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Do asset pricing models explain sector returns on the Johannesburg Stock Exchange?



Masters of Commerce (Finance and Investments) Research

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Summary

This study is conducted to evaluate whether style factors-based asset pricing models can explain sector returns on the Johannesburg Stock Exchange (JSE). The time frame for this research is between January 2007 to July 2023. Daily return data for both styles and sectors were used and calculated on a buy and hold basis with values that were obtained from Bloomberg and Iress. The methodology applied is a time-series regression used for a Gibbons-Ross-Shanken (1989) alpha test. This research provides investors with valuable insights into the specific asset pricing models and their underlying related style factors that can elucidate the cross-sectional variation of both sector and more comprehensively, share returns on the JSE. The results of the study confirm the effectiveness of various factor models in explaining sector returns on the JSE, with the six-factor model demonstrating superior performance. Notably, the six-factor model exhibits explanatory power for the financial and industrial sectors, highlighting its comprehensive ability to explain sector returns. The significance of size and value premiums across models underscores their importance in sector return analysis. Additionally, the six-factor model strengthens its ability to elucidate cross-sectional variation in styles and sector returns. Overall, the six-factor model emerges as a robust framework for analysing sector returns on the JSE, providing valuable insights into risk factors and how sectors perform.

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1. Introduction

1.1 Background and overview

Assessing financial assets is a critical concern for both individual investors and institutional entities. The compensation for enduring systematic risks, or market risks linked to wider economic factors, is what investor returns are seen as in all asset pricing models (Goyal, 2012). The central point of divergence among these models is the representation of systematic risk through specific variables or indicators.

The research study aims to test three primary asset pricing models, namely the Fama and French three, five and six-factor model (Fama & French, 1993,2015,2018) ability to explain sector returns on the JSE. This approach can also evaluate whether adding a factor affects the models' ability to explain sector returns. Therefore, all three models are tested together rather than relying on just one. Notably, the Capital Asset Pricing Model (CAPM) and the Carhart model are also discussed as they underpin the models to be tested.

The origins of asset pricing literature lie in Markowitz's (1952) mean-variance portfolio theory, which suggests that assets have varying correlations and risks that can be split into market and non-market components. According to this theory, investors should allocate part of their portfolio to the market portfolio, which offers the highest return per unit of risk, and the rest to the risk-free rate. Investors focus on stock returns and their fluctuations due to market risk. Investment theory demonstrates a positive relationship between risk and return, a notion supported by modern portfolio theory (MPT), which suggests that only market risk increases expected returns (Elton & Gruber, 1997). However, MPT does not account for other factors affecting expected returns beyond market risk.

Building on MPT, the CAPM incorporates assumptions about risk and returns, treating the investor as Markowitz's rational efficient investor. The CAPM is widely known, linking expected asset returns to a singular risk factor which is beta. The principle of investor returns as remuneration for facing systematic risks is at the core of all asset pricing models, which are, in turn, connected to extensive economic variables (Goyal, 2012). Due to criticism, these assumptions have been modified, leading Ross (1976) to develop the arbitrage pricing model (APM) as an alternative to CAPM. Unlike CAPM, APM considers multiple variables affecting asset returns. Despite its critique of CAPM, APM could not fully identify all factors influencing asset returns. Over time, factors affecting asset prices have been extensively debated, and recent literature has evolved CAPM into multifactor models to explain asset price shifts.

Fama and French (1993) addressed stock market anomalies of the 1980s with their three-factor asset pricing model, positioning CAPM as the foundational model for explaining changes in cross-sectional asset returns. Through observation from several different studies by Fama & French (2015); Fama & French (1996) and Hou, Xue and Zang (2014), the Fama-French three-factor model cannot adequately explain; momentum-based, investment-based, and profitability-based anomalies. Hence the Carhart four-factor (1997) model, expands on the Fama and French three-factor model by including a momentum factor to the existing model. This model is not applied in testing as Carhart's (1997) momentum factor is based more on behavioural finance arguments than the efficient market hypothesis.

The Fama and French (2015) five-factor model adds a profitability factor and an investment factor, extending the Fama and French three-factor model. It is documented that the five-factor model outperforms other factor models, such as the Fama and French three-factor model (Fama & French, 1993) and the Carhart four-factor model (Carhart, 1997). With respect to the JSE, Cox and Britten (2019) and Charteris, Rwishema, and Chidede (2018) note that the Fama and French five-factor model outperforms both the three-factor model and the Carhart (1997) four-factor model. However, in the United States, the five-factor model struggles to explain the returns of small-stock portfolios that behave like high-investment, low-profitability firms (Fama & French, 2015). To address this limitation, Barillas and Shanken (2018) and Fama and French (2018) explore whether adding a momentum factor could enhance the model's explanatory power. They conclude that a range of models incorporating a momentum factor outperform the latest models from Hou et al. (2014) and Fama and French (2015, 2016). Given the superior performance of the six-factor model, it is compelling to examine if this model can retain its efficacy, particularly when tasked with explaining sector returns on the JSE.

From the 276 companies listed on the JSE, the financial sector and industrial sectors are among the sectors most companies belong to (Johannesburg Stock Exchange, 2024). This means that there is great activity in this sector, regardless of whether South Africa has an emerging market; South Africa has an advanced financial and industrial sector. Specifically, there is a limited amount of literature that examines whether asset pricing models can explain sector returns. Previous investigations primarily focus on comparing various asset pricing models or analysing specific style factors in relation to different global indices and different economies. Some studies that are noted are (1) Van Rensburg's (2001) study examines a series of style factors to determine if they could explain the expected returns on JSE industrial shares. The results indicate that only the style factors of earnings to price, market capitalization, and twelve-month

past positive returns, representing the momentum factor, explain the expected industrial share returns on the JSE. (2) Fraser and Page (2000) conduct a comparable study that challenges the findings of Asness (1997). The authors intend to evaluate the effectiveness of momentum and value strategies separately when applied to the industrial sector of the JSE. The results, indicate that on a univariate basis the momentum strategy alone could explain the cross-section of share returns. (3) Charteris (2014), study emphasizes the importance of estimated dual beta in explaining returns, especially within the industrials and financials sectors on the JSE from January 2000 to December 2009.

Most of these studies assess asset pricing models in relation to specific industries or anomalies used to estimate expected stock returns, often resulting in conflicting findings. None of these studies address how asset pricing models impact sector returns specifically on the South African market. Given the strong performance of the six-factor model, it would be valuable to explore whether this model continues to be effective in explaining sector returns. Additionally, with limited research on asset pricing models and sector returns, it would be worthwhile to investigate whether the six-factor model, along with the three- and five-factor models, can effectively explain returns across different sectors.

1.2 Knowledge gap

There is a current gap in the existing body of emerging market asset pricing research that this study aims to fill. Specifically, there is a limited amount of literature that examines whether asset pricing models can explain sector returns.

Hence this research will specifically scrutinise all sectors and their respective returns that form the cross-section of listed shares on the JSE. The goal is to determine if the style factors combined into three different asset pricing models can effectively explain these sector returns from a risk-based perspective. Prior literature on industries within the JSE predominantly focuses on the Fama and French three- and five-factor models. This study aims to extend the analysis by incorporating the Fama and French six-factor model to provide a more comprehensive understanding. Consequently, investors will gain insights into which asset pricing model and corresponding style factors can most accurately explain the cross section of sector and more broadly, share returns on the JSE. The reason why sector returns are used in this research is that they behave differently from market returns. When examining returns from various sectors, it's essential to recognise that certain sectors are governed by regulations and

come with distinct risks. This explains why sector-specific returns may not always align with overall market or index returns due to these unique risk profiles. In terms of asset pricing models, it is evident that each sector possesses a distinct beta, indicating its specific sensitivity to market fluctuations. This is influenced by the diverse business cycles and growth opportunities that each sector experiences.

1.3 Research objective

The goal of this study is to investigate whether the style factors within a Fama and French three-factor, five-factor, and six-factor asset pricing model can explain the variation in sector returns on the JSE.

1.4 Problem statement

Do asset pricing models premised on style factor premiums explain sector returns on the JSE?

1.5 Potential benefits of the study

When examining if the asset pricing models can explain sector returns on the JSE, it is equally vital to understand, how financial markets set prices for securities and subsequently forecast returns. This study intends to explore whether sector returns can be elucidated using style-based models. Furthermore, it aims to ascertain if these sector-related risks can be accounted for by style factors and whether these factors have a pivotal role in dissecting the differences in share returns across the JSE. This will allow investors to see if styles factors explain sector returns, then the style-based asset pricing models are a better representation of the data generating process that governs returns on the JSE. Studies has been based on different style factors and early asset pricing models. This study expands and looks at multiple style factors with multiple sectors.

Understanding if asset pricing models explain sector returns can provide investors with a competitive edge for making profitable investments, aiding in decision making and risk management. When examining risk management, it's vital to understand the factors that explain sector returns. As this could be useful to investors as they then can manage their risk and diversify their portfolio effectively. Another advantage by seeing if style-based models can explain sector returns is that investors can tailor their portfolios to individual risk tolerances and investment objectives. By understanding whether style factors explain sector returns and

if it could aid in creating benchmarks for future evaluation of performance of portfolios or investment funds.

The remaining sections of this research will further investigate, the intricacies of asset pricing models and their implications for the JSE. Section two provides a review of the pertinent literature, scrutinizing the theoretical underpinnings and empirical investigations of the respective asset pricing models. Section three outlines the data and methodological framework that underpins this study, addressing the research design and analysis techniques. Section four presents an empirical analysis and documents the results of the tests conducted. Section five addresses the limitations of the study highlighting the challenges encountered both in the preparatory phase and following the execution of the tests. Lastly, Section six provides a conclusive analysis of the research project, the principal outcomes and significance as well as future contributions to academic research.

2. Literature Review

Past literature provides an understanding of asset pricing models and the sectors of the Johannesburg Stock Exchange (JSE). This research will explore the spectrum of asset pricing models, starting with the fundamental CAPM by exploring its principles, criticisms, and applications. Following this, the Fama and French three-factor model which expands on the CAPM by introducing size and value factors, which will be further investigated. The Carhart four-factor model will then be discussed, where the momentum factor is added to the existing three-factor asset pricing model. Fama and French five-factor model, which incorporates profitability and investment factors, offering an even more intricate understanding of asset pricing. Lastly, the analysis of Fama and French six-factor model aims to further refine the model's predictive power by incorporating momentum as an additional factor.

2.1 Asset pricing models

2.1.1 Capital Asset Pricing Model (CAPM)

The developers of CAPM, Sharpe (1964), Lintner (1969), and Black (1972), created a basis for defining the relationship between risk and return. CAPM seeks to account for stock returns by examining its market exposure, denoted by the variable beta. A stock that has a high beta value is understood to be closely tied to market movements, shifting in correspondence with the market's variations at a magnitude reflected by its beta. CAPM's fundamental premise is that

market risk is the singular factor responsible for explaining returns, as it's considered the exclusive risk that investors face. This asset pricing model also looks at how the market portfolio influences asset returns. This model's theoretical framework is rooted in Markowitz's (1952) mean-variance portfolio theory.

The mean-variance portfolio theory concept of Markowitz's (1952), suggests that all assets exhibit varying degrees of correlation with one another and that risk could be divided into two components: market risk and non-market risk. The latter of the two examines unique risks which are specific to firms with different characteristics and it is seen that this risk is eliminated when assets have a correlation coefficient that is less than one. This concept according to Markowitz (1952), implies that all investors hold a portion of the market portfolio, which represents the portfolio with the highest returns per unit of risk, often referred to as the efficient frontier. The remaining portion of the investment is allocated to the risk-free rate.

CAPM possesses both advantages and disadvantages. One notable benefit is that it is relatively easy to test compared to other models, as it does not require a large amount of data or extensive computational power. With CAPM, only a few basic parameters such as the risk-free rate, market risk premium, and beta are needed. This simplicity allows them to easily estimate an asset's required rate of return. This model can effectively gain a preliminary understanding of financial markets and assets (Fama & French, 2004).

CAPM's disadvantages are that it relies on assumptions that are deemed unrealistic. Such as the ability of investors to borrow and lend at a risk-free rate, the absence of transaction costs, tax, arbitrage opportunities and homogeneous expectations. Roll (1977) conducted a study revealing the challenges associated with measuring risk against a market portfolio. He criticised CAPM by arguing that it is impossible, to directly observe a fully diversified market portfolio, and any market index serving as a proxy would inherently possess predictive errors. Contradictions emerge when considering CAPM, especially in relation to the tendency of returns to reverse over extended periods. The observation that stocks exhibiting poor returns over the past three to five years tend to have higher average returns in subsequent years is further supported by a study conducted by Chopra, Lakonishok, and Ritter (1992). Which concluded that beta, a key factor in the CAPM, is unable to account for the differences in these average returns.

Previously, numerous studies have rejected CAPM based on its inability to decompose the risk and return of stylistic investment strategies. The consistent international findings of small

capitalisation and value shares outperforming their large capitalisation and growth counterparts have raised doubts about the validity of CAPM. The conventional measurement of CAPM beta fails to capture the cross-sectional variation in portfolio returns based on size and value (Fama & French, 2004). Several studies conducted by Fama and French (1993, 1996) have determined that CAPM falls short in explaining the cross-sectional variation of average stock returns. Van Rensburg and Robertson (2003a) research outlined that CAPM does not fully capture the variability of stock returns. More recently, Ward and Muller (2013) rejected the CAPM for the South African market. These researchers found that lower beta stocks actually outperformed high beta stocks, the opposite of the CAPM premise.

2.1.2 Fama and French three-factor model

There are several contradictions surrounding CAPM. All of the contradictions primarily arose from empirical evidence, which indicated that expected returns of assets are influenced not only by market risk but also by additional factors such as size, value, investment, profitability and momentum factors. The Carhart four factor, the Fama and French three, five and six-factor models (Fama & French, 1993,2015,2018) have been developed to expand upon CAPM by incorporating these additional risk factors, which may reduce the explanatory power of CAPM or even exclude the CAPM beta altogether. Similar to other analyses based on alphas, it is necessary for benchmark factors to be traded as portfolio excess returns or return spreads.

One widely used model that extends CAPM is the Fama and French (1993) three-factor model, which introduces two additional factors: the book-to-market or value factor (HML – high minus low) and the size factor (SMB – small minus big) based on stock market capitalisation. The value factor can be measured in various ways, including the earnings-to-price ratio, cash flow yield, and the book value of equity to market value of equity (Basiewicz & Auret, 2009).

Research by Banz (1981) initially identified the size effect in US stock data. He demonstrated that the size factor of a firm can be determined by market capitalisation, this is the worth of the company which is determined by the stock market. The author observes that small sized companies have higher risk-adjusted returns than large size companies. Also, evidence was found that firms with low market capitalisation have higher averages than large capitalisation stocks, hence, the small capitalisation premium was formed.

Van Rensburg and Robertson (2003a) conducted a study spanning from 1990 to 2000, analysing style strategies in a manner akin to Van Rensburg (2001). Their study employed

monthly dividend-adjusted Johannesburg Stock Exchange (JSE) data, performed on individual share characteristics through the Fama and Macbeth (1973) cross-sectional regression method and a multifactor model. The results identified only two significant styles: size and price-to-earnings. Another study by Robertson and Van Rensburg (2003) investigated whether style characteristics differ across major JSE industry sectors, focusing on the financial, industrial, and resource sectors. They used monthly data from July 1990 to June 2000 on a broad sample of actively traded JSE shares. The study analysed stock returns each month by regressing them on lagged style characteristics, with sectors indicated by dummy variables, and conducted a cross-sectional regression similar to Fama and Macbeth (1973). The findings reveal that a smaller size and value indicators are positively correlated with equity returns in all three major sectors. The effect of these value factors is especially pronounced in the financial and industrial sectors, while the impact is weaker in the resource sector. Additionally, the small size effect is consistent across all sectors on a univariate basis. Stocks associated with growth, such as those with high returns on assets, are notably rewarded in the resource sector.

Bradfield, Barr, and Affleck-Graves (1988) carried out numerous tests on the Johannesburg Stock Exchange (JSE), evaluating CAPM, size, and liquidity. Evidence was gathered affirming CAPM's ability to explain the cross-sectional variation in share returns on the JSE. However, there was lack of evidence to support the effects of size or liquidity premium. Similarly, Page and Palmer (1993) conducted research concentrating on size and value styles in the cross-section of shares listed on the JSE. They solely found evidence for a value premium, specifically related to the earnings-to-price ratio, but discovered no support for the size effect.

The chosen value metric is the book-to-market (BTM) factor, this is described as ratio of the book value of equity as per balance sheet to the market value of equity (Auret & Sinclaire, 2006). Fama and French (1993) find a strong positive BTM effect as this suggests that higher BTM ratios have higher expected average returns. Auret and Sinclaire (2006) evaluated the book-to-market ratio and the returns on the JSE. It was seen that a lower book-to-market has less risky investments. There is an element of risk related to the value metric and it is incorporated into a return model through a high minus low-risk premium or a returns styles approach. These authors used the book-to-market ratios which is the explanatory variable in explaining stock returns. The findings show that the book-to-market ratio has a strong role in explaining stock returns and is similar to the findings of Fama and French (1993), which examined the role of leverage, market beta, size, and book-to-market equity in explaining cross-sectional expected returns.

Basiewicz and Auret (2009) conducted a study on the cross-section of shares listed on the JSE between the period 1992 to 2005. The authors used dividend-adjusted returns by utilising the Fama-MacBeth (1973) method and performed annual portfolio evaluations to confirm the existence of size and price to earnings effects while accounting for illiquidity. The observations from the study were similar to those of Auret and Sinclaire (2006) as, they found that the most efficient gauge of the value premium is the book-to-market ratio and a significant small capitalisation premium.

Numerous investment strategies are well-documented in global studies. Stattman (1980) observed a positive correlation between the average return and the book value of common equity to its market value for U.S. equities, a sentiment echoed by Rosenberg, Reid, and Lanstein (1985). Whereas, Fama and French (1996) used data from international markets to document the findings of the above authors. The studies found a positive correlation between expected returns and a company's book-to-market ratio, showing that companies with substantially higher book-to-market ratios was rewarded with a return premium. Similarly, Chan, Hamao, and Lakonishok (1991) established that book-to-market ratio is effective in commenting on Japanese stocks returns.

Fama and French (1993) study spanned over 1962 to 1989, illustrated that future returns on stocks and bonds could be accurately forecasted by using a company's book-to-market ratio. These authors found a strong positive book-to-market effect and this metric has a stronger impact on average returns than size. Similarly, Lakonishok, Shleifer, and Vishny (1993) highlighted that using a company's cash flow-to-price ratio as a metric provides an effective value-based investment approach. A study conducted by Chen and Zhang (1998) propose that the book-to-market ratio could encapsulate three distinct risks: a company's financial distress, financial hazards, and the volatility of cash inflows. In contrast, Akgun and Gibson (2001) believe that the book-to-market ratio (alongside company size) might offer valuable insights into both the likelihood of insolvency and the rates of recovery, encompassing financial distress risk.

Fama and French (1996) examined the effectiveness of the three-factor model in comparison to long-term reversal in share prices identified as well as the momentum premium proposed by Jegadeesh and Titman (1993, 2001). Findings, revealed that Fama and French three-factor model successfully accounted for the long-term reversal phenomenon but failed in explaining the momentum premium. The model generated alphas that were higher than those derived from

the CAPM. The four-factor model, although not as widely recognised as previously mentioned models, gained attention through Carhart's (1997) paper. This was first seen by Jegadeesh and Titman (1993) when they discovered that poor or strong stock performance persisted for several months, indicating a momentum effect.

Several studies by Van Rensburg and Robertson (2003b), Auret and Sinclaire (2006), and Page and Auret (2014), discovered evidence supporting the existence and significance of both value and size premiums in the cross-section of shares listed on the JSE. Basiewicz and Auret (2009) noted the robustness of size and value factors after adjusting for trading costs. This significantly influenced the magnitude and persistence of these effects, particularly the size premium on the JSE. The size and value factors were identified as superior predictors of returns, indicating that the Fama and French three-factor model outperforms CAPM by more effectively accounting for risk factors. However, it should be noted that there are studies indicating that alternative asset pricing models may outperform the Fama and French three-factor model.

Basiewicz and Auret (2009) noted that the JSE suffers from illiquidity and thin trading. They observed that the SMB portfolio, which tracks smaller shares, indicates that the overall market return on the JSE is largely driven by larger shares. This is further supported by the fact that the JSE's returns are significantly influenced by the ALSI 160 index, with the top 40 shares within this index having the greatest effect on the returns of the top 160 shares. To address this issue, Van Rensburg and Robertson (2003a) included only shares with a turnover ratio greater than 0.01%, where the turnover ratio is determined by dividing the average daily shares traded by the number of shares outstanding at the beginning of the month. Although this approach helps account for infrequent trading. Shares with small market capitalizations might be traded often but with low trading value, which can present challenges for investors due to scale constraints. Such shares may be mispriced for extended periods, potentially biasing the results of studies due to thin trading.

Fama and French (1993) integrated the findings of Banz (1981) into a three-factor model, incorporating market beta, size and value (BTM) factors. These studies revealed that the three-factor model provided a better explanation for stock returns compared to the CAPM. In a similar comparison analysis by Cox and Britten (2019), found that three-factor models incorporating size or value yielded the best performance. The five-factor model was the most effective in capturing the diverse cross-sectional premiums associated with the market, size, value, profitability, and investment factors (Cox & Britten ,2019).

Shaker and Elgiziry (2014) investigated various asset pricing models in the Egyptian Stock Market to determine which model was most effective. They examined the CAPM, Fama and French three-factor (Fama & French, 1993) and five-factor models Fama and French (2015), the Carhart four-factor model Carhart (1997), and the liquidity-augmented four-factor model. The Fama and French models were considered due to recommendations for future research on additional risk factors and high-frequency data. To evaluate these models, a GRS test was conducted on 55 stocks, organised into six portfolios based on size and book-to-market ratio. However, due to data limitations, 45 stocks were excluded from the analysis. The study found that the Fama and French three-factor model outperformed all other models. This model had the lowest GRS statistic of 2.336, which indicated that it could not be rejected as an asset pricing model due to its ability to explain the variation in the cross-section of average returns. Additionally, its p-value was greater than one, further supporting its effectiveness. In contrast, the other models failed to account for the cross-section of average returns, as their p-values were also larger than one.

2.1.3 Carhart four factor model

Carhart (1997) drew on previous research and extended the Fama and French three-factor model by including a style factor called momentum (WML - winner minus loser). The momentum factor lacks a universally accepted risk-based explanation, yet there are momentum strategies marketed to the public as passively managed investment instruments that generates significant positive risk-adjusted returns. The momentum factor is based on past performance that can be used to get superior returns in the short run. It was observed that shares that are classified as winners on the basis of past performance will outperform those of loser shares based on the same basis (Fraser and Page, 2000). With respect to the JSE there are numerous studies that look at the momentum anomaly. The inclusion of the momentum factor in Carhart (1997) was used as a tool to evaluate mutual funds, unlike Fama and French (1993), who conducted their regression analysis on individual stocks. The results of Carhart's four-factor model indicated that when a momentum factor was added to the existing model it increased the explanatory power of returns for mutual fund managers.

Historically, the momentum factor has been explored across different time periods, markets, and variations in trading strategies. Generally, this factor involves investing on past trends which is indicated by historical stock prices. As illustrated by Jegadeesh and Titman (1993), assets with positive performance tend to outperform poorly performing stocks. This suggests

that employing the momentum strategy can have a positive impact on stock returns, leading to higher expected returns.

Asness (1997) looks at the interaction between two strategies namely value and momentum as they both demonstrate the ability to predict cross-section of stock returns. The results of this study, conducted on a bivariate basis, revealed an interaction between the two strategies, showing that the value strategy is most effective with underperforming shares, while momentum strategies excel with high-growth (glamour) shares. A similar study conducted by Fraser and Page (2000) contradicts the findings of Asness (1997). This study evaluates the value and momentum strategies on a bivariate basis with respect to the JSE. These authors aimed to assess the validity of momentum and value strategies independently when applied to the industrial sector of the JSE. It was concluded from the results which were performed on a univariate basis that when applied independently the momentum strategy explained the cross-section of share returns.

Upon reviewing the literature, it becomes apparent that the testing of the momentum factor is constrained by its methodology, whether it is on a univariate or bivariate basis. This emerges particularly when momentum is combined with other factors such as value (Fraser & Page, 2000) or liquidity (Page, Britten, & Auret, 2013). When evaluating momentum and liquidity on a univariate and bivariate basis it was seen that Page, Britten, and Auret (2013) conducted a study on momentum strategies on a short and medium-term basis on the JSE. This study was free from survivorship bias as they adjusted monthly returns for all corporate significant actions. The momentum strategy employed now on a univariate base with liquidity with a proxy of turnover. The results from this conclude that when momentum portfolios produced significantly positive excess returns irrespective of the holding period. On the contrary, when conducted on a bivariate basis with liquidity it was seen that momentum excess returns were positive and have significant effect on the JSE.

Another study by Muller and Ward (2013) used a univariate ranked style characteristic to observe the effects over a period of 1985 to 2011. The style factors such as momentum, value, liquidity, return on capital and equity as well as interest cover were all examined. The findings were that there was strong evidence of the momentum and value effect when proxied by earnings yield and cash-flow to price and results revealed no evidence of the size effect. These findings are consistent with Van Rensburg's (2001) study as they examined a series of style factors and whether they could explain the expected returns on the JSE industrial shares. The

results additionally suggested that the style factors of earnings to price, market capitalisation and a twelve month past positive returns which represented the momentum factor were the only factors that explained expected returns on the JSE.

Regarding the momentum factor, Moskowitz and Grinblatt (1999) revealed that it comprises both an industry component and an individual component. The study established that when the momentum effect was altered within the industry components of stock returns it largely accounted for the individual stock momentum anomaly. With respect to industry momentum anomaly, purchasing previous stocks that won and selling those that previously lost become significantly less profitable. Although, with industry momentum strategies, which buy stocks from winning industries and sell stocks from losing industries are still profitable, even after considering factors such as size, book-to-market equity, individual stock momentum and cross-sectional dispersion in mean returns.

Bello (2008) conducted a test to compare three different asset pricing models, CAPM, the three-factor model, and the four-factor model. Unlike previous studies focusing on stocks, Bello utilised mutual funds as data to evaluate these models. The results indicated that the three-factor model outperformed the CAPM, and further, the four-factor model demonstrated superior performance compared to the three-factor model.

2.1.4 Fama and French five-factor model

Studies, including those by Fama and French (2015) and Carhart (1997), indicate that additional elements impact stock returns, thereby implying the insufficiency of the three-factor model in explaining these returns fully. Fama and French (2015) introduced the five-factor model, an expansion of the original three-factor model by, incorporating two new variables: profitability (RMW- robust minus weak) and investment (CMA- conservative minus aggressive) which could better the explanatory power of the model. The profitability anomaly suggests that stocks with a higher Return on Equity (ROE) will yield greater returns than those with lower ROE (Novy-Marx, 2013). Hou et al. (2015) introduced an investment factor, also known as the asset growth anomaly, which underscores a trend where firms with slower asset growth experiences greater average returns relative to those with faster asset growth. Fama and French's (2015) investment anomaly observes that firms with higher investments will generate lower average returns than those with lower investments (Xing, 2007).

With respect to the style factors such as profitability and investment, Fama and French (2006) investigated the relationship between these two. The proxies for profitability include a lagged book-to-market ratio as well as the earnings per share which is divided by value of equity. The proxy for the investment includes growth of assets with a lagged component. It was observed that high-investment companies, generally yield lower returns compared to their lower-investment counterparts, whereas highly profitable firms exhibit higher returns.

The five-factor model surpasses its three-factor predecessor in explaining the spectrum of stock returns, evidenced by fewer pricing errors when explaining asset-pricing anomalies. It is noted that the value factor becomes redundant when expanding the three-factor model and adding profitability and investment factors (Fama & French, 2015). This is due to the weakness of the market capitalisation to earnings and investment forecasts; the value factor might serve as a "noisy proxy" for anticipated returns.

Leite, Klotzle, Pinto, and da Silva (2018) delve into style factors that are integral to a five-factor asset pricing model. This study is a comparison of the three models: the Fama and French three-factor model, the Carhart four-factor model, and the Fama and French five-factor model. Their analysis, focused on the post-2008 global economic crisis era, revealing the impact of size, value, profitability, and investment on the surplus returns of stock portfolios. Their findings suggested that the four-factor and five-factor models outperforms the three-factor model by better explaining portfolio excess returns and it reduces the unexplained dispersion. In the context of the profitability and investment factors, the value factor appears to be less pivotal, mirroring findings from U.S. data as observed by Fama and French (2015).

Kamstra and Shi (2021) look at Gibbons, Ross, and Shanken (1989) (GRS) tests within asset pricing models and have seen prevalent misconception among financial economists regarding the study by Gibbons, Ross, and Shanken (1989). Specifically, these authors address the inappropriate adjustment of degrees of freedom while determining the sample covariance matrix estimator of factor portfolios. Through mathematical demonstrations, simulations, and revisiting well-referenced research like that of Fama and French (2015), they illustrate that adjusting the GRS statistic for degrees of freedom can lead to excessive rejection. This often skews results favourably towards models with fewer factors. This issue becomes particularly significant in studies with data spanning less than 15-20 years.

Zaremba (2016) examined the role of quality investing as a determinant of a cross-sectional variation in country level stock returns. His study from 2000 to 2013, evaluated 66 country

portfolios. The findings of the paper shows that the inter-market variation in returns are explained with the quality proxy such as profitability and has potential as a quality effect on the JSE. Similarly, Foye (2018) studied emerging economies, including Eastern Europe, Latin America, and Asia, applying the five-factor model. The observations from this were consistent with Lin's (2017) findings, which revealed a profitability premium in Eastern Europe and Latin America but not in Asia. Other factors such as investment and size proved irrelevant across these three regions. Even though the five-factor model could not outperform the three-factor models explanatory power in Asia, it still found relevance that the five-factor model does improve on the three-factor model.

Regarding the South African market, Cox and Britten (2019) conducted an analysis comparing CAPM, the three-factor model and the five-factor model using data from the JSE from 1994 to 2017. These authors found that both market and investment premiums were small while the size premium was strongly negative and large, the value and profitability factors were prominent and significant. With regards to model performance, it was observed that both the three-factor model and a size-profitability three-factor model outperformed the five-factor model in accounting for time-series returns in most portfolio sets. It was noted that the profitability factor adds more explanatory power than the investment factor. Conversely, the five-factor model outperformed the other models in explaining cross-sectional returns.

Mosoeu and Kodongo (2019) investigated the relationship between firm characteristics and stock returns using the Fama and French five-factor model over the period between January 2010 to December 2015. Their sample included six emerging markets: China, India, Egypt, Malaysia, South Korea, and South Africa. The motivation for this study extended beyond just focusing on emerging markets, as previous studies in various markets have produced inconsistent findings. The study analysed the impact of size, value, profitability, and investment patterns on average weekly returns. Portfolios were constructed based on four size categories and four book-to-market categories, with additional portfolios formed based on profitability and investments. The researchers employed both the Generalised Method of Moments (GMM) and the GRS test to regress portfolio returns against the five-factors, assessing pricing errors. The findings revealed that, for South Africa, the size factor was negatively correlated with the market factor. This contrasts with Fama and French (2015), who suggested that smaller stocks typically have higher market betas compared to larger stocks, and thus, the size factor should be positively correlated with the market. In addition, value, profitability, and investment showed insignificant correlations with the market factor,

indicating limited explanatory power of the five-factor model for South African equity returns. The GRS test results indicated significant intercepts, suggesting the model fails to adequately capture variations in returns. Notably, the profitability factor was the most consistent in explaining returns in the South African market, suggesting that investors rely on firm accounting performance. Overall, the study concluded that the five-factor model performs poorly in explaining average returns for small stocks and geographically diversified portfolios in emerging markets.

Separately, Charteris, Rwishema, and Chidede (2018) investigated whether the Fama and French three-factor and five-factor models could explain momentum in the South African market (JSE). Previous research indicated that both the capital asset pricing model and Fama and French's (1993) three-factor model consistently failed to account for momentum in stock returns, with only Carhart's (1997) four-factor model showing some success. The study found that the five-factor model outperformed the three-factor and Carhart models, exhibiting fewer pricing errors. Additionally, the researchers observed a positive relationship between profitability and momentum.

Chiah, Chai, Zhong, and Li (2016) scrutinised the five-factor model's pertinence to Australian equities from 1982 to 2013. The results from this study indicated that the five-factor model better represented returns than the three-factor model, although it could not explain the time-series variation in portfolio returns. Fama and French (2017) also tested the five-factor model's performance in four developed markets, which found that the five-factor model does far better than the three-factor model but the model's main issue was that it failed to explain the returns of small stocks, which show similar returns to low-profitability and high-investment stocks.

For the same Australian market, Huynh (2017) compared the effectiveness of the three-factor and five-factor models in explaining the profitability of a broad range of anomalies in equity returns. The study found that after performing risk adjustments, the anomalies that persisted were better explained by the five-factor model. The results supported the inclusion of the recently proposed investment and profitability factors. However, both the three-factor and five-factor models failed the GRS test, indicating that the search for an improved asset-pricing model is ongoing. The study also noted that the Gibbons, Ross, & Shanken (1989) test frequently rejected the five-factor model.

2.1.5 Fama and French six-factor model

Fama and French (2018) expanded the five-factor model by adding another style factor to the model which was the momentum factor. The concept of adding a momentum factor to an existing model was introduced by Carhart (1997) to expand the three-factor model. It was observed that stocks yielding above average returns in the past are likely to continue their high performance in the future. According to Fama and French (2018), a stock's momentum can be gauged by its accumulated returns from the twelfth to the second month before the current one. Challenges were evident, regarding the risk-based premium for the momentum effect due to little correlation with other risk factors.

Hoffman (2012) conducted a study that bears resemblance to the research of Van Rensburg and Robertson (2003a), investigating various pricing anomalies on the JSE. This study focused on anomalies in share returns on the JSE, using dividend-adjusted returns from the period 1985 to 2010. The methodology employed was akin to that of Fama and French (1998), involving share-by-share time-series regressions. Key explanatory variables included size, value, momentum, liquidity, leverage, and investment. Among these, size, value, and momentum were identified as the most significant factors in explaining the cross-sectional variation in share returns. Hoffman (2012) challenged the efficient market hypothesis by showing that share values on the JSE can fluctuate independently of their β risk, with the smallest shares exhibiting the most consistent anomalous returns. This study emphasized the significance of the book-to-market (BTM) effect in explaining returns that β risk alone cannot account for. In line with this, early South African research found the size effect to be minimal overall, but particularly pronounced among the smallest shares (Van Rensburg and Robertson, 2003a). Later studies, using more robust methodologies, confirmed that while size is a significant factor on the JSE, its impact is especially notable in very small shares (Auret and Sinclaire, 2006; Basiewicz and Auret, 2009).

Likewise, similar results were found in the study by Hodnett, Hsieh and Van Rensburg (2012), which investigates the use of firm-specific characteristics as investment styles in the cross-section of shares listed on the JSE over a ten-year period. The study incorporated five styles: fundamental ratios, value, size and momentum, and analyst forecasts. The methodology applied in this research is similar to that of Van Rensburg (2001), where the approach was derived from Jegadeesh and Titman (1993). The results reveal that firms with higher fundamental ratios, dividend earnings, short-term momentum, and earnings forecasts, as well as those with lower size factors, are likely to earn relatively higher returns in the subsequent period. This showed

that two out of the four, explained the cross-section on share returns and these are fundamental growth, size and return momentum. These findings align with the works of Van Rensburg (2001) and Jegadeesh and Titman (1993), as they demonstrate a short-term momentum reversal, while longer periods do yield higher momentum profits.

All existing literature thus far concerning the momentum anomaly has found it to be significant in explaining the cross-section of shares listed on the JSE. Yet, these findings have often been tested on either a univariate or bivariate basis with respect to gross returns. A study by Page and Auret (2018) explored explanatory factors on a multifactor basis, using market proxies such as size, value, and market beta. The purpose of this study was to investigate whether a combination of independent variables, specifically non-momentum factor premiums, could elucidate the momentum premium on the JSE. The study took into account Van Rensburg (2002) two-factor Arbitrage Pricing Theory (APT) model. This model is to be employed to explain JSE share returns with the factors being the Financial Industrial Index and the Resources Index. The results concluded that Van Rensburg (2002) industry-based risk factors fail to explain the momentum premium on the JSE Additionally, it examined whether these independent variables were capable of explaining variations in momentum portfolio alphas on the JSE. While previous research has repeatedly confirmed the existence of the momentum premium on the JSE, there hasn't been much exploration of this phenomenon in a multivariate and risk-based setting. In this context, the study employed a Gibbons, Ross, and Shanken (1989) test to evaluate the momentum portfolio alphas. The results demonstrated that non-momentum factors were ineffective in explaining the momentum premium. This finding is consistent with another study by Muller and Ward (2013), which also concluded that momentum is an independent style on the JSE.

In asset pricing literature, style characteristics are not usually defined as explanatory factors. An explanatory factor is characterised as a component that can independently account for a segment of the cross-sectional variation in share returns. With this perspective, Page and Auret (2019) determined whether investment styles such as size, value, momentum, low beta, currency risk, low volatility, and liquidity could be considered explanatory factors capable of elucidating a portion of the cross-sectional variation in share returns. Contrary to the Fama and Macbeth (1973) two-pass regression method, their study employed a panel data analysis approach. The findings revealed that four out of the six styles—namely size, value, momentum, and low beta—are significantly and independently priced factors within the JSE, providing an explanation for the cross-sectional variation in share returns. These conclusions align with a

study by Page, Britten, and Auret (2016), who also discovered evidence of value and momentum effects when applied independently, although they did not find supporting evidence for a size effect.

The six-factor model has generated mixed results in different economies. This was evident in a test conducted in Indonesia by Foye and Valentinčič (2020**)** who aimed to add the momentum factor to the five-factor model. Their methodology resembled Fama and French (2015), although there was no portfolio sorted for momentum. The result from this study indicated that the addition of the momentum effect was weak and statistically insignificant which indicated that the momentum factor didn't increase the five-factor model's explanatory power. The authors concluded that a six-factor model comprising size, value, profitability, investment, and momentum best described stock returns. The five-factor model remained robust even with the elimination of the size factor.

Zsolt and Tünde (2022) conducted a study on the Fama and French six-factor asset pricing model in the Polish stock market, extending the five-factor model by including a momentum factor to assess its relevance in an emerging market. This study, which covered the period from 2010 to 2018, utilised monthly data from the Warsaw Stock Exchange, analysing 90 stocks. A GRS test was performed to test the significance of the regression intercepts in the six-factor model. The findings revealed that the six-factor model had significantly higher adjusted R-squared values compared to the five-factor model, indicating improved overall performance. However, the GRS statistic was slightly higher, suggesting that the six-factor portfolios were not necessarily more efficient than the five-factor ones. In both models, the null hypothesis of zero regression intercepts could not be rejected, meaning these asset pricing factors explained a substantial portion of the variation in portfolio returns. Additionally, the regression coefficients were more significant in the six-factor model, particularly for the momentum factor. In many of the six-factor regressions, all factor coefficients were highly significant, leading the authors to conclude that the six-factor asset pricing model is more suitable for the Warsaw market.

3. Description of data and research methodology

This section examines the data and methodology used in this study, providing a comprehensive explanation of the research design and analytical procedures.

3.1 Data

The research requires sector returns from the Johannesburg Stock Exchange and style-based returns to be applied as factor premiums to the asset pricing models to be tested. The historical style factor data of daily accounting ratios such as book-to-market, market capitalisation, operating income, total assets and price are obtained from the Bloomberg and Iress databases. Typically, accounting data is released every quarter or semi-annually and hence static values are used for the remaining time frame until new data is released. The data obtained is used in calculations for returns and premiums of the style factors. The returns are being calculated on a buy and hold basis and these will be utilised to create style portfolios. Bloomberg and Iress, provide comprehensive financial data on every share listed on the JSE All Share Index, covering all sectors from January 2007 to July 2023. The time frame applied takes into consideration that the JSE only started incorporating the ICB classification in 2005. The time frame spans 16 years and encompasses a broad spectrum of information, including data from the post-democratic era. It also considers significant economic events that transpired during this duration although this analysis not test the robustness of asset pricings models' ability to explain sector returns during times of economic stress. The sample specifically looks at the top 100 shares based on market capitalisation as this filters out penny shares.

This research will make use of the Global Industry Classification Standard (GICS) as an internationally recognised system for grouping companies into sectors and industries. Widely accepted in the field of investment research, portfolio management, and asset allocation, the GICS methodology forms an industry analysis framework. As it stands, the GICS classification system includes 11 sectors: Energy, Materials, Industrials, Consumer Discretionary, Consumer Staples, Healthcare, Financials, Information Technology, Communication Services, Utilities, and Real Estate (MSCI,2023). This standard will be used to extract sector returns from the JSE. The JSE sectors align with eight of the eleven GICS sectors. The ones that diverge are Technology, Telecommunications, and Basic Materials. Despite different nomenclature, these categories essentially represent the same sectors as in the GICS system.

To accurately represent returns, we will calculate both sector and style-based returns using daily data, excluding public holidays and weekends. A filtering process will be implemented to eliminate any survivorship bias, which will involve including shares from the point of listing up to their delisting, at this point they'll be no longer eligible for portfolio sorts although these shares will not be removed from the sample. The data will also be adjusted for corporate actions such as dividends, share splits, transaction costs, consolidations and unbundling's.

3.2 Detailed hypothesis and theoretical framework

The hypothesis to be tested is centred on regression alphas that are generated via time-series regressions in conjunction with the Gibbons, Ross & Shanken (GRS) test and the GRS statistic will either reject the null hypothesis or accept it.

The null hypothesis is stated as:

H0: The joint test of time-series α_i's are insignificantly different from zero

This entails that if the GRS statistic is not significantly different from zero then the style premiums from the respective asset pricing models explain the sector returns on the JSE. The alphas are the regression alphas of the sector portfolios regressed on the style-based regressions. The null hypothesis will be rejected if the p-value is less than or equal to the level of significance.

The alternative hypothesis is stated as:

H1: The joint test of time-series α_i's are significantly different from zero

This alternative hypothesis means that if the GRS statistic is statistically different from zero then the style factor premiums from the respective asset pricing models fail to explain the sector returns on the JSE.

3.3 Portfolio Construction

The study utilises the Fama and French three, five, and six-factor models. The asset pricing model features portfolios tailored to each style factor. The market value data is sourced directly from the JSE returns, proxied by returns on the JSE All-Share index. The constructed portfolio

is a combination of all style factor premiums from the three-factor, five-factor, and six-factor Fama and French asset pricing models.

Portfolios are constructed by evaluating each style factor from the three, five, and six-factor asset pricing models. These portfolios are constructed using Python, as it is widely utilised in the financial sector. The initial step involves reindexing and filtering these factors before they are utilised in portfolio creation. All data used must be aligned with price data to ensure consistency across datasets. The price data filtered out weekends and public holidays before it was imported into Python. During the filtering process, only the top 100 shares based on market capitalization are considered, eliminating shares priced below 100c. Regarding listed shares that become delisted, their values are included until delisting, after which they are marked as not applicable (n.a). A method is employed to fill n.a values by propagating the last valid observation to the subsequent valid one, ensuring these shares remain in the sample despite delisting.

The shares of each style factor will be ranked on either market capitalisation, book-to-market, operating income, total assets and a historical cumulative return. The ranking process will be conducted using quantile breakpoints. The size factor ranking's top 20th percentile includes big shares (high market capitalization), while the bottom 20th percentile consists of low market capitalization shares. The value factor ranking's top 20th percentile includes high book to market shares, while the bottom 20th percentile consists of low book to market shares. The profitability factor ranking's top 20th percentile includes shares with high return on equity, while the bottom 20th percentile consists of shares with low return on equity. The investment factor ranking's top 20th percentile includes shares with faster total asset growth, while the bottom 20th percentile consists of shares with slower total asset growth. Lastly, the momentum factor ranking's top 20th percentile includes historical cumulative return of outperforming shares, while the bottom 20th percentile consists of historical cumulative return of underperforming shares. Portfolios are rebalanced monthly, applying the most recent data and is consistent with literature, and is resorted based on new cross-sectionally defined quantile break points the duration of the sample period. The rebalancing will adjust for corporate actions such as dividends, share splits, transaction costs, consolidations and unbundling’s.

The long-only portfolios are then calculated and then the factor premiums will be calculated. The calculation of style premiums will employ a theoretical long-short framework. For the size

factor, this entails subtracting the performance of small capitalisation stocks from that of large capitalisation stocks (small minus big; SMB). In the case of the value factor, it involves the subtraction of value returns from growth returns (high minus low; HML). For the profitability factor, the approach subtracts robust-performing stocks from weak-performing ones (robust minus weak; RMW). The investment factor calculation subtracts conservative investment strategy stocks from aggressive investment strategies (conservative minus aggressive; CMA). Finally, for the momentum factor, the calculation is based on subtracting winners (outperforming) from losers (underperforming), (winners minus losers; WML). With respect to the market risk premium this is calculated by subtracting the from the market return risk-free rate (Rm-Rf; EMRP). Lastly, sector returns are also reindexed to match the same time frame as the independent styles they also use the risk-free rate to calculate excess return values. The style premium returns will be used in a regression model together with sector returns from each sector index from the JSE to produce a time-series alphas and betas. These will be used in further regressions and tests.

3.4 Regression tests

Upon constructing the portfolio, this study conducts time-series regressions for each Fama and French model per sector and the resulting alphas per model are grouped together and are utilised for the Gibbons, Ross, and Shanken (GRS) test. Conversely, for the GRS test, time-series regressions will be applied across the entire period considered with each sector.

3.4.2 Time-series regression

Time-series regressions trace their origins back to the initial techniques used to examine the CAPM, but they have since evolved into attribution tests aiming to identify risk-adjusted excess returns. It's crucial to understand that these methods are not intended as asset pricing tests, but rather as attribution tests aiming to evaluate whether style factors can account for sector returns on the JSE. A variety of econometric techniques are implemented to examine the excess returns based on style, even though there's a lack of econometric models specifically targeted at sector returns.

The general mathematical formula for a time-series regression is stated below but the variable explanations would be in the context of the research.

$$R_{it} - rf = \alpha_i + \sum_{j=1}^{L} \beta_{i,j} X_{j,t} + \varepsilon_{it} \quad (1)$$

R_{it} represents various sectors and their corresponding sector returns from the JSE, rf denotes the risk-free rate, represented by a 91-day SA government treasury bill rate. α_i is the time-series alpha signifying the risk-adjusted return surplus earned by portfolio i. $\beta_{i,j}$ refers to the betas of the independent style factor of asset pricing models, $X_{j,t}$ this variable refers to a matrix of style premiums. ε_{it} is the regression residual, which is presumed to be stationary, homoscedastic, and to follow a normal distribution.

There will be six different regression models employed in this study as there are three different types of asset pricing models and two types of regressions. The first model will be based on the Fama-French three-factor model, where the style factors will be regressed against the sector returns from the JSE. This model will incorporate the following factors: the market factor derived from the JSE, the size factor, and the value factor.
The three-factor model as per Fama & French (1993) is described below:

$$R_{i,t} - rf_t = \alpha_i + \beta_{EMRP}(R_{Mt} - rf_t) + \beta_{SMB}SMB_t + \beta_{HML}HML_t + \varepsilon_{i,t} \quad (2)$$

$R_{i,t}$ represents the excess return from sector from the JSE, while rf_t signifies the risk-free rate, demonstrated by a three-month treasury bill rate. α_i is the time-series alpha. R_{Mt} is the expected return on the overall market portfolio of assets, and the market premium is defined by the difference $R_{Mt} - rf_t$.

β_{EMRP} refers to the sensitivity of stock i to the return on the market premium, while β_{SMB} denotes the factor loadings of share i on the size factor. The size factor, SMB (small minus big), is characterised by the returns on a constructed portfolio of small stocks subtracted from those of big stocks within the same portfolio. This is also identified as the firm's market capitalization or market equity.

β_{HML} denotes the factor loadings of share i on the value premium. The value factor, HML (high minus low), is defined by the returns on a constructed portfolio of high book-to-market equity stocks subtracted from those of low book-to-market-equity stocks within the same portfolio. Book-to-market equity is computed as the book value of equity divided by market capitalization. Lastly ε_{it} is the error term.

The second model will extend the analysis by including the Fama-French five-factor model. In this model, the sector returns will be regressed on the style factor premiums, which will now include the profitability factor and the investment factor in addition to the factors included in the Fama-French three-factor model.

The five-factor model as per Fama and French (2015) is described below:

$$R_{it} - rf_t = \alpha_i + \beta_{EMRP}(R_{Mt} - rf_t) + \beta_{SMB}SMB_t + \beta_{HML}HML_t + \beta_{RMW}RMW_t + \beta_{CMA}CMA_t + \varepsilon_{it} \quad (3)$$

The coefficients $\beta_{EMRP}, \beta_{SMB}$ and β_{HML} mentioned earlier denote the factor loadings of share i on the $(R_{Mt} - rf_t)$, SMB_t and HML_t premiums and ε_{it} represents the error term, as decried in the preceding model. The extended version of the Fama-French three-factor model introduces β_{RMW} and β_{CMA}which represent the factor loadings of share i on the profitability and investment premiums, respectively.

The profitability factor, RMW (robust minus weak), is defined as the returns on a constructed portfolio of robustly profitable stocks and the value-weighted returns of weakly profitable stocks within the same portfolio. Profitability is typically computed as operating income divided by the book value of equity.

The investment factor, CMA (conservative minus aggressive), refers to the returns on a constructed portfolio of stocks representing firms that adopt a conservative investment strategy, subtracted by the returns from firms that invest aggressively. The calculation for the investment measure generally involves the growth rate of total assets, formulated as (total assets in period t minus total assets in period t-1) divided by total assets in period t-1

Lastly, the third regression model will expand further by incorporating the Fama-French six-factor model. The sector returns will be regressed on the style-based factor premiums, which will now include an additional momentum factor along with the factors from the Fama-French five-factor model.

The six-factor model as per Fama and French (2018) is described below:

$$R_{it} - rf_t = \alpha_i + \beta_{EMRP}(R_{Mt} - rf_t) + \beta_{SMB}SMB_t + \beta_{HML}HML_t + \beta_{RMW}RMW_t + \beta_{CMA}CMA_t + \beta_{WML}WML_t + \varepsilon_{it} \quad (4)$$

The coefficients $\beta_{EMRP}, \beta_{SMB}, \beta_{HML}, \beta_{RMW}$ *and* β_{CMA} as described in the earlier models, represent the factor loadings of share i on the market risk premium, size, value, profitability and investment premiums as well as ε_{it} is the error term.

The expansion of the Fama-French five-factor model introduces, β_{WML} which symbolises the factor loadings of share i on the momentum premium. The momentum factor, WML (winner minus loser), is calculated as the value-weighted returns of stocks within the winning portfolios subtracted from those in the losing portfolios. The momentum factor is also computed using the cumulative total returns, formulated as (total returns in period t-2 minus total returns in period t-12) divided by total returns in period t-12. This calculation will skip the most recent month to mitigate the impact on short term reversal and microstructure effects.

Collot and Hemauer (2020) look at the time-series and Fama and Macbeth (1973) regression when dealing with asset pricing models as it requires factors to be traded. Moreover, it implicitly assumes that the test assets' factor loadings are constant. As this is unlikely to hold for single stocks, the test assets used in this approach are usually portfolios. Although, this approach is well established in the literature, it has multiple shortcomings. If important factors are omitted, it suffers from omitted variable bias. The model cannot include too many factors without making the results prone to in-sample overfitting. Moreover, the need to use portfolios as test assets is also associated with some major drawbacks. Contrary to the time-series regression approach, the two-pass regression approach does not require the factors to be traded. The factors are usually either some firm characteristic and/or some macroeconomic state variables.

3.4.1 Gibbons-Ross-Shanken (1989) Test

The regression test is conducted to answer the object of this research paper. The style factors typically originate from three different asset pricing models, specifically the Fama and French three, five, and six-factor models. Within this context, the style factors of the asset pricing model serve as the independent variables, while the sector returns on the Johannesburg Stock Exchange (JSE) function as the dependent variables. The linear time-series regression is run on each sector and produced a set of alphas for each asset pricing model. These resulting alphas from the time-series are used in GRS test.

The research report uses the Gibbons-Ross-Shanken (1989) F-test to examine the null hypothesis that the alphas estimated for a set of portfolios. The main focus of these tests is to assess the magnitude, significance, and economic implications of the time-series alphas. The GRS statistic, proposed by Gibbons, Ross, and Shanken (1989), will be used as a formal test to evaluate the alphas. This statistic is based on a finite sample F-test, assuming that all time-series alphas estimated using various style asset pricing model portfolios are jointly equal to zero.

In this study, the GRS statistic is applied to determine whether the sector returns of the JSE can be explained by the style factor premiums of asset pricing models. The GRS statistic is then evaluated alongside the average alpha and the average adjusted R^2, which takes into account degrees of freedom, to assess the explanatory power of each model. The adjusted R^2 represents the percentage (ranging from 0 to 100%) of variation in sector returns that can be explained by the factors in the model. The factor models will be ranked based on the size of the GRS statistic, when the statistic displays smaller values, this will indicate that these values perform better. Additionally, the p-value associated with the GRS statistic is considered.

If the null hypothesis is rejected, it suggests that none of the asset pricing models under consideration can adequately explain sector returns. In such a case, further research will be conducted to determine which asset pricing model, based on the GRS statistic with the best performance, can effectively explain sector returns. A larger value of the GRS statistic indicates larger joint values of the alphas, signifying a greater deviation from zero and poorer performance of an asset pricing model (Gibbons, Ross, & Shanken, 1989).

The GRS Test Statistic is below:

$$GRS = \frac{T(T-N-L)}{N(T-L-1)} \times \frac{(\widehat{\alpha'_0}\,\widehat{\Sigma^{-1}}\,\widehat{\alpha_0})}{(1+\overline{r_p}'\,\widehat{\Omega}\,\overline{r_p})} \sim (F_{N,T-N-L}) \qquad (9)$$

$T =$ Number of time-series observations

$N =$ Number of test portfolios

$L =$ Number of factors

$\overline{r_p}' =$ Transposed vector of factor portfolios

$\widehat{\Omega} =$ Matrix of factor portfolios not adjusting for degrees of freedom

$\overline{r_p}$ = Vector of factor portfolios

$\widehat{\alpha'_0}$ = Transposed vector of estimated time-series alphas

$\widehat{\sum^{-1}}$ = Inverted covariance matrix

$\widehat{\alpha_0}$ = Vector of estimated time-series alphas

4. Empirical Results

The study utilised employed a linear time-series regression for conducting a Gibbon, Ross and Shanken (1989), aimed at analysing sector returns on the JSE. In order to test whether the three, five and six factor asset pricing models explain sector returns, time-series regression alphas are utilised in the GRS test. Each portfolio consists of the top 100 shares on the JSE, selected based on market capitalisation for each industry over the sample period.

The GRS null hypothesis states that the time-series alphas are jointly equal to zero and therefore fully explain sector returns on the various factor model being tested. Given the p-value if it is less than or equal to the 5% level of significance then the decision would be to reject the null hypothesis, on the other hand if the p-value is greater than the 5% level then the decision would be to fail to reject the null hypothesis.

In regression analysis, the assessment of model fit typically involves examining two key metrics: the R^2 and the adjusted R^2. While the R^2 tends to increase with the addition of factors or predictors, regardless of whether they truly enhance the model's explanatory power, the adjusted R^2 offers a better evaluation by considering whether the added factors contribute meaningfully to explaining the variation in the dependent variable. In this instance the adjusted R^2 is used to determine whether the applied asset pricing models can explain sector returns.

	Sector Code	Sector Names
1	JBINDTR	Basic materials
2	JFINXTR	Financials
3	JNCCGTR	Healthcare
4	JCSEVTR	Consumer Discretionary
5	JCCGDTR	Consumer Staples
6	JGINDTR	Industrials
7	JNCSVTR	Telecommunications

Table 1: Classification of indices on the JSE

4.1 Time-series regression results

Sector Name	α	β_{EMRP}	β_{SMB}	β_{HML}	Adj.R^2
Basic materials	0.0003	1.1634***	-0.3850***	0.1338	0.0694
Financials	-0.0003***	0.8995***	0.1915***	0.2698***	0.6115
Health Care	-0.0001	0.7148***	0.2413***	-0.0967***	0.2527
Consumer discretionary	0.0011	1.0683***	0.1574	-0.2866***	0.0226
Consumer staples	0.0025	0.7751**	-0.2645	-0.1919	0.0031
Industrials	-0.0004***	0.8854***	0.3165***	0.1007***	0.5470
Telecommunications	0.0011	0.9837***	-0.1272	-0.0106	0.0144
Technology	-0.0001	0.9061***	0.3026***	-0.2372***	0.2316

Table 2: Three-factor time-series regression

*Note: Regression parameters are presented alongside with the significance level where *, ** and *** indicate significance at the 10%, 5% and 1% level, α represents time-series portfolio alphas, β represents the coefficients of factor loading on applied regressor, the adjusted R^2 is related to specific time-series regression.*

Analysing the data in Table 2 reveals that the alphas and betas originate from the time-series regression. Subsequently, these results will be subject to further discussion. The results indicate all factors loadings of the three-factor model are positive and statistically significant at the 1% for four out of the eight sectors. The Financial, Healthcare, Industrial and Technology sector load positively on all premiums in the three-factor model. The coefficient values of the result indicate that small capitalisation and growth-oriented stocks dominate the Financial and Industrial sector. With the Healthcare and Technology sector stocks with small capitalisation and value-oriented stocks dominate. The adjusted R^2 results presented in Table 2 ranges from 0.31% to 61.15% for all sectors. The three-factor regression indicates that the market, size and value seem to capture the highest and second highest value which explains 61.15% of the Financial sector's variation and 54.70% of the Industrial sectors variation on the JSE.

The Basic Materials sector loads positively on the market premium and negatively on the size premium with both displaying significance at the 1% level. The coefficient values for the market factor indicate that a single positive unit change will result in a positive Basic Material

sector return of 1.16%. Conversely a one-unit positive change in the size factor will result in a negative -0.39% change in the Basic Materials sector return. Hence for the Basic Material sector the market and stocks with large capitalisation dominate.

The regression results indicate that a single positive unit increase in the market factor will result in an increase of 1.07% of the Consumer Discretionary sector return. Conversely a one-unit increase in the value factor will result in reducing the Consumer Discretionary sector return by -0.29%. This indicates that Consumer Discretionary loads positively on the market premium and negatively on the value premium although still exhibits significance at the 1% and 5% level respectively. It is also observed from the coefficients that the market and growth-oriented stocks dominate the Consumer Discretionary sector.

On the other hand, Consumer Staples and Telecommunications sectors loads positively on the market premium and demonstrate statistical significance observed at the 5% and 1% level respectively and therefore dominates these sectors. The coefficient value indicates a positive one-unit change of the market factor which will result in a positive 0.78% change in the Consumer Staples sector return and a 0.98% change in the Telecommunications sector return.

The three-factor model reveals four positive alphas (Basic Materials, Consumer Discretionary, Consumer Staples, and Telecommunications) and four negative alphas (Financials, Healthcare, Industrials, and Technology). The three-factor model falls short in explaining returns across all sectors, as the alpha, market beta, size, and value are not consistently statistically significant in all eight sectors. However, only two alphas, along with all three factors of the model, demonstrate statistical significance at the 5% and 1% level and accounts for returns in the Financial and Industrial sectors.

The results are consistent with the findings of Robertson and Van Rensburg (2003), which indicate that size and value-related measures have a positive relationship with returns in the Financial and Industrial sectors. In this research, the Resource sector is further divided into the Basic Materials and Energy sectors, and it similarly shows weaker performance, aligning with the results observed by Robertson and Van Rensburg (2003).

Several studies, including those by Van Rensburg and Robertson (2003b), Auret and Sinclaire (2006), and Page and Auret (2014), provide evidence of significant value and size premiums in shares listed on the JSE. Basiewicz and Auret (2009) highlight the robustness of these size and value factors even after accounting for trading costs, which impact the magnitude and persistence of these premiums, especially the size premium. These findings suggest that the

size and value factors are strong predictors of returns, showing that the Fama and French three-factor model is more effective than the CAPM in addressing risk factors. Although some studies suggest that alternative asset pricing models outperform the Fama and French three-factor model and this is consistent with this study as the five-factor model does outperform the three-factor model.

Sector Name	α	β_{EMRP}	β_{SMB}	β_{HML}	β_{RMW}	β_{CMA}	$Adj.R^2$
Basic materials	0.0004	1.1651***	-0.3577***	0.4325**	0.2620	-0.7210***	0.0715
Financials	-0.0004***	0.8949***	0.1624***	-0.0466*	-0.2586***	0.8312***	0.7000
Healthcare	-0.0002	0.7188***	0.2194***	-0.3382***	-0.2497***	0.4465***	0.2658
Consumer Discretionary	0.0010	1.0606***	0.1350	-0.5295**	-0.1686	0.7452**	0.0247
Consumer Staples	0.0024	0.7708***	-0.2958	-0.5341	-0.2846	0.8814	0.0031
Industrials	-0.0005***	0.8784***	0.3056***	-0.0158	-0.0580**	0.4396***	0.5905
Telecommunications	0.0008	0.9788***	-0.1687	-0.4634	-0.3814	1.1487*	0.0166
Technology	-0.0001	0.9003***	0.3100***	-0.1541***	0.1174**	-0.0407	0.2329

Table 3: Five factor time-series regression

*Note: Regression parameters are presented alongside with the significance level where *, ** and *** indicate significance at the 10 %, 5% and 1% level, α represents time-series portfolio alphas, β represents the coefficients of factor loading on applied regressor, the adjusted R^2 is related to specific time-series regression.*

The results from Table 3 are obtained from the alphas and factor loadings of the five-factor model. The regression results indicate that a single unit increase in the market, size and investment factor will result in a 0.89%, 0.16% and 0.83% increase in the Financial sector returns and 0.72%,0,22% and 0,45% in the Healthcare sector returns. All these being significant at the 1% level and having the market, stocks with small capitalisation and conservative investment strategies dominate this market. This indicates that the Financial and Healthcare sector loads positively on the market, size and investment premiums. Conversely a single unit increase in the value and profitability factor will reduce the Financial sector returns by -0.05 % and -0.26% and the Healthcare sector by -0.34% and -0.25%. Hence it shows that the growth-orientated stocks and weak performing stocks will dominate this sector as well as being significant at the 10% and 1% level respectively. This indicates that the Financial sector loads negatively on the value and profitability premiums. The adjusted R^2 results presented in Table 4 ranges from 0.31% to 70% for all sectors. The five-factor regression indicates that the

market, size, value, profitability and investments seem to capture the highest which explains 70% of the Financial sector's variation.

Basic Materials load positively on the market and value premiums with each being significant at the 1% and 5% level respectively. Similarly, the sector loads negatively on the size and investment factors and both are significant at the 1% level. The coefficient values indicate that a one-unit positive change in the market and value factor will result in a positive Basic Material sector return of 1.17% and 0.43%. On the contrary a single unit positive change in the size and investment factor will result in a negative -0.36% and -0.72% change in the Basic Material sector return. From above, it shows that the sector is dominated by the market, stocks with large capitalisation, weak performing stocks and aggressive investment strategies.

Consumer Discretionary sector is dominated by the market, growth-orientated stocks and conservative investment strategies. Hence the sector demonstrates positive loadings on both the market and investment factors, with each exhibiting significance at the 1% and 5% levels respectively. Conversely, the sector displays a negative loading on the value factor, although significant at the 5% level. These coefficients show that a one-unit positive change in the market and investment factor will results in positive Consumer Discretionary sector return of 1.06% and 0.75%. The other coefficient indicates that a positive one-unit change in the value factor results in a negative 0.53% change in the Consumer Discretionary sector return. The regression results for the market factor indicate that a one-unit increase in this factor will results in a 0.77% increase in the Consumer Staples sector returns and is significant at the 1% level. This shows that the market and growth stocks are the only ones that dominate this sector.

Industrials sector exhibits positive loadings on the market, size, and investment premiums, all significant at the 1% level. The coefficients illustrate that a unit-one increase in these factors corresponds to a 0.88%, 0.31%, and 0.44% positive change in Industrial sector returns respectively. Additionally, the results highlight that a one-unit increase in the profitability factor leads to a reduction in Industrial sector returns by -0.06%, also significant at the 5% level. From the above, market, stock with small capitalisation, conservative investment strategies and weak performing stocks dominate this sector.

Telecommunications load positively on the market and investment premium also being significant at the 1% and 5% level respectively. The coefficients show that the positive single unit change of the market and investment factor will result in a positive Telecommunications

sector returns of 0.98% and 1.15%. These coefficients also indicate that market and conservative investment strategies dominate this sector.

In the Technology sector the market, stocks with small capitalisation, growth-oriented stocks and strong performing stocks predominantly dominate the sector. The market, size and profitability factor coefficients indicate that a one-unit increase of these factors will results in 0.90%, 0.31% and 0.11% increase in the Technology sector returns. The effect is significant at the 1% and 5% level. Similarly, the value coefficient indicates that a single unit increase of the value factor will result in reducing the Technology sector returns by -0.15% and is also significant at the 1% level.

For the five-factor model there are four positive alphas (Basic materials, Consumer Discretionary, Consumer Staples and Telecommunications) and 4 negative alphas (Financials, Healthcare, Industrials and Technology). From the eight alphas only two are statistically significant at the 1% level along with all five-factors of the model which are also significant at the same level and accounts for returns in the Financial sector.

In this study, the five-factor model was found to outperform the three-factor model, particularly in explaining returns in the Financial, Industrial and Health Care sector. This finding aligns with similar research by Zaremba (2016), which highlight the effectiveness of quality investing factors like profitability in accounting for cross-sectional variations in stock returns, suggesting their potential impact on the JSE. Additionally, Foye (2018) applied the five-factor model to emerging markets and found a profitability premium in Eastern Europe and Latin America, although not in Asia, indicating that the five-factor model provides improvements over the three-factor model in specific regions.

A study by Leite, Klotzle, Pinto, and da Silva (2018) explores style factors essential to a five-factor asset pricing model. The study compares three models: the Fama and French three-factor model, the Carhart four-factor model, and the Fama and French five-factor model. Their analysis focused on the post-2008 global economic crisis era. Their findings suggest that the four-factor and five-factor models outperform the three-factor model by better explaining portfolio excess returns and reducing unexplained dispersion. The sample period for this study ranged from 2007 to 2023. Although the study does not specifically examine the effects of economic events and stress, it demonstrates that the five-factor model is superior to the three-factor model in explaining sector returns. The events that occurred during the time frame

conducted in this research could have had an influence on the asset pricing models' ability to explain sector returns.

Lastly, Cox and Britten (2019) analyse the CAPM, three-factor, and five-factor models using data from the South African market. These authors find that while the five-factor model was more effective in explaining cross-sectional returns, the three-factor model and a size-profitability variant performed better for time-series returns. Therefore, although the five-factor model excels in cross-sectional analysis, it is less effective than some other models in explaining time-series returns.

Sector Name	α	β_{EMRP}	β_{SMB}	β_{HML}	β_{RMW}	β_{CMA}	β_{WML}	$Adj.R^2$
Basic materials	0.0004	1.1649***	-0.3581***	0.4237*	-0.7181***	0.2590	-0.0091	0.0713
Financials	-0.0004***	0.8928***	0.1590***	-0.1148***	0.8533***	-0.2817***	-0.0703***	0.7034
Healthcare	-0.0001	0.7158***	0.2146***	-0.4338***	0.4775***	-0.2821***	-0.0986***	0.2717
Consumer Discretionary	0.0010	1.0568***	0.1289	-0.6515**	0.7848**	-0.2100	-0.1258	0.0248
Consumer Staples	0.0024	0.7675**	-0.3012	-0.6411	0.9161	-0.3208	-0.1103	0.0029
Industrials	-0.0004***	0.8758***	0.3014***	-0.1006***	0.4671***	-0.0867***	-0.0874***	0.5967
Telecommunications	0.0010	0.9723***	-0.1792	-0.6740**	1.2170***	-0.4528	-0.2171	0.0169
Technology	-0.0001	0.8983***	0.3068***	-0.2173***	-0.0202	0.0959	-0.0652***	0.2342

Table 4: Six-Factor time-series regression

*Note: Regression parameters are presented alongside with the significance level where *, ** and *** indicate significance at the 10%, 5% and 1% level, α represents time-series portfolio alphas, β represents the coefficients of factor loading on applied regressor, the adjusted R^2 is related to specific time-series regression.*

The results from Table 4 are the alphas and factor loadings from the time-series regressions. The regression analysis reveals that all six factors in the model exhibit statistical significance at the 1% level across the Financial, Healthcare, and Industrial sectors. The Financial, Healthcare and Industrial sectors load positively on the market, size and profitability premiums. Hence the market, stocks with small capitalisation and robust performing stocks dominate these sectors. Specifically, the coefficients for market, size, and profitability suggest that a one-unit increase in these factors corresponds to a 0.89%, 0.16%, and 0.85% rise in Financial sector returns, a 0.72%, 0.21%, and 0.48% increase in Healthcare sector returns, and a 0.88%, 0.30%, and 0.46% increase in Industrial sector returns, respectively. Conversely, the Financial, Healthcare and Industrial sectors load negatively on the value, investment and momentum

premiums. This demonstrates that these sectors are also significantly dominated by growth-oriented stocks, aggressive investment strategies, and underperforming (loser) stocks. The coefficients of these factors indicate that a single unit increase in value, investment and momentum factors is associated with a reduction in sector returns. For the Financial sector, this translates to a decrease of -0.11%, -0.28%, and -0.07%, while for the Healthcare sector, it corresponds to a decline of -0.43%, -0.28%, and -0.095%. Similarly, for the Industrial sector, the reduction amounts to -0.10%, -0.09%, and -0.09% respectively. When looking at the adjusted R^2 results presented in Table 4 ranges from 0.29% to 70.34% for all sectors. The regression based on the six-factor model elucidates the most substantial proportion, capturing 70.34% of the Financial sector's variation on the JSE.

In the regression the coefficients of the market and value factor indicate that a one-unit increase in these factors will result in a 1.16% and 0.42% increase in the Basic Material sector returns and the effect is significant at the 1% and 10% level. Likewise, the coefficients of the size and profitability factors indicate that a single unit increase in these factors will reduce the Basic Material sector returns by -0.36% and -0.28% respectively and is significant at the 1% level. This indicates that the market, value-oriented stocks, stocks with a large capitalisation and weak performing stocks dominate the Basic Material sector.

Consumer Discretionary is dominated by the market, robust performing stocks and growth-oriented stocks, the effect is significant at the 1% and 5% level respectively. The coefficient values indicate that a single unit positive change in the market and profitability factors will result in a positive Consumer Discretionary return of 1.06% and 0.78%. On the other hand, a positive change in the value factor results in a negative -0.65% change in the Consumer Discretionary sector return. With respect to Consumer Staples the only factor that dominates this sector is the market. The regression findings for the market factor reveal that a one-unit increase in this factor corresponds to a 0.77% rise in Consumer Staples sector returns, achieving statistical significance at the 5% level.

Telecommunications sector demonstrates that the market and robust performing stocks dominate this sector, with significance observed at the 1% level. Conversely, it displays that the growth-oriented stocks also dominate this sector with significant at the 5% level. The coefficient values indicate that a single unit positive change in the market and profitability factors will result in a positive Telecommunication sector return of 0.97% and 1.21%.

Conversely a positive change in the value factor results in a negative -0.67% change in the Telecommunications sector return.

With the Technology sector it is evident that the market, stocks with small capitalisation, growth-oriented stocks and stocks that underperform (loser) dominate in this sector. The market and size factor coefficients indicate that a one-unit increase of these factors will results in 0.90% and 0.31% increase in the Technology sector returns and the effect is significant at the 1%. Similarly, the value and momentum coefficient indicate that a single unit increase of the value and momentum factor will results in reducing the Technology sector returns by -0.22% and -0.07% respectively and is also significant at the 1% level.

For the six-factor model there are four positive alphas (Basic materials, Consumer Discretionary, Consumer Staples and Telecommunications) and 4 negative alphas (Financials, Healthcare, Industrials and Technology). From the eight alphas only two are statistically significant along with all six factors of the model at the 5% and 1% level and these are in the Financial and Industrial sector respectively.

It is also observed in this study that the financial and industrial sectors were the best explained across the factor models. Although out of the three models the Financial and Industrial sector was explained best by the six-factor model as each factor and alpha was statistically significant. This finding resonates with Charteris (2014), whose study also highlighted the significance of estimated dual beta in explaining returns, particularly within the industrials and financials sectors during the period from January 2000 to December 2009. A similar study was conducted by Van Rensburg (2001) which looked at the style-based risk factors for the JSE of industrial shares and showed the importance of the size and value metrics. Then another author Robertson and van Rensburg (2003) expanded on his work by evaluating if the size and value measures are able to explain returns across all sectors. There was some similarity where there were value effects but it was more the size effect across the models.

In this model the value premium is negative and significant for all except one sector. The value premium found to be negative and significant, which is inconsistent with Van Rensburg and Robertson (2003a). Additional evidence supporting the size and value effects is provided by Basiewicz and Auret (2009), who conducted a reassessment of the cross-sectional returns on the JSE. Their findings reaffirmed the existence of size and value premiums, even after accounting for transaction costs. However, the effects' magnitudes were diminished compared to earlier studies, primarily due to transaction costs and illiquidity, with the size premium being

particularly affected by these factors. The momentum premium is observed to be negative and statistically insignificant for four of the sectors. Notably, the results of this study align with Boamah's (2015) regarding the lack of significance in the momentum premium, as neither study found it to be significant.

4.2 Gibbon Ross and Shanken Test (1989) results

	FF3F	FF5F	FF6F
GRS	1.1152	1.1561	1.0378
P-value	0.3492	0.3220	0.4047

Table 5: GRS

*Note: Regression parameters are presented alongside with the significance level where *, ** and *** indicate significance at the 10%, 5% and 1% level.*

The GRS test utilised the alphas derived from a time-series regression that was performed on the whole sample. The GRS statistic for the three-factor asset pricing model shown in Table 5 yielded a value of 1.1152, resulting in a p-value of 0.35, exceeding the 0.05 significance threshold. This implies that the study failed to reject the null hypothesis as the statistic is greater than the p-value. Therefore, based on the specified significance level, the joint test of time-series α is not considered significantly different from zero. The test results indicate insufficient evidence to reject the null hypothesis asserting that the joint alphas are collectively zero. The implication is that the style premiums from respective asset pricing models adequately account for sector returns on the JSE.

Subsequently the GRS five-factor asset pricing model shown in Table 5 yielded a statistic with a corresponding p-value of 0.32, exceeding the 0.05 significance threshold. Consequently, failing to reject the null hypothesis suggests that there is insufficient evidence to claim that at least one alpha is different from zero. Thus, the GRS statistic is statistically indifferent from zero, suggesting that the style premiums from the asset pricing models do effectively explain the sector returns on the JSE. Similarly, the six-factor asset pricing model GRS statistic is 1.0378 and its associates p-value of 0.4047. In this case, with a p-value of 0.40, which is greater than 0.05, you would fail to reject the null hypothesis. Therefore, based on your specified significance level, the joint test of time-series α is not considered significantly different from

zero. The results of the statistical test, that has a t-statistic of 1.04 and a corresponding p-value of 0.40, reveals a lack of substantial evidence to reject the null hypothesis. This suggests that the style premiums derived from various asset pricing models effectively clarify the patterns in sector returns on the JSE. This reinforces the idea that the examined style premiums proficiently capture the variations in sector returns.

With regards to the time-series regression and GRS test in Table 5, it is evident that the null hypothesis for all factor models is accepted, signifying their ability to effectively explain sector returns on the JSE. Notably, the six-factor model stands out with the lowest GRS statistic, indicating superior performance, while the five-factor model displays the highest GRS statistic, indicating comparatively weaker performance.

Shaker and Elgiziry's (2014) study conclude that the Fama and French three-factor model was superior to other models in the Egyptian Stock Market, with a GRS statistic of 2.336 and a p-value greater than one, indicating its robustness in explaining the variation in the cross-section of average returns. However, my research presents different results for the Fama and French models. Specifically, the three-factor model in my study yielded a GRS statistic of 1.1152 and a p-value of 0.3492. Which is the highest among the five-factor model and the six-factor model. These findings suggest that, unlike Shaker and Elgiziry's (2014) results, this research indicates a closer performance among the three, five, and six-factor models, with none of them significantly outperforming the others. Here it is seen that that the six-factor model has the smallest GRS statistic and p-value less than one.

Focusing on the adjusted R^2 values, it is evident that the Financial, Industrial, and Healthcare sectors are statistically significant across all factor models and have the highest adjusted R^2 values, indicating their explanatory power for sector returns. For instance, in the three-factor model, the adjusted R^2 values are 0.6115 for Financial, 0.5470 for Industrial, and 0.2527 for Healthcare. These values increase to 0.7000 for Financial, 0.5967 for Industrial, and 0.2717 for Healthcare in the five-factor model. The six-factor model shows further improvements with adjusted R^2 values of 0.7034 for Financial, 0.5967 for Industrial, and 0.2717 for Healthcare. This progression indicates that the five-factor model outperforms the three-factor model, and the six-factor model surpasses the five-factor model, demonstrating improved overall performance. This also indicates that adding additional factors to expand the asset pricing model each time improves the model's ability to explain sector returns. The strong performance of the Financial and Industrial sectors in terms of sector returns may be attributed to their

substantial representation on the JSE, with 97 companies in the Financial sector and 45 companies in the Industrial sector. Despite the Healthcare sector having only 7 companies, it still boasts a higher adjusted R^2 value compared to the Basic Materials sector, which also consists of 45 companies (Johannesburg Stock Exchange, 2024).

A study by Zsolt and Tünde (2022) produces similar results, showing that the Fama and French six-factor model, which includes a momentum factor, outperformed the Fama and French five-factor model as indicated by higher adjusted R^2 values. However, the GRS test for the six-factor model was higher, suggesting that the model was not necessarily more efficient than the five-factor model. Despite this, many of the six-factor regressions had highly significant factor coefficients, leading the authors to conclude that the six-factor asset pricing model is more appropriate for the Warsaw market.

5. Limitations

The study had certain limitations. Firstly, it focused solely on equities, whereas other studies also incorporate bonds in their asset pricing models. Additionally, the study is confined to analysing the Johannesburg Stock Exchange and does not encompass developed economies. It should be noted that there are very few studies that look at the relationship between style factors and sector returns of respective stock exchanges. As there was limited literature to compare and validate accuracy of results. Another limitation of this study is that it excluded three sectors: real estate, utilities and energy. The reason for the excluded sectors is due to them having few data points as these sectors were introduced at a later stage. As the JSE only started incorporating the ICB classification on 2005. This limited the ability to accurately measure if the asset pricing models do explain the returns within these sectors. A major limitation to the study is the robustness of the results as the research does not explicitly measure the impact of economic stress such as the Global economic crisis and Covid-19 on sector returns. As this would provide understanding how asset pricing models perform under such circumstances which could provide valuable insights into their robustness and effectiveness in explaining sector returns during periods of economic stress. In terms of limitations to the methodology, the study only conducted one test, which was a standard time-series regression with a GRS test. Employing a Fama and Macbeth (1973) two-pass regression analysis, which incorporates multiple time-series regressions followed by a cross-sectional regression along with a GRS test, could have potentially yielded more accurate results.

6. Conclusion

South African and international asset pricing literature is situated around evaluating financial assets within various asset pricing models, particularly concerning the Johannesburg Stock Exchange (JSE) and broader market indexes. Researchers are interested in evaluating returns on listed shares across portfolios based on a variety of determining factors. To this, multiple models have been devised to capture the underlying risk factors that influence returns.

The most well-known asset pricing models in academic literature are the Capital Asset Pricing Model (CAPM), the Fama and French Three Factor Model and Five Factor Model. Over time, additional models like the Carhart Four Factor Model and the Fama and French Six Factor Model have emerged to improve the method of capturing underlying risk factors in explaining returns. The CAPM, pioneered by Harry Markowitz, revolutionised finance by associating expected returns with a single risk factor, focusing on mean variance efficiency (Markowitz,1952). Fama and French extended the model to include firm size (market capitalisation) and value (book-to-market ratio) in their three-factor model (Fama & French, 1993). This model provided valuable insights into the cross-section of expected returns by accounting for the size and value effect. Subsequently, the five-factor model (Fama & French, 2015) expanded on the three-factor model as researchers needed additional factors to capture the risk-return relationship. The five-factor model incorporated profitability (return on equity) and investment factors to provide a more comprehensive understanding of risk and return dynamics. The latest expansion, the Fama and French six-factor model (Fama & French, 2018), introduced a momentum factor to further enhance the model's explanatory power as it was seen in other literature to be a driver of returns in finical markets. This inclusion also offered investors a comprehensive tool to asset risk and expected returns.

This research aimed to expand the existing body of South African literature concerning asset pricing models, focusing on specific risk factors that influence sector returns. It differs from previous studies by examining whether asset pricing models can elucidate sector returns on the JSE, whereas prior research primarily focused on portfolio and asset returns within these models. The study's objective is to investigate whether asset pricing models can account for the cross-sectional variation in shares and sectors on the JSE. The models employed include the three, five, and six-factor (Fama & French, 1993,2015,2018) asset pricing models,

alongside sectors identified using the GICS classification system from the JSE (MSCI,2023). The test that was utilised in this study was a time-series regression analysis for the GRS test. In this regression analysis it is a linear time-series regression per sector using a single model. The resulting alphas from this analysis are utilised in the Gibbons, Ross, and Shanken test to evaluate whether style-based risk factors can explain sector returns on the JSE.

The results revealed that multiple factor models explain sector returns on the JSE. The acceptance of the null hypothesis across all factor models in the time-series regression, as evidenced by the GRS test, highlights their ability to effectively capture the complexities of sector returns, indicating that the asset pricing models do explain sector returns. Particularly noteworthy, is the superior performance of the six-factor model, as indicated by its lowest GRS statistic, suggesting a comprehensive explanation of sector returns. Additionally, the six-factor model demonstrates explanatory power for the financial sector, evident in its highest adjusted R^2 among the models. Moreover, the analysis revealed that the financial and industrial sectors are best explained across the factor models, with the six-factor model notably providing statistically significant results for each factor and alpha within these sectors. This underscores the value of incorporating additional factors in enhancing the model's ability to explain cross-sectional variation in styles and sector returns. In conclusion, the six-factor model emerges as the most robust framework for analysing sector returns on the JSE, offering valuable insights into the interplay between various risk factors and sector performance.

In terms of the research objective of assessing the effectiveness of asset pricing models in explaining sector returns on the JSE, several avenues for future exploration are evident. Firstly, researchers could broaden their analysis by investigating international market indices and conducting comparative studies with the JSE. Additionally, alternative asset pricing models such as the Carhart model, which incorporates the momentum factor, could be explored to determine if the six-factor model remains the most suitable for explaining sector returns on the JSE. Furthermore, there is potential for expanding the existing six-factor model by incorporating additional factors such as liquidity and volatility, which may offer deeper insights into sector performance. As this study focused on a limited number of sectors due to data constraints, future research could delve into specific sectors and explore their individual determinants, assessing how these factors impact their ability to explain sector returns.

Moreover, considering the influence of global events on market dynamics, future research could investigate how international crises, such as pandemics, wars and natural disasters could

affect the cross-sectional variation between styles and sectors. Overall, these avenues for future research have the potential to enhance our understanding of asset pricing models and their ability to explain sector returns on the JSE and contributing to the advancement of academic literature in this field.

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