.99	23.11	25.54	30.34
$r = 3$	12.06	16.85	18.96	23.65
$r = 4$	7.24	10.49	12.25	16.26

When the cointegrating rank is set to zero ($r = 0$), the null hypothesis is rejected at the 10%, 5%, and 1% levels of significance. The null hypothesis is also rejected at the 10%, 5%, and 1% levels of significance when the cointegrating rank is set to one ($r =$

1). On the other hand, fail to reject the null hypothesis of there being two cointegrating vectors ($r = 2$) at the 10%, 5%, and 1% levels of significance which implies that there are two cointegrating vectors.

The trace and maximum eigenvalue tests emphasise that a long-run relationship exists between the time series variables. Thus, a VECM with two cointegrating vectors is estimated for the office property sector.

4.4.3.2 Cointegrating vector

Table 44 provides a synopsis of the cointegrating vector of the estimated VECM for the office property sector.

Table 44: Cointegrating vector for the office property sector

	Office sector total return	Economic growth	Inflation	Interest rates	Stock market returns	Trend
$\widehat{\boldsymbol{\beta}}^{\boldsymbol{T}}$	1.0000	−1.3651	−0.2271	0.9409	−0.0470	0.0023

By normalising the office property sector total return, the cointegrating vector can be written as follows:

$$office_t = 1.3651grow_t + 0.2271inf_t - 0.9409int_t + 0.0470jse_t - 0.0023t + ec_t$$

where $office_t =$ office property sector total return.

To ascertain whether a significant long-run relationship exists between the respective macroeconomic factors and the office property sector total return, likelihood ratio tests are conducted on the beta coefficients of the macroeconomic factors. Specifically, restrictions are imposed on the beta coefficients such that they are equal to zero. The results of the likelihood ratio tests for imposing restrictions on the beta coefficients are presented in Table 45.

Table 45: Likelihood ratio tests for imposing restrictions on β for the office property sector

Null hypothesis	Chi-squared value	P-value	Reject/Fail to reject null hypothesis
$\hat{\beta}_{grow} = 0$	38.27	0	Reject
$\hat{\beta}_{inf} = 0$	14.64	0	Reject
$\hat{\beta}_{int} = 0$	22.18	0	Reject
$\hat{\beta}_{jse} = 0$	11.19	0	Reject

Reject the null hypotheses that the beta coefficients are equal to zero at the 5% level of significance. As such, there is a significant long-run relationship between the macroeconomic factors and the office property sector total return.

The cointegrating vector results reveal that the following long-run relationships exist between the macroeconomic factors and the office property sector total return:

- Economic growth is significantly positively associated with the office property sector total return with a coefficient of 1.3651.
- Inflation is significantly positively associated with the office property sector total return with a coefficient of 0.2271.
- Interest rates are significantly negatively associated with the office property sector total return with a coefficient of −0.9409.
- Stock market returns are significantly positively associated with the office property sector total return with a coefficient of 0.0470.

Evidently, it can be concluded that a rise in economic growth, inflation, and stock market returns causes the total return of the office property sector to increase in the long run. Conversely, the total return of the office property sector decreases in the long run when interest rates rise.

4.4.3.3 Loading matrix

The loading matrix containing the speed of adjustment coefficients of the estimated VECM for the office property sector is presented in Table 46.

Table 46: Loading matrix for the office property sector

	Office sector total return	Economic growth	Inflation	Interest rates	Stock market returns
$\hat{\alpha}^T$	−0.7636	0.0219	0.5123	0.2946	0.6978

Likelihood ratio tests are conducted on the speed of adjustment coefficients to establish whether the time series variables are weakly exogenous. To achieve this, zero restrictions are imposed on the speed of adjustment parameters. Table 47 details the findings of the likelihood ratio tests for imposing restrictions on the speed of adjustment coefficients.

Table 47: Likelihood ratio tests for imposing restrictions on α for the office property sector

Null hypothesis	Chi-squared value	P-value	Reject/Fail to reject null hypothesis
$\hat{\alpha}_{office} = 0$	8.23	0.02	Reject
$\hat{\alpha}_{grow} = 0$	7.33	0.03	Reject
$\hat{\alpha}_{inf} = 0$	9.55	0.01	Reject
$\hat{\alpha}_{int} = 0$	13	0.01	Reject
$\hat{\alpha}_{jse} = 0$	10.67	0.01	Reject

Reject the null hypotheses that the speed of adjustment coefficients are equal to zero at the 5% level of significance. Accordingly, none of the time series variables are weakly exogenous which suggests that they respond to the deviation from the long-run equilibrium relationship.

4.4.4 Industrial property sector

The Johansen cointegration tests, cointegrating vector, and loading matrix of the VECM for the South African industrial property sector is summarised below.

4.4.4.1 Johansen cointegration tests

The findings of the trace test are recorded in Table 48.

Table 48: Trace test for the industrial property sector

Null hypothesis	Test statistic	Critical values		
		10%	5%	1%
$r = 0$	135.37	83.20	87.31	96.58
$r = 1$	83.50	59.14	62.99	70.05
$r = 2$	46.36	39.06	42.44	48.45
$r = 3$	22.28	22.76	25.32	30.45
$r = 4$	9.35	10.49	12.25	16.26

The null hypothesis of there being no cointegrating vectors ($r = 0$) is rejected at the 10%, 5%, and 1% levels of significance. Increasing the cointegrating rank to one ($r = 1$) also results in the null hypothesis being rejected at the 10%, 5%, and 1% levels of significance. Setting the cointegrating rank to two ($r = 2$) leads to the null hypothesis being rejected at the 10% and 5% levels of significance. Fail to reject the null hypothesis of there being three cointegrating vectors ($r = 3$) at the 10%, 5%, and 1% levels of significance. Therefore, the trace test suggests that there are three cointegrating vectors. Table 49 captures the results from the maximum eigenvalue test.

Table 49: Maximum eigenvalue test for the industrial property sector

Null hypothesis	Test statistic	Critical values		
		10%	5%	1%
$r = 0$	51.87	34.75	37.52	42.36
$r = 1$	37.14	29.12	31.46	36.65
$r = 2$	24.08	23.11	25.54	30.34
$r = 3$	12.93	16.85	18.96	23.65
$r = 4$	9.35	10.49	12.25	16.26

When the cointegrating rank is set to zero ($r = 0$), the null hypothesis is rejected at the 10%, 5%, and 1% levels of significance. Likewise, when the cointegrating rank is increased to one ($r = 1$), the null hypothesis is rejected at the 10%, 5%, and 1% levels of significance. Reject the null hypothesis of there being two cointegrating vectors ($r = 2$) at the 10% level of significance, however, fail to reject the null hypothesis at the 5%

and 1% levels of significance. As a result, the maximum eigenvalue test reveals that there are two cointegrating vectors.

Given the results of the trace and maximum eigenvalue tests, it can be said that there is a long-run relationship between the time series variables. It must be noted, however, that the two types of tests yield conflicting results. As mentioned previously, Lütkepohl et al. (2001) favour the trace test as these authors observed that the small-sample power of the trace test is superior to that of the maximum eigenvalue test in some situations. Thus, according to the trace test, a VECM with three cointegrating vectors is estimated for the industrial property sector.

4.4.4.2 Cointegrating vector

The cointegrating vector of the estimated VECM for the industrial property sector is presented in Table 50.

Table 50: Cointegrating vector for the industrial property sector

	Industrial total return	Economic growth	Inflation	Interest rates	Stock market returns	Trend
$\widehat{\boldsymbol{\beta}}^{\boldsymbol{T}}$	1.0000	−1.0142	−1.6088	0.2614	−0.2289	−0.0895

By normalising the industrial property sector total return, the cointegrating vector can be written as follows:

$$industrial_t = 1.0142grow_t + 1.6088inf_t - 0.2614int_t + 0.2289jse_t + 0.0895t + ec_t$$

where $industrial_t =$ industrial property sector total return.

Likelihood ratio tests are conducted on the beta coefficients of the macroeconomic factors to determine whether there is a significant long-run relationship between the respective macroeconomic factors and the industrial property sector total return. In doing so, restrictions are imposed on the beta coefficients such that they are equal to zero. Table 51 outlines the results from the likelihood ratio tests for imposing restrictions on the beta coefficients.

Table 51: Likelihood ratio tests for imposing restrictions on β for the industrial property sector

Null hypothesis	Chi-squared value	P-value	Reject/Fail to reject null hypothesis
$\hat{\beta}_{grow} = 0$	16.63	0	Reject
$\hat{\beta}_{inf} = 0$	17.05	0	Reject
$\hat{\beta}_{int} = 0$	7.05	0.03	Reject
$\hat{\beta}_{jse} = 0$	15.56	0	Reject

Reject the null hypotheses that the beta coefficients are equal to zero at the 5% level of significance. As such, a significant long-run relationship exists between the macroeconomic factors and the industrial property sector total return.

The aforementioned cointegrating vector results indicate that the following long-run relationships exist between the macroeconomic factors and the industrial property sector total return:

- Economic growth is significantly positively related to the industrial property sector total return with a coefficient of 1.0142.
- Inflation is significantly positively related to the industrial property sector total return with a coefficient of 1.6088.
- Interest rates are significantly negatively related to the industrial property sector total return with a coefficient of −0.2614.
- Stock market returns are significantly positively related to the industrial property sector total return with a coefficient of 0.2289.

In conclusion, an increase in economic growth, inflation, and stock market returns translates into an increase in the total return of the industrial property sector in the long run. In contrast, an increase in interest rates causes the total return of the industrial property sector to decline in the long run.

4.4.4.3 Loading matrix

Table 52 reports the loading matrix containing the speed of adjustment coefficients of the estimated VECM for the industrial property sector.

Table 52: Loading matrix for the industrial property sector

	Industrial total return	Economic growth	Inflation	Interest rates	Stock market returns
$\hat{\boldsymbol{\alpha}}^{\boldsymbol{T}}$	−0.5069	0.2998	0.2013	0.1483	0.3721

To ascertain whether the time series variables are weakly exogenous, likelihood ratio tests are conducted on the speed of adjustment coefficients. Specifically, zero restrictions are imposed on the speed of adjustment coefficients. Table 53 summarises the results of the likelihood ratio tests for imposing restrictions on the speed of adjustment coefficients.

Table 53: Likelihood ratio tests for imposing restrictions on α for the industrial property sector

Null hypothesis	Chi-squared value	P-value	Reject/Fail to reject null hypothesis
$\hat{\alpha}_{industrial} = 0$	8.1	0.04	Reject
$\hat{\alpha}_{grow} = 0$	6.94	0.03	Reject
$\hat{\alpha}_{inf} = 0$	7.18	0.03	Reject
$\hat{\alpha}_{int} = 0$	8.79	0.01	Reject
$\hat{\alpha}_{jse} = 0$	9.65	0.02	Reject

Reject the null hypotheses that the speed of adjustment coefficients are equal to zero at the 5% level of significance. Hence, none of the time series variables are weakly exogenous which indicates that they respond to the deviation from the long-run equilibrium relationship.

4.5 SUMMARY

This chapter estimated VAR models and VECMs for the overall South African REIT market as well as the retail, office, and industrial property sectors. These models are estimated to analyse the influence that various macroeconomic factors have on South African REIT returns as well as to identify the extent of the impact that the macroeconomic factors have on the returns of South African REITs. The impulse response functions show that a one-unit shock to economic growth, inflation, and stock market returns has a significant positive influence on South African REIT returns.

Contrarily, a shock to interest rates induces a significant negative impulse response in South African REIT returns. The forecast error variance decompositions reveal that economic growth and stock market returns explain a negligible percentage of the variation in South African REIT returns. Inflation and interest rates explain a slightly larger, albeit small, proportion of the forecast error variance of South African REIT returns. Moreover, the Granger causality analysis highlights that inflation Granger causes South African REIT returns together with the other macroeconomic factors. This suggests that lagged values of the inflation rate may be useful in forecasting South African REIT returns. The cointegrating vector results indicate that a significant positive long-run relationship exists between South African REIT returns and economic growth, inflation, and stock market returns. On the other hand, there is a significant negative long-run relationship between interest rates and South African REIT returns. Finally, the loading matrix results show that none of the time series variables are weakly exogenous which suggests that they respond to the deviation from the long-run equilibrium relationship.

CHAPTER 5 – DISCUSSION OF RESULTS

5.1 INTRODUCTION

The purpose of this chapter is to review and interpret the main findings of the present study. As such, sections 5.2 to 5.5 discuss the results from the estimated vector autoregression (VAR) models and vector error correction models (VECMs) to analyse the influence as well as the extent of the impact that each of the macroeconomic factors have on the returns of South African real estate investment trusts (REITs). Additionally, this chapter compares the results of the present study to that of prior literature to ascertain whether South African REIT returns are affected by macroeconomic factors in the same manner as the returns of REITs in other international markets. A summary concludes the chapter in section 5.6.

5.2 ECONOMIC GROWTH

This section summarises the results from the estimated VAR models and VECMs to analyse the influence that economic growth has on South African REIT returns. These results are then compared to that of previous studies.

5.2.1 Vector autoregression models

A discussion of the findings relating to the impulse response functions, forecast error variance decompositions, and Granger causality analysis is presented below.

5.2.1.1 Impulse response functions

Table 54 presents the results of the impulse response of the respective total return series to a one-unit change in economic growth.

Table 54: Impulse response from a shock to economic growth

Total return series	Short-run response	Magnitude of impulse response	Duration of impulse response
REIT market	Significant positive	1.8 percentage points	3 quarters

Retail property sector	Significant positive	0.2 percentage points	3 half-years
Office property sector	Significant positive	0.5 percentage points	Longer than 7 half-years
Industrial property sector	Significant positive	0.6 percentage points	7 half-years

The impulse response functions indicate that a one-unit change in economic growth induces a significant positive impulse response in South African REIT returns in the short run. The magnitude of the positive impulse response is the largest for the overall South African REIT market, albeit for the shortest duration. Hence, the retail, office, and industrial property sectors are less affected by a shock to economic growth compared to the overall South African REIT market. However, the smaller positive impulse response experienced by these property subtypes persists for longer than the larger impulse response of the overall South African REIT market.

5.2.1.2 Forecast error variance decompositions

The proportion of the forecast error variance of South African REIT returns that is caused by the variability in a structural shock to economic growth is captured in Table 55.

Table 55: Forecast error variance decompositions of economic growth

Total return series	Forecast error variance decompositions
REIT market	0.6938
Retail property sector	0.9594
Office property sector	33.3160
Industrial property sector	26.1121

These results indicate that a negligible percentage of the forecast error variance of the overall South African REIT market total return is due to the variability in a structural shock to economic growth. A similar percentage is observed for the retail property sector, however, a substantially larger percentage of the variation in the total return of the office and industrial property sectors is explained by a shock to economic growth. Evidently, economic growth exerts a larger impact on the variance of the total return

of these property subtypes compared to the total return of the overall South African REIT market and retail property sector.

5.2.1.3 Granger causality analysis

Economic growth does not Granger cause the total return of the overall South African REIT market together with the other macroeconomic factors. Similar results are obtained for the retail, office, and industrial property sectors. Consequently, it can be said that lagged values of the economic growth rate are not useful in predicting South African REIT returns.

5.2.2 Vector error correction models

Table 56 reports the beta coefficients of economic growth for the respective total return series to show the long-run relationship between economic growth and South African REIT returns.

Table 56: Long-run relationship between economic growth and REIT returns

Total return series	Coefficient	Long-run relationship
REIT market	7.2358	Significant positive
Retail property sector	1.1396	Significant positive
Office property sector	1.3651	Significant positive
Industrial property sector	1.0142	Significant positive

The findings highlight that there is a significant positive long-run relationship between economic growth and South African REIT returns. This significant positive relationship implies that an increase in economic growth results in higher REIT returns in the long run. Notably, the beta coefficient for the overall South African REIT market is substantially larger than that for the retail, office, and industrial property sectors. This result indicates that, in the long run, the total return of the overall REIT market rises more when there is an increase in the economic growth rate compared to the property subtypes. A possible reason for the positive long-run relationship between economic growth and South African REIT returns is that economic expansion leads to increased rental income which is the main source of revenue for REITs. The increase in rental income is as a result of there being more demand for real estate when the economy

is growing which in turn leads to higher occupancy rates and rental charges as well as reduced arrears (Paolone et al., 2019).

5.2.3 Comparison with prior literature

This study reveals that a shock to economic growth has a significant positive influence on South African REIT returns. However, economic growth only explains a small proportion of the forecast error variance of the total return of the overall South African REIT market. Moreover, the results indicate that a significant positive relationship exists between economic growth and South African REIT returns in the long run. A study that is in support of these findings is that of McCue and Kling (1994) who explored the relationship between the macroeconomy and real estate returns in the United States for the period 1974-1991. These authors found that a shock to economic growth induced a significant positive impulse response in REIT returns. Additionally, they discovered that economic growth explained a small percentage of the variation in REIT returns.

The results of the present study are also consistent with that of Naranjo and Ling (1997). These authors analysed the effect that macroeconomic factors had on real estate returns in the United States from 1978-1994. Similar to the significant positive relationship observed in the present study, Naranjo and Ling (1997) found that economic growth was a fundamental driver that positively affected REIT returns. Results obtained from studies conducted in Asia and the United Kingdom also correspond well with that of the current study. For instance, Liow et al. (2006) investigated the association between expected risk premia on property stocks and various macroeconomic factors in Singapore, Hong Kong, Japan, and the United Kingdom from 1986-2003. Through their analysis, the authors were able to conclude that economic growth predicted positive excess returns for listed property stocks in all of the markets studied. Likewise, Yunus (2012) examined the interaction between REITs and macroeconomic factors in several markets in North America, Europe, Australia, and Asia for the period 1990-2007. This author observed that a shock to economic growth induced a temporary positive impulse response in REIT returns for most of the markets analysed. The author also found that economic growth Granger caused REIT returns in the short run. This in contrast to the Granger causality analysis

conducted in the current study which shows that economic growth does not Granger cause South African REIT returns together with the other macroeconomic factors, and thus, lagged values of the economic growth rate are not useful in forecasting South African REIT returns. However, Granger causality analysis undertaken by Loo et al. (2016) corresponds with the results of the present study. These authors analysed the relationship between Asian REIT markets and their respective macroeconomic factors and found that economic growth did not Granger-cause REIT returns in Japan, Hong Kong, Singapore, Thailand, Taiwan, and South Korea.

Although the findings of the aforementioned studies primarily coincide with that of the present study, it must be noted that other studies have reported contrasting results. For example, Chang et al. (2011) investigated the relationship between several macroeconomic factors and REIT returns in the United States for the period spanning 1975-2008. By conducting impulse response functions, the authors found that a shock to economic growth had a statistically insignificant impact on REIT returns. Similarly, Kola and Kodongo (2017) also found that economic growth had an insignificant effect on the returns of REITs in the United States, Bulgaria, and South Africa. Another study that found conflicting results to the current study is that of Ewing and Payne (2005) who examined the response of the United States REIT market to changes in various macroeconomic factors over the period 1980-2000. Their results indicated that the impulse response of REIT returns to a shock to economic growth was insignificant in the first month following the shock, however, the impulse response became negative and significant from the second to seventh month following the initial shock.

By comparing the results of the present study to that of previous literature, it can be concluded that the significant positive relationship that exists between economic growth and South African REIT returns is in accordance with what has been observed in the majority of other international REIT markets.

5.3 INFLATION

This section provides an overview of the findings from the VAR models and VECMs to examine the impact that inflation has on South African REIT returns. Thereafter, a comparison is drawn between these results and that of prior literature.

5.3.1 Vector autoregression models

An evaluation of the findings pertaining to the impulse response functions, forecast error variance decompositions, and Granger causality analysis is outlined below.

5.3.1.1 Impulse response functions

The results of the impulse response of the respective total return series to a shock to inflation are displayed in Table 57.

Table 57: Impulse response from a shock to inflation

Total return series	Short-run response	Magnitude of impulse response	Duration of impulse response
REIT market	Significant positive	1.5 percentage points	6 quarters
Retail property sector	Significant positive	0.35 percentage points	6 half-years
Office property sector	Significant positive	0.25 percentage points	4 half-years
Industrial property sector	Significant positive	0.3 percentage points	2 half-years

The impulse response functions reveal that a one-unit shock to inflation has a significant positive effect on South African REIT returns in the short run. A shock to inflation induces the largest positive impulse response from the overall South African REIT market, however, the duration of this impulse response is the shortest compared to the property subtypes. As such, the retail, office, and industrial property sectors are less affected by a one-unit change in inflation compared to the overall South African REIT market. Nevertheless, the smaller positive impulse response experienced by these property subtypes is sustained for a longer period than the larger impulse response of the overall South African REIT market.

5.3.1.2 Forecast error variance decompositions

Table 58 summarises the percentage of the forecast error variance of South African REIT returns that is attributable to a shock to inflation.

Table 58: Forecast error variance decompositions of inflation

Total return series	Forecast error variance decompositions
REIT market	1.6232
Retail property sector	3.6955
Office property sector	3.6620
Industrial property sector	3.3404

The findings highlight that a small proportion of the forecast error variance of the overall South African REIT market total return is caused by a shock to inflation. A slightly higher, albeit small, percentage of the forecast error variance of the total return of the retail, office, and industrial property sectors is explained by the variability in a structural shock to inflation. Therefore, inflation has a slightly stronger influence on the variance of the total return of these property subtypes compared to the total return of the overall South African REIT market.

5.3.1.3 Granger causality analysis

Inflation Granger causes the total return of the South African REIT market together with the other macroeconomic factors. Comparable results are found for the retail, office, and industrial property sectors. Accordingly, lagged values of the inflation rate may be useful in forecasting South African REIT returns.

5.3.2 Vector error correction models

Table 59 outlines the beta coefficients of inflation for the respective total return series to show the association between inflation and South African REIT returns in the long run.

Table 59: Long-run relationship between inflation and REIT returns

Total return series	Coefficient	Long-run relationship
REIT market	1.2118	Significant positive
Retail property sector	1.7092	Significant positive
Office property sector	0.2271	Significant positive
Industrial property sector	1.6088	Significant positive

The results indicate that South African REIT returns are significantly positively related to inflation in the long run. Hence, a rise in inflation causes South African REIT returns to increase in the long run. The beta coefficient for the office property sector is comparatively smaller than that of the overall South African REIT market as well as the retail and industrial property sectors. This implies that the total return of the office property sector increases by a smaller percentage when inflation rises. A possible reason for the positive long-run relationship between inflation and REIT returns is that real estate prices tend to rise when the overall price level increases. Moreover, REITs include annual rental escalations in lease agreements in order to account for inflation and are thus able to manage the level of inflation risk that they may be exposed to (Paolone et al., 2019). Given the positive association between inflation and South African REIT returns, it can be said that South African REITs provide an inflation hedge to investors.

5.3.3 Comparison with prior literature

The present study reveals that a one-unit change in inflation induces a significant positive impulse response in South African REIT returns. Furthermore, the results indicate that inflation explains a small percentage of the forecast error variance of South African REIT returns. Additionally, there is a significant positive association between inflation and South African REIT returns in the long run. These findings correspond with those reported by Simpson et al. (2007) who investigated the relationship between REIT returns in the United States and changes in expected and unexpected inflation over the period 1981-2002. These authors found that REIT returns exhibited a significant positive relationship with expected and unexpected increases in inflation.

Although Simpson et al. (2007) found similar results to the present study, it is important to highlight that the majority of prior studies have concluded that a negative relationship exists between inflation and REIT returns. One such study that contradicts the results of the present study is that of Adrangi et al. (2004). These authors analysed the long-run relationship between inflation and United States REIT returns for the 27-year period spanning 1972-1999. Their results indicated that there was a negative relationship between inflation and REIT returns. Comparably, Ewing and Payne (2005)

conducted impulse response functions and also found that inflation had a negative impact on the returns of REITs in the United States for the period 1980-2000. Particularly, these authors observed that the negative impulse response of REIT returns to a shock to inflation remained significant for two months following the initial shock. Patterson (2009) also reported contrasting results to the current study. This author examined the influence of numerous macroeconomic factors on the retail, office, residential, and industrial REIT property subtypes in the United States from 1989-2006. Patterson (2009) found that there was a statistically significant relationship between inflation and the retail and office REITs whereas there was a statistically insignificant relationship between inflation and the residential and industrial REITs. Additionally, the author found that a shock to inflation resulted in a negative impulse response from both the retail and office REITs.

The positive association between inflation and South African REIT returns identified in the present study also contradicts studies from the Asian region. For example, Fang et al. (2016) conducted a study to analyse the impact of macroeconomic factors on REIT returns in Japan, Singapore, and China over the period 2008-2012. Through their analysis, the authors found that there was a significant negative association between inflation and REIT returns in all three countries. Moreover, the authors observed that inflation Granger caused REIT index changes in Japan and Singapore. This, however, coincides with the Granger causality analysis conducted in the current study which shows that lagged values of the inflation rate may be useful in predicting South African REIT returns.

Another study that found contrasting results to the present study is that of Sukor et al. (2020). These authors examined the relationship between several macroeconomic factors and the return and dividend characteristics of Malaysian REITs for the period 2011-2017. In doing so, they found that a significant negative relationship existed between inflation and the dividend yield of the REITs analysed. On the other hand, there was an insignificant negative relationship between inflation and the price index return of the REITs analysed. Other authors have also concluded that inflation has a statistically insignificant influence on REIT returns. For instance, Chatrath and Liang (1998) found no evidence of a relationship between inflation and REIT returns in the

United States for the period 1972-1995. A study conducted by Olanrele et al. (2020) on the Nigerian REIT market over the period 2008-2017 also revealed that inflation did not have a direct causal effect on REIT returns both in the short run and long run.

In conclusion, the significant positive relationship between inflation and South African REIT returns observed in the current study conflicts with the results of studies conducted in other global REIT markets which primarily reported a significant negative relationship between inflation and REIT returns.

5.4 INTEREST RATES

This section reviews the findings from the VAR models and VECMs to investigate the impact that interest rates have on South African REIT returns. Following this, the results of previous studies are compared to that of the current study.

5.4.1 Vector autoregression models

The findings from the impulse response functions, forecast error variance decompositions, and Granger causality analysis are discussed below.

5.4.1.1 Impulse response functions

Table 60 summarises the findings of the impulse response of the respective total return series to a one-unit change in interest rates.

Table 60: Impulse response from a shock to interest rates

Total return series	Short-run response	Magnitude of impulse response	Duration of impulse response
REIT market	Significant negative	−1.7 percentage points	3 quarters
Retail property sector	Significant negative	−0.5 percentage points	Longer than 7 half-years
Office property sector	Significant negative	−0.4 percentage points	7 half-years
Industrial property sector	Significant negative	−0.65 percentage points	Longer than 7 half-years

The impulse response functions reveal that a shock to interest rates has a significant negative influence on South African REIT returns. The magnitude of the negative impulse response is the largest for the overall South African REIT market. However, in comparison to the property subtypes, the duration of this negative impulse response is the shortest. Thus, the retail, office, and industrial property sectors are less affected by a shock to interest rates compared to the overall South African REIT market although the negative impulse response of the property subtypes persists for longer.

5.4.1.2 Forecast error variance decompositions

The proportion of the forecast error variance of South African REIT returns that is explained by the variability in a structural shock to interest rates is detailed in Table 61.

Table 61: Forecast error variance decompositions of interest rates

Total return series	Forecast error variance decompositions
REIT market	2.0927
Retail property sector	8.8171
Office property sector	3.2208
Industrial property sector	9.5963

These results highlight that a small percentage of the forecast error variance of the overall South African REIT market total return is due to the variability in a structural shock to interest rates. A similar percentage is observed for the office property sector, however, the variability in a structural shock to interest rates explains a larger percentage of the forecast error variance of the total return of the retail and industrial property sectors. As a result, interest rates have a larger influence on the variance of the total return of these property subtypes compared to the total return of the overall South African REIT market and office property sector.

5.4.1.3 Granger causality analysis

Interest rates do not Granger cause the total return of the South African REIT market together with the other macroeconomic factors. Similar results are obtained for the retail property sector, however, interest rates Granger cause the total return of the office and industrial property sectors together with the other macroeconomic factors.

Hence, lagged values of interest rates are not useful in predicting the return of the overall South African REIT market and the retail property sector whereas they may be useful in predicting the returns of the office and industrial property sectors.

5.4.2 Vector error correction models

Table 62 presents the beta coefficients pertaining to interest rates for the respective total return series to show the long-run relationship between interest rates and South African REIT returns.

Table 62: Long-run relationship between interest rates and REIT returns

Total return series	Coefficient	Long-run relationship
REIT market	−2.1832	Significant negative
Retail property sector	−0.3234	Significant negative
Office property sector	−0.9409	Significant negative
Industrial property sector	−0.2614	Significant negative

The findings indicate that there is a significant negative association between interest rates and South African REIT returns in the long run. This suggests that higher interest rates result in lower REIT returns in the long run. The absolute value of the beta coefficient for the overall South African REIT market is larger than that for the retail, office, and industrial property sectors. This result implies that, in the long run, the total return of the overall South African REIT market declines more when there is an increase in interest rates compared to the property subtypes. A possible reason for the negative long-run relationship between interest rates and REIT returns is that REITs are sensitive to interests rates since they rely on the debt market to expand their business as a result of having to pay out the majority of their earnings in the form of dividends. Hence, when interest rates rise, REITs incur higher interest expenses which has a negative impact on their profitability (Paolone et al., 2019).

5.4.3 Comparison with prior literature

The current study identifies that a shock to interest rates has a significant negative impact on South African REIT returns. However, interest rates only explain a small percentage of the forecast error variance of the total return of the overall South African

REIT market. In addition, the findings reveal that a significant negative long-run relationship exists between interest rates and South African REIT returns. Similar results were reported by K. Chen and Tzang (1988) who conducted a study to establish whether REITs in the United States were sensitive to movements in short-term and long-term interest rates over the period 1983-1985. They found that changes in interest rates had a negative impact on the return-generating process of REITs. Mueller and Pauley (1995) also provided evidence to suggest that interest rates were negatively related to REIT returns in the United States for the period 1972-1993.

The results of the present study also correspond with those reported by Brooks and Tsolacos (1999) who analysed the influence of macroeconomic factors on the listed property market in the United Kingdom for the period 1985-1998. These authors found that a shock to short-term interest rates had a negative impact on the real estate market in the six months following the initial shock. Furthermore, they observed that short-term interest rates explained a small proportion of the variance in the real estate return series. Liow and Huang (2006) also found consistent results to that of the current study. These authors investigated whether interest rates had an impact on the excess returns of the listed property markets in Hong Kong, Japan, Singapore, and the United Kingdom from 1987-2003. These authors found that changes in long-term interest rates had a negative effect on the excess returns of the listed property markets in all three countries. Changes in short-term interest rates had a negative influence on the excess returns of these listed property markets except for the United Kingdom where it was positive.

Consistent with the statistically significant relationship between interest rates and South African REIT returns in the current study, Razali et al. (2020) also found that interest rates played a significant role in the return volatility of Malaysian REITs from 2010-2017. Studies conducted in Australia have also observed a statistically significant relationship between interest rates and REIT returns. For instance, West and Worthington (2006) found that interest rates were significant risk factors in Australian commercial property returns over the period 1985-2002. Likewise, Reddy and Wong (2018) undertook a study to explore the relationship between interest rates and different Australian REIT sectors including diversified, specialised, retail, office,

and industrial REITs over the period 1995-2016. This analysis led the authors to conclude that interest rates played a significant role in the return generating process of Australian REITs.

When comparing the findings of previous studies to that of the present study, it is evident that the significant negative relationship that exists between interest rates and South African REIT returns corresponds with what has been observed in other REIT markets around the world.

5.5 STOCK MARKET

This section provides a synopsis of the findings from the VAR models and VECMs to analyse the influence that the stock market has on South African REIT returns. Moreover, this section contrasts these findings to those reported in prior studies.

5.5.1 Vector autoregression models

The results of the impulse response functions, forecast error variance decompositions, and Granger causality analysis are presented below.

5.5.1.1 Impulse response functions

The findings of the impulse response of the respective total return series to a one-unit change in stock market returns is captured in Table 63.

Table 63: Impulse response from a shock to stock market returns

Total return series	Short-run response	Magnitude of impulse response	Duration of impulse response
REIT market	Significant positive	0.4 percentage points	4 quarters
Retail property sector	Significant positive	0.09 percentage points	3 half-years
Office property sector	Significant positive	0.2 percentage points	6 half-years
Industrial property sector	Significant positive	0.2 percentage points	3 half-years

The impulse response functions show that a one-unit shock to stock market returns induces a significant positive impulse response in South African REIT returns in the short run. The magnitude of the positive impulse response is the largest for the overall South African REIT market although this response persists for the shortest duration. Therefore, the retail, office, and industrial property sectors are less affected by a shock to stock market returns compared to the overall South African REIT market. Nevertheless, the smaller positive impulse response experienced by these property subtypes persists for longer than the larger impulse response of the overall South African REIT market.

5.5.1.2 Forecast error variance decompositions

Table 64 outlines the percentage of the forecast error variance of South African REIT returns that is caused by the variability in a structural shock to stock market returns.

Table 64: Forecast error variance decompositions of stock market returns

Total return series	Forecast error variance decompositions
REIT market	0.7534
Retail property sector	0.7106
Office property sector	0.7081
Industrial property sector	1.1977

These findings highlight that a negligible percentage of the forecast error variance of the overall South African REIT market total return is attributable to the variability in a structural shock to stock market returns. Similar percentages are observed for the retail, office, and industrial property sectors. As such, it can be said that stock market returns have a similar impact on the variance of the overall South African REIT market to that of the total return of the property subtypes.

5.5.1.3 Granger causality analysis

Stock market returns do not Granger cause the total return of the South African REIT market together with the other macroeconomic factors. Similar results are discovered for the retail and industrial property sectors, however, stock market returns Granger causes the total return of the office property sector together with the other macroeconomic factors. Accordingly, lagged values of stock market returns are not

useful in forecasting the return of the overall South African REIT market as well as the retail and industrial property sectors. On the other hand, lagged values of stock market returns may be useful in predicting the returns of the office property sector.

5.5.2 Vector error correction models

Table 65 reports the beta coefficients relating to stock market returns for the respective REIT total return series to show the long-run association between the stock market and South African REIT returns.

Table 65: Long-run relationship between stock market returns and REIT returns

Total return series	Coefficient	Long-run relationship
REIT market	0.8810	Significant positive
Retail property sector	0.0621	Significant positive
Office property sector	0.0470	Significant positive
Industrial property sector	0.2289	Significant positive

The results reveal that a significant positive long-run relationship exists between stock market returns and South African REIT returns. This significant positive relationship indicates that a rise in stock market returns results in higher South African REIT returns in the long run. It must be noted that the beta coefficient for the overall South African REIT market is larger than that for the retail, office, and industrial property sectors. Thus, in the long run, the total return of the overall REIT market increases more compared to the property subtypes when there is a rise in stock market returns. A possible reason for the positive long-run relationship between stock market returns and South African REIT returns is that investors may reallocate their funds to the real estate market when stocks earn a positive return and outperform the other asset classes in an investor's portfolio (Liu & Su, 2010). This is because the proportion of an investor's portfolio that is allocated to stocks is directly impacted by stock performance. Hence, when the allocation to stocks increases, investors rebalance their portfolios by reducing their allocation to stocks to keep in line with their strategic asset allocation. Rebalancing may lead to an inflow of investment in the real estate market which would positively affect REITs' operating performance (Arnott et al., 2007).

5.5.3 Comparison with prior literature

This study identifies that a shock to stock market returns has a significant positive impact on South African REIT returns. Additionally, stock market returns only explain a small percentage of the forecast error variance of South African REIT returns. The findings of the present study also shows that there is a significant positive relationship between stock market returns and South African REIT returns in the long run. Other studies have discovered similar results with one such study being that of Allen et al. (2000). These authors investigated the sensitivity of REIT returns to stock market and interest rate changes in the United States for the period 1992-1996. In doing so, a significant positive relationship was identified between changes in stock market returns and non-equity REIT returns. Payne (2003) also observed a positive association between the United States stock market and REIT returns. This author analysed the influence of macroeconomic factors on the excess returns of equity, mortgage, and hybrid REITs in the United States from 1981-2003. The results indicated that a shock to the excess return of the stock market had a positive impact on the excess returns of the three types of REITs.

Another study that is in support of the present study's findings is that of Laopodis (2009) who examined the relationship between REITs, the stock market, and economic activity in the United States for the period spanning 1971-2007. This author found that a shock to stock market returns induced a positive response in REIT returns. Moreover, it was observed that a small proportion of the variation in REIT returns was explained by the stock market. A study conducted by Fang et al. (2016) in the Asian REIT market also reported similar results to the present study. These authors found that there was a significant positive association between the stock market and REIT returns in Japan, Singapore, and China over the period 2008-2012. Granger non-causality tests conducted by the authors revealed that there was a significant unidirectional relationship between the stock market and REIT returns in which stock market movements caused REIT index changes in Singapore. This result is in contrast to the Granger causality analysis conducted in the current study which shows that stock market returns do not Granger cause South African REIT returns together with the other macroeconomic factors, and thus, lagged values of stock market returns are not useful in predicting South African REIT returns.

Similarly, the results of Okunev et al. (2000) do not correspond with the present study. These authors evaluated the relationship between the United States real estate market and the stock market during the period 1972-1998. Non-linear Granger causality tests conducted by the authors revealed that there was a strong unidirectional relationship from the stock market to the real estate market. A study conducted in Australia by the same authors discovered similar findings. Okunev et al. (2002) undertook linear and non-linear causality tests to examine the relationship between the Australian real estate market and the stock market from 1980-1999. These authors found that there was a strong unidirectional relationship from the stock market to the real estate market. Liu and Su (2010) who investigated the relationship between the real estate market and stock market in China also found conflicting results to the current study. By conducting Granger causality tests, the authors concluded that there was a short-run unidirectional relationship from the stock market to the real estate market over the period 1996-2008.

By contrasting the findings of the present study to those reported by other authors, it can be said that the significant positive relationship that exists between the stock market and South African REIT returns is consistent with what has been observed in the majority of other international REIT markets.

5.6 SUMMARY

The findings from the VAR models and VECMs show that South African REIT returns are significantly positively associated with economic growth, inflation, and stock market returns whereas they are significantly negatively related to interest rates. However, changes in these macroeconomic factors only explain a small percentage of the variability in South African REIT returns. Prior literature investigating the impact that macroeconomic factors have on REIT returns have predominantly reported that economic growth and stock market returns are positively related to REIT returns. Contrarily, previous studies have found that inflation and interest rates are negatively related to REIT returns. Therefore, except for inflation, the relationship between macroeconomic factors and South African REIT returns is in accordance with what has been observed in other international REIT markets.

CHAPTER 6 – CONCLUSION AND RECOMMENDATIONS

6.1 INTRODUCTION

This chapter summarises the main findings from the present study in section 6.2 whereafter concluding remarks on the study are provided in section 6.3. Subsequently, recommendations for future research are presented in section 6.4.

6.2 SUMMARY OF FINDINGS

The purpose of this study is to analyse the influence that various macroeconomic factors, namely economic growth, inflation, interest rates, and the stock market, have on the returns of South African real estate investment trusts (REITs). This study also identifies the extent of the impact that these macroeconomic factors have on South African REIT returns. In addition to analysing the relationship between macroeconomic factors and the returns of the overall South African REIT market, this study also analyses the impact that macroeconomic factors have on the returns of various REIT property subtypes in South Africa. These REIT property subtypes include the retail, office, and industrial sectors. To achieve this, vector autoregression (VAR) models and vector error correction models (VECMs) are employed. The VAR models examine the short-run relationships between the macroeconomic factors and South African REIT returns. In particular, the estimated VAR models are used to conduct impulse response functions, forecast error variance decompositions, and Granger causality analysis. The estimated VECMs are used to generate cointegrating vectors and loading matrices containing speed of adjustment parameters to determine whether significant long-run relationships exist between the respective macroeconomic factors and South African REIT returns. Following this, a comparison is drawn with the findings from previous international studies to ascertain whether the relationship between macroeconomic factors and South African REIT returns is in accordance with what has been observed in other international REIT markets.

The impulse response functions reveal that a one-unit shock to economic growth, inflation, and stock market returns induces a significant positive impulse response in South African REIT returns in the short run. On the other hand, a shock to interest rates has a significant negative impact on South African REIT returns. The forecast

error variance decompositions indicate that economic growth and stock market returns explain a negligible proportion of the variation in South African REIT returns in the short run. Inflation and interest rates explain a slightly larger, albeit small, percentage of the forecast error variance of South African REIT returns. The findings from the Granger causality analysis highlights that inflation Granger causes South African REIT returns together with the other macroeconomic factors in the short run. Hence, lagged values of the inflation rate may be useful in forecasting South African REIT returns. The cointegrating vectors and loading matrices containing the speed of adjustment parameters show that there is a significant positive long-run relationship between South African REIT returns and economic growth, inflation, and stock market returns. In contrast, there is a significant negative long-run relationship between South African REIT returns and interest rates. Thus, the aforementioned results from the VAR models and VECMs indicate that an increase in economic growth, inflation, and stock market returns translates into higher returns for the South African REIT market whereas a rise in interest rates causes South African REIT returns to decrease.

Previous studies have primarily observed that economic growth and stock market returns are positively related to REIT returns. Furthermore, authors have identified that a negative relationship exists between inflation and REIT returns as well as between interest rates and REIT returns. Given these results, it can be concluded that except for inflation, South African REIT returns are influenced by macroeconomic factors in the same manner as the returns of REITs in other global markets.

6.3 CONCLUSION

REITs have become a popular investment vehicle for investors seeking to gain exposure to the real estate market. This is as a result of the numerous advantages associated with investing in REITs compared to directly investing in real estate. For example, REITs provide investors with greater liquidity, diversification, active professional management, earnings predictability and high income payout ratios, smaller capital outlay, and access to superior quality and range of properties. Furthermore, studies have showed that including an allocation of REITs to a mixed-asset portfolio is advantageous to investors as it results in both return-enhancement and risk-reduction benefits.

The South African REIT regime became effective on 1 May 2013 and since then, it has been characterised by notable return volatility. This raises the question as to whether changes in important macroeconomic factors influence South African REIT returns, and if this is the case, to what extent do changes in macroeconomic factors have on the returns of South African REITs. Many researchers have undertaken studies to examine whether macroeconomic factors are useful in explaining REIT returns. These studies have predominantly been conducted in the United States, Europe, the Asia-Pacific region and, to a smaller degree, Africa. The findings of these studies suggest that economic growth, inflation, interest rates, and the stock market have a significant influence on REIT returns. Although a considerable amount of research has been conducted on the relationship between the aforementioned macroeconomic factors and REIT returns in an international context, there is limited empirical research relating to the impact that these macroeconomic factors have on the returns of South African REITs. Therefore, this study is undertaken to shed light on the relationship between these macroeconomic factors and South African REIT returns.

To estimate and evaluate the relationships between the stated macroeconomic factors and South African REIT returns, VAR models and VECMs are estimated. The results reveal that South African REIT returns are significantly positively associated with economic growth, inflation, and stock market returns whereas they are significantly negatively related to interest rates. However, changes in these macroeconomic factors only explain a small percentage of the variability in REIT returns. Importantly, the findings of this study are consistent with that of international studies expect for inflation in which a negative association has generally been reported. Therefore, it can be concluded that except for inflation, the relationship between macroeconomic factors and South African REIT returns is in accordance with what has been observed in other international REIT markets.

By analysing the influence that macroeconomic factors have on the returns of South African REITs, this study makes a contribution to the existing body of knowledge and strengthens the field of REIT research in South Africa. Moreover, the findings of this study may be beneficial to REIT asset managers as it could possibly assist them in

making portfolio allocation decisions. These results may also be useful to real estate collective investment scheme fund managers in specifying an optimal strategic asset allocation as well as in making tactical asset allocation adjustments to capitalise on changes in macroeconomic factors. In addition, the results could enhance investors' knowledge on the relationship between macroeconomic factors and South African REIT returns which may aid them in making more informed investment decisions.

6.4 RECOMMENDATIONS FOR FUTURE RESEARCH

The author has several recommendations for future research that extend the present study. Firstly, this study reveals that there is a positive relationship between inflation and South African REIT returns whereby a rise in inflation results in higher REIT returns. This is in contrast to the negative relationship that has been observed in the majority of other REIT markets around the world. Consequently, researchers could analyse why the South African REIT market reacts differently to changes in inflation compared to REITs in other markets.

Secondly, the analysis of the South African REIT property subtypes shows that macroeconomic factors influence the retail, office, and industrial sectors differently. For instance, only 0.96% of the forecast error variance of the retail property sector total return is due to the variability in a structural shock to economic growth. Contrarily, 33.32% and 26.11% of the variation in the total return of the office and industrial property sectors is explained by a shock to economic growth. Evidently, economic growth exerts a substantially larger impact on the office and industrial property sectors compared to the retail property sector. Accordingly, future research could examine why the various South African REIT property subtypes react differently to shocks in macroeconomic factors.

Thirdly, the findings of this study indicate that changes in macroeconomic factors only explain a small percentage of the variation in South African REIT returns. This implies that other factors excluded from the present study could also impact South African REIT returns. For example, international studies have shown that firm-specific factors such as size, leverage, dividend yield, and book-to-market ratio may affect REIT returns. As such, future research could analyse the influence that these firm-specific

factors have on the returns of South African REITs. Particularly, the extent of the impact that these firm-specific factors have on South African REIT returns could be investigated to identify whether firm-specific factors explain a larger percentage of the variance in South African REIT returns compared to the macroeconomic factors analysed in this study.

Lastly, this study highlights that there is a significant relationship between South African REIT returns and various macroeconomic factors. However, over the past few decades, globalisation has led to financial markets around the world becoming more integrated with one another. This then posits the following question: do foreign financial markets have a significant influence on the South African REIT market? Thus, an interesting area for future research would be to examine whether a significant relationship exists between South African REIT returns and macroeconomic factors in other major markets such as the United States or the United Kingdom.

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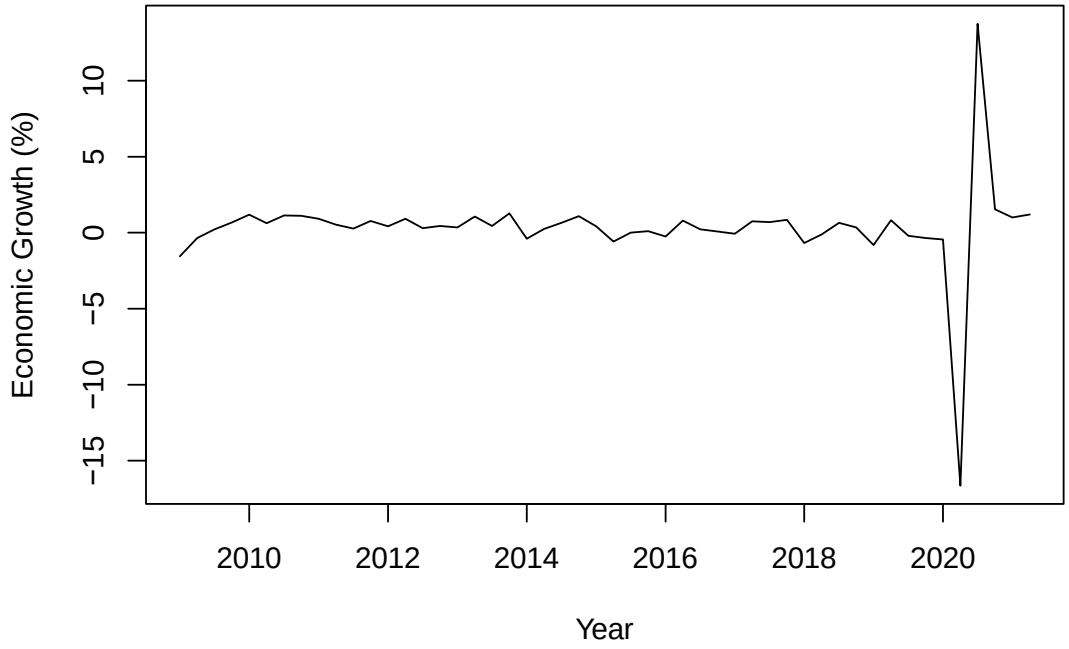
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APPENDIX A

Appendix A determines the order of integration of the economic growth rate series by conducting Augmented Dickey Fuller (ADF) and Dickey Fuller generalised least squares (DF-GLS) unit root tests. Figure 23 graphically illustrates the quarterly South African economic growth rate from 2009-Q1 to 2021-Q2 represented by the quarter-on-quarter percentage change in gross domestic product (constant 2015 prices, seasonally adjusted and annualised).

Figure 23: Quarterly South African economic growth rate



An overview of important descriptive statistics relating to the economic growth rate series is captured in Table 66.

Table 66: Descriptive statistics of the economic growth rate series

Descriptive statistic	Value
Minimum	−16.63442
Quartile 1	−0.05631
Median	0.43466
Mean	0.30537
Quartile 3	0.83327

Maximum	13.72972

When analysing the graph and the descriptive statistics of the economic growth rate series, it is evident that this series has a constant but no trend term. Therefore, the ADF-τ_μ test and the DF-GLS$^\mu$ test are the appropriate unit root tests to run on this series. The results of these unit root tests are summarised in Table 67.

Table 67: Unit root tests of the economic growth rate series

Test statistic	Percent	Critical value	Reject/Fail to reject null hypothesis
ADF-τ_μ test			
−0.7987	1	−3.58	Fail to reject
	5	−2.93	Fail to reject
	10	−2.60	Fail to reject
DF-GLS$^\mu$ test			
−1.1234	1	−2.61	Fail to reject
	5	−1.95	Fail to reject
	10	−1.62	Fail to reject

In summary, fail to reject the null hypothesis that the series has a unit root for the ADF-τ_μ test and the DF-GLS$^\mu$ test at the 10%, 5%, and 1% levels of significance. Given these results, it can be said that the economic growth rate series has a unit root. As such, it is necessary to run the unit root tests on the first difference of the series to determine the order of integration. The first difference of the quarterly South African economic growth rate series from 2009-Q1 to 2021-Q2 is plotted in Figure 24.

Figure 24: First difference of the quarterly South African economic growth rate

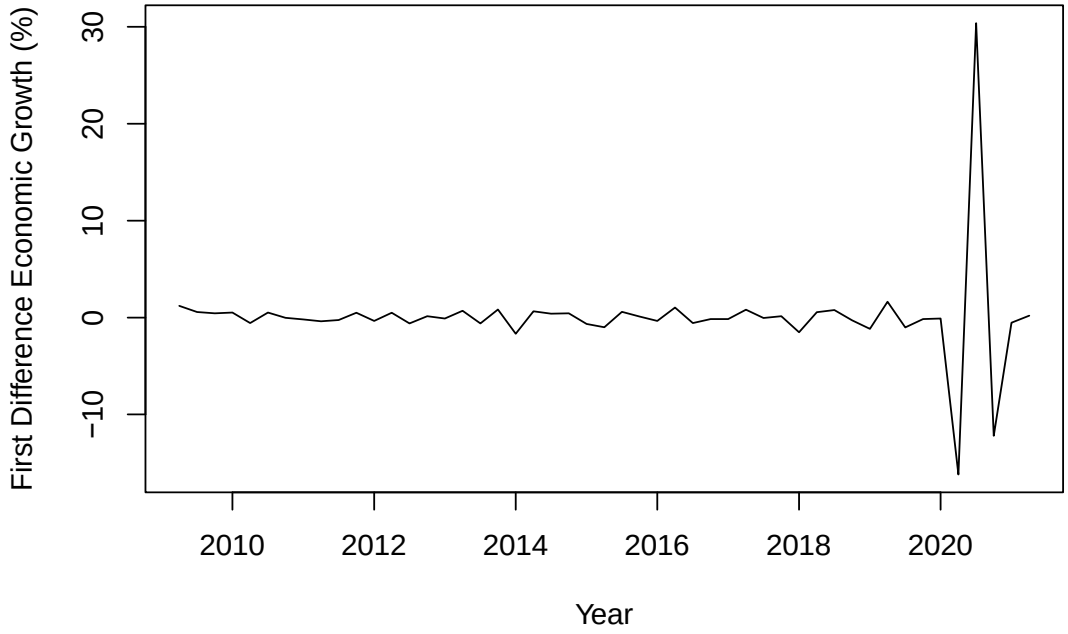


Table 68 provides a synopsis of the main descriptive statistics pertaining to the first difference of the economic growth rate series.

Table 68: Descriptive statistics of the first difference of the economic growth rate series

Descriptive statistic	**Value**
Minimum	−16.18135
Quartile 1	−0.53910
Median	−0.04894
Mean	0.05635
Quartile 3	0.51145
Maximum	30.36414

The graph and the descriptive statistics of the first difference of the economic growth rate series indicates that this series has no constant and no trend term. Accordingly, the ADF-τ test is run to test for a unit root. The DF-GLS test can only be run on data that has a constant and/or a trend term, hence, this unit root test is not run on the first difference of the economic growth rate series. The result of the ADF-τ unit root test is reported in Table 69.

Table 69: Unit root test of the first difference of the economic growth rate series

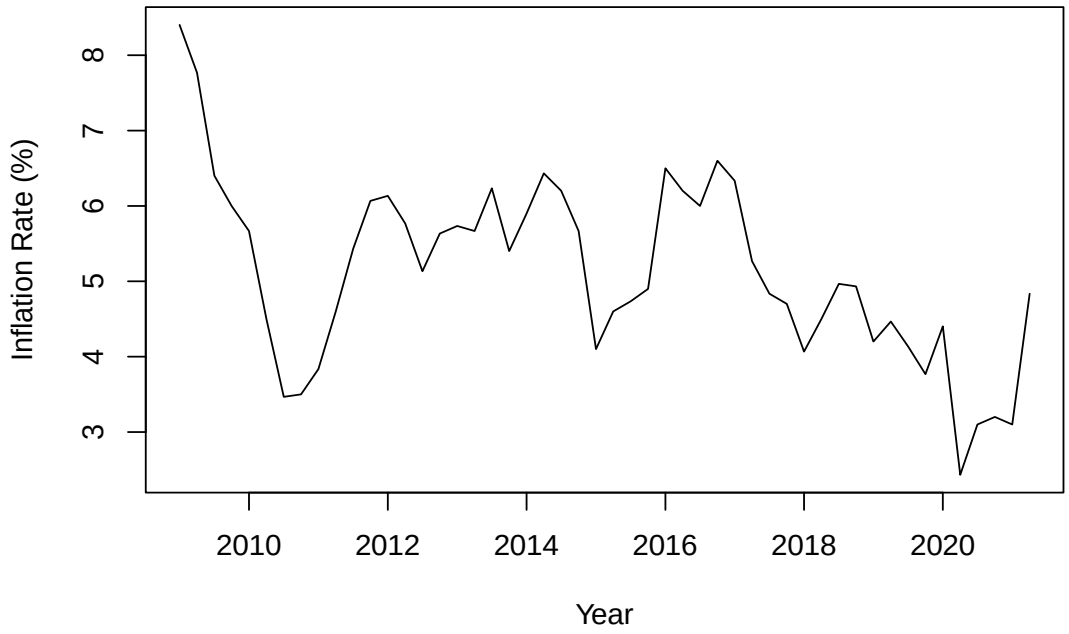
Test statistic	Percent	Critical value	Reject/Fail to reject null hypothesis
ADF-τ test			
−8.2636	1	−2.62	Reject
	5	−1.95	Reject
	10	−1.61	Reject

Evidently, the first difference of the economic growth rate series does not have a unit root as the null hypothesis of the ADF-τ test is rejected at the 10%, 5%, and 1% levels of significance. Thus, it can be concluded that the quarterly South African economic growth rate series is integrated of order one denoted as $I(1)$.

APPENDIX B

The order of integration of the inflation rate series is analysed in Appendix B by conducting Augmented Dickey Fuller (ADF) and Dickey Fuller generalised least squares (DF-GLS) unit root tests. Figure 25 displays the quarterly South African inflation rate from 2009-Q1 to 2021-Q2 represented by the quarter-on-quarter percentage change in the headline consumer price index.

Figure 25: Quarterly South African inflation rate



The descriptive statistics regarding the inflation rate series is outlined in Table 70.

Table 70: Descriptive statistics of the inflation rate series

Descriptive statistic	Value
Minimum	2.433
Quartile 1	4.417
Median	5.050
Mean	5.128
Quartile 3	6.000
Maximum	8.400

The graph and the descriptive statistics of the inflation rate series highlights that this series has a constant but no trend term. Therefore, the applicable unit root tests to run on this series include the ADF-τ_μ test and the DF-GLS$^\mu$ test. The results of these unit root tests are presented in Table 71.

Table 71: Unit root tests of the inflation rate series

Test statistic	Percent	Critical value	Reject/Fail to reject null hypothesis
ADF-τ_μ test			
−1.5123	1	−3.58	Fail to reject
	5	−2.93	Fail to reject
	10	−2.60	Fail to reject
DF-GLS$^\mu$ test			
−0.7886	1	−2.61	Fail to reject
	5	−1.95	Fail to reject
	10	−1.62	Fail to reject

To summarise, fail to reject the null hypothesis that the series has a unit root for the ADF-τ_μ test and the DF-GLS$^\mu$ test at the 10%, 5%, and 1% levels of significance. These results indicate that the inflation rate series has a unit root. As a consequence, unit root tests on the first difference of the series are run so as to ascertain the order of integration. Figure 26 graphically illustrates the first difference of the quarterly South African inflation rate series from 2009-Q1 to 2021-Q2.

Figure 26: First difference of the quarterly South African inflation rate

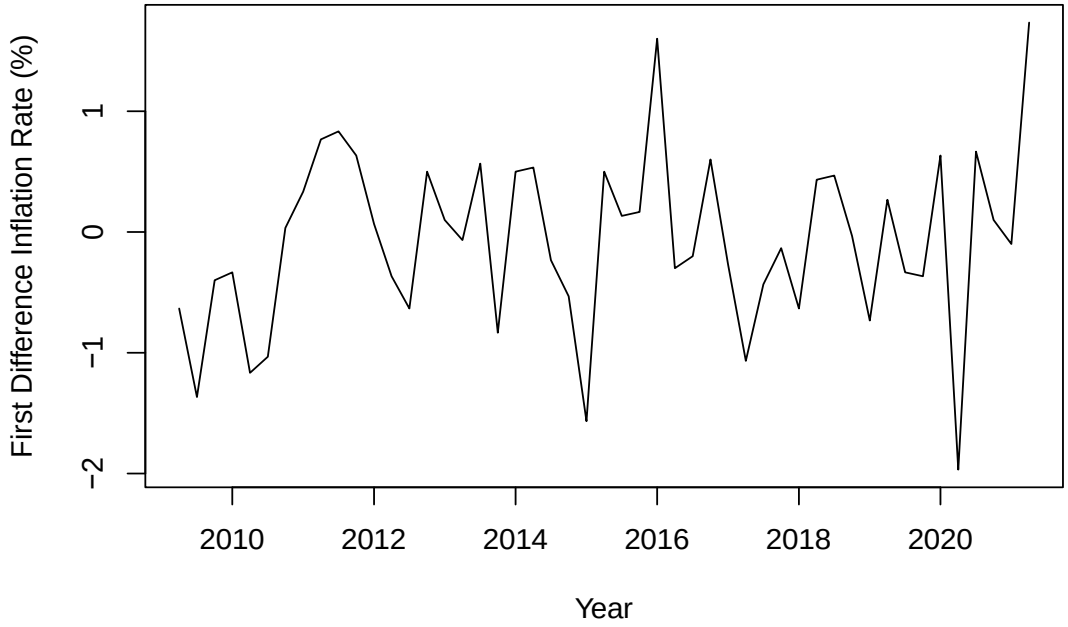


Table 72 highlights the fundamental descriptive statistics applying to the first difference of the inflation rate series.

Table 72: Descriptive statistics of the first difference of the inflation rate series

Descriptive statistic	Value
Minimum	−1.96667
Quartile 1	−0.43333
Median	−0.06667
Mean	−0.07279
Quartile 3	0.50000
Maximum	1.73333

When analysing the graph and the descriptive statistics of the first difference of the inflation rate series, it is apparent that this series has no constant and no trend term. As such, the ADF-τ test is the relevant unit root test that needs to be run on this series. As mentioned previously, the DF-GLS test can only be run on data that has a constant and/or a trend term, thus, this unit root test is not run on the first difference of the inflation rate series. Table 73 summarises the result of the ADF-τ unit root test.

Table 73: Unit root test of the first difference of the inflation rate series

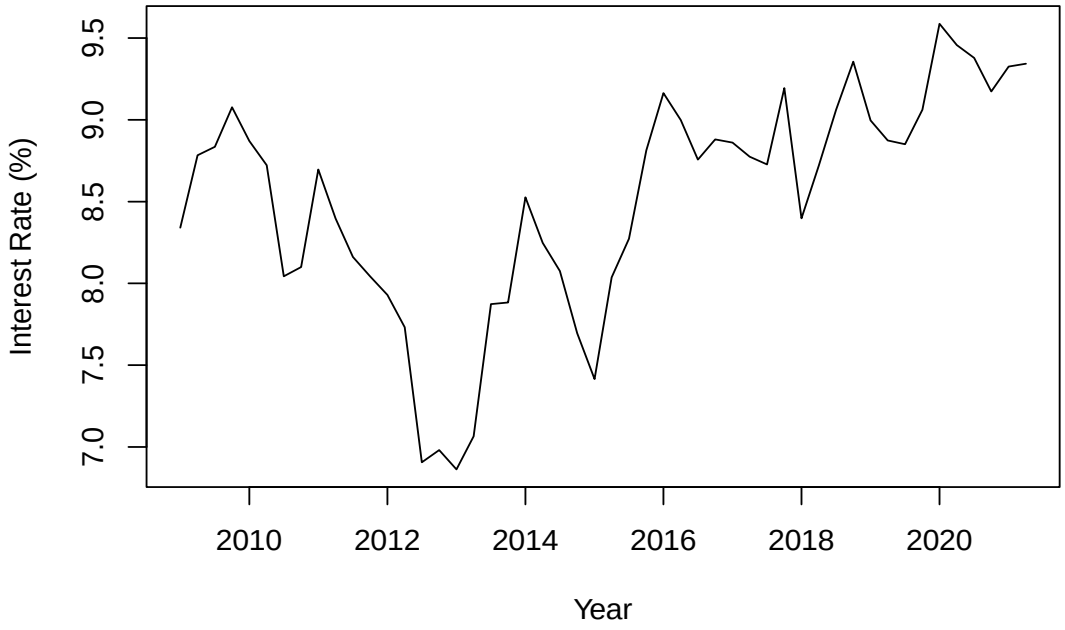
Test statistic	Percent	Critical value	Reject/Fail to reject null hypothesis
ADF-τ test			
-5.3376	1	-2.62	Reject
	5	-1.95	Reject
	10	-1.61	Reject

The findings of the ADF-τ test demonstrate that the first difference of the inflation rate series does not have a unit root since the null hypothesis is rejected at the 10%, 5%, and 1% levels of significance. As a result, it can be inferred that the quarterly South African inflation rate series is an $I(1)$ process.

APPENDIX C

Appendix C investigates the order of integration of the interest rate series by conducting Augmented Dickey Fuller (ADF) and Dickey Fuller generalised least squares (DF-GLS) unit root tests. Figure 27 displays the quarterly South African interest rate from 2009-Q1 to 2021-Q2 represented by the South African 10-year government bond yield.

Figure 27: Quarterly South African interest rate



A summary of prominent descriptive statistics relating to the interest rate series is reported in Table 74.

Table 74: Descriptive statistics of the interest rate series

Descriptive statistic	Value
Minimum	6.863
Quartile 1	8.052
Median	8.725
Mean	8.507
Quartile 3	8.998
Maximum	9.587

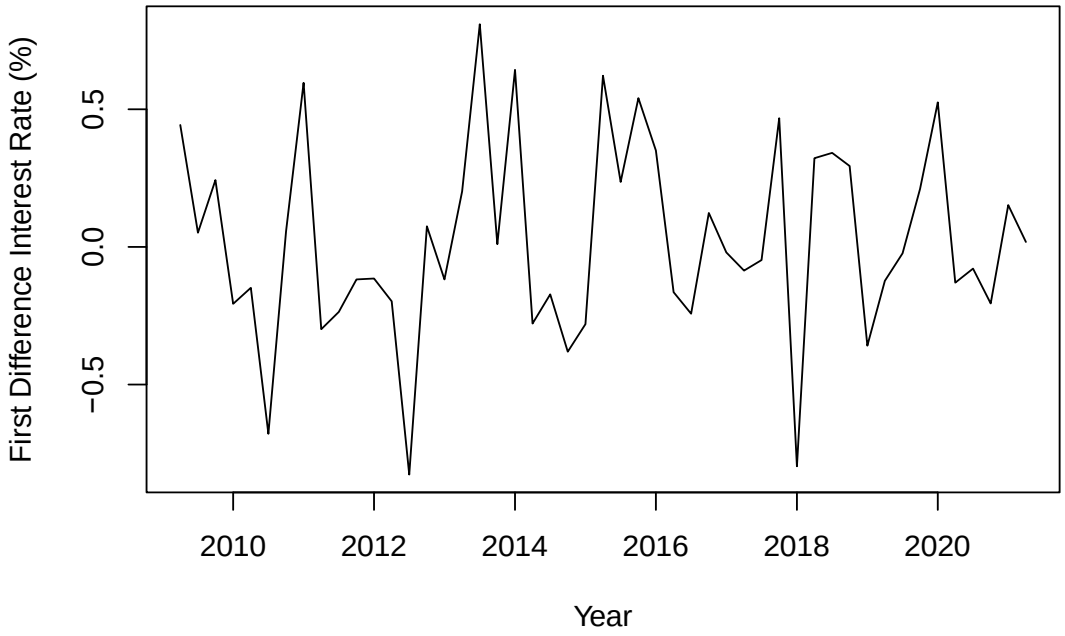
An analysis of the graph and the descriptive statistics of the interest rate series reveals that this series has a constant but no trend term. Therefore, the ADF-τ_μ test and the DF-GLS$^\mu$ test are the appropriate unit root tests to run on this series. The results of these unit root tests are recorded in Table 75.

Table 75: Unit root tests of the interest rate series

Test statistic	Percent	Critical value	Reject/Fail to reject null hypothesis
ADF-τ_μ test			
−1.492	1	−3.58	Fail to reject
	5	−2.93	Fail to reject
	10	−2.60	Fail to reject
DF-GLS$^\mu$ test			
−0.7077	1	−2.61	Fail to reject
	5	−1.95	Fail to reject
	10	−1.62	Fail to reject

Failing to reject the null hypothesis of the ADF-τ_μ test and the DF-GLS$^\mu$ test at the 10%, 5%, and 1% levels of significance indicates that the interest rate series has a unit root. As such, it is required to run unit root tests on the first difference of the interest rate series to establish the order of integration. The first difference of the quarterly South African interest rate series from 2009-Q1 to 2021-Q2 is plotted in Figure 28.

Figure 28: First difference of the quarterly South African interest rate



The descriptive statistics pertaining to the first difference of the interest rate series is captured in Table 76.

Table 76: Descriptive statistics of the first difference of the interest rates series

Descriptive statistic	**Value**
Minimum	−0.82633
Quartile 1	−0.19733
Median	−0.02300
Mean	0.02047
Quartile 3	0.24267
Maximum	0.80867

The graph and the descriptive statistics of the first difference of the interest rate series shows that this series has no constant and no trend term. Consequently, the ADF-τ test should be run to test for a unit root. As was the case for the prior macroeconomic factors, the DF-GLS test cannot be run on the first difference of the interest rate series as this test can only be run on data that has a constant and/or a trend term. Table 77 summarises the result of the ADF-τ unit root test.

Table 77: Unit root test of the first difference of the interest rate series

Test statistic	Percent	Critical value	Reject/Fail to reject null hypothesis
ADF-τ test			
−3.8548	1	−2.62	Reject
	5	−1.95	Reject
	10	−1.61	Reject

In summary, reject the null hypothesis that the interest rate series has a unit root for the ADF-τ test at the 10%, 5%, and 1% levels of significance. These results imply that this series does not have a unit root. Therefore, it can be concluded that the quarterly South African interest rate series is an $I(1)$ process.

APPENDIX D

Appendix D determines the order of integration of the stock market total return series by conducting Augmented Dickey Fuller (ADF) and Dickey Fuller generalised least squares (DF-GLS) unit root tests. The quarterly total return of the South African stock market from 2009-Q1 to 2021-Q2 is displayed in Figure 29. This series is represented by the JSE All Share Total Return Index.

Figure 29: Quarterly total return of the South African stock market

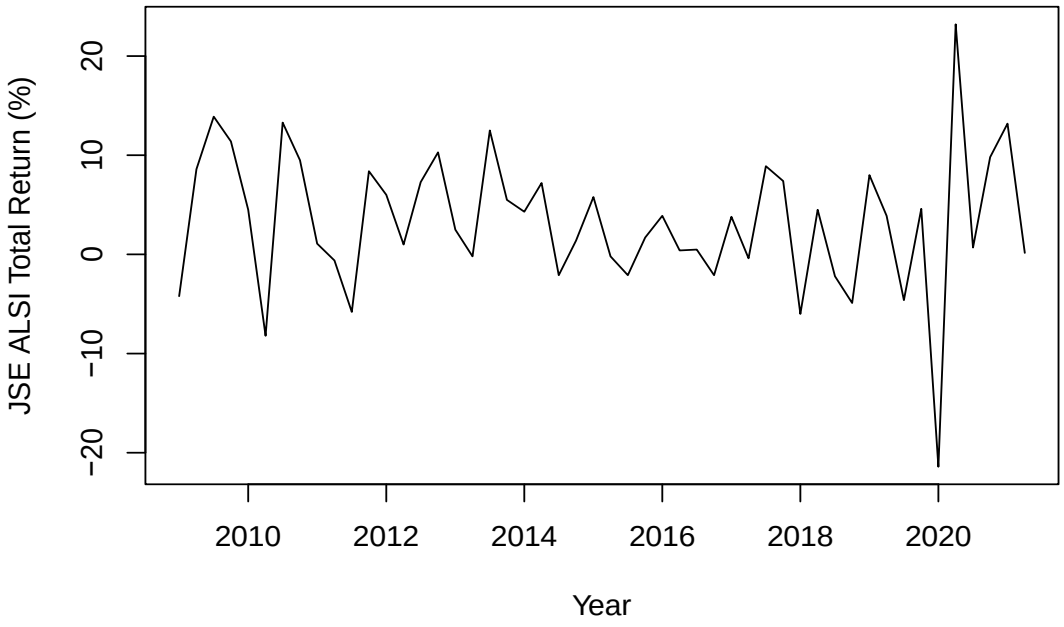


Table 78 highlights important descriptive statistics applicable to the stock market total return series.

Table 78: Descriptive statistics of the stock market total return series

Descriptive statistic	Value
Minimum	−21.400
Quartile 1	−0.350
Median	3.850
Mean	3.283
Quartile 3	7.850
Maximum	23.200

When analysing the graph and the descriptive statistics of the stock market total return series, it is clear that this series has a constant but no trend term. As a result, the ADF-τ_μ test and the DF-GLS$^\mu$ test are the relevant unit root tests that should be run on this series. The results of these unit root tests are summarised in Table 79.

Table 79: Unit root tests of the stock market total return series

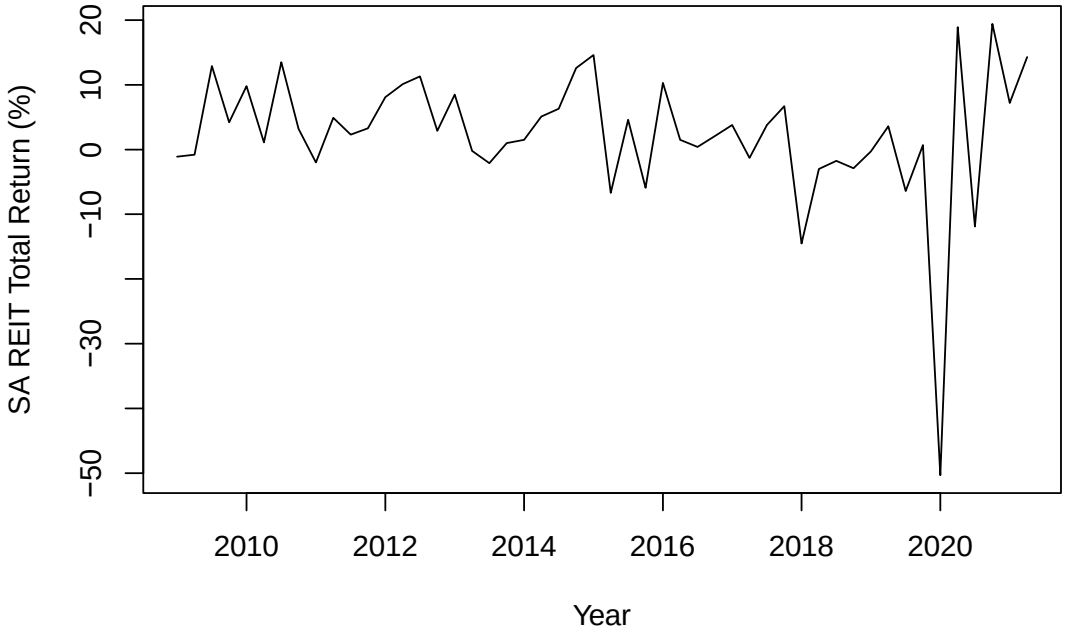
Test statistic	Percent	Critical value	Reject/Fail to reject null hypothesis
ADF-τ_μ test			
−5.1996	1	−3.58	Reject
	5	−2.93	Reject
	10	−2.60	Reject
DF-GLS$^\mu$ test			
−2.7389	1	−2.61	Reject
	5	−1.95	Reject
	10	−1.62	Reject

The findings of the unit root tests highlight that the stock market total return series is stationary since the null hypothesis of the ADF-τ_μ test and the DF-GLS$^\mu$ test are rejected at the 10%, 5%, and 1% levels of significance. Thus, it can be said that the quarterly total return of the South African stock market series is integrated of order zero denoted as $I(0)$.

APPENDIX E

The order of integration of the real estate investment trust (REIT) market total return series is analysed in Appendix E by conducting Augmented Dickey Fuller (ADF) and Dickey Fuller generalised least squares (DF-GLS) unit root tests. Figure 30 graphically illustrates the quarterly total return of the South African REIT market from 2009-Q1 to 2021-Q2 represented by the South African REITs Total Return Index.

Figure 30: Quarterly total return of the South African REIT market



An overview of the main descriptive statistics relating to the REIT market total return series is reported in Table 80.

Table 80: Descriptive statistics of the REIT market total return series

Descriptive statistic	Value
Minimum	−50.300
Quartile 1	−1.025
Median	3.050
Mean	2.467
Quartile 3	7.875
Maximum	19.400

The graph and the descriptive statistics of the REIT market total return series indicates that this series has a constant but no trend term. Accordingly, the ADF-τ_μ test and the DF-GLS$^\mu$ test should be run to test for a unit root. The results of these unit root tests are presented in Table 81.

Table 81: Unit root tests of the REIT market total return series

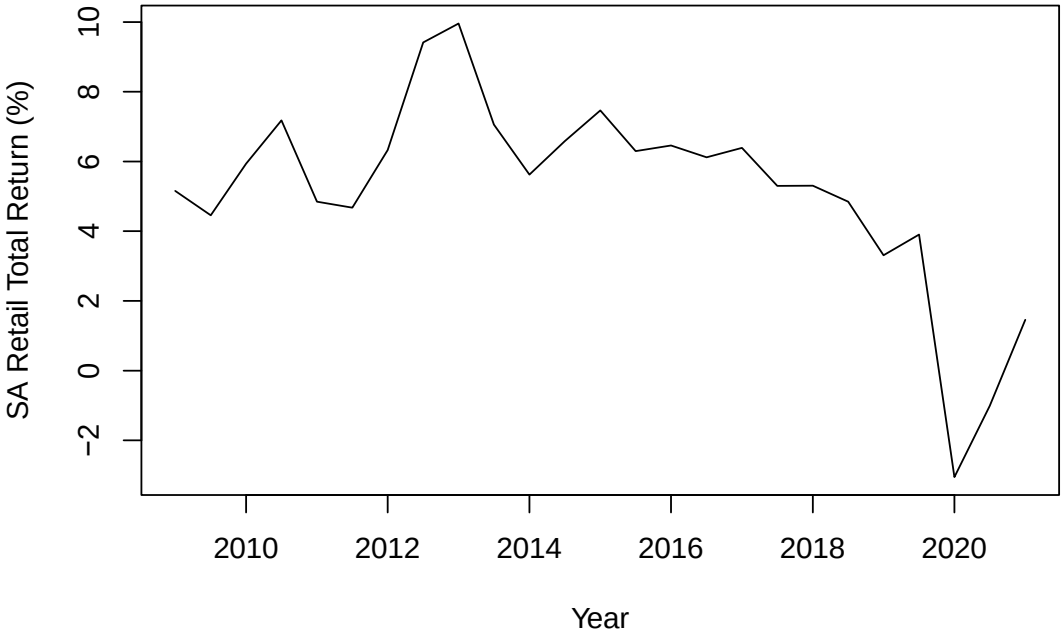
Test statistic	Percent	Critical value	Reject/Fail to reject null hypothesis
ADF-τ_μ test			
−3.3732	1	−3.58	Fail to reject
	5	−2.93	Reject
	10	−2.60	Reject
DF-GLS$^\mu$ test			
−2.9598	1	−2.61	Reject
	5	−1.95	Reject
	10	−1.62	Reject

To summarise, reject the null hypothesis that the series has a unit root for the ADF-τ_μ test at the 10% and 5% levels of significance, and reject the DF-GLS$^\mu$ test at the 10%, 5%, and 1% levels of significance. As such, it can be inferred that the quarterly total return of the South African REIT market series is stationary, and hence, classified as an $I(0)$ process.

APPENDIX F

Appendix F examines the order of integration of the retail property sector total return series by conducting Augmented Dickey Fuller (ADF) and Dickey Fuller generalised least squares (DF-GLS) unit root tests. Figure 31 displays the semi-annual total return of the South African retail property sector from 2009-H1 to 2021-H1 represented by the total return of the retail market segment of the MSCI South Africa Biannual Property Index.

Figure 31: Semi-annual total return of the South African retail property sector



The descriptive statistics regarding the retail property sector total return series is outlined in Table 82.

Table 82: Descriptive statistics of the retail property sector total return series

Descriptive statistic	Value
Minimum	−3.049
Quartile 1	4.675
Median	5.622
Mean	5.201
Quartile 3	6.460
Maximum	9.954

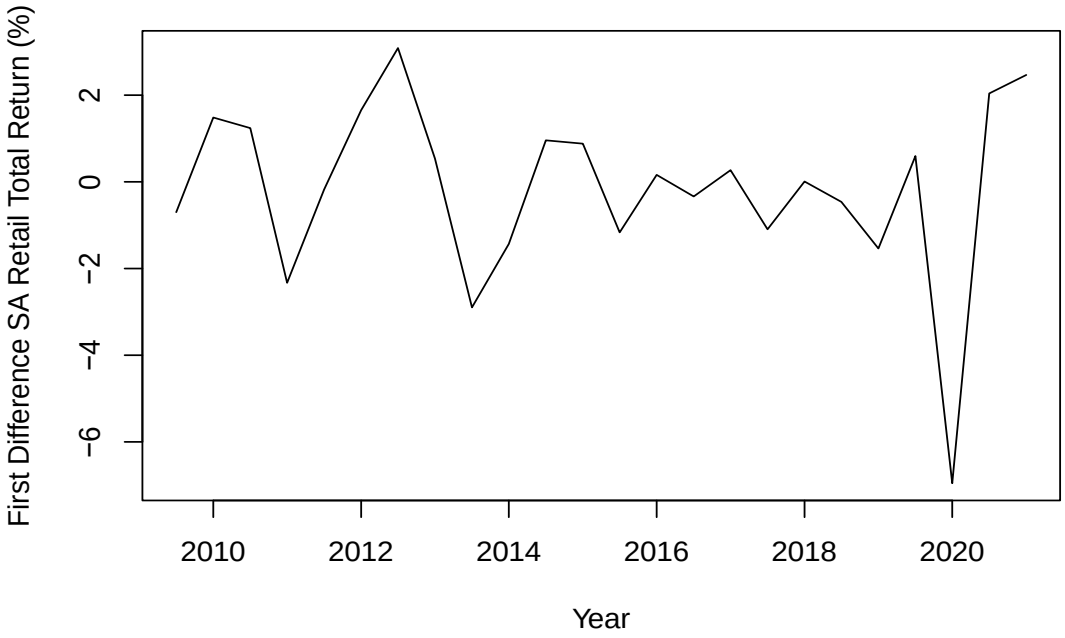
The graph and the descriptive statistics of the retail property sector total return series shows that this series has a constant but no trend term. Therefore, the appropriate unit root tests to run on this series include the ADF-τ_μ test and the DF-GLS$^\mu$ test. Table 83 summarises the results of these unit root tests.

Table 83: Unit root tests of the retail property sector total return series

Test statistic	Percent	Critical value	Reject/Fail to reject null hypothesis
ADF-τ_μ test			
−1.2017	1	−3.75	Fail to reject
	5	−3.00	Fail to reject
	10	−2.63	Fail to reject
DF-GLS$^\mu$ test			
−0.5685	1	−2.66	Fail to reject
	5	−1.96	Fail to reject
	10	−1.62	Fail to reject

Fail to reject the null hypothesis of the ADF-τ_μ test and the DF-GLS$^\mu$ test at the 10%, 5%, and 1% levels of significance which implies that the retail property sector total return series has a unit root. Consequently, it is necessary to run unit root tests on the first difference of the retail property sector total return series to identify the order of integration. The first difference of the semi-annual total return of the South African retail property sector series from 2009-H1 to 2021-H1 is illustrated in Figure 32.

Figure 32: First difference of the semi-annual total return of the South African retail property sector



A summary of the descriptive statistics pertaining to the first difference of the retail property sector total return series is reported in Table 84.

Table 84: Descriptive statistics of the first difference of the retail property sector total return series

Descriptive statistic	Value
Minimum	−6.95424
Quartile 1	−1.11153
Median	0.08581
Mean	−0.15394
Quartile 3	1.03028
Maximum	3.08667

An analysis of the graph and the descriptive statistics of the first difference of the retail property sector total return series reveals that this series has no constant and no trend term. Therefore, the ADF-τ test should be run to test for a unit root. As mentioned previously, the DF-GLS test can only be run on data that has a constant and/or a trend term, hence, this unit root test cannot be run on this series. The result of ADF-τ test is presented in Table 85.

Table 85: Unit root test of the first difference of the retail property sector total return series

Test statistic	Percent	Critical value	Reject/Fail to reject null hypothesis
ADF-τ test			
−3.8727	1	−2.66	Reject
	5	−1.95	Reject
	10	−1.60	Reject

The findings of the ADF-τ test demonstrate that the first difference of the retail property sector total return series does not have a unit root as the null hypothesis is rejected at the 10%, 5%, and 1% levels of significance. Subsequently, it can be concluded that the semi-annual total return of the South African retail property sector series is an $I(1)$ process.

APPENDIX G

Appendix G analyses the order of integration of the office property sector total return series by conducting Augmented Dickey Fuller (ADF) and Dickey Fuller generalised least squares (DF-GLS) unit root tests. Figure 33 plots the semi-annual total return of the South African office property sector from 2009-H1 to 2021-H1. This series is represented by the total return of the office market segment of the MSCI South Africa Biannual Property Index.

Figure 33: Semi-annual total return of the South African office property sector

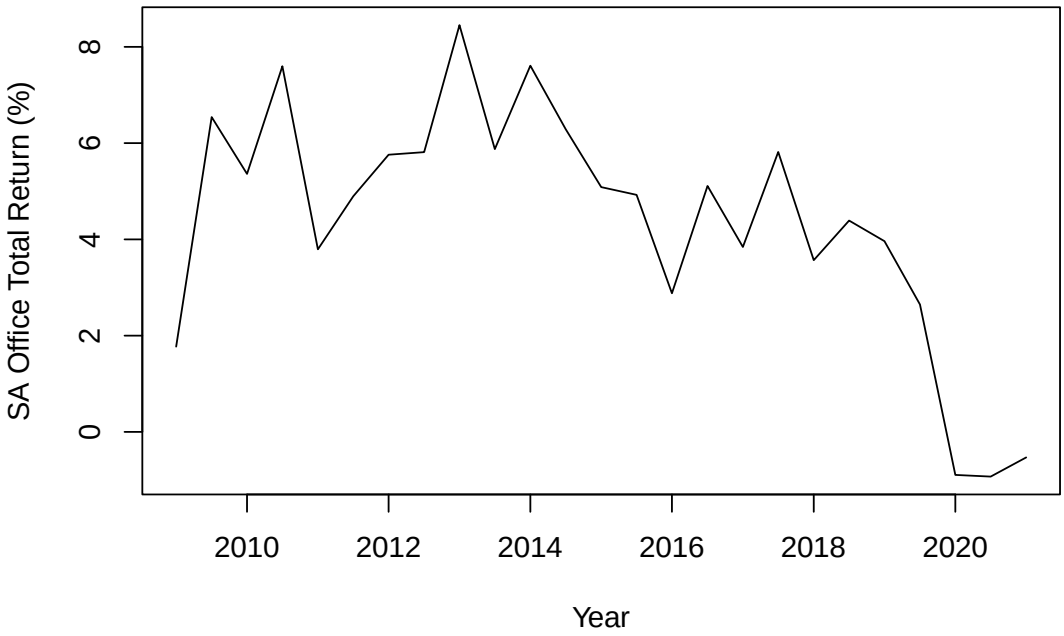


Table 86 provides a synopsis of the key descriptive statistics relating to the office property sector total return series.

Table 86: Descriptive statistics of the office property sector total return series

Descriptive statistic	Value
Minimum	−0.9285
Quartile 1	3.5686
Median	4.9245
Mean	4.3843
Quartile 3	5.8152
Maximum	8.4493

The graph and the descriptive statistics of the office property sector total return series reveals that this series has a constant but no trend term. Accordingly, the suitable unit root tests to run on this series include the ADF-τ_μ test and the DF-GLS$^\mu$ test. The results of these unit root tests are captured in Table 87.

Table 87: Unit root tests of the office property sector total return series

Test statistic	Percent	Critical value	Reject/Fail to reject null hypothesis
ADF-τ_μ test			
0.2482	1	−3.75	Fail to reject
	5	−3.00	Fail to reject
	10	−2.63	Fail to reject
DF-GLS$^\mu$ test			
−0.5247	1	−2.66	Fail to reject
	5	−1.96	Fail to reject
	10	−1.62	Fail to reject

In summary, fail to reject the null hypothesis for the ADF-τ_μ test and the DF-GLS$^\mu$ test at the 10%, 5%, and 1% levels of significance. Given these results, it can be said that the office property sector total return series has a unit root. As such, it is required to run unit root tests on the first difference of the series to ascertain the order of integration. Figure 34 displays the first difference of the semi-annual total return of the South African office property sector series from 2009-H1 to 2021-H1.

Figure 34: First difference of the semi-annual total return of the South African office property sector

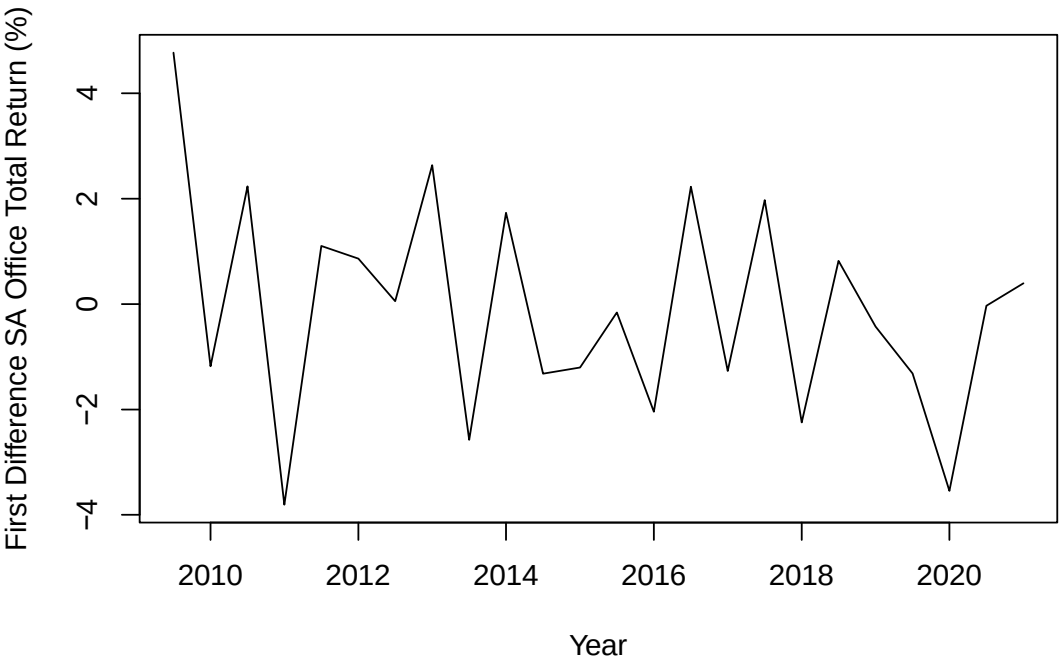


Table 88 highlights fundamental descriptive statistics applicable to the first difference of the office property sector total return series.

Table 88: Descriptive statistics of the first difference of the office property sector total return series

Descriptive statistic	Value
Minimum	−3.80479
Quartile 1	−1.31797
Median	−0.09518
Mean	−0.09597
Quartile 3	1.26050
Maximum	4.77001

When analysing the graph and the descriptive statistics of the first difference of the office property sector total return series, it is apparent that this series has no constant and no trend term. Thus, the ADF-τ test is the relevant unit root test that needs to be run on this series. The DF-GLS test is not run on the first difference of this series as it can only be run on data that has a constant and/or a trend term. Table 89 summarises the result of the ADF-τ unit root test.

Table 89: Unit root test of the first difference of the office property sector total return series

Test statistic	Percent	Critical value	Reject/Fail to reject null hypothesis
ADF-τ test			
−2.473	1	−2.66	Fail to reject
	5	−1.95	Reject
	10	−1.60	Reject

Evidently, the first difference of the office property sector total return series does not have a unit root as the null hypothesis of the ADF-τ test is rejected at the 10% and 5% levels of significance. Accordingly, it can be inferred that the semi-annual total return of the South African office property sector series is an $I(1)$ process.

APPENDIX H

The order of integration of the industrial property sector total return series is examined in Appendix H by conducting Augmented Dickey Fuller (ADF) and Dickey Fuller generalised least squares (DF-GLS) unit root tests. Figure 35 depicts the semi-annual total return of the South African industrial property sector from 2009-H1 to 2021-H1 represented by the total return of the industrial market segment of the MSCI South Africa Biannual Property Index.

Figure 35: Semi-annual total return of the South African industrial property sector

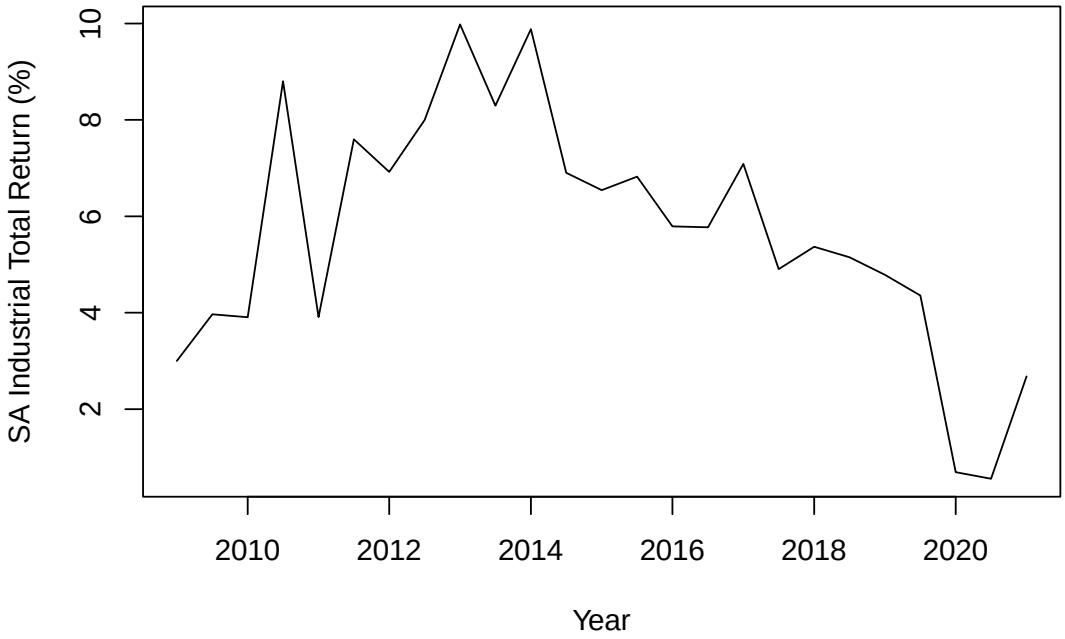


Table 90 summarises important descriptive statistics applying to the industrial property sector total return series.

Table 90: Descriptive statistics of the industrial property sector total return series

Descriptive statistic	Value
Minimum	0.5582
Quartile 1	3.9667
Median	5.7741
Mean	5.6674
Quartile 3	7.0870
Maximum	9.9788

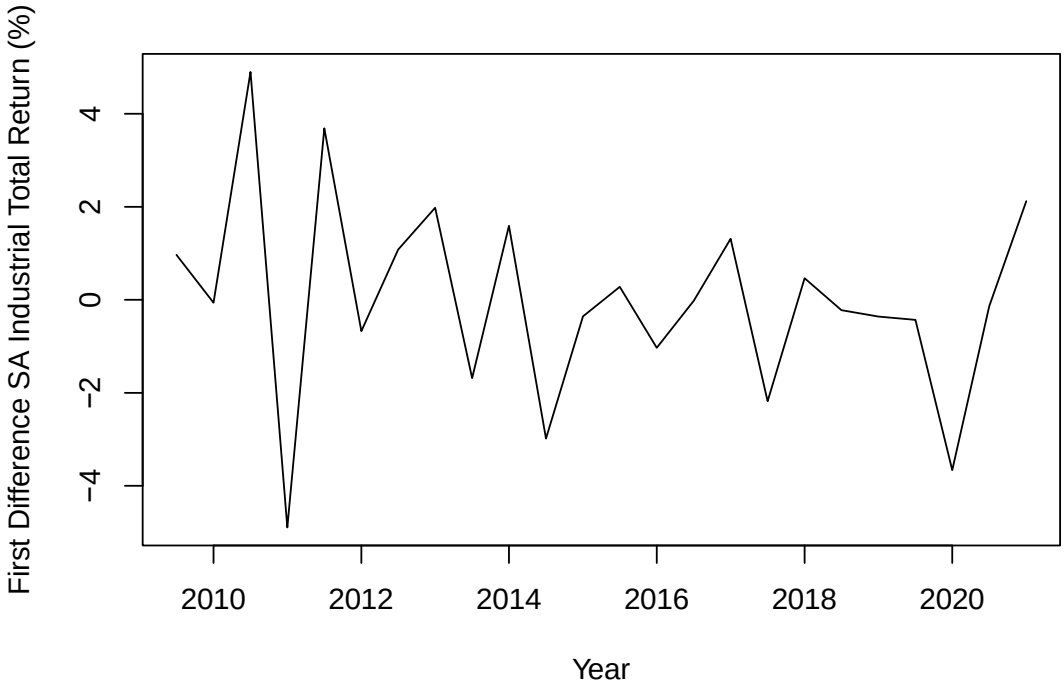
The graph and the descriptive statistics of the industrial property sector total return series indicates that this series has a constant but no trend term. As a result, the ADF-τ_μ test and the DF-GLS$^\mu$ test should be run to test for a unit root. The results of these unit root tests are outlined in Table 91.

Table 91: Unit root tests of the industrial property sector total return series

Test statistic	Percent	Critical value	Reject/Fail to reject null hypothesis
ADF-τ_μ test			
−0.4786	1	−3.75	Fail to reject
	5	−3.00	Fail to reject
	10	−2.63	Fail to reject
DF-GLS$^\mu$ test			
−0.9413	1	−2.66	Fail to reject
	5	−1.96	Fail to reject
	10	−1.62	Fail to reject

To summarise, fail to reject the null hypothesis that the series has a unit root for the ADF-τ_μ test and the DF-GLS$^\mu$ test at the 10%, 5%, and 1% levels of significance. These results show that the industrial property sector total return series has a unit root. Subsequently, unit root tests on the first difference of the series need to be run so as to establish the order of integration. Figure 36 graphically illustrates the first difference of the semi-annual total return of the South African industrial property sector series from 2009-H1 to 2021-H1.

Figure 36: First difference of the semi-annual total return of the South African industrial property sector



An overview of prominent descriptive statistics relating to the first difference of the industrial property sector total return series is recorded in Table 92.

Table 92: Descriptive statistics of the first difference of the industrial property sector total return series

Descriptive statistic	Value
Minimum	−4.8927
Quartile 1	−0.7643
Median	−0.0986
Mean	−0.0133
Quartile 3	1.1369
Maximum	4.8975

The graph and the descriptive statistics of the first difference of the industrial property sector total return series highlights that this series has no constant and no trend term. As such, the ADF-τ test should be run on the first difference of this series. As was the case for some of the other time series variables, the DF-GLS test cannot be run on the first difference of this series since it can only be run on data that has a constant and/or a trend term. Table 93 summarises the result of the ADF-τ unit root test.

Table 93: Unit root test of the first difference of the industrial property sector total return series

Test statistic	Percent	Critical value	Reject/Fail to reject null hypothesis
ADF-τ test			
−2.9118	1	−2.66	Reject
	5	−1.95	Reject
	10	−1.60	Reject

The findings of the ADF-τ test demonstrate that the first difference of the industrial property sector total return series does not have a unit root since the null hypothesis is rejected at the 10%, 5%, and 1% levels of significance. As a consequence, it can be concluded that the semi-annual total return of the South African industrial property sector series is an $I(1)$ process.