The Adaptive Markets Hypothesis: Testing for Variable Efficiency and Cyclical Profitability in the South African Market

BY

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Dedication

I dedicate this to my mother, Geary Rachel Botes, who demonstrated the power of determination and perseverance and has never stopped believing in me.

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Acknowledgement

I would like to extend my gratitude to my mother for her endless support in all that I do. Without your love and good example, the completion of this thesis would not have been possible.

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Finally, I would like to express my appreciation to all of those who have contributed positively to my life in one way or another.

We live and we learn. All mistakes are my own.

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Abstract

This research attempts to discover whether the Adaptive Market Hypothesis theory is applicable in the South African financial market and explores the innovation and cyclical profitability implications of the Adaptive Market Hypothesis theory. This is achieved in two parts: first by determining if returns follow a random walk or not and second by analysing the consistency of technical and fundamental factors to explain the cross-section of equity returns between 1 January 1998 to 31 December 2017.

The tests of stock return dependency include a total of five tests on the average monthly returns for each stock in the ALSI covering normality and random walk theory for the duration of the two sub-periods and entire examination period. The results of these tests would provide some insight into the level of market efficiency of the JSE and to what extent this efficiency is cyclical. The results for the Jarque-Bera test and Q-Q plots are in agreement, with both tests presenting a strong case for non-normally distributed returns. By contrast, the results of the random walk tests are rather mixed. The results of the Ljung-Box and runs tests suggest that very few stocks in the sample have returns that are randomly generated while the results from the three different variance ratio tests convey quite the opposite in that all stocks in the sample have non-randomly generated returns. Mixed findings for this section are not an unexpected result given that this is the case in the literature as well. The results in support of the Adaptive Markets Hypothesis are present, albeit feint. A larger number of stock returns switch between being normally distributed and non-normally distributed during the two sub-periods, however, with respect to predictability, as few as 30 stocks possessed returns that were found to switch between a state of predictability and non-predictability.

The findings of the univariate test provide strong support for the Adaptive Markets Hypothesis, with particular respect to the idea of varying efficiency of financial strategies and the requirement for innovation. The payoff to the statistically significant style attributes in the fundamental to price and operating performance categories have become progressively weaker, suggesting a shift from trade decisions based on these attributes.

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The combined results of the two phases of this research violate the assumptions of the efficient market hypothesis which suggests that price movements are unpredictable. The findings also suggest that markets go through periods of efficiency and inefficiency and that in an effort to maintain a profitable position, investors are required to be more innovative.

These findings motivate greater exploration into how the factors identified in the univariate test could be used in quantitative models for comparison between adaptive and non-adaptive active strategies. This would assist in providing further insight into the Adaptive Markets Hypothesis, particularly on how constant innovation is key in the pursuit of profitable strategies. A promising direction for this would be the exploration into using machine-learning techniques to create dynamic or adaptive portfolios and compare the performance of their non-adaptive counter-parts. One such technique is the genetic algorithm, which is based on the same evolutionary principles that inspires the Adaptive Markets Hypothesis.

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1

Introduction

1.1. Background

Fama (1970)'s Efficient Market Hypothesis (EMH) has come under much scrutiny since its inception. Researchers have employed many different techniques to test its validity as a theory explaining market behaviour. The support for EMH that prevailed during the 1960s and 1970s had withered from the 1980s as a result of the voluminous number of research papers discovering that stock returns are not independent (rejecting weak-form EMH) and that publicly available financial information is useful in the prediction of stock returns, enabling the formation of alpha-generating investment strategies (rejecting the semi-strong strong EMH). As of present, the financial community has yet to reach an agreement on the efficiency of financial markets.

Lo (2004) suggests that the theory of efficient markets has been incomplete all along, giving rise to the confusion that surrounds the topic. Introducing the Adaptive Market Hypothesis (AMH), Lo (2004) suggests that efficiency should be observed as constantly evolving with the passage of time, rather than the steady-state that the market should maintain. By adding the elements that the EMH denies as valid (active strategy profitability and investor irrationality) into the same universe and justifying its existence through evolutionary principles, Lo (2004) believe that AMH becomes a more practical description of financial markets.

While the AMH has recently garnered attention in the literature, research is comparatively dearth relative to the theories it attempts to reconcile, namely EMH and behavioural finance. This thesis seeks to reduce the scarcity in AMH-related literature by applying it to a South African financial market.

Research conducted in South African financial markets have identified that a variety of style attributes are able to explain the cross-section of equity returns (Van Rensburg and Robertson (2003), Hodnett, Hsieh and Van Rensburg (2012)). Furthermore, recent research indicates that value stocks outperform growth stocks in a cyclical manner on the JSE (Graham and Uliana, 2001).

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These works serve as the motivation to discover if profitable strategies exist and if these strategies earn consistent returns or, as the adaptive market hypothesis suggests, do strategies require regular adaption.

1.2. Research Problem

Efficient Market Theory's description of market efficiency has been debated among academics for decades, with multiple arguments from different fields being used to debunk its implications. The Adaptive Markets Hypothesis (AMH) attempts to reconcile these arguments while creating a more practical description of market efficiency. The current literature suggests that the South African stock market is weak-form efficient. When compared to EMH or behavioural finance, research into AMH for African markets is rather scarce. Furthermore, the arguments provided against efficient market theory has to yet to be sufficient to invalidate EMH completely. Thus, this thesis seeks to discover whether AMH is a better description of market behaviour than the efficient market hypothesis for the South African stock market, with particular interest in the AMH's suggestion of the presence of short-term profitability and constant innovation to maintain a profitable position.

1.3. Research Questions

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i. Does the efficiency of the South African equities market vary with time?
ii. Do these periods of evolving efficiency allow for the creation of profitable investment strategies?
iii. If profitable strategies can be created, does it maintain its profitability with the passage of time?

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1.4. Research Objectives

The objectives of this research aim to:

1. Identify candidate firm-specific style attributes that possibly explain the cross-sectional equity returns on the JSE for the sample period 1 January 1998 to 31 December 2017.
2. Estimate the cross-sectional factor payoffs to the firm-specific attributes for the sample period to determine which variables have significant explanatory power and how consistent this explanatory power is.
3. Identify if the JSE is an efficient or adaptive market.
4. Identify if strategy innovation is required for consistent profitability.

1.5. Contribution

To the author's knowledge at the time of writing, minimal research existed on the applicability of the Adaptive Market Hypothesis, more so in the South African context. In contrast to other studies, the traditional random walk tests used in this research have generally not be used to analyse if the South African equity market's efficiency is of an evolving nature. Similarly, with the extension of the time period and observation of the cumulative attribute payoffs to the style attributes, this thesis builds on the suggested direction of the conclusion of Hodnett, Hsieh and Van Rensburg (2012). When discussing this thesis' results within the context of the Adaptive Market Hypothesis, it provides greater insight on the factors that can be used in practice to produce profitable active strategies and to estimate how long these profits may last.

1.6. Outline of the Study

This research attempts to discover whether the Adaptive Market Hypothesis theory is applicable in the South African financial market and explores the innovation and cyclical profitability implications of the Adaptive Market Hypothesis theory. This is achieved in two parts: first by determining if returns follow a random walk or not and second by analysing the consistency of technical and fundamental factors to explain the cross-section of equity returns between 1 January 1998 to 31 December 2017.

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Chapter 2 presents the theoretical overview of the research including mean-variance theory, Capital Asset Pricing Model, Efficient Markets Hypothesis, arguments against efficient market theory, behavioural finance, market anomalies, multi-factor pricing models, and the adaptive markets hypothesis.

Significant findings within the literature are presented in Chapter 3, including the topics of traditional market efficiency tests, evolving efficiency, market dynamism, the identification of asset pricing anomalies, cyclical profitability, and active strategy innovation. Chapter 4 presents the problem statement, research objectives, data and methodology along with potential research biases and their remedies.

Chapter 5 presents the results of a series of five tests to identify if stock price changes follow a random walk or not. In Chapter 6, the objective is to identify possible factors that explain the cross-section of returns on the JSE, with particular interest in the consistency of the explanatory power of each attribute with the passage of time. The methodology used here is inspired by the work of Fama and Macbeth (1973), Haugen and Baker (1996), and Hsieh, Hodnett and Van Rensburg (2012). Chapter 7 summarises the findings of this thesis and provides suggestions on the direction for further research.

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2

Theoretical Overview

2.1. Introduction

This chapter provides a theoretical background of the research. The sections in this chapter provide an overview of modern portfolio theory, asset pricing models, the efficient market hypothesis, behavioural finance, and the adaptive markets hypothesis.

When presented with choice, a decision can only be made once the particular scenario is thoroughly understood. Within the context of finance, investors are faced with a number of possible options when selecting amongst securities. If the intended goal is to maximise return, then selecting securities that provide the greatest returns may seem like an enticing and simple strategy to undertake, however, failing to account for a security's risk and the relationship of risk amongst securities would be a regrettable oversight. The identification of the importance of risk is notably accredited to Markowitz (1952)'s Modern Portfolio Theory (MPT). In particular, Markowitz (1952) mathematically shows that a risky asset is described by two measures, its expected return, and variance. As opposed to viewing securities in isolation, Markowitz (1952) shows that the collective effect of holding many uncorrelated securities is a decrease in overall risk. This is known as portfolio diversification.

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While diversification decreases risk, it does not completely negate it. Fully diversified portfolios are still subject to firm-specific non-diversifiable risk. Sharpe (1964) suggests that non-diversifiable risk is most relevant, as it is the only risk that the investor would have to consider once the portfolio is fully diversified. The Capital Asset Pricing Model (CAPM) of Sharpe (1963,1964), Linter (1965), and Mossin (1966) prices this non-diversifiable risk and calculates the appropriate rate of return that an asset should generate given its current correlation with movements in the market. Assuming that all investors have the goal of maximising return for the lowest possible risk, when this particular mean-variance efficient portfolio is identified, Sharpe (1964) suggests that it is logical to assume that all investors would hold this portfolio, aptly called the "market" portfolio.

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Fama (1970)'s Efficient Market Hypothesis (EMH) states that the market portfolio cannot be succeeded by any other portfolio since the market itself contains all available information. As investors constantly discover new information, the price of the security will adjust and thus, no asset would be unfairly priced. As this implies that the market is unpredictable and that no arbitrage opportunities exist, active management strategies that analyse past price history or company performance are argued to be unprofitable in an efficient market.

As these implications are rather profound, the EMH has been fiercely contested from various angles. Roll (1977) argues that the market portfolio described by capital market theory cannot be observed in reality and that using a substitute for the market portfolio results in biased outcomes. Grossman and Stiglitz (1981) attack the logic of EMH's informationally efficient market which relies on arbitrageurs to seek new information to ensure that asset prices are in equilibrium, despite the existence and knowledge of the superior market portfolio, an assumption that is paradoxical in nature. Proponents of behavioural finance suggest that investors do not always behave rationally when making investments decisions, disregarding the rational investor assumption of capital market theory.

As research into these various counters to market efficiency continues, a number of notable cases highlight the possibilities for profits to be made from various information sources, including price history and firm announcements and accounting ratios. As these results do not confer with classic market theory, these phenomena are classed at market anomalies. In an effort to capture the effects that market anomalies produce, various asset pricing models have been developed, either extending the CAPM, as in Fama and French (1992)'s three factor model, or using a completely unique set of explanatory variables through the use of Ross (1976)'s arbitrage pricing theory.

While the argument for and against efficiency spans decades, no real conclusion has become clear. The Adaptive Markets Hypothesis (AMH) of Lo (2004) creates a hybrid theory, taking elements from both efficient market theory and behavioural finance, by applying evolutionary principles to financial markets. An adaptive market allows for the existence of irrational investors and arbitrage opportunities by accepting these aspects of financial markets as requirements for markets to tend to the ideal level of efficiency as proposed by EMH, but never truly reach a steady-state efficiency

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level, as markets are expected to be constantly evolving.

2.2. Mean-Variance Theory

Prior to Markowitz (1952), the field of investments was void of financial theory capable of analysing the trade-off between risk and return of a security. Markowitz (1952, 1959)'s Modern Portfolio Theory (MPT) mathematically demonstrates that a risky asset can be explained by its expected return and variance. This provides a model for investors to make decisions under uncertainty (since future asset prices are unknown) and thus, investors are able to safeguard against potential losses by including uncorrelated assets (that is, diversifying) into a portfolio with the goal of decreasing overall risk. Furthermore, investors are assumed to make rational, utility maximising investment decisions, which entails that the investor would only include an asset into a portfolio that would either increase its expected return for a given level of risk or decrease its risk for a given level of return. While the desired level of risk and return is determined by the risk appetite of the investor, investors are assumed to be risk-averse. Figure 2.1 below, an adaption of the two asset portfolio case taken from Sharpe (1964), simply illustrates an investors' rational choice and the impact of diversification on portfolio performance.

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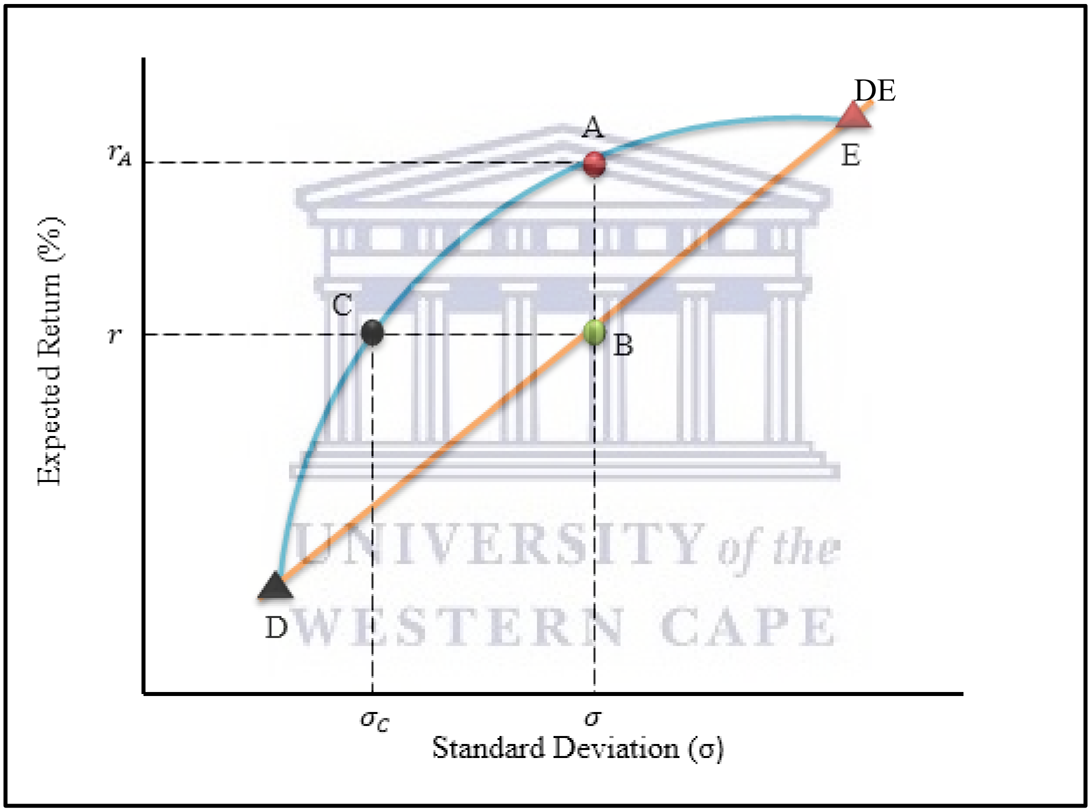
Figure 2. 1 Rational Choice and Diversification

Figure 2.1 is adapted from Sharpe (1964:430). It illustrates how the rational investor selects securities and the benefits of diversification. Security A or C would be preferred to security B, as A generates a greater return for the same level of risk while security C generates the same level of return for lower risk. The line DE shows all combinations of D and E in a portfolio void of diversification, while the curve DE shows the same combination of D and E if the stocks were uncorrelated, or diversified. Curve DE is superior to line DE for any given level of risk.



Consider the two securities, A and B, which have different rates of return but the same level of risk. According to MPT, a rational investor prefers security A, as a higher level of return relative to B is received for the same level of risk. Similarly, securities B and C have the same rate of return but differing levels of risk. Security C would be preferred to security B, as C provides the same rate of return as B but for a lower level of risk. Choosing between A and C would depend on the investor's risk appetite.

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Alternatively, an investor may decide to form a portfolio of assets. Consider a case in which the portfolio consists of two securities, D and E. The expected return of the portfolio is computed as:

$$E(r_p) = w_D * E(r_D) + w_E * E(r_E) \tag{2.1}$$

Where:

$E(r_p)$ = the expected rate of return of portfolio *p*;

w_D = the weight invested in D;

$E(r_D)$ = the expected rate of return of security D;

w_E = the weight invested in E;

$E(r_E)$ = the expected rate of return of security E.

While the calculation of the expected return of the portfolio is a simple weighted average, the portfolio risk calculation is considerably more significant. Portfolio variance and standard deviation are computed as:

$$\sigma_p^2 = w_D^2 * \sigma_D^2 + w_E^2 * \sigma_E^2 + 2w_D w_E \sigma_D \sigma_E \rho_{DE} \tag{2.2}$$

$$\sigma_p = \sqrt{\sigma_p^2} \tag{2.3}$$

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Where:

σ_p^2 = the variance of returns of portfolio *p*;

σ_D^2 = the variance of returns of security D

w_D = the weight invested in D;

σ_E^2 = the variance of returns of security E

w_E = the weight invested in E;

ρ_{DE} = the correlation between securities D and E;

σ_p = the standard deviation of returns of portfolio *p*.

As shown in equation 2.2 above, the portfolio risk is not only comprised of the summation of the individual security's risk but also the correlation between the two securities. Markowitz (1952)

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deemed this is as significant as the correlation between the two securities may result in an increase or decrease in the total risk of the portfolio. The line DE represents the risk and return for all possible investment portfolios consisting of securities D and E, with varying weights invested in D and E, when the correlation coefficient (ρ_{DE}) is equal to 1. When securities have a perfectly positive correlation, the standard deviation of the portfolio is a simple weighted average of the standard deviations of the two securities. Since the expected return and the standard deviation of both securities in the portfolio are simple weighted averages, both values increase linearly with changes in the portfolio weights. This is indicative that the portfolio is void of diversification, that is, the reduction of the total risk of the portfolio by holding assets uncorrelated assets. This may occur if D and E are securities from within the same industry and thus, are likely to be affected in the same way. For example, if both D and E are gold mining stocks and there are reports of gold miners striking, resulting in a halt in productivity at mines, share prices in both D and E will fall, leading to an overall decrease in the value of the portfolio.

When ρ_{DE}< 1, DE starts to bow out leftwards, towards lower risk. At correlation coefficients less than 1, unsystematic (firm-specific) risk is diversified away. Expanding on the previous example, consider E as a pharmaceutical stock instead, with news of a drug capable of curing HIV. This positive announcement would have a converse effect on E's share price compared to stock D, as stock E's price would now rise. The decrease in D may affect the portfolio's performance less significantly depending on the size of the increase in E. This is indicative that firm-specific risks amongst stocks of different industries are negated by each other. As a result of diversification, portfolios on the curve DE are "efficient" portfolios, since each portfolio provides the highest level of expected return for a given amount of risk or the lowest amount of risk for a given expected return.

While the preceding example of mean-variance efficiency is seemingly elegant, it assumes that the investor solely considers the mean and variance when choosing between the two portfolios, the covariance and correlations between assets in all portfolios are determined in a single period, and that both the return distribution and investor utility function are given. These prerequisites are often emphasised when mean-variance efficiency is criticised, as the assumptions are deemed impractical.

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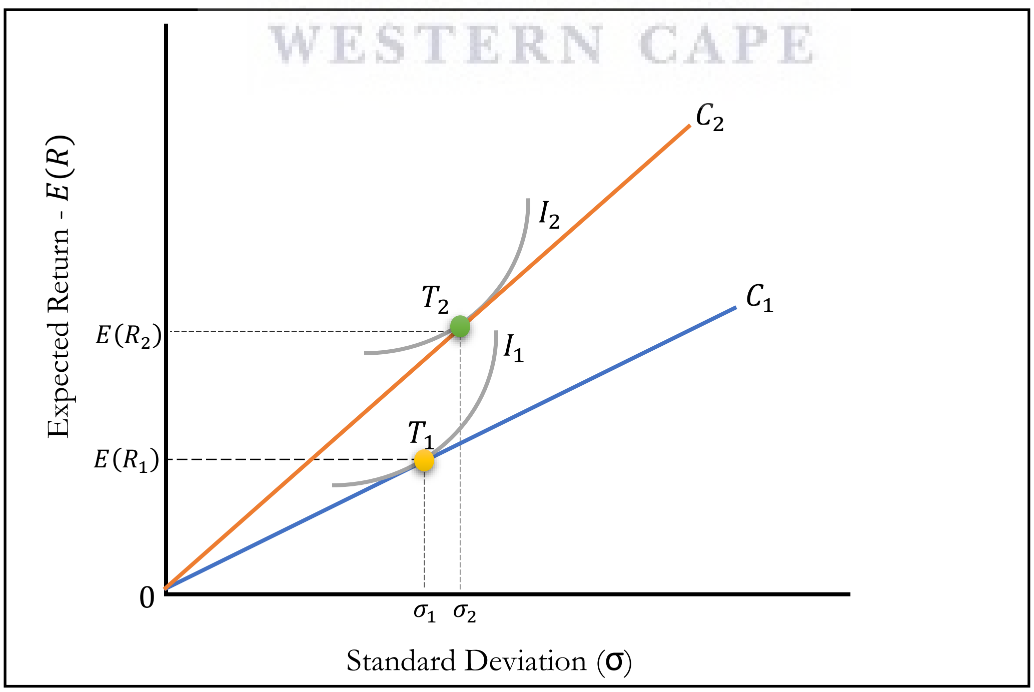
2.3. Tobin's Portfolio Separation

Risky assets are not the only assets that an investor has the decision of investing into. Assets such as Treasury Bills and Treasury Bonds are considered "risk-free" since both assets have a guaranteed rate of return. Therefore, any risk-free asset's variance is 0, with the correlation coefficient between itself and any risky asset equal to 0 as well. The choice that investors make between assets of differing levels of liquidity is described by liquidity preference theory of Keynes (1936). This asset allocation process is further explained by portfolio separation theory (Tobin, 1958) which states that rational investors make investment decisions through a two-step process. Firstly, investors find the optimal combination of risky assets and secondly, include a risk-free asset into this optimal portfolio, to attain the level of risk desired. This theory implies that each investor has an indifference curve which represents their risk-return preferences, as illustrated by Figure 2.2.

Figure 2. 2 Inclusion of risk-free assets into risky portfolios

Figure 2.2 is adapted from Tobin (1958:73). The opportunity loci $0C_1$ and $0C_2$ are representative of combinations of risky assets and risk-free assets. I_1 and I_2 are the investor's indifference curves for differing levels of risk. Investors who are willing to take on more risk will be rewarded with more return (on higher indifference curves), while those who are risk-averse (on lower indifference curves) will earn less return.



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The opportunity loci $0C_1$ and $0C_2$ are representative of combinations of risky assets and risk-free assets while $I_1$and I_2 are the investor's indifference curves for differing levels of risk. Optimal portfolios are found at the point of tangency T between an investor's opportunity locus and indifference curve. The higher indifference curve I_2 is comprised of more risky assets than risk – free assets while the lower indifference curve I_1 is comprised of more risk-free than risky assets. Since investors are assumed to prefer greater returns to lesser returns, all portfolios on I_2 are more desirable to investors than those on I_1, however, this comes at the cost of having to accept greater risk. Tobin (1958) defines those investors on I_2 who accept this greater risk as "risk-lovers" while those investors on I_1 are "risk-averters", opting to accept less risk for a lower return. This shows that the amount of risky assets and risk-free assets held in a particular investor's portfolio is dependent on the investor's appetite for risk.

2.4. Modern Portfolio Theory

Now including the findings made by Tobin (1958), Markowitz (1959) develops Markowitz (1952)'s mean-variance framework further, to find the mean-variance optimal portfolio. This development can be demonstrated by extending the two asset case from Figure 2.1 for N number of risky assets, allowing a multitude of portfolios to be formed. This "investment opportunity set" is bound by a parabolic curve, where the concave down - increasing portion of the curve represents the efficient frontier with the point of inflection as the minimum variance portfolio, as illustrated in figure 2.2. The minimum variance portfolio (point MVP) provides the lowest level of risk for the lowest level of return. Any portfolio on the efficient frontier (curve EF) provides the highest level of return for a given level of risk when compared to any other portfolio within the investment opportunity set.

To demonstrate how the inclusion of a risk-free asset affects the investment opportunity set and efficient frontier, consider an arbitrary risky portfolio, A, and risk-free asset,R_f, presented mathematically in equation 2.4 as

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$$E(R_p) = R_f + \sigma_p \frac{(E(R_A) - R_f)}{\sigma_A} \tag{2.4}$$

Where:

$E(R_p)$	=	the expected rate of return of portfolio p;
R_f	=	the risk-free asset;
σ_p	=	the standard deviation of portfolio p;
σ_A	=	the standard deviation of asset A;
$E(R_A)$	=	the expected rate of return of security A.

This results in a straight line formally known as the Capital Allocation Line (CAL_A), representing all the possible portfolios that may be formed from varied weights of investments in the risky portfolio (A) and risk-free asset. Including a risk-free asset into the risky portfolio A extends the investment opportunity set with new, previously unattainable, portfolios, with lower levels of both risk and return, evidenced by the portfolios available on the CAL between R_f (y-axis intercept, 100% investment in risk-free assets) and the EF curve. However, every portfolio on CAL_A after the intersection with EF is not as efficient as the portfolios above it, which lie on the efficient frontier. Therefore, the line that represents the optimal combination of risk-free assets and risky assets is the line tangent to the efficient frontier, or the Capital Market Line (CML), with the market portfolio (m), at the point of tangency, being a value-weighted portfolio containing all investments within the investment universe. The Capital Market Line is derived mathematically by equation 2.5 as:

$$E(R_p) = R_f + \sigma_p \frac{E(R_m) - R_f}{\sigma_m} \tag{2.5}$$

Where:

$E(R_p)$	=	the expected rate of return of portfolio p;
R_f	=	the risk-free asset;
σ_p	=	the standard deviation of portfolio p;
σ_m	=	the standard deviation of the market portfolio m;
$E(R_m)$	=	the expected rate of return of security A.

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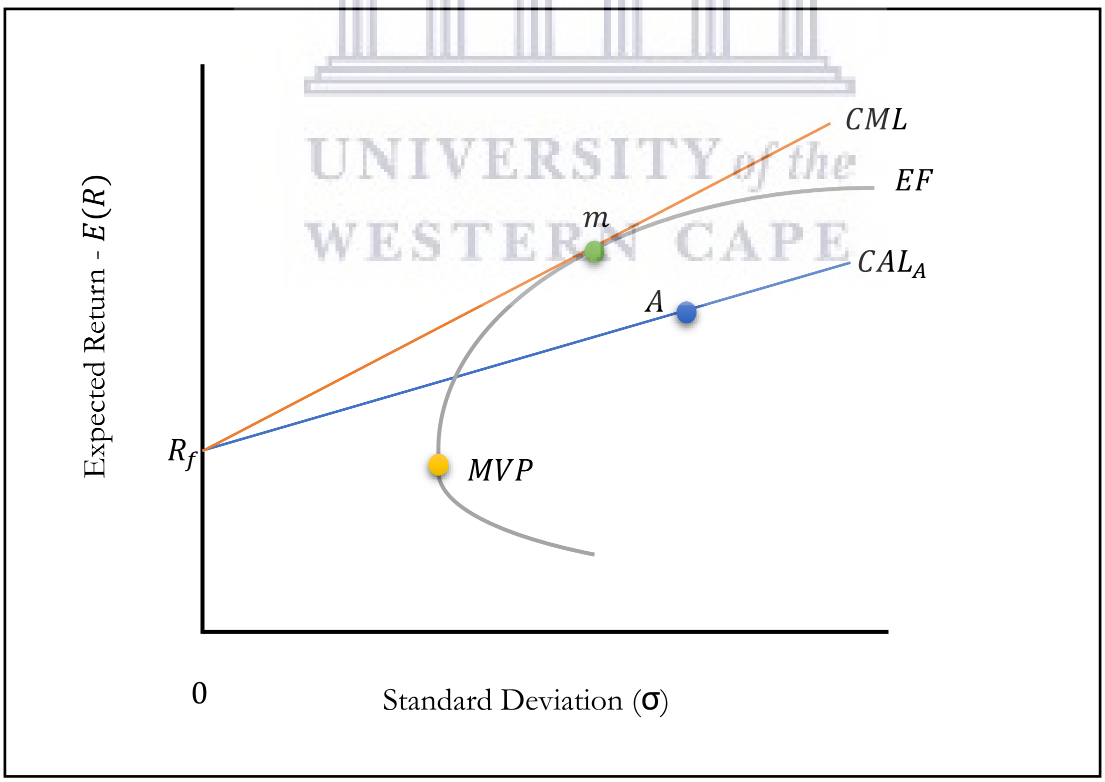
This tangency portfolio maximises the trade-off between risk and expected return, as shown by the slope of the CML, known more formally as the Sharpe ratio. The market portfolio has the lowest risk for any given return and the greatest return for any given level of risk, thus, the market portfolio has the highest Sharpe ratio compared to any other portfolio on the CML. Therefore, Markowitz (1959) suggests that when a riskless asset is available, all rational investors should hold the market portfolio.

Figure 2. 3 The Capital Market Line

Figure 2.3 is adapted from Sharpe (1964:426). It illustrates the result of combining portfolios of risky assets with a risk-free asset, forming the Capital Allocation Line, CAL_A. While any point on CAL_A prior to the intersection of CAL_A and EF were previously unattainable, post intersection, the portfolios on CAL_A are inferior to those on EF. The CAL tangent to the efficient frontier is called Capital Market Line (CML), with the point of tangency m being the market portfolio. This portfolio provides the highest level of risk for any level of return and is thus regarded as the most desirable portfolio for the risk-averse investor.



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2.5. Capital Asset Pricing Model

While diversification reduces the risk of the portfolio, its effects are limited. Sharpe (1964: 426) states that since part of the risk inherent to an asset can be negated via diversification, that particular risk does not significantly influence price. This is logical since investors are to be rewarded for accepting risk and thus, a premium should be allocated to the risk that cannot be avoided, as that is "risk" by definition. It is thus that Sharpe (1964) distinguishes between two types of risk, the diversifiable firm-specific risk, and non-diversifiable market risk. This market risk is represented by β in the Capital Asset Pricing Model (CAPM), an equilibrium model that demonstrates the relationship between risk and return and provides a means of calculating the required rate of return of an asset for a given level of risk. The CAPM is computed as:

$$E(R_i) = R_f + \beta_i(E(R_M) - R_f)) \tag{2.6}$$

Where:

$E(R_i)$	=	expected rate of return of security i;
R_f	=	rate of return of the risk-free asset;
R_M	=	rate of return of the market portfolio;
$(E(R_M - R_f)$	=	the market risk premium;
β_i	=	beta of security i.

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β_i in equation 2.6 above measures the sensitivity of changes of an asset's return to changes in the market portfolio and is computed as:

$$\beta_i = \frac{\sigma_{im}}{\sigma_m^2} \tag{2.7}$$

Where:

σ_{im}	=	the covariance between asset *i* and the market portfolio;
σ_m^2	=	the variance of the market portfolio

The value of beta indicates the strength of the asset's movement with the market portfolio. For a

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beta greater than one, e.g. 1.5, this would be indicative that the volatility of an asset's price movement is greater than that of the market portfolio (or 50% greater than the market for a beta of 1.5), with the converse being true for portfolios with betas of less than one while portfolios with betas equal to one simply move along with the market. Firms with betas greater than that of the market are generally sensitive to changes in the business cycle (such as airline firms) while firms with betas less than that of the market are those in which demand for the product offered or service rendered is relatively inelastic (retail firms). As greater values of beta imply greater risk, this must be accompanied by a greater return.

The CAPM is not unconditional. As assumed by MPT, investors are risk-averse, which means that any rational investor would seek to hold the mean-variance optimal efficient portfolio that maximises their return for any given risk or minimise risk at any given return. Further still, it is assumed that all these rational investors have access to the same information, can lend or borrow at a given risk-free rate, markets are frictionless and investors have the same estimate of means, variances, and co-variances amongst all assets. Sharpe (1964) shows that if all the aforementioned conditions are met, then each and every investor will hold the mean-variance optimal portfolio or more aptly, the "market" portfolio, as the market is said to be in equilibrium.

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Mossin (1966) explains that when graphed, the CAPM is a Security Market Line (SML) which illustrates when asset prices deviate from their equilibrium price. While the CML related expected return to standard deviation (the total risk), the SML relates expected return to beta (market risk). The slope of the security market line shows the risk premium of a given security (reward-to-risk ratio or Treynor ratio). Portfolio m represents the market portfolio, which is a value-weighted portfolio containing all assets in the investment universe.

From equation 2.6, the CAPM predicts a positive and linear relationship between the expected return and beta and as such, the SML is a upward sloping straight line, as illustrated in figure 2.3 below. Securities above the SML are undervalued, as these securities provide a greater return for the amount of systematic risk the investor must accept, while those securities below the SML are overvalued, as these securities provide a lesser return for the amount of systematic risk the investor must accept. As per Jensen (1967), the difference between an undervalued or overvalued security's

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actual return realised and equilibrium expected return is known as alpha (α), as shown in equation 2.8:

$$\alpha_i = R_p - R_f + \beta_i(E(R_M) - R_f)) \quad (2.8)$$

Where:

α_i	=	abnormal rate of return of security i in excess of the equilibrium expected return predicted by CAPM
R_p	=	actual rate of return realised by the security;
$R_f + \beta_i(E(R_M) - R_f))$	=	expected rate of return of security as predicted by CAPM.

This shows that positive alpha exists for undervalued securities and negative alpha for overvalued securities. Consider the overvalued security H and undervalued security L in figure 2.3. Using equation 2.8, security H would generate an alpha of 3.5% (20% - (10%+1.3*(15%-10%)) while L generates an alpha of -4.5% (8%-(10%+0.5(15%-10%)). Thus, in times of disequilibria, investors would exploit these mispriced assets (buy the undervalued and sell the overvalued) until an equilibrium price is established.

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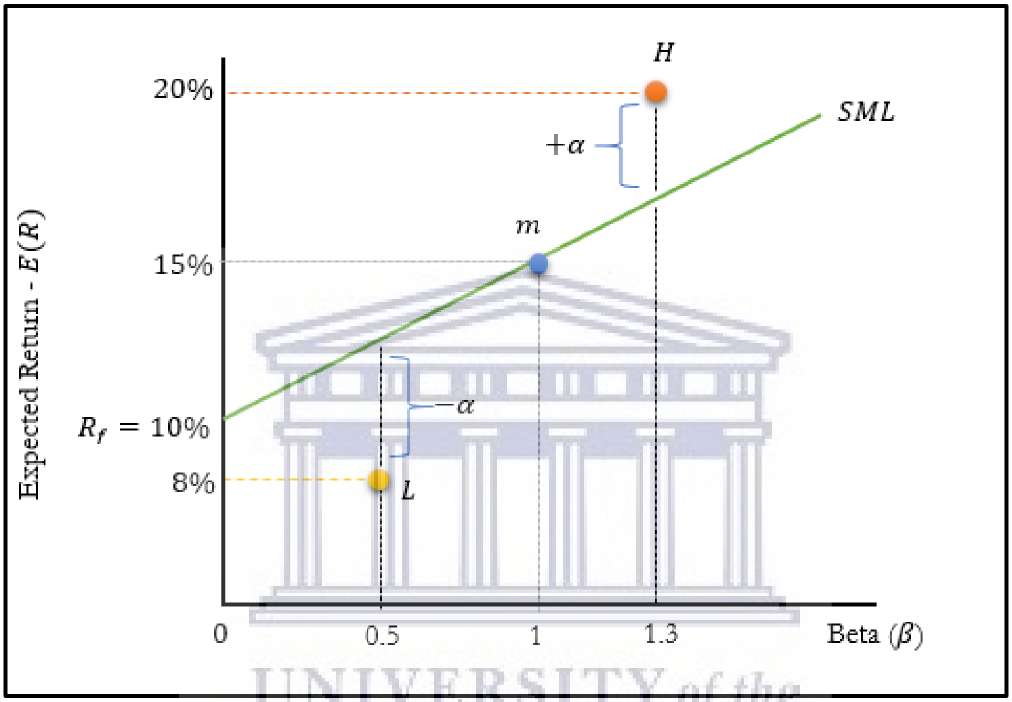
Figure 2. 4 The Security Market Line

Figure 2.4 is adapted from Bodie, Kane and Marcus (2010:195). The Security Market Line (SML) shows the trade - off between systematic risk and expected return for an individual asset or portfolio. Assets above the SML are undervalued while assets below the SML are overvalued.



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2.6. The Efficient Market Hypothesis

As per Fama (1970)'s seminal work on efficient market theory, an asset's price in a financial market is driven by the information associated with that asset. This information is expected to adjust the price of the asset at a rapid rate, as the market is assumed to be comprised of a multitude of investors attempting to profit from incoming information with the further assumption that these market participants have rational expectations, as defined by Muth (1960) as the optimal use of all available information. This would continue until the asset is "efficiently priced", that is, the asset becomes representative of all relevant information available in the market. If all asset prices are expected to rapidly calibrate with the addition of new information, then a market constituted of these types of assets would be described as an efficient market. This implies that an investor seeking to earn returns greater than those offered by the market will not be able to do so without

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incurring greater risk than the market. Furthermore, the use of any technique that attempts to outperform the market, using either price history or public information (examples of which include firm financial statements, public announcements, amongst others) is thought to be an exercise in futility, as the value of the information provided from these sources is expected to be inherent in the asset's price. Since new information is unpredictable, so is the movement of an asset's price, or more formally, asset prices in efficient markets follow random walks (Kendall, 1953; Samuelson, 1965).

While the idea of a matchless market may seem farfetched and impractical, as successful investors such as Berkshire Hathaway's Warren Buffet or Peter Lynch of Fidelity Investments are a testament, it should be noted that the predictability of asset prices varies with the market's level of efficiency, which implies that the performance of market-beating techniques varies in kind. Thus, the aforementioned description of market efficiency would be archetypal of its most absolute (and arguably, most unrealistic) form. Fama (1970:388) acknowledges this, proclaiming "*...security prices at any given point in time "fully reflect" all available information. Though we shall argue that the model stands up rather well to the data, it is obviously an extreme null hypothesis. And, like any other extreme null hypothesis, we do not expect it to be literally true.*" Fama (1970) then proceeds to classify market efficiency into three distinct forms.

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The weak-form of the efficient market hypothesis (EMH) implies that the use of historical information, such as security price or volume, to predict future prices is ineffective. This in turn means that active investment strategies using historical information to predict future stock prices, formally known as technical analysis, would yield no significant returns. While initial findings testing its usefulness were inconclusive (Cowles, 1933; Fama and Blume, 1966), this has not prevented the strategy from being used by financial managers or explored further by academics, the latter of which has produced some supportive results in the literature (see Brock, Lakonishok and LeBaron, 1992; Lo, Mamasky and Wang, 2000). Shifting focus from price history to public financial data, the semi-strong form EMH suggests that the implementation of an active strategy such as fundamental analysis, which refers to the practice of evaluating public information to determine whether the market price of an asset is undervalued or overvalued, would be redundant since all public information available is reflected in the share price in a semi-strong efficient

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market. In contrast to this, early literature suggests that fundamental metrics, such as the Price to Earnings Ratio or Cash-flow to Price ratio, have significant predictive power (see Basu, 1977; Ball and Brown, 1968; Banz, 1981; Fama and French, 1989; Chan, Hamao and Lakonishok, 1991; Lakonishok, Sheifer and Vishny, 1994). The strong-form EMH essentially encompasses all the available information from the preceding weaker strengths with the addition of private information. This form is representative of absolute efficiency, as both private and public information are available to investors, rendering all active management strategies unprofitable.

2.7. Arguments Against Efficiency

From the preceding sections, it is noticeable that MPT, CAPM, and EMH are largely dependent on a number of impractical assumptions and thus, these assumptions have been largely scrutinized by both financial practitioners and academics. Roll (1977) argues that the definition of the market portfolio as per the CAPM makes the market portfolio unobservable and untestable. Sharpe (1964)'s definition of the true market portfolio would include all investable assets from all markets, be it U.S. treasury bonds or a rare Spanish coin from the 1700s. Roll (1977) states that is it improbable to hold all such assets at once and thus, the value of the true market portfolio is unknown.

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Following this, Roll (1977) states that using an index as a proxy for the market portfolio would lead to inaccurate results when testing the CAPM. For example, while the Wilshire 5000 index may include a multitude of securities from the U.S. stock market, it does not include the assets available in all other markets and as such, even this broad index would not be a sufficient representative of the market portfolio. Furthermore, when using a market proxy, false conclusions may be drawn on the mean-variance efficiency of the market portfolio. While tests may find that the market proxy is mean-variance efficient, the actual unobservable market portfolio may be mean-variance inefficient, and vice versa.

Fama (1970) notes that EMH is plagued by the joint hypothesis problem that occurs during tests of market efficiency. This means that any test of market efficiency is also a test of the equilibrium model used as a representative for efficiency. Roll (1978) suggests that due to the problems explained in Roll (1977), the CAPM beta fails to correctly explain asset returns. As the true market

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portfolio cannot be identified, when a market proxy is used instead, the calculated beta would show how risky an asset is relative to the selected proxy, rather than the true market portfolio. Roll (1978: 1056) makes use of a theoretical example to show that selecting different market proxies changes the evaluation of the same portfolio's performance relative to the different security market lines, where the same asset is shown to be both underperform and outperform the market. This implies that the CAPM is a misspecified model.

Other critics attack the EMH definition of efficiency in which prices reflect all information due to all market participants actively seeking to profit from mispriced securities, even though EMH states that the market portfolio would be the optimal portfolio to hold and thus attempting to beat the market would yield no economic benefit. As argued by Grossman and Stiglitz (1980), it is impossible for a market to be efficient as per EMH, following the logic that if market participants believed that the market is efficient, there would be no need to actively seek new information (which will incur costs but no return) and simply buy and hold the market portfolio. Therefore, since new information is not gathered, it is effectively ignored, and firm fundamental prices will differ from its market prices thus leading to market inefficiency.

2.8. Behavioural Finance

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As financial markets are governed by humans, each individual's emotions and uniqueness may impact the way they operate, and since these individuals constitute the market, interactions within the market should reflect human behaviour. Theoretical models such as EMH and CAPM, ignore this facet of the market by assuming that all investors have the same goal, maximising their utility, classing any other behaviour as irrational. Behavioural Finance is the school of thought which makes use of psychology-based theories to analyse stock market anomalies and investment decisions.

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To contextualise this, consider a situation in which a nature-conscious investor has identified a stock that belongs to a firm proven to be involved in pollution. Regardless of whether the stock would benefit the investor's portfolio or not, proponents of Behavioural Finance would suggest that due to the investor's character or belief, the stock would not be selected. This is converse to the rational investor or "homo-economicus" who has unwavering control of their emotions and solely seeks to maximise portfolio returns. When rational and irrational investors value assets differently, Thaler (1999) provides a set of criterion that should hold so that the price of the asset is evaluated correctly:

I. The market should consist of a few irrational investors with limited capital.
II. Costless short-selling should be allowed by the market, such that rational investors may drive down abnormally high prices.
III. Only the rational investors may go short, else rational investors would not be able to restore equilibrium.
IV. With the passage of time, both the rational and irrational investor should agree on the same value of the asset.
V. Rational investor's investment horizon should be long enough to include the aforementioned agreement period.

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In reality, these assumptions are too stringent to be likely. As such, the rational investor's ability to correct prices is limited and thus asset prices fail to reflect its informationally efficient value. It is with this logic that behavioral finance seeks to assist in explaining market inefficiency.

2.8.1. Prospect Theory

Rational investors are assumed to make utility maximising decisions, implying that the risk-averse investors exhibit diminishing marginal utility of wealth and would not accept any prospective opportunities that do not offer a risk premium. Kahneman and Tversky (1979) describe the opposite of the traditional investor archetype, the irrational investor, by observing how investors make decisions under uncertainty, as portrayed by the value function in figure 2.5 below.

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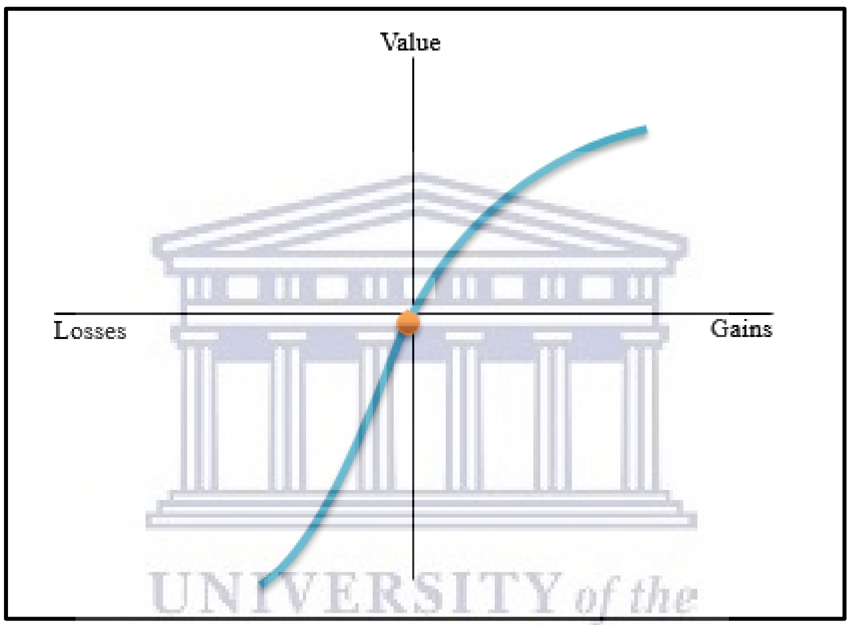
Figure 2. 5 The Value Function

Figure 2.5 is adapted from Kahneman and Tversky (1979:279) and illustrates the S-shaped value function. The slope of the value function measures the sensitivity to change in value, with the greatest sensitivity at the point of inflection (the origin). Sensitivity decreases with increased distance from the reference point. Therefore, for any given change, the effect is greater at the origin than further away from it.



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The orange point at the origin is defined as the reference point, which is typically indicative of the current wealth possessed by the individual and is the point at which gains and losses are estimated. The reference point is psychological and subject to manipulation, as different presentations of the same scenario to the same group of individuals result in different choices (Kahneman and Tversky, 1979). Additionally, gains and losses are not weighted linearly. In the positive quadrant (gains are positive), the curve is concave down and diminishing marginal value exists for gains, with the converse applying to losses. Near the origin, there is a notable kink in the curve, which is indicative of the high sensitivity of investors to small changes in their wealth. Notably, there is a higher sensitivity to losses than there are to gains.

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To demonstrate the idea behind prospect theory, consider an example adapted from an experiment conducted by Kahneman and Tversky (1979) in which individuals participate in fictitious bets which involve selecting between two choices, one with a single certain outcome and the other with two possibilities with equal probability. The first bet being the selection between gaining R240 with certainty or gaining R1000 with a probability of 25% and R0 with a probability of 75%. Results indicate that most participants would select the first option of a certain R240, despite the higher expected value of the second option of R750 $((1000 * 0.75) + (1000 * 0.25))$. Conversely, when faced with the option of losing R750 with certainty or losing R1000 with a probability of 75% and losing R0 with a probability of 25%, individuals tend to select the second option, even though both options have the same expected value of –R750. This behaviour indicates two notable characteristics about how investors make decisions. Firstly, individuals are risk-averse in the face of gains and risk-seeking in the face of losses and secondly, the primary concern of the investor is not that of the terminal value of the asset but rather the risk and return associated with the asset for the duration of the investment period. Both of these results are inconsistent with the behavior of the utility-maximising, rational investor.

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2.8.2. Investor Overreaction

In an efficient market, market prices adjust rapidly to new information, however, if this 'rapid adjustment' results in an incorrect price movement as a result of investor irrationality, the market becomes less efficient. Following the research of Kahneman and Tversky (1982), who show that humans are more sensitive to current information than later information, De Bondt and Thaler (1985) investigate the manner in which investors respond to information. EMH assumes all rational investors assimilate incoming information at the same time and make logical decisions regarding the given information. On the contrary, Kahneman and Tversky (1979)'s research shows that individuals do not always make logical choices, thus De Bondt and Thaler (1985)'s investigation is justified.

If investors are highly sensitive to new information, this results in an equally responsive movement in the share price, effectively creating an inefficienctly priced share. Over time, the market realises that the share is mispriced and thus, the share price reverts to its intrinsic value.

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De Bondt and Thaler (1985) suggest that this process of mean reversion is predictive on the premise that a sizable movement in the share price will be followed by yet another large movement in the share price in the converse direction. The size of the reversal is a function of the size of the initial share price movement.

By classifying portfolios comprised of stocks with extreme differences in performance with respect to capital gains or losses (winners with extreme gains, losers with extreme losses), De Bondt and Thaler (1985) find that winner portfolios would generate a lower return to loser portfolios and loser portfolios generate a higher return for a lower risk, which is in violation of the CAPM (risk-return relation is imbalanced) and EMH (stocks are not priced correctly if such an imbalanced relationship exists). In addition to showing how irrationality results in market inefficiency, these findings also assist in explaining the existence of market anomalies.

2.9. Anomalies

If MPT, CAPM and EMH set the standard for the operations of an ideal financial market, then any inconsistencies would be regarded as irregular or, anomalous. These differentials from classic financial theory may be as a result of the market being inefficient or an incorrect specification of the equilibrium model. While EMH maintains that the market portfolio is the only portfolio that investors should consider, research against this notion has uncovered that trading strategies based on different types of information are capable of generating abnormal returns.

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2.9.1. Momentum and Calendric Anomalies

EMH in its weakest form would predict that the past has no correlation with the present and is opposed to the idea of seasonal or cyclical patterns in prices. Research has however found that stock prices seem to continue to move in a single direction for a considerable amount of time before changing direction and thus, strategies can be formed to take advantage of this. De Bondt and Thaler (1985)'s discovery that loser portfolios earn greater returns than winner portfolios is evidence of a contrarian effect, as the stock price moves conversely to the initial direction of the portfolio at formation (winners steadily fall, losers steadily rise). Jegadeesh and Titman (1993) find similar results in the short-term (1 year) however, portfolios movements are found to continue in the same direction as at portfolio formation, which implies

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that winner portfolios continue to earn greater returns than loser portfolios and vice versa. Both De Bondt and Thaler (1985) and Jegadeesh and Titman (1993) suggest that investor overreaction may be the cause for these anomalies however De Bondt and Thaler (1985)'s results also show that loser portfolios outperform winner portfolios in January, supporting the possible existence of calendric anomalies.

The seasonality of capital markets was notably identified by Rozeff and Kinney (1976). For the equally-weighted New York Stock Exchange index, Rozeff and Kinney (1976) found returns to be significantly larger in January when compared to any other month between 1904 and 1974. This anomaly is known as the "January effect". Not long after Rozeff and Kinney (1976)'s work, a number of other calendric anomalies were discovered for different time lengths. Various researchers have found security returns to be lower during weekends (French, 1980), be positive only during the first half of the month (Ariel, 1987), or positive before holidays (Lakonishok and Smidt, 1988). While Rozeff and Kinney (1976) cannot provide an explanation for their findings, Lakonishok and Smidt (1986) show that the January effect is not prevalent for indices comprised of larger firms, attributing the anomaly to firm size.

2.9.2. Firm Characteristic Anomalies

Markets that are efficient in the semi-strong form of the EMH would deny investors the opportunity to profit from investment strategies centred around public information such as earning announcements, financial statements, and other such accounting information sources. Ball and Brown (1968) investigate if a relationship exists between firm earnings and its stock price, with a specific interest in the timing of earnings announcements and its effect on return. To test this, a firm's actual earnings are compared to an estimate of earnings by means of a time-series forecasting model. Ball and Brown (1968) classify firms relative to their earnings performance, where firms that earn more than the predicted earnings are classified as "*good news firms*" while firms earning below the predicted earnings are "*bad news firms*". Two portfolios comprised of good news and bad news stocks are then formed and the performance of these portfolios are observed pre-announcement and post-announcement. Ball and Brown (1968) find that the good news portfolio earns positive cumulative abnormal returns whereas the bad news portfolio earns negative cumulative abnormal returns. This phenomenon is

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termed post-earnings announcement drift (PEAD). While this is indicative that earnings may be used for predicting returns, it is noteworthy that the performance of good news and bad news portfolios showed no significant sensitivity to the earnings announcement. Ball and Brown (1968) state that about 85% to 90% of abnormal returns occurred before the announcement date, which may imply that other sources of information available to investors are able to explain returns.

Following Ball and Brown (1968)'s finding, Basu (1977) shows that forming portfolios with the security selection criteria based on the firm's price to earnings (P/E) financial ratio can result in abnormal returns. Results from Basu (1977) imply that securities with lower P/E ratios outperform securities with higher P/E ratios, with lower P/E stocks granting greater returns for lower risk. Furthermore, in an effort to test market efficiency, Basu (1977) test how these P/E based portfolios perform relative to portfolios comprised of randomly selected shares with similar risk to the portfolios in the P/E portfolios. The portfolio comprised of low P/E securities outperformed the random portfolio on a risk-adjusted basis. Since stocks of the same level of risk provide different levels of return, Basu (1977) asserts that that is this indicative of market inefficiency and that security prices fail to include the information contained in the P/E ratio. Basu (1977) attributed the excess returns to the sensitivity of the investor's response to changes in earnings, where a series of poor earnings reports results in undervalued securities. Resultantly, Basu (1977)'s findings propelled research into using fundamental ratios to create abnormal-return-generating strategies. Portfolios formed on the basis of high book-to-market (B/M) ratios (Rosenberg, Reid and Lanstein, 1985), high dividend to price (D/P) ratios (Litzenberger and Ramswamy, 1979), and high cash-flow to price ratios (C/P) (Lakonishok, Vishny and Shleifer, 1994) are all found to perform similarly as the low P/E portfolio (or, high E/P) in Basu (1977). The aforementioned examples of outperformance of high accounting value to price ratios relative to low accounting value to price ratios describes the value anomaly.

Further evidence supporting value anomalies uncovered the existence of other market anomalies, of which value anomalies served as a proxy. While confirming Basu (1977)'s prior findings, Reinganum (1980) identifies that once firm size (as measured by market

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capitalisation) is controlled, the P/E effect is no longer prevalent. Notably, Reinganum (1980) finds that when controlling the P/E ratio instead, that smaller firms earn greater abnormal returns than larger firms. This anomaly is known as the size effect. Banz (1981) conducts similar research which supports Reinganum (1980)'s results, asserting that the outperformance of these small-cap stocks is more likely to be a result of a misspecification of the CAPM rather than market inefficiency. It should be noted that Banz (1981) states that while the results show that smaller firms tend to outperform larger firms, the reason for this phenomenon is uncertain and therefore, the size effect may be a proxy for yet another unknown factor, just as the P/E effect was for the size effect before.

With mounting evidence against the CAPM, its misspecification was acknowledged even by efficient market theory pioneers, as evidenced by the work of Fama and French (1992). Maintaining that securities are priced rationally, Fama and French (1992)'s findings suggest that security risk is multidimensional, with firm size and the book-to-market ratio being explanatory variables missing from the CAPM.

2.10. Multi-factor Asset Pricing Models

If the equilibrium model used to test efficiency fails and additional significant variables are discovered that explain returns are found to be consistent, then a newly specified model, which includes the previously omitted variables, should be more accurate. The anomalies presented previously would thus no longer be considered abnormalities since the effects of each variable would be captured in the model.

Ross (1976) introduces an alternative theory to CAPM in arbitrage pricing theory (APT). As opposed to a single factor describing returns, APT states that the expected return of securities can be modeled as a linear function of macroeconomic or firm characteristic specific factors, as shown in equation 2.9 below:

$$E(R_i) = b_1\lambda_1 + b_2\lambda_2 + \cdots + b_k\lambda_k \quad (2.9)$$

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Where:

$E(R_i)$ = expected rate of return of security i

b_k = sensitivity of security i to movements to a risk factor k;

λ_k = risk premium associated with factor k;

The APT does not require the market portfolio as a risk factor and thus, negates the issue of the incapability of observing the market portfolio, as per Roll (1978). While the APT has less stringent requirements than the CAPM, the challenge involved when implementing the APT model is identifying which factors are to be included in the model.

Following Fama and French (1992)'s idea that the value effect and size effect represent risk factors not captured in CAPM's beta, Fama and French (1993) introduce a three-factor model (FF3), mathematically represented in equation 2.10 as:

$$E(R_i) - R_f = b_i\big(E(R_m) - R_f\big) + s_i SMB + h_i HML \qquad (2.10)$$

Where:

$E(R_i) - R_f$ = expected rate of return of portfolio i in excess of the risk-free rate;

R_f = rate of return of the risk-free asset;

b_i = sensitivity of portfolio i to movements in the market;

$(E\big(R_M - R_f\big)$ = the market risk premium;

s_i = sensitivity of portfolio i to movements in the small securities;

SMB = return to portfolio of small-cap securities less the return to portfolio of large-cap securities;

h_i = sensitivity of security i to movements in the value stocks;

HML = return to portfolio of high B/M securities less the return to portfolio of low B/M securities.

FF3 extends the CAPM with the addition of the size premium, SMB, and value premium, HML. Investors are expected to pay a size premium for holding smaller firm's stock, as smaller firms are more susceptible to negative economic shocks than larger firms, implying a negative relation

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between returns and firm size. The logic that warrants a value premium is that firms with higher B/M ratios, or value stocks, are assumed to be in greater financial distress than firms with low B/M ratios (growth stocks) and thus, investors are to be compensated for the additional risk borne. While results from Fama and French (1993, 1996) suggest that value and size anomalies are indeed captured in FF3, the model does not account for short-term momentum. This variable is later added by Carhart (1997), in the Carhart 4 factor model. Research continues in the pursuit of the ideal asset pricing model, as to be elaborated upon further in Chapter 3.

2.11. The Adaptive Markets Hypothesis

Classic capital market theory has failed to adequately explain the cyclical fashion of market efficiency. The existence (and more importantly, persistence) of market anomalies is a testament to the idea that markets do not converge to efficiency as time progresses. In defense, proponents of EMH theory would argue that these anomalies are but a collection of infrequent occurrences that the market eventually adjusts for, dismissing the behavioural perspective almost completely (Malkiel, 2003; Schwert, 2003). In an attempt to explain time-varying market efficiency within a universe that accepts both EMH and behavioral theory, Lo (2004) introduces the Adaptive Markets Hypothesis, an evolutionary approach to financial markets.

As opposed to homo-economicus, Lo (2004, 2005) suggests that investors act with personal interest in mind, are prone to making mistakes, will learn and adapt from these mistakes, and that those investors that make the most suitable adjustments as the environment changes will prosper and eventually define success within the market. These underlying principles of AMH are listed in Lo (2005) as follows:

1. Individuals act in their own self-interest
2. Individuals make mistakes
3. Individuals learn and adapt
4. Natural selection shapes market ecology
5. Evolution determines market dynamics

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Driven by the Grossman-Stiglitz paradox, the AMH implies that arbitrage opportunities do exist, with new exploits being discovered as the preceding one is exhausted. This forces investors to adapt to changes within the market, facing “extinction” otherwise. Some investors make irrational decisions, to their detriment, and are thus forced to exit the market (being “killed off” through natural selection). “Surviving” investors can only ensure longevity through constant innovation, as the financial environment may not always favour the currently prevailing investment strategy. Lo (2005) states that under AMH, any particular variable may be considered a risk factor and as the market changes and its participants adapt, the relationship between risk and return is expected to vary.

These implications are illustrated by Lo (2005) in Figure 2.5, the five-year rolling first-order autocorrelation coefficient for stock returns on a monthly basis for the S&P Composite Index from January 1871 to April 2003.

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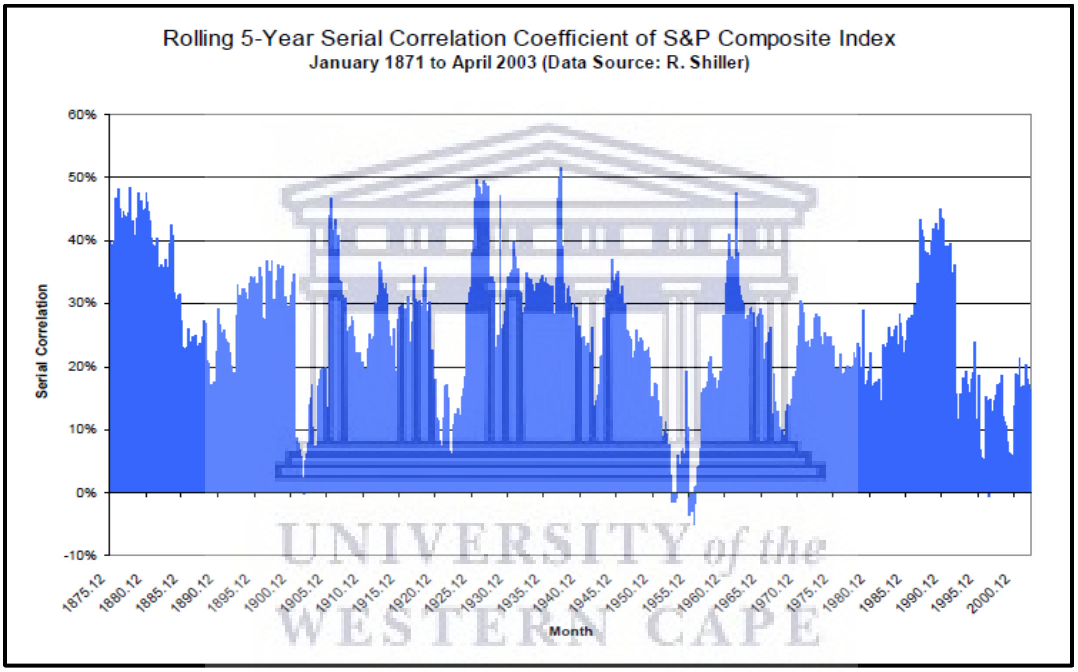
Figure 2. 6 Cyclical Market Efficiency

Figure 2.6 is adapted from Lo (2005:35) and illustrates rolling 5-Year serial correlation of the S&P composite index from January 1871 to April 2003. Efficient market theory would suggest that historic price information has no correlation with future prices, which implies that serial correlation would be 0% across all years. Figure 2.6 however shows that not only is this not the case but also that markets do not become monotonically more efficient with the passage of time but rather that market efficiency is cyclical. This result supports the Adaptive Markets Hypothesis.



Lo (2005) states that if EMH is true, the first-order autocorrelation of monthly returns should be 0 and therefore, there would be no correlation between month t and month t_{-1} or month t_{+1}. If any autocorrelation existed, the EMH would be violated as the information from the previous month could be used to make decisions for the following month. However, it is evident in Figure 2.5 that autocorrelation indeed exists. Additionally, the autocorrelation does not decline monotonically with time but instead, is cyclical. Lo (2004, 2005) suggests that this may be attributed to the population of investors who interact with one another. This can be exemplified by the introduction of e-trading in the 1990s and the Dot Com speculative bubble which burst in 1999/2000. Figure 2.5 shows higher autocorrelation near the 1990s, as the type of traders in the market broadened

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from sophisticated investors who are trained to invest, to any individual able to trade. Thus, when the IT bubble burst, a sharp decline in the autocorrelation is evident, as many of these unsophisticated individuals left the market, leaving the trained investors to bid away any existing arbitrage opportunities, resulting in more accurately (efficiently) priced stocks. While AMH is relatively new compared to EMH, the existing literature supports its ideas, with positive results across global markets.

2.12. Conclusion

The Efficient Market Hypothesis (EMH) states that the market portfolio cannot be succeeded by any other portfolio since the market itself contains all available information. As investors constantly discover new information, the price of the security will adjust and thus, no asset would be unfairly priced. As this implies that the market is unpredictable and that no arbitrage opportunities exist, active management strategies that analyse past price history or company performance are argued to be unprofitable in an efficient market. Assuming that all investors have the goal of maximising return for the lowest possible risk, when this particular mean-variance efficient portfolio is identified, CAPM suggests that it is logical to assume that all investors would hold the market portfolio. Since these concepts have been developed, mounting evidence to the contrary from different perspectives have surfaced. The Adaptive Markets Hypothesis attempts to explain how the deviations from EMH can be explained in a more realistic context.

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3

A Review of Prior Literature

3.1. Introduction

The ongoing debate on the validity of the Efficient Market Hypothesis (EMH) persists as its conclusion has a significant impact on the field of finance. If EMH is true, there are no profitable strategies that beat the market portfolio and therefore no further research into market efficiency or investment management is necessary. Research into the contrary, however, continues to surface, with evidence suggesting that markets are not consistently efficient, allowing different active investment strategies to periodically sustain profitability. Primarily, these results are found in the literature testing the weak and semi-strong forms of EMH.

Weak-form market efficiency tests investigate the forecasting power of past asset prices on future asset prices (that is, if asset prices follow random walks) and tests of the performance of technical analysis, which uses historic data, such as price and volume, to develop trading rules. Various studies employ different methodologies. Linear tests include the variance ratio test, runs test, unit root tests, amongst others. While these methods are simple to conduct, they do not capture nonlinear dependence in asset returns (Hinich and Paterson, 1985). As a result, research in the implementation of non-linear methods such as the Mcleod and Li (1983)'s portmanteau test, Tsay (1989)'s test or Hinich and Patterson (1995)'s window test, garnered greater interest.

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Since semi-strong form market efficiency maintains that publicly available information cannot be used to generate abnormal returns, researchers have tested this hypothesis through the use of firm financial data and other macroeconomic information. From the 1980s, there was an increase in research on the ability of non-risk characteristics in asset pricing models to explain equity returns. Fama and French (1992)'s seminal paper showed that the book-to-market financial ratio and firm size (as measured by market capitalization) were able to explain the cross-sectional variation in equity return where the CAPM beta could not. These findings would then be classed as market anomalies.

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The reasoning behind the existence of these anomalies is a frequently debated topic, with the crux of the argument being the inherent characteristics of asset prices. Either market prices are efficient, meaning that the asset pricing model used as a benchmark fails to incorporate the relevant variables that explain asset returns, or market prices are inefficiently priced due to investor irrationality.

Additionally, it should be noted that traditional tests of market efficiency share a common flaw in that each study tests whether the market is efficient or not during a given period. This is problematic as tests spanning sample periods that overlap may produce conflicting results. A solution to this problem is to observe efficiency as constantly evolving, rather than a steady-state.

The idea of an evolving market, with asset pricing anomalies and irrational investors abound, is described by the Adaptive Markets Hypothesis (AMH) of Lo (2004). This theory, which applies Darwinism to financial markets, has garnered attention recently, with evidence suggesting AMH as a more suitable descriptor for market behavior than EMH. The methodology used for the majority of tests of an adaptive market is similar in nature to those tests of weak-form efficiency, though the results are interpreted from the perspective of AMH, rather than to simply disprove or approve of EMH. A spin-off effect of research into the validity of AMH is increased interest in the use of more sophisticated techniques for creating financial models, such as the use the genetic algorithm for parameter optimization or stock selection, since the AMH suggests that more complex models are more likely to prosper than simpler models.

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This chapter is arranged as follows: Section 3.2 in this chapter discusses the results of traditional market efficiency tests from research conducted in markets across the globe. Section 3.3 discusses the findings of evolving marketing efficiency in different markets. 3.4 reviews the empirical research on using and improving traditional market efficiency in an effort to identify cyclical or evolving efficiency and how an adaptive market may result in periods of opportunity for active trading strategies. Section 3.5 discusses the traditional asset pricing anomalies found in both international and South African markets and the cyclicality of the profits to strategies using these techniques. Section 3.6 reviews the empirical findings on new and innovative methods in active strategy development.

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3.2. Traditional Market Efficiency Tests

As defined by Fama (1970), the weak-form of market efficiency suggests that historic information cannot be used in the prediction of asset price movements, as prices follow random walks. Early investigations of this theory involved the use of serial autocorrelation tests, spectral analysis, unit root tests, variance-ratio test, amongst others, with evidence suggesting that weak-form EMH was indeed valid.

Kendall (1953) found stock returns to follow random walks for the Chicago wheat weekly series between 1883 and 1934, while patterns in stock prices detected in the British Industrial Index and New York monthly cotton prices were considered insignificant, and thus ignored. While Moore (1964) finds similar results to Kendall (1953) for the S&P 500, conflicting evidence between publications from Alfred Cowles (Cowles and Jones, 1937; Cowles, 1960; Cowles, 1962) and Sidney Alexander (1961) prevented consensus on randomness in financial markets. Soon after, Fama (1965) assimilates the ideas presented in the aforementioned research, inter alia, propelling the testing of EMH through serial correlation. This method is still globally prevalent in recent literature, including studies from emerging markets such as South Africa (High and Honikman, 1995), China (Cai, Laurence and Qian, 1997), Greece (Kavussanos and Dockery, 2001), and developed markets such as Germany, UK, and France (Borges, 2010).

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The variance-ratio test of Lo and MacKinlay (1988) assisted in the progression of tests of the weak-form EMH, becoming a popular choice of methodology within the weak-form EMH literature. Hoque, Kim and Pyun (2007) note that this is particularly the case for studies in emerging markets, listing 18 studies between 1994 and 2004 that utilize the variance-ratio test for markets including, but not limited to, those in Brazil, China, and South Africa. While Lo and Mackinlay (1988) show evidence that the VR test is superior to other weak-form tests of its time, such as the Box-Pierce Q test or Dickey-Fuller Test, it has seen significant innovations, as seen by the contributions of Chow and Denning (1993) and Wright (2000).

The aforementioned tests do not consider the possibilities of nonlinear dependence in stock returns. Returns can only be considered truly random if the returns are statistically independent and this requires that both linear and nonlinear functions of returns have no autocorrelation (Granger and

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Anderson, 1978). Exploring this idea, Hinich and Patterson (1985) test if the daily returns of 15 US stocks are generated by a nonlinear process, using the bispectrum test of Hinich (1982), with evidence in support of nonlinearity. Similar research by McLeod and Li (1983), Tsay (1986), and Brock, Dechert and Scheinkman (1996) present different methods, named after the respective authors, of testing nonlinearity that have since been applied extensively. These methods do not, however, test nonlinearity against better a specified linear model, and thus provides minimal insight into the nonlinear dynamics upon rejection of the null hypothesis. In efforts to remedy this drawback, alternative tests such as the autoregressive conditional heteroskedasticity process (Engle, 1982) or self-exciting threshold autoregressive – type nonlinearity model (Tsay, 1989), have been adopted by researchers. With access to these numerous tools, a surge of research into nonlinear serial dependence reported global evidence in support of nonlinearity in stock returns between 1985 - 2005 (Lim and Brooks, 2006).

3.3. Evolving Efficiency

The traditional tests of market efficiency share a common flaw in that each test assesses market efficiency as a steady-state equilibrium over a predetermined period, rather than evaluating the evolving nature of financial markets. Therefore, the conclusions drawn from research with overlapping subsamples may produce conflicting results. While Lo (2004) formalises the idea of evolving markets in an intellectually consistent manner, literature preceding the AMH exists, supporting its proposed ideas.

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One of the earliest studies showing evidence for the evolution of market efficiency is that of Emerson, Hall and Zaleweska-Matura (1997), who test if market efficiency increases with time for the Sofia Stock Exchange in Bulgaria between 1994 and 1996. With a focus on less developed markets, Emerson *et al.* (1997) suggest that market participants in newer markets need time to learn the price discovery process and thus expect the level of efficiency to increase as the market matures. Notably, Emerson *et al.* (1997) employ the Kalman Filter framework which, unlike the methods mentioned in 3.2, allows for time-varying parameters, with a GARCH model for the residuals. By employing this methodology, Emerson *et al.* (1997) are able to assess the current level of market efficiency and speed of convergence to efficiency. Results from this study were in favour of varying efficiency, rather than convergence to it. This method would later be classified

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by Zalewska-Mitura and Hall (1999) as the Test for Evolving Efficiency (TEE). Since Emerson *et al.* (1997), emerging markets have been the main subject of TEE, with research conducted on markets in Central and Eastern Europe (Rockinger and Urga, 2000), China (Li, 2003), and Africa (Jefferies and Smith, 2005). The collective results from these studies are inconclusive as findings vary from suggesting that markets become more efficient with time or switch between states of efficiency and inefficiency.

The evolution of market efficiency has also been tested through the application of the conventional weak-form literature in rolling estimation windows. An early demonstration of this is evident by Cajueiro and Tabak (2004), testing whether long-memory exists in Asian markets, as measured by the Hurst exponent, a static measure of long-range dependence developed by Hurst (1951), applied iteratively with a rolling window between 1992 and 2000. Cajueiro and Tabak (2004a)'s results suggest the existence of episodic long-range dependence in Asian markets, an indication of varying efficiency. In two follow-up studies, Cajueiro and Tabak (2004b, 2005) include both Latin American and US markets into the initial sample, using Lo (1991)'s more robust modified R/S statistic to calculate the Hurst exponent, once again applying a rolling window approach. The results are consistent with the authors' prior findings and the varying efficiency implication of AMH, although the latter is not explicitly mentioned.

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Following Cajueiro and Tabak (2004, 2005)'s findings, Lim and Brooks (2006) use the portmanteau bicorrelation test statistic, of Hinich (1995) and Hinich and Patterson (1996), within a rolling sample, to test the presence of short-term non-linear dependence in a financial time series for 27 emerging markets and 23 developed markets for the period 12 December 1989 – 31 December 2005. Lim and Brooks (2006) find episodic non-linear dependence in all markets tested, with the emerging markets being less efficient than developed markets. While differing in levels of efficiency amongst themselves, all markets shared a common feature of cyclical efficiency. These results are affirmed by a series of follow-up studies by Lim and Brooks (2009a, 2009b, 2009c, 2009d), with the focus on Asian market efficiency rather than global market efficiency.

Popović, Mugoša and Đurović (2013) examine the degree of market efficiency of the Montenegro Stock Exchange over time for the period 13 January 2004 - 31 December 2011, applying a rolling

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sample approach to both the first-order correlation coefficient and the p-values of the runs test. The sample is split into two sub-samples, representing pre- and post- the 2009 global financial crisis. Popovića *et al.* (2013)'s findings are in line with the adaptive markets hypothesis, as the pre-crisis period level of efficiency is found to be lower than the post-crisis period level of efficiency.

While Smith and Dyakova (2013)'s research investigates the martingale hypothesis and relative efficiency of African markets, the authors explain the findings in terms of the AMH. The markets of all countries considered (South Africa, Egypt, Kenya, Nigeria, Morocco, Tunisia, and Zambia) exhibited periods of return predictability and non-predictability between 2 February 1998 – 31 December 2011. Furthermore, Smith and Dyakova (2013) attribute the degree of predictability to market size, liquidity, and quality. Financial markets located in Zambia and Kenya are found to be more predictable than comparatively larger, more liquid markets situated in Egypt or South Africa. This study is replicated in Bulgarian (Dyakova and Smith, 2013) and Middle Eastern (Niemczack and Dyakova, 2013) markets, with identical results. These results are further investigated by Gyamfi, Kyei and Gill (2016) through the use of a non-parametric Generalised Spectral Test (GST) in a rolling-window approach to analyse the returns of indices in Botswana, Egypt, Kenya, Morocco, Mauritius, Nigeria, Tunisia and South Africa for the period 28 August 2000 to 28 August 2015. The results show evidence for AMH as return series for each country showed time-varying predictability. Additionally, a number of the sampled markets do not converge to efficiency with time. Results show evidence for a degression in stock market efficiency with the passage of time in Botswana, Mauritius and, Nigeria while the converse is found for Tunisia and Morocco. South Africa was found to be the least predictable of the eight countries. The authors also suggest the use of rolling windows when analysing stock market efficiency to avoid the incorrect classification of a market's level of efficiency.

Obalade and Muzindutsi (2018) investigate cyclical efficiency in stock markets located in Nigeria, South Africa and Mauritius using the BDS test and variance ratio for the period January 1998 to September 2017. In corroboration with the literature, Nigerian and Mauritian markets exhibited larger periods of predictability while the South African equities market showed smaller periods of predictability.

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Seetharam (2016) tests cyclical efficiency, as described by the AMH, in the South African stock market by running a series of traditional random walk tests and examining return generating processes and trading strategies using data of over five frequencies (including daily, weekly, monthly, quarterly and semi-annual data) from 44 shares and six JSE indices between September 1997 and October 2014. The results of the random walk tests revealed a sensitivity to the frequency of the data, with an increased number of shares exhibiting non-random behaviour at lower data frequencies. While a passive strategy outperformed an active strategy for the sample period, the active strategy experienced periods of fluctuating accuracy which is interpreted by the author as an indicator of time-varying efficiency.

3.4. Exploiting Market Dynamism

If a financial market's efficiency follows an evolutionary pattern, then during the period between changes in the market environment and adaption by its constituents is when the market is least efficient. The profitability of active management strategies during this period of adaption should be particularly greater than any other period. While the studies presented in section 3.3 identified how often financial markets are efficient or inefficient, none investigated which strategies provide the greatest risk-adjusted return. Tests of the performance of traditional technical and modern trading rules are briefly discussed here.

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Prior to the availability of fully disclosed and standardised financial statements, investors would attempt to forecast future asset price movements by searching for patterns in an asset's price or volume. Popularised by the work of Hamilton (1922), the technique would be used by 90% of investment analysts by 1992 (Taylor and Allen, 1992). Technical analysis' appeal is also attributed to its incredible flexibility, as many different trading strategies can be developed through combinations of rules, as extensively reviewed by Bauer and Dahlquist (1998). Despite its popularity, results on the performance of technical analysis in generating abnormal returns have been mixed.

Initial findings from Brock, Lakonishok and LeBaron (1992) support the use of technical analysis in the U.S through tests of the performance of the moving average and trading-range break trading rules against buying and holding the stocks of the DJIA between 1897 and 1986. These results are,

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as acknowledged by Brock *et al.* (1992), exempt of transaction costs and are subject to data snooping, as the two investigated methods were amongst the most popular and historically successful. When these areas of fault are addressed, the results change considerably. Hudson, Dempsey and Keasey (1996) and Bessembinder and Chan (1998) replicate and extend Brock *et al.* (1992)'s study, with the inclusion of transaction costs and find significantly converse results to Brock *et al.* (1992).

The data snooping bias is mitigated by White (2000)'s Reality Check, which seeks to discover the most superior trading rule amongst a wide selection. Given the large number of tested trading rules, survivorship bias is negated as well, a bias which White (2000) attributes to data snooped results. Sullivan, Timmerman and White (1999) implement the reality check to test the validity of Brock *et al.* (1992)'s results, extending both the number of trading rules (from 26 to 8000) and sample period (by 10 years). While in-sample tests supported the existence of profitable trading rules, these results are not reflected out-of-sample.

While emerging markets have been found to be more predictable than developed markets (Harvey, 1995), the performance of technical analysis in these markets is akin to that of developed markets. Recent studies implement Brock *et al.* (1992)'s method in markets situated in Southern Asia (Gunasekarage and Power, 2001; Tian, Wan and Guo, 2002) and Latin America (Parisi and Vasquez, 2000), with results suggesting profitability in technical analysis, however, data snooping and transaction costs are ignored. While investigating eight Asian markets, of which five are emerging markets, Chen, Huang and Lai (2009) find that any results supporting the profitability of technical analysis disappear when trading costs are considered. These mixed results are in accordance with the findings of Park and Irwin (2004)'s review on the evidence of profitability of technical analysis, where 56 of 95 studies considered found positive results for technical analysis, however, Park and Irwin (2004) state these studies used defective methodologies. Although the results are inconclusive, the literature generally does not deny that technical analysis has predictive power, but rather suggests that it is not economically sustainable or more profitable than passive alternatives.

The literature reviewed thus far has been more concerned with the overall performance of the

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technical trading rule, rather than its forecast ability during periods of inefficiency. Todea, Ulici and Silagh (2009) investigate the performance of moving average strategies for several Asia-Pacific equity markets for the period 1997 – 2008. To differentiate between periods of efficiency and inefficiency, Todea *et al.* (2009) use the portmanteau test and bi-correlation test. Todea *et al.* (2009)'s findings suggest that the moving average strategies generated greater excess returns relative to the market during periods of inefficiency. Using the same methodology, similar findings are reported by Todea, Zoicas-Ienciu and Maria-Filip (2009) in European equity markets. These results are in line with the AMH, which suggests that market efficiency varies with time and therefore, strategy performance may be inconsistent as the level of efficiency fluctuates. It should be noted, however, that both results do not explicitly consider risk. Additionally, the methodology employed may be indicative of data snooping, since tests are conducted on a single most optimal strategy, from a selection 15 000.

3.5. Identification of Asset Pricing Anomalies

As previously discussed in section 2.9.2, a variety of firm-specific attributes, such as earnings (Basu, 1977) and firm size (Banz, 1981), have been discovered to have forecasting power when attempting to predict stock prices, with the belief that these variables capture information that the traditional CAPM beta fails to explain. Since then, the possibility of generating abnormal returns from strategies using accounting information has garnered overwhelming interest, as evidenced by the abundance of literature investigating the size and value effect anomalies.

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Firm fundamentals expressed as a fraction of its stock price became the focal point of a majority of the early research into the forecasting power of fundamental variables, establishing a significant positive relationship between the return of common stocks and dividend yield (Litzenberg and Ramaswamy, 1979), book-to-market ratio (Stattman, 1980), debt-to-equity ratio (Bhandari, 1988), among others. Stocks are classified as either value or growth stocks, with higher fundamental to price ratios representing value stocks and low fundamental to price ratios as growth stocks. Under the assumption of rational asset pricing, Fama and French (1992, 1993) suggest that the existence of these anomalies is indicative of missing factors in the CAPM, and provide a three-factor model, including the firm size and book-to-market ratio factors, which captures both the size and value anomalies.

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Conversely, Lakonishok, Shleifer and Vishny (1994) assume investor irrationality and investigate a broad range of fundamental variables (including the book to market ratio, cash flow-to-price ratio, earnings-to-price ratio and sales growth) between 1963 to 1990 for securities on the NYSE and AMEX. Lakonishok, Shleifer and Vishny (1994)'s findings suggest that portfolios formed of value stocks (value portfolios) earner greater returns than growth portfolios, five years post-formation. These findings of abnormal returns are debunked by Fama and French (1996), using the three-factor model from Fama and French (1993).

Fama and French (1993) explained the existence of excess returns earned by small firms with high book-to-market ratios as exposure to unknown risk factors. Conversely, Daniel and Titman (1997) found that it is not exposures that explain the cross-sectional return variation in stock returns but the size and book-to-market ratio characteristics. When characteristics are controlled for, the loadings do not matter.

Shortly after, Fama and French (1998) report results that contrast their earlier findings from 1995, after extending research into the value effect to international markets, now including markets within 12 EAFE (Europe, Australia and Far East) countries. By comparing returns among the market, value, and growth portfolios during the period 1975 – 1995, Fama and French (1998) find that the portfolios comprised of value stocks earn greater risk-adjusted returns than both the market and growth portfolios in 12 of the 13 markets studied. These results were prevalent across markets in countries with differing levels of development, implying that the value effect, and possibly other market anomalies, not only exists in developed markets, but in emerging markets as well.

This was found to be true in some of the earliest works on the presence of CAPM-anomalies in South Africa (see De Villiers, Lowlings, Petit and Affleck-Graves (1986), Bradfield, Barr and Affleck-Graves (1988), Bradfield (1990), Page and Palmer (1993), Page (1996)).

Evidence for a long-run price reversal effect for the Johannesburg Stock Exchange is presented by Page and Way (1992, 1993) who implement the method developed by De Bondt and Thaler (1985) for the Johannesburg Stock Exchange for the period 1972 to 1989. Winner and loser portfolios

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based on 36-month prior cumulative excess returns are formed. The findings suggest that 36 months after formation, the loser portfolios outperform the winner portfolios by 14.5% on average.

Hsieh and Hodnett (2011) further investigate the existence of overreaction in the JSE between 1993 and 2009. The results are similar to that of De Bondt and Thaler (1985) and Page and Way (1992, 1993) as loser portfolios are found to exhibit a more prominent mean reversal than the winner portfolios over the same examination period. Hsieh and Hodnett (2011) suggest that these mean reversals are attributed to behavioural biases such as fear and regret. A finding pertinent to this study is that the mean reversals were found to be cyclical in nature. These findings are corroborated by a similar study of Itaka (2015) who found significant mean reversion in 24-month and 36-month returns along with a decline in contrarian returns from 2007.

Research into the aforementioned anomalies has presented mounting evidence on the variables that are expected to explain returns. Noteworthy work comes from Haugen and Baker (1996) who test more than 50 factors that may explain the cross-section of equity returns in five different developed countries from 1979 to 1993. These "style attributes" were split into different classes including risk factors, liquidity factors, price level factors, growth factors, and price history factors. The findings suggest that the signs and relative significance of the payoffs to the examined factors are consistent over the sub-periods and that none of CAPM or APT variables were deemed significant. Instead, technical and fundamental factors are found to have significant positive signs. Haugen and Baker (2009) extend this study to incorporate a longer examination period from 1963 to 2007. The results are consistent with those of Haugen and Baker (1996).

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One of the earliest works in the investigation of style attributes in the South African context is that of Van Rensburg (2001), who examines 23 different style attributes from shares within the industrial sector from 1983 to 1999. These factors are grouped into value, future earnings and growth, and irrationality or regret. A portfolio-based method is implemented to create factor mimicking portfolios. The results suggest that there are risk premiums associated with value stocks and firms with small market-capitalisation. Van Rensburg and Robertson (2003) extend on their 2001 study through the use of Daniel and Titman (1997)'s characteristic-based approach by cross-sectionally regressing share returns on 24 factors from June 1990 to June 2000. The results from

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the univariate test suggest that a value and size effect exists given significant attributes such as price-to-net asset value, dividend yield, price-to-earnings, cash flow-to-price, price-to-profit, and market capitalization.

These results are corroborated by Hodnett, Hsieh and Van Rensburg (2012) who analyse the univariate payoffs to style attributes on the JSE over the period 1997 to 2007. Similarly to Van Rensburg and Robertson (2003), factors are divided into five categories: fundamentals values relative to share price, solvency and liquidity, fundamental growth, size and return momentum, and consensus analyst forecast. Hodnett, Hsieh and Van Rensburg (2012) find that all style attribute categories besides those factors in the solvency and liquidity categories are significant.

These findings are of particular interest to this thesis as the literature suggests that there is a set of variables that consistently explains returns from at least 2001. If AMH is to have any validity, the effectiveness of these attributes is expected to be cyclical.

3.6. Cyclical Profitability

The effectiveness of technical and fundamental analysis within the context of the efficient market hypothesis has yet to conclude. Given that the debate is still ongoing, Lo (2004)'s adaptive markets hypothesis provides a solution in the suggestion that active strategies may be profitable, albeit cyclically, as market participants learn and the economic environment changes.

As researchers discover and publish their findings on possible methods of outperforming the market, investors would attempt to use this knowledge to their advantage. In doing so, the effectiveness of those strategies falls to levels that are no longer considered abnormal. This effect, known as publication bias, is among many of the arguments against the usefulness of active strategies. This finding is notably presented by Schwert (2003). Analysing most of the popular anomalies discovered, and testing its performance out of sample, Schwert (2003) finds that seasonal, value, and size effects attenuate shortly after its publication, as investors implement techniques inspired by findings of profitability presented in academia. Similarly, Moosa (2007) tests the January effect during 1970 – 2005 in the U.S., and while the anomaly had disappeared between 1990 and 2005, a prominent negative July surfaced during its absence.

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Similar conclusions have been found for technical analysis. Olson (2004) studies the profitability of moving average rules in currency markets for the period 1971 to 2000, finding that the successful strategies developed during the 1970s and 1980s had lost its profitability by the early 1990s. Additionally, Olson (2004) suggests that this finding may be indicative of temporary inefficiencies being corrected and that more complex trading rules may need to be developed in order to outperform the market. Neely, Wellar and Ulrich (2007) confirm Olson (2004)'s result, with the additional finding that while the renowned or classic technical trading rules (moving averages and filter rules) no longer showed signs of profitability, the more sophisticated and less studied technical trading rules were still profitable, albeit declining.

These findings that suggest the dissipation of active strategies support the AMH, since this process is expected by the theory. Indeed, Timmerman and Granger (2004) state that those who discover profitable strategies will be able to exploit them for an extended period of time, as the market is unlikely to adjust instantaneously. However, the aforementioned tests are centered around the consistency of the strategy, rather than its ability to be profitable again after a period of underperformance. While these studies provide evidence that there are opportunities for active management to be profitable, it does not fully explore the AMH's implication of adaptation or cyclical profitability.

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In an effort to explicitly test this, Butler and Kazakov (2012) observe cyclical effectiveness of trading strategies, where an effective strategy is defined as a profitable active strategy that outperforms the market. To test this, a variation of a classic technical trading indicator, the Bollinger Band, is combined with Particle Swarm Optimization (a population-based algorithm), forming an Adaptive Bollinger Band (ABB). Tests are conducted using data from the S&P 500 index for the period 2001 - 2010, where the first five years are used to train the ABB. Butler and Kazakov (2012) find that the ABBs experienced both periods of activity and inactivity, as the optimal parameter from a previous period may not be suitable for the next period's market environment, resulting in fewer trades. The ABB's ability to maintain profitability while outperforming the market varied with time as well. Thus, Butler and Kazakov (2012) conclude that these results are indicative that an active strategy fit to a particular period may be effective in

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a future period and that through innovation, investment strategies may be enhanced to accentuate its earnings potential.

3.7. Active Strategy Innovation

Lo (2004) asserts that if an investor is to be successful in an ever-changing market environment, this would be achieved through constant innovation. Considering the notion of cyclical profitability, Butler and Kazakov (2012) suggest that an investor developing a model should not ignore the information present in previously profitable methods, as a method with deteriorating performance may still contain some valuable information. Therefore, a suitable method of active strategy formation should be one that learns from historical information and makes adjustments as the situation changes. This can be achieved through the use of the genetic algorithm, an evolutionary computing technique of Holland (1975). The genetic algorithm has recently garnered attention within the context of financial markets, being used for trading rule optimization, trading rule discovery, and return forecasting.

Fernández-Rodríguez, González-Martel and Sosvilla-Rivero (2001) test the profitability of technical analysis using daily data from the General Index of the Madrid Stock Exchange for the period 2 January 1972 – 15 November 1997. A genetic algorithm is implemented to discover the optimal parameters of the general moving average trading rule in-sample, test its out-of-sample performance, and compare this performance with that of a buy and hold strategy. Fernández-Rodríguez *et al.* (2001) find that the evolved general moving average trading rules outperform the risk-adjusted buy and hold strategy after transaction costs as well as both in and out-of-sample.
Also focused on optimisation of a moving average strategy, Papadamou and Stephanides (2007) present similar results to that of Fernández-Rodríguez *et al.* (2001), using data from a UBS mutual fund which invests in various emerging countries (South Korea, Brazil, Taiwan, South Africa, Russia, India, amongst others) for the period 1 May 1998 – 25 June 2004. Papadamou and Stephanides (2007) compare the returns from the evolved strategy to those of funds using alternative software, including "*FinTradeTool*" of Papadamou and Stephanides (2003) and Computer Asset Management's "*MetaStock*". The results show that the strategy evolved through the genetic algorithm completed optimisation in less than half the time of both alternatives, beating MetaStock's return and underperforming that of FinTradeTool. These results do not examine the

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risk associated with these strategies, though Papadamou and Stephanides (2007) do explicitly state that the purpose of their research was not to test the validity of technical analysis as a profitable investment strategy, but rather to show that the genetic algorithm is powerful for parameter optimisation. Finally, Papadamou and Stephanides (2007) state that the genetic algorithm's crossover rate does not impact the results of the solutions and rather that the population size is of greater significance.

These results, however, do not compare the performance of the evolved models to those of the classic, simpler models, and thus, do not provide insight as to whether the additional effort involved in the evolution of the moving average indicator is justifiable. Additionally, only one trading rule is tested out-of-sample in each study, as opposed to two or more, which provides no confirmation on the validity of the trading rule (Murphy, 2000).

Mahfoud and Mani (1996) test the capability of both the genetic algorithm and neural network in forecasting the return of individual stocks twelve weeks into the future. The models assess more than approximately 1600 stocks and use 15 attributes from both technical and fundamental analysis to determine which direction a stock will take. In comparison to S&P500, S&P400, and Russell 2000, the returns produced by both the genetic algorithm and neural network outperform the aforementioned three market indices, with the genetic algorithm producing the best results overall when tested individually. Similar results are presented in a follow-up study by Mahfoud, Mani and Reigel (1997), showing that the nonlinear methods significantly outperform a linear regression model, the latter of which produced no predictive power. Furthermore, Mahfoud, Mani and Reigel (1997) attribute the linear regression's poor performance to its popularity and ease of implementation, suggesting that this issue does not exist for more complex nonlinear models. This finding is in line with the AMH's implication that innovation is the key to survival.

Yiyi and Nuñez (2012) explore the use of the genetic algorithm in an attempt to develop a trading system that is able to adapt to changing market conditions. The evolving trading models optimise indicators, from both fundamental analysis (10 different variables) and technical analysis (4 different variables), which trigger buy, neutral or sell trade commands for stocks belonging to the S&P 500 between 1986 and 2006. For example, the genetic algorithm finds the correct upper and

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lower threshold values for the “Price-to-Book Value” fundamental indicator, where a long trade is executed if the company’s ratio is below the lower threshold value (representing an underpriced stock). To compare the performance of static and evolving strategies, the in-sample optimal solutions found by the GA are tested out-of-sample, while the evolving strategy continues to optimize the indicators after its training period. Additionally, both static and evolved strategies are compared to a passive investment strategy. Yiyi and Nuñez (2012)’s findings suggest that the evolved strategy based on fundamental analysis can significantly reduce the risk of investing in individual stocks and thus earn greater risk-adjusted returns than either its static counterpart or a passive strategy, while no significant results from the technical trading systems are reported. Notably, both the evolved fundamental and technical trading systems outperformed their respective non-adaptive versions, supporting the AMH’s claim that innovation is required for continued success.

3.8. Conclusion

Proponents of the Efficient Market theory assert that stock prices move unpredictably. There is however mounting evidence of the contrary from sources conducting research in different parts of the world. In an effort to reconcile the arguments presented both for and against the idea of an efficient market, Lo (2004) introduces the Adaptive Markets Hypothesis, presenting ideas of evolving efficiency and cyclical profitability.

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As a formal approach to testing the AMH has not yet been established, a number of different methods have been documented. While linear dependency tests are amongst the most popular in the earlier AMH tests, more advanced non-linear techniques have been adopted in the more recent literature.

This chapter reviews significant prior research and provides insight on the current body of knowledge pertinent to this study. Thus far, there is evidence that, globally, markets do go through periods of inefficiency and that there are factors that explain the cross-section of returns in South Africa. This provides sufficient motivation to investigate if South African equity markets experience similar cycles and if the factors that have previous proven to explain returns have the same or wavering predictive power.

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4

Data and Methodology

4.1. Introduction

Over the past 50 years, thousands of academic articles have examined Fama (1970)'s Efficient Market Hypothesis (EMH), using different methods to test its validity as a theory explaining market behaviour. The support for EMH that prevailed during the 1960s and 1970s had withered from the 1980s as a result of the voluminous number of research papers discovering that stock returns are not independent (rejecting weak-form EMH) and that publicly available financial information is useful in the prediction of stock returns, enabling the formation of alpha-generating investment strategies (rejecting the semi-strong strong EMH). As of present, the financial community has yet to reach an agreement on the efficiency of financial markets.

Lo (2004) suggests that the theory of efficient markets has been incomplete all along, giving rise to the confusion that surrounds the topic. Introducing the Adaptive Market Hypothesis (AMH), Lo (2004) suggests that efficiency should be observed as constantly evolving with the passage of time, rather than the steady-state the that market should maintain. By adding the elements that the EMH denies as valid (active strategy profitability and investor irrationality) into the same universe and justifying its existence through evolutionary principles, Lo (2004) believe that AMH becomes a more practical description of financial markets.

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While the AMH has recently garnered attention in the literature, research is comparatively dearth relative to the theories it attempts to reconcile, namely EMH and behavioural finance. This thesis seeks to reduce the scarcity in AMH-related literature by applying it to a South African financial market.

Research conducted in South African financial markets has identified that a variety of style attributes can explain the cross-section of equity returns and that these attributes may be used to develop expected return factor models. Furthermore, recent research indicates that value stocks outperform growth stocks in a cyclical manner on the JSE (Graham and Uliana, 2001). These works serve as the motivation to discover if profitable strategies exist and if these strategies earn

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consistent returns or do strategies require regular adaption, as the adaptive market hypothesis suggests.

4.2. Problem Statement and Research Objectives

This research attempts to discover whether the Adaptive Market Hypothesis theory is applicable in the South African financial market and explores the innovation and cyclical profitability implications of the Adaptive Market Hypothesis theory. This is achieved in two parts: first by determining if returns follow a random walk or not and second by analysing the consistency of technical and fundamental factors to explain the cross-section of equity returns between 1 January 1998 to 31 December 2017.

This thesis seeks to discover whether the adaptive market hypothesis (AMH) is a better description of market behaviour than the efficient market hypothesis for the South African stock market, with a particular interest in the AMH's suggestion of the presence of short-term profitability and constant innovation to maintain a profitable position.

The objectives of this research aim to:

1. Identify candidate firm-specific style attributes that possibly explain the cross-sectional equity returns on the JSE for the sample period 1 January 1998 to 31 December 2017.
2. Estimate the cross-sectional factor payoffs to the firm-specific attributes for the sample period to determine which variables have significant explanatory power and how consistent this explanatory power is.
3. Identify if the JSE is an efficient or adaptive market.
4. Identify if strategy innovation is required for consistent profitability.

4.3. Data and Sample Selection

The research sample is comprised of 153 shares included in the JSE/ALSI index for the period 1 January 1998 to 31 December 2017, a total of 240 months. This study duration is of a sufficient length to observe and compare different market conditions and fluctuations in the market over both longer and shorter periods of time. Monthly data for closing sample share prices and 22 firm-

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specific attributes grouped into 5 categories (fundamental values relative to share price, solvency and liquidity, fundamental growth, operating performance, and size and return momentum) were extracted from I-Net Bridge and StockGround databases. These attributes are grouped and tabulated in Table 4.1. These variables have been selected to observe if the previously documented findings are consistent with the passage of time and to what extent those results can be explained by AMH. The number of included shares is limited by the availability of those that possess the required data across for all categories for the sample duration.

Table 4. 1 List of Firm-Specific Style Attributes

The 22 style attributes are grouped into 5 categories, namely, fundamental values relative to share price, size and return momentum, fundamental growth, operating performance, and solvency.

No.	Descriptor	Style Attribute
FUNDAMENTAL VALUES RELATIVE TO SHARE PRICE		
1	BVTP	Book value-to-price
2	SALESTP	Cash flow-to-price
3	DY	Trailing dividend yield
4	HEY	Headling Earnings Yield
SIZE AND RETURN MOMENTUM		
5	MOM1	1-month cumulative return momentum
6	MOM3	3-month cumulative return momentum
7	MOM12	12-month cumulative return momentum
8	MOM24	24-month cumulative return momentum
9	MOM36	36-month cumulative return momentum
10	MOM48	48-month cumulative return momentum
11	MOM60	60-month cumulative return momentum
12	LSIZE	Log of market capitalisation
FUNDAMENTAL GROWTH		
13	YOYSALES	Year-on-Year Sales Growth
14	YOYHEY	Year-on-Year Headling Earnings Growth
15	PEG	PEG Ratio
OPERATING PERFORMACE		
16	NPM	Net profit margin
17	TAT	Total Asset Turnover
18	ROE	Return on Equity
19	ROIC	Return on Invested Capital
SOLVENCY		
20	DtE	Debt-to-Equity ratio
21	DtM	Debt-to-Market ratio
22	DebtRatio	Debt Ratio

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The fundamental values relative to share price category assists in the identification of value and growth stocks, where value stocks are those stocks with relatively smaller fundamental value to share price ratios compared to growth stocks. Return-momentum measures the growth rate in the total return index of the sample shares. The size attribute refers to the natural log of the market capitalization of the sample shares, serving an indication of its current market value. The size and return momentum style attributes are share price-sensitive factors. The style attributes under the fundamental growth category refer to the historical growth rates of headline earnings, diluted headline earnings, sales, and earnings before interest, taxation, depreciation and amortization (EBITDA). Net Profit Margin in the operating performance category provides insight into the firm's operational profitability while ROE and ROIC are indicators of the sustainability of profits in the company. Total Asset Turnover shows the operating efficiency of the shares within the sample. The solvency ratios are indicators of the individual firms' financial positions.

4.4. Possible Research Biases and their Remedies

When working with financial data, a number of issues exist that may lead to the misrepresentation of the sample. These included biases such as the existence of outliers, data-snooping, survivorship bias, and look-ahead bias. The effects of these biases must be mitigated such that accurate conclusions are drawn from the data.

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In an effort to minimize the effect of outliers in the dataset, the variables are winsorised such that the largest and smallest values of the variables are set as the 99.5^{th} and 0.5^{th} percentiles, respectively. This assists in preventing shares with extraordinary values from indicating false buy or sell signals.

Data-snooping bias refers to the practice of conducting research in a manner in which the reported results are spurious since the data has been vigorously used until a pre-specified desired result is attained. These types of results have very little value and thus, data-snooping is best avoided. A common approach to validating results is to conduct out-of-sample tests, with the idea being to observe if the results from the in-sample are consistent with data other than the in-sample data.

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The selected sample should be a suitable representation of the population it portrays, with no exclusions. In the financial context, databases that fail to include the relevant information of firms that are no longer in existence (for example, due to delisting or bankruptcy) would be subject to survivorship bias. In this study, the data for any security in the sample is recorded until the time of delisting or suspension, and therefore, survivorship bias is not expected to impact the research.

Look-ahead bias refers to the situation in which the data required to conduct the research was not available during the period under study. For example, back-testing the performance of a trading strategy based on an annual earnings figure that was only available three months after the trade was made would provide a false indication of the strategy's predictive power. Firms in South Africa have varying fiscal years, however, Stockground does not update the data accordingly. Instead, interim financial reports are captured in April while end-of-year reports are recorded in October. To mitigate look-ahead bias, the data extracted on the firm-specific attributes is delayed by 3 months of its capture date in Stockground. As an example, consider that African Bank Limited's (ABL) financial year ends in September, with its data recorded and updated by Stockground in October. The financial data recorded in October is then shifted forward 2 months, to December, to create a 3-month delay. Finally, any interim report values are converted to annual values by adding the previous year's financial year-end value to the current interim report value.

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4.5. Overview of the Research Methodology

As per the Efficient Market Hypothesis, market efficiency requires the independence of stock price movements and unpredictability in returns. Conversely, the Adaptive Markets Hypothesis suggests that these requirements are unlikely and proposes instead that variable levels of market efficiency present opportunities for non-periodic cyclical profitability, the implications of which this thesis seeks to test.

While the adaptive markets hypothesis has no formal methodology, prior works within the literature apply techniques that can be used to test for adaptation, regardless of whether the adaptive markets hypothesis was explicitly referred to or not. As such, this thesis adopts and modifies techniques from several sources including Hiremath and Kumari (2014) for the selection

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of suitable statistical tests used for the analysis of stock price independence; Fama and Macbeth (1973), Haugen and Baker (1996), Hodnett, Hsieh and van Rensburg (2012a), Hodnett, Hsieh and van Rensburg (2012b) for the research design of estimating and examining the consistency of the payoffs to firm-specific style attributes. The tests are split into two phases; sub-section 4.5.1 describes tests examining time-varying market efficiency while sub-section 4.5.2 describes the univariate test used to estimate the monthly cross-sectional payoffs for each style attribute. More detail on the methods described in these subsections is provided in their respective chapters.

4.5.1. Time-Varying Market Efficiency

The first series of tests examine the idea of time-varying market efficiency, as the possibility of profitable strategies relies on inefficiencies in the market and thus, if there is no indication of inefficiency, testing for the presence of abnormal profits would be redundant.

This study makes use of popular test choices within the literature including the Ljung-Box test, Jarque-Bera test, Quantile-Quantile plots, Runs test, and three versions of the variance-ratio tests. These tests are easily recognisable as classic tests for stock price randomness used in tests for weak-form market efficiency, selected as such as each subsequent test is in furtherance of the test preceding it.

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4.5.2. Cyclical Profitability

Adaptive markets theory suggests that the speed of adjustment is not instantaneous, as suggested by the efficient markets hypothesis, thus allowing active managers to earn profits that are expected to decay with time. Thus, the second phase of testing focuses on the existence of cyclically profitable strategies. Different strategies are expected to have varying levels of effectiveness in different environments and to maintain profitability, the active manager is required to adapt to changing market environments. To test this, a univariate test is conducted on each of the style attributes listed in Table 4 for two sub-periods as well as over the entire examination period.

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To examine the sensitivity of the cross-sectional sample share returns to each of the style attributes over the examination period 1 January 1998 – 31 December 2018, a univariate test using the Fama and Macbeth (1973)'s two-step linear regression model is conducted. By implementing the ordinary least squares method, the cross-sectional factor payoffs for each month are estimated, regressing the return of each of the sample shares in month t+1 on each of the lagged style attributes in month t, with this process being repeated over the entire examination period 1 January 1998 – 31 December 2017.

To test each of the style attributes' relative significance in explaining the cross-sectional returns, the time-series average payoff to each style attribute is subject to Student's t-test at a 5% significance level.

Additionally, the binomial sign test is conducted to test for the consistency of the signs of the payoffs to the style attributes. The sign tests assume that there is an equal amount of values less than and greater than the median, therefore, the null hypothesis for the sign test is that the median of each style attributes' factor payoff is equal to zero.

Finally, the cumulative payoff for each style attribute over the entire examination is calculated and graphed.

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5

Stock Return Dependency Tests

5.1. Introduction

A series of five tests in this chapter serves to identify if price changes follow a random walk or not. Furthermore, if any evidence for stock return dependence exists, the prevalence of this dependence is observed to identify possible cyclical efficiency. Evidence of non-random behaviour here will motivate an attempt to explore it in the following chapter.

After calculating the descriptive statistics, the Jarque-Bera test and Quantile-Quantile methods are conducted to test if the 153 sampled stock returns are normally distributed for the period 1 January 1998 to 31 December 2017.

To determine if the sampled stock returns follow a random walk for the period 1 January 1998 to 31 December 2017, the Ljung-Box test, Runs test, Lo and Mackinlay (1988) variance ratio test, Wright (2000) variance-ratio test, and Chow Denning (1993) multiple variance-ratio test techniques are employed.

Findings from the sub-periods are observed for possible indications for cyclical efficiency. If stock returns change from following a random walk to a predictable pattern or vice versa, this may be indicative that efficiency is time-varying.

5.2. Descriptive Statistics and Methodology

The mean, standard deviation, minimum, skewness, and excess kurtosis are calculated for 153 stocks in the sample for both sub-periods and the entire sample period.

As total return data is non-existent for 32 shares in the first sub-period, the first sub-period's sample size is 121.

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This study makes use of popular test choices within the literature including the Ljung-Box test, Jarque-Bera test, Quantile-Quantile plots, Runs test, and three versions of the variance-ratio test.

5.2.1. Ljung Box test

The autocorrelation coefficient measures the relationship between a random variable's past and present values, where zero autocorrelation is indicative that the series behaves as a random walk. The Ljung and Box (1978) portmanteau Q statistic, shown in equation 5.1, is implemented to test the joint hypothesis that all autocorrelation coefficients are simultaneously equal to zero.

$$LB = n(n+2)\sum_{k=1}^{m}\left(\frac{\hat{\rho}_k^2}{n-k}\right) \quad (5.1)$$

Where:

n	=	number of observations
m	=	maximum number of lags included in the test
$\hat{\rho}_k$	=	autocorrelation at lag k

The test follows a chi-square distribution with the null hypothesis being rejected for p-values greater than 0.05.

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5.2.2. Runs test

This paper uses the runs test to examine if successive monthly stock returns are independent. A run is defined as a maximal subsequence of like elements. Within the financial context, stock prices may rise, fall, or remain unchanged, thus defining three possible run types.

A series may be deemed random if the expected number of runs is similar to the actual number of runs. The expected number of runs and variance of runs is calculated using formula 5.2 and 5.3 respectively;

$$E(u) = \frac{2PN(P+N)}{P+N} + 1 \quad (5.2)$$

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Where:

$E(u)$	=	expected number of runs
P	=	number of positive runs
N	=	number of negative runs

$$\sigma^2 = \frac{2PN(2PN-P-N)}{(P+N)^2(P+N-1)} \qquad (5.3)$$

Where:

σ^2	=	variance of runs
P	=	number of positive runs
N	=	number of negative runs

A z-test is conducted to test if stock price movements are independent at the 5% significance level, with the z-statistic computed as:

$$z = \frac{R-\hat{R}}{\frac{s}{\sqrt{n}}} \qquad (5.4)$$

Where:

z	=	z-statistic
R	=	observed number of runs
$\hat{R}$	=	expected number of runs
s	=	standard deviation of runs
n		number of runs

5.2.3. Lo and Mackinlay Variance Ratio Test

The variance ratio (VR) test of Lo and Mackinlay (1988) has become one of the primary methods of testing whether stock returns are serially correlated or not. According to random walk theory, if a time-series follows a random walk, then the variance of the q-period difference should be q times the first difference, for example, the variance of a 5-day return is equal to the variance of 5 times the variance of the daily return. This is shown in equation 5.5;

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$$Var(p_t - p_{t-q}) = qVar(p_t - p_{t-1}) \quad (5.5)$$

Where:

$Var(p_t - p_{t-q})$	=	variance of q-period return
$Var(p_t - p_{t-1})$	=	variance of the first period return
p_t	=	stock price at time t
p_{t-1}	=	stock price at time $t-1$

Following this, Lo and MacKinlay (1988) suggest that for a finite number of $nq + 1$ successive stock price movements, the ratio of $P_t - P_{t-1}$ to $\frac{1}{q}$ times the variance of $P_t - P_{t-1}$ should provide insight into whether the stock price follows a random walk. Defining estimators for the mean and variance of the first difference and the q^{th} variance in equations 5.6, 5.7, and 5.8 respectively, the variance ratio is determined in equation 5.9:

$$\hat{\mu} = \frac{\Sigma(p_t - p_{t-1})}{nq-1} \quad (5.6)$$

Where:

P_t	=	current price of stock
P_{t-1}	=	previous period's stock price
n	=	number of stock price movements
q	=	qth difference

$$\hat{\sigma}^2(1) = \frac{\Sigma(p_t - p_{t-1} - \hat{\mu})^2}{n-1} \quad (5.7)$$

Where:

P_t	=	current price of stock
P_{t-1}	=	previous period's stock price
n	=	number of stock price movements
$\hat{\mu}$	=	mean of first difference

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$$\hat{\sigma}^2(q) = \frac{\Sigma\left(p_t - p_{t-q} - q\hat{\mu}\right)^2}{q(nq+1-q)(1-\frac{q}{nq})} \tag{5.8}$$

Where:

P_t	=	current price of stock
P_{t-1}	=	previous period's stock price
n	=	number of stock price movements
$\hat{\mu}$	=	mean of first difference
q	=	q^{th} sampling frequency

$$VR(q) = \frac{\sigma^2(q)}{\sigma^2(1)} \tag{5.9}$$

Where:

VR	=	variance ratio
$\sigma^2(q)$	=	q period variance
q	=	q^{th} sampling frequency

Under the random walk hypothesis, the variance ratio should be a value close to unity and thus, the null hypothesis is that $VR(q)$ is not statistically different from 1. To test this, Lo and MacKinlay (1988) derive two standard normal test statistics, $Z(q)$ under the assumption of homoscedasticity and $Z*(q)$ under the assumption of heteroskedasticity, presented below as equation 5.10 and 5.11, respectively.

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$$Z(q) = \frac{VR(q)-1}{\sqrt{\frac{(2*2q-1)(q-1)}{3q(nq)}}} \tag{5.10}$$

$$Z*(q) = \frac{VR(q)-1}{\Sigma\left[\frac{2(q-j)}{q}\right]^2 \hat{\partial}(j)} \tag{5.11}$$

5.2.4. Chow-Denning Multiple Variance Ratio Test

Problematically, the test statistics of Lo and MacKinlay (1988) requires q to be specified, while random walk theory suggests that the variance ratio should be unity for all lag orders. While testing multiple variance ratios at different lag orders is necessary, Chow and Denning (1993)

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suggest that conducting separate single VR tests for different lag orders will lead to misleading results, in particular, to the over rejection of the null hypothesis of a joint test.

In an attempt to remedy this problem, Chow and Denning (1993) introduce the multiple variance ratio (MVR) test, allowing the examination of a vector of individual variance ratio tests without the threat of results affected by large Type I errors. For a set of variance ratio estimates $\{VR(q_i)|i = 1,2,3, \dots, m\}$, with lag orders $\{q_i|i = 1,2,3, \dots, m\}$, the null sub-hypotheses H_{0i} to be tested is defined as:

$$H_{0i}: VR(q_i) = 1 \text{ for } i = 1,2,3, \dots m$$

If any of the sub-hypotheses are rejected, then the random walk hypothesis is rejected as well and thus, Chow and Denning (1993) use the maximum absolute values of the individual variance ratio test statistics to decide whether to reject H_0. The test statistics are under the assumption of homoscedasticity and heteroscedasticity are defined as:

$$Z_1(q) = \max_{1 \le i \le m} |Z(q_i)| \quad (5.12)$$

$$Z_2(q) = \max_{1 \le i \le m} |Z * (q_i)| \quad (5.13)$$

The test statistic follows the Studentised Modulus Maximum distribution with parameter m and sample size T degrees of freedom. The null hypothesis is rejected at the 5% significance level.

5.2.5. Non-parametric Variance Ratio Test

Unlike the Lo and MacKinlay (1988) and Chow and Denning (1993) variants of the variance ratio test, the variance ratio test using signs and ranks of Wright (2000) does not derive its test statistics from asymptotic theory, enabling the calculation of the exact sampling distribution. This also makes the Wright (2000) VR test more powerful when the distribution is non-normal.

Consider a time series of Y_t asset returns, with sample size T, where $Y_t = P_t - P_{t-1}$. It follows then that the standardised rank r_{1t} and van de Waerden scores r_{2t} are defined as:

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$$r_{1t} = \frac{r(Y_t) - \frac{T+1}{2}}{\frac{\sqrt{(T-1)(T+1)}}{12}} \tag{5.14}$$

$$r_{2t} = \phi^{-1} \frac{r(y_t)}{T+1} \tag{5.15}$$

The test statistics are similar to that of Lo and Mackinlay (1988)'s VR test assuming homoskedasticity, however, r_{1t} and r_{2t} replace $(p_t - p_{t-1})$ from equation 5.10, resulting in the rank-based variance ratio test statistics R_1 and R_2:

$$R_1 = \frac{\frac{1}{Tk}\sum_{t=k}^{T}(r_{1t} + r_{1t-1} \dots r_{1t-k+1})^2}{\frac{1}{Tk}\sum_{t=1}^{T} {r_{1t}}^2} * \left(\frac{2(2k-1)(k-1)}{3kT}\right)^{-\frac{1}{2}}$$

$$R_2 = \frac{\frac{1}{Tk}\sum_{t=k}^{T}(r_{2t} + r_{2t-1} \dots r_{2t-k+1})^2}{\frac{1}{Tk}\sum_{t=1}^{T} {r_{2t}}^2} * \left(\frac{2(2k-1)(k-1)}{3kT}\right)^{-\frac{1}{2}}$$

Wright (2000)'s sign statistic S_t assigns P_t the value 0.5 if positive and -0.5 when if negative. The sign test statistic S_1 is defined in equation 5.16 as:

$$S_1 = \frac{\frac{1}{Tk}\sum_{t=k}^{T}(s_{1t} + s_{1t-1} \dots s_{1t-k+1})^2}{\frac{1}{Tk}\sum_{t=1}^{T} {s_{1t}}^2} * \left(\frac{2(2k-1)(k-1)}{3kT}\right)^{-\frac{1}{2}} \tag{5.16}$$

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5.3. Results

This section displays and discusses the results used to determine if market efficiency is cyclical. After the preliminary statistics are calculated, two normality tests and four random walk tests are conducted on all 153 shares over both sub-periods and the entire sample period. Due to the magnitude of the results, only notable excerpts of the results of each test are presented under each section.

5.3.1. Descriptive Statistics

A summary of the descriptive statistics is displayed in Table 1. For the first sub-period, the mean returns are positive for 115 of the 121 stocks. Similar results are found in the second sub-period (122/152), albeit with a greater number of stocks with negative returns. For the entire sample period, only 10 of the 153 stocks exhibited a negative mean return. From the first to the second sub-period, 106 equities experienced a decrease in averages monthly returns while the remaining 47 experienced an increase. This is accompanied by 126 equities showing a decrease in volatility while the remaining 23 showed an increase in volatility. Between the two sub-periods, there are 20 equities that have experienced a fall in return along with increased volatility while 41 equities have an increased return with decreased volatility.

For both sub-periods and the entire sample period, a larger proportion of stocks have returns that are positively skewed rather than negatively skewed, however, the number of shares with negatively skewed returns are more pronounced in the second sub-period. The results of the excess kurtosis indicate that the return distribution of the majority of the sample shares is leptokurtic.

Given these results, stock return independence may be a poor assumption, justifying further statistical testing.

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Table 5. 1 Descriptive Statistics

Table 5.1 displays a summary of the results of the calculated descriptive statistics for the average returns of the sampled 153 stocks for both sub-periods and the entire examination period.

	Sub Period 1 (1 JAN 98 - 31 DEC 07)	Sub Period 2 (1 JAN 08 - 31 DEC 17)	Full Sample (1 JAN 98 - 31 DEC 17)
MEAN			
No. of postive average returns	115	122	143
No. of negative average returns	6	31	10
SKEWNESS			
No. of positively skewed returns	79	83	94
No. of negatively skewed returns	39	70	59
KURTOSIS			
Leptokurtic	107	142	143
Platykurtic	9	11	10
CHANGE BETWEEN PERIODS			
No. of stocks with lower sub 2 returns			106
No. of stocks with greater sub 2 returns			47
No. of stocks with lower sub 2 volatility			126
No. of stocks with greater sub 2 volatility			23

5.3.2. Jarque-Bera

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An excerpt from the results of the Jarque-Bera test for normality is displayed in Table 5.2 below. The results indicate that the null hypothesis of normality is rejected at a significance level of 5% for 73 of the 121 equities (60%) during the first sub-period. For the second sub-period, normality is rejected at a significance level of 5% for 93 of the 153 equities (61%). Over the entire sub-period 124 of the 153 (77%), stocks are rejected at the 5% significance level. Additionally, 53 stocks have Jarque-Bera statistics that are only significant in one of the two sub-periods.

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Table 5. 2 Jarque-Bera Test

Table 5.2 displays an excerpt of the results of the Jarque-Bera test for the average monthly returns. The Jarque-Bera statistics (JB stat) and p-values for 9 of the sampled 153 stocks for both sub-periods and the entire examination period are displayed. P-values highlighted in bold indicate that the null hypothesis for normality is rejected at the 5% significance level.

	Sub Period 1 (1 JAN 98 - 31 DEC 07)			**Sub Period 2 (1 JAN 08 - 31 DEC 17)**			**Full Sample (1 JAN 98 - 31 DEC 17)**	
	JB Stat	p-value		JB Stat	p-value		JB Stat	p-value
ABL	82.5652	**0.0000**		2921.2800	**0.0000**		1848.4196	**0.0000**
ACL	11.8690	**0.0026**		1.5398	0.4631		6.2107	**0.0448**
ADH	31.9606	**0.0000**		6.8768	**0.0321**		321.6824	**0.0000**
ADR	4.2511	0.1194		9.7185	**0.0078**		18.1784	**0.0001**
AEG	1.9109	0.3846		7.9235	**0.0190**		19.8220	**0.0000**
AFE	211.2159	**0.0000**		2.6299	0.2685		649.3955	**0.0000**
AFT	0.2739	0.8720		59.9106	**0.0000**		56.8002	**0.0000**
AFX	11.4227	**0.0033**		6.0489	**0.0486**		17.8641	**0.0001**
AGL	37.4571	**0.0000**		170.1420	**0.0000**		215.2055	**0.0000**

5.3.3. Quantile-Quantile Plot

The Quantile-Quantile (Q-Q) plot assists in the assessment of the normality of a given distribution. If the set of observations is approximately normally distributed, a normal Q-Q plot of the observations will result in a straight line at a 45-degree angle. The results of the Q-Q plots of the monthly return data show that 9 (ACL, ANG, BIL, CLS, GFI, IMP, INL, NT1, SHP) of the 153 stocks demonstrate normality over the entire sample period, although not perfectly so. Four Q-Q plots are displayed in Figure 5.3 demonstrating both normally and abnormally distributed returns.

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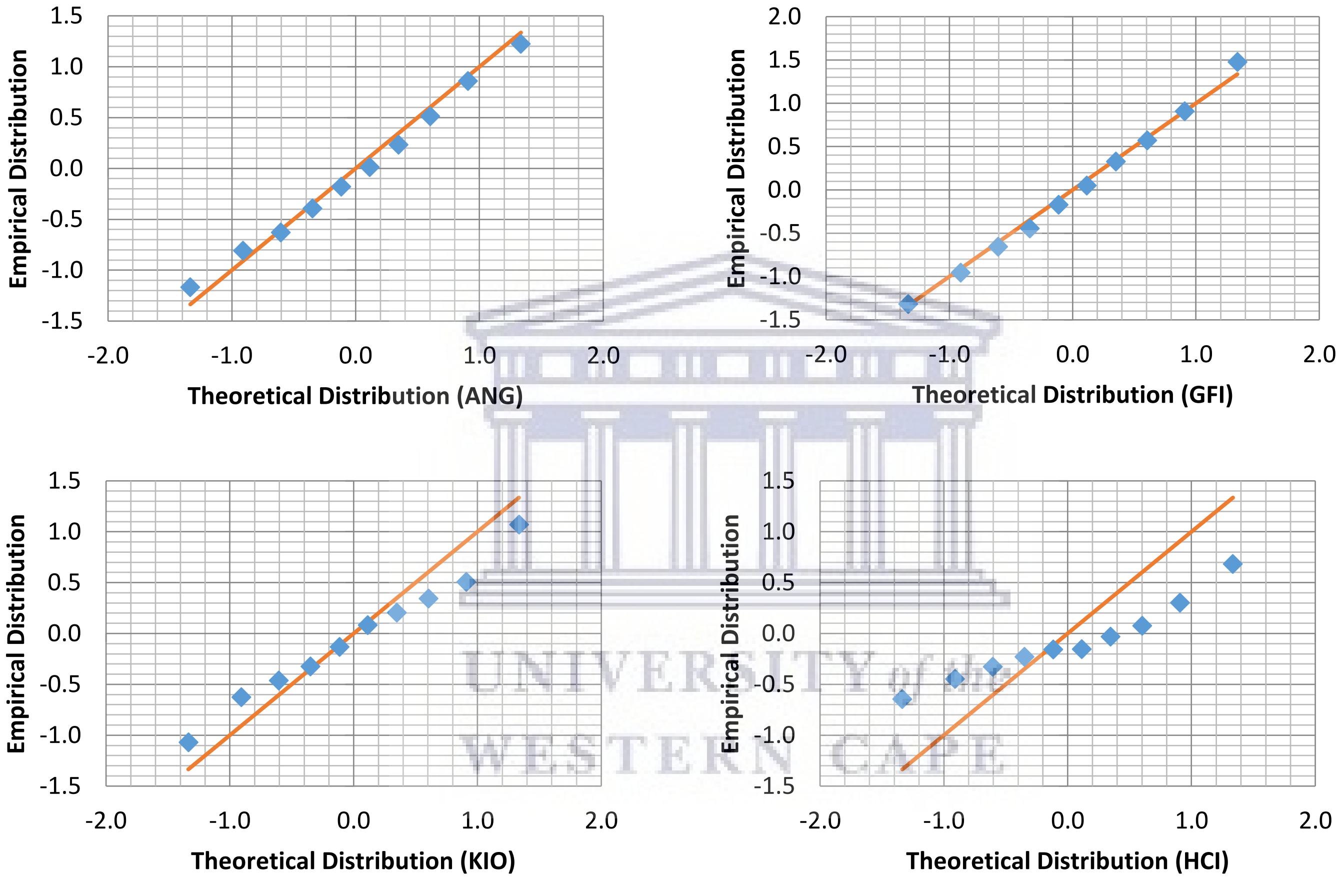
Table 5. 3 Q-Q Plots

Table 5.3 displays the Q-Q plots for the monthly returns of ANG, GFI, KIO, and HCI for the period 1 Jan 1998 – 31 Dec 2017. The Q-Q plots for ANG and GFI are show evidence for normality while the Q-Q plots for KIO and HCI show evidence for heavy-tailed distributions.



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By examining the Q-Q plots of stocks that exhibit normality for the monthly return data, it is evident that the normality for these stocks is strong but not perfect. For stocks that do not display evidence for normality, a common trait shared amongst these Q-Q plots is a heavy-tailed distribution.

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5.3.4. Ljung-Box Test

The Ljung-Box test is employed over both sub-periods and the entire examination period to check if the autocorrelations of the sampled stocks are simultaneously equal to zero for lags 1 to 10. An excerpt of the results is presented in table 5.4 below.

Table 5. 4 Ljung-Box Test

Table 5.4 displays an excerpt of the results of the Ljung-Box test for the average monthly returns. The p-values for 6 stocks from lags 1 to 10 for both sub-periods and the entire examination period are displayed. P-values highlighted in bold indicate that the null hypothesis for autocorrelation is rejected at the 5% significance level.

	Sub Period 1 (1 Jan 98 - 31 Dec 07)						**Sub Period 2 (1 Jan 08 - 31 Dec 17)**						**Full Sample (1 Jan 98 - 31 Dec 17)**					
Lag	ACL	ADH	ADR	AEG	AFE	AFT	ACL	ADH	ADR	AEG	AFE	AFT	ACL	ADH	ADR	AEG	AFE	AFT
1	**0.01**	0.41	0.77	0.54	0.23	0.77	0.47	0.42	0.95	**0.00**	0.51	**0.02**	0.99	0.35	0.78	**0.00**	0.09	**0.02**
2	**0.00**	0.71	0.86	0.15	0.43	0.57	0.77	0.26	0.61	**0.00**	0.66	**0.04**	0.06	0.64	0.77	**0.00**	0.21	**0.03**
3	**0.00**	0.87	0.93	0.20	0.15	0.66	0.17	0.35	0.73	**0.01**	0.84	0.09	**0.03**	0.83	0.86	**0.00**	0.07	0.08
4	**0.00**	0.78	0.95	0.33	0.05	0.68	0.08	0.43	0.83	**0.01**	0.61	**0.03**	0.06	0.67	0.92	**0.00**	**0.05**	**0.02**
5	**0.00**	0.87	0.97	0.45	0.07	0.20	0.12	0.37	0.69	**0.02**	0.64	**0.02**	0.09	0.80	0.96	**0.00**	0.08	**0.01**
6	**0.00**	0.81	0.89	0.56	0.08	0.11	0.19	0.33	0.46	**0.03**	0.73	**0.04**	0.10	0.71	0.62	**0.00**	0.10	**0.01**
7	**0.00**	0.88	0.93	0.66	**0.00**	0.13	0.13	0.36	0.57	**0.05**	0.66	**0.03**	0.12	0.78	0.73	**0.00**	**0.00**	**0.01**
8	**0.00**	0.92	0.95	0.71	**0.00**	0.18	0.17	0.47	0.36	0.06	0.75	0.05	0.17	0.84	0.65	**0.00**	**0.00**	**0.02**
9	**0.00**	0.95	0.94	0.78	**0.00**	0.23	0.19	0.26	0.23	0.06	0.68	0.08	0.18	0.90	0.48	**0.00**	**0.00**	**0.04**
10	**0.00**	0.97	0.83	0.83	**0.00**	0.28	0.10	0.16	0.23	0.08	0.77	0.10	0.16	0.91	0.51	**0.01**	**0.00**	**0.04**

Evidence for the presence of autocorrelation is lacking in both sub-periods. Less than 30 of the 153 stocks show signs of return predictability in either sub-period. It should however be noted that the presence of autocorrelation is stronger in the second sub-period. There also is a small number of equities that have returns that show evidence for predictability in the second sub-period that was not present in the first sub-period.

The results for the entire sample period are similar to those found in the sub-periods. Fewer stock returns show any evidence of non-random behavior at lower lags, with a minimum of 17 stocks with significant p-values at a lag of 1 while at lags 7 and greater, the number of stocks with significant p-values are within a range of 28 to 32.

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5.3.5. Runs Test

An excerpt of the results of the runs test for the monthly returns data for each sub-period and the entire sample period is displayed in Tables 5.5. For the first sub-period, 30 of 116 (26%) stocks have statistically significant p-values at the 5% level of significance. This number falls in the second sub-period despite an increased number of stocks in the sample, with 18 of 153 (11%) stocks possessing statistically significant p-values at the 5% level of significance. When calculated over the entire sub-period, 74 of 153 (48%) stocks show evidence of significance at the 5% level. Of the stocks which have data in both sub-periods, 17 of 116 (14%) are randomly generated in either sub-period but not in the other.

Table 5. 5 Runs Test

Table 5.5 displays an excerpt of the results of the Runs test for the average monthly returns. The p-values for 7 stocks for both sub-periods and the entire examination period are displayed. P-values highlighted in bold indicate that the null hypothesis for autocorrelation is rejected at the 5% significance level.

	Sub Period 1 (1 Jan 98 - 31 Dec 07)			**Sub Period 2 (1 Jan 08 - 31 Dec 17)**			**Full Sample (1 Jan 98 - 31 Dec 17)**	
Stock	Z-Stat	P-Value		Z-Stat	P-Value		Z-Stat	P-Value
ITU	1.26	0.21		0.75	0.46		0.38	0.71
IVT	0.07	0.94		0.40	0.69		0.19	0.85
JSE	5.44	**0.00**		0.97	0.33		4.44	**0.00**
KAP	4.53	**0.00**		0.83	0.41		3.22	**0.00**
KIO	1.75	0.08		0.50	0.61		5.43	**0.00**
LBH	0.59	0.55		0.21	0.83		0.28	0.78
LEW	5.04	**0.00**		0.89	0.37		5.23	**0.00**

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These results suggest that returns of a small portion of the sampled stocks are not randomly generated when observed over shorter periods. The results for randomness are also weaker in the second sub-period further suggesting that any factors influencing return predictability in the first sub-period are slowly becoming less effective. When stock returns are observed over longer periods, however, there is substantially greater evidence for patterns in the stock returns than found for the sub-periods.

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With respect to adaptive markets, there are very few stocks (17 of 116) that switch between possessing returns that are randomly or non-randomly generated between the two sub-periods.

5.3.6. Variance-Ratio Tests

Three different variance ratio tests are used to test whether the monthly return series follows a random walk.

An excerpt of the results of the conventional variance-ratio test of Lo and Mackinlay (1988) is presented in Table 5.6. The results suggest that the variance ratios of all sampled stocks at lags 2, 4, 8, and 16 for both sub-periods and the entire examination period are statistically different from 1. Additionally, the size of the variance ratio decreases with an increase in lag. Given these results, the null hypothesis that the variance-ratio is significantly different from unity is rejected.

Table 5. 6 Lo-Mackinlay Variance Ratio Test

Table 5.6 displays an excerpt of the results of the Lo-Mackinlay (1988) Variance Ratio test, showing the variance ratios and z-statistics for the average monthly returns at lags 2, 4, 8, and 16 for both sub-periods and the entire examination period. Z-statistics highlighted in bold are significant at the 5% level.

	Sub Period 1 (1 Jan 98 - 31 Dec 07)						**Sub Period 2 (1 Jan 08 - 31 Dec 17)**						**Full Sample (1 Jan 98 - 31 Dec 17)**					
	ABL	ACL	ADH	ADR	AEG	AFE	ABL	ACL	ADH	ADR	AEG	AFE	ABL	ACL	ADH	ADR	AEG	AFE
VR(2)	0.55	0.20	0.53	0.53	0.37	0.58	0.24	0.33	0.26	0.26	0.35	0.28	0.51	0.41	0.53	0.52	0.54	0.57
Z(2)	**-4.94**	**-6.71**	**-5.10**	**-5.15**	**-6.31**	**-4.55**	**-8.34**	**-7.30**	**-8.08**	**-8.13**	**-7.12**	**-7.94**	**-7.57**	**-8.15**	**-7.25**	**-7.37**	**-6.77**	**-6.57**
VR(4)	0.28	0.13	0.28	0.27	0.22	0.32	0.26	0.30	0.22	0.24	0.32	0.23	0.27	0.24	0.27	0.26	0.29	0.30
Z(4)	**-4.12**	**-3.87**	**-4.14**	**-4.23**	**-4.08**	**-3.90**	**-4.33**	**-4.11**	**-4.57**	**-4.42**	**-3.97**	**-4.50**	**-5.97**	**-5.61**	**-5.98**	**-6.09**	**-5.60**	**-5.75**
VR(8)	0.11	0.10	0.12	0.12	0.12	0.16	0.12	0.13	0.12	0.10	0.18	0.14	0.12	0.12	0.12	0.11	0.16	0.16
Z(8)	**-3.17**	**-2.45**	**-3.14**	**-3.15**	**-2.86**	**-3.00**	**-3.26**	**-3.21**	**-3.25**	**-3.34**	**-3.02**	**-3.18**	**-4.54**	**-4.03**	**-4.53**	**-4.57**	**-4.13**	**-4.35**
VR(16)	0.06	0.05	0.07	0.07	0.06	0.05	0.05	0.06	0.06	0.06	0.09	0.07	0.05	0.06	0.07	0.07	0.08	0.06
Z(16)	**-2.19**	**-1.64**	**-2.16**	**-2.16**	**-1.99**	**-2.20**	**-2.37**	**-2.33**	**-2.35**	**-2.34**	**-2.26**	**-2.32**	**-3.23**	**-2.85**	**-3.17**	**-3.18**	**-2.99**	**-3.22**

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The individual variance ratios are further tested through the use of Wright (2000)'s non-parametric variance ratio test. The test results displayed in Table 5.7 suggest the monthly return series for all stocks over the entire examination period at lags 2, 4, 8, and 16 do not follow a random-walk.

Table 5. 7 Wright Test

Table 5.7 displays an excerpt of the results of the Wright (2000) Variance Ratio test, showing the z-statistics and p-values for the average monthly returns at lags 2, 4, 8, and 16 for both sub-periods and the full sample period. P-values highlighted in bold are significant at the 5% level.

	ABL	ACL	ADH	ADR	AEG	AFE
Z(2)	-7.59	-8.17	-7.27	-7.39	-6.78	-6.59
p-value	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Z(4)	-6.02	-5.67	-6.04	-6.15	-5.66	-5.81
p-value	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Z(8)	-4.63	-4.13	-4.62	-4.66	-4.22	-4.44
p-value	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Z(16)	-3.31	-8.17	-7.27	-7.39	-6.78	-6.59
p-value	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**

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These findings are echoed by the results of the Chow and Denning (1993) test, as presented in Table 5.8. As 152 of the 153 stocks possess incredibly small p-values, the null hypothesis of a random walk is strongly rejected.

Table 5. 8 Chow-Denning Test

Table 5.8 displays an excerpt of the results of the Chow-Denning (1993) Multiple Variance Ratio test, showing the z-statistics and p-values for the average monthly returns for the entire examination period. P-values highlighted in bold are significant at the 5% level.

	ABL	ACL	ADH	ADR	AEG	AFE	AFT
Z-Stat	7.586046	8.171099	7.26512	7.386627	6.784183	6.586404	5.014065
P-Value	**0**	**0**	**0**	**0**	**0**	**0**	**0**

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5.4. Conclusion

The tests of stock return dependency include a total of five tests on the average monthly returns for each stock in the ALSI covering normality and random walk theory for the duration of the two sub-periods and entire examination period. The results of these tests would provide some insight into the level of market efficiency of the JSE and to what extent this efficiency is cyclical.

The results for the Jarque-Bera test and Q-Q plots are in agreement, with both tests presenting a strong case for non-normally distributed returns across both sub-periods and the entire examination period.

The results of the random walk tests are rather mixed. The results of the Ljung-Box and runs tests suggest that very few stocks in the sample have returns that are randomly generated while the results from the three different variance ratio tests convey quite the opposite in that all stocks in the sample have non-randomly generated returns. Mixed findings here are not an unexpected result given that this is the case in the literature as well.

The results in support of the Adaptive Markets Hypothesis are present albeit feint. A larger number of stock returns switch between being normally distributed and non-normally distributed during the two sub-periods, however, with respect to predictability, as few as 30 stocks possessed returns that were found to switch between a state of predictability and non-predictability.

The test results are limited by the number of included tests and the frequency of the data. An increased number of tests of greater power and variety may have produced more conclusive results. There are also only two lengthy sub-periods comprised of monthly data. An increased number of sub-periods or additional data at different frequencies may capture more short-term return predictability, however, it should be noted that data at higher frequencies tend to be noisier than those at lower frequencies.

The objective of this chapter was to identify if there is any stock return dependence exists and to what extent it is cyclical. While results are mixed, the findings are sufficient to pursue an attempt to discover possible factors that contribute towards this inefficiency.

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6

The Univariate Regression Test

6.1. Introduction

The objective of this chapter is to identify possible factors that explain the cross-section of returns on the JSE, with a particular interest in the consistency of the explanatory power of each attribute with the passage of time.

Fama and Macbeth (1973)'s univariate regression model provides a robust method of estimating whether a theory pertaining to a set of selected factors are capable of explaining returns. Using this model, the univariate test is conducted on each of the style attributes listed in Table 4.1 for two sub-periods as well as over the entire examination period.

By regressing the sample share returns on each style attribute for each month during the examination period, the monthly payoffs to each style attribute is estimated. These payoffs are then subject to Student's *t*-test to identify possible significant style attributes. The results are compared among the different sample periods to assess the effect of time and changing market environments on the predictive ability of the attributes.

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Haugen and Baker (1996) suggest that the signs of these payoffs should be consistent and that the style attributes should explain returns in a manner that agrees with its theoretical expectation. To test the consistency of the attributes, a binomial sign test is conducted. The cumulative factor payoffs to each style attribute are presented graphically to observe the consistency of the size and sign of the payoff to each style attribute.

The style attributes are grouped into five categories: fundamental value relative to price, fundamental growth, operating performance, solvency, and return momentum and size. The univariate test is then conducted on each of the attributes in all categories for the period 1 January 1998 to 31 December 2017, with the examination period split into two 120-month sub-periods (1 Jan 98 – 31 Dec 07, 1 Jan 08 – 31 Dec 17).

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6.2. Descriptive Statistics and Methodology

This study makes use of the Fama and Macbeth (1973) univariate factor model (Equation 6.1) to determine each style attribute's ability to explain the cross-section of equity returns over the two sub-periods and the entire examination period.

$$R_{i,t+1} = a_{t+1} + b_{t+1} \text{ x } F_{i,t} + e_{i,t+1} \quad (6.1)$$

Where:

$R_{i,t+1}$ = the realised return on share *i* for month *t*+1

a_{t+1} = the intercept term

b_{t+1} = the estimated cross-sectional factor payoff for the style attribute

$F_{i,t}$ = the lagged standardised value of the style attribute

By implementing the ordinary least squares method, the cross-sectional factor payoffs for each month are estimated, regressing the return of each of the sample shares in month *t*+1 on each of the lagged style attributes in month *t*, with this process being repeated over the entire examination period 31 December 1997 – 31 December 2017.

To test each of the style attributes' relative significance in explaining the cross-sectional returns, the time-series average payoff to each style attribute is subject to Student's *t*-test at a 5% significance level.

Additionally, the binomial sign test is conducted to test for the consistency of the signs of the payoffs to the style attributes. The sign tests assume that there is an equal amount of values less than and greater than the median, therefore, the null hypothesis for the sign test is that the median of each style attributes' factor payoff is equal to zero.

Finally, the cumulative payoff for each style attribute over the entire examination is calculated and graphed. The shape of the graph is compared with the results of the aforementioned tests.

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6.3. Results

The characteristics of the payoffs to the style attributes are demonstrated in Tables 6.1 - 6.5, respectively displaying the univariate test results of the style attributes for the following five categories: fundamental values relative to share price, operating performance, solvency, size and return momentum, and fundamental growth. Each table shows the time-series means, t-statistic, and results from the binomial sign test on the median of the payoffs of each of the style attributes within a given category for both sub-periods and the entire examination period. A significance level of 5% is selected for both the Student's *t*-test on the time-series means of the factor payoffs and sign tests on the time-series median of the factor payoffs, with significant values highlighted in bold.

6.3.1. Fundamental Values Relative to Share Price

From Table 6.1, the results for the *t*-statistics of the mean factor payoffs to each of the style attributes in the fundamental values relative to share price category display a weakening of the value effect. For the first sub-period (1 Jan 1997 – 31 Dec 2007), BVTP and SALESTP are the only attributes that possess significant mean payoffs, while in the second sub-period (1 Jan 08 – 31 Dec 17), none of the attributes indicate significance. None of the attributes show any significance over the entire examination period.

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While many of the attributes with insignificant payoffs possess insignificant signs, the results from the binomial sign test are somewhat mixed. The SALESTP attribute possesses a consistently positive sign for the first sub-period followed by a significant negative sign in the second sub-period. The BVTP attribute does not possess a significant sign in the first sub-period (though this test statistic is but 0.01 below the critical value) while consistently negative in the second sub-period. The HEY attribute showed no significance during the t-tests but possesses a consistently positive sign for each sub-period.

The cumulative geometric factor payoffs to the attributes within the fundamental values to share price category are graphically illustrated in Figure 6.1. The shape of the graphs reflects the results above. Up until early 2007, the BVTP style attribute provides the greatest payoff amongst all the attributes in this category, with moderately volatile but an overall increasing

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cumulative payoff until May 2007. From then on, the payoff to BVTP exhibits a decreasing trend. Similarly, the SALESTP attribute exhibits a consistently increasing payoff until May 2007, converging with the payoff to BVTP, with the two attributes at almost identical levels by the end of the examination period.

Through observation of the t-statistics of the mean factor payoffs of each of the style attributes in this category, it is apparent that the size of the payoffs is time-varying. While the t-statistics of the mean factor payoff to SALESTP and BVTP are significant within the first sub-period, neither attribute shows similar strength within the second sub-period.

While not as pronounced, these results suggest that the value effect documented in prior literature (as discussed in Chapter 3) was indeed present on the JSE, however, this effect has since diminished with no clear indication of a possible resurgence.

The value effect captured by the BVTP attribute is well-documented and unsurprising, however, despite reports of significant earnings-yield (HEY) and cash-flow-to-price (similar to EBITDATP) in prior studies, these variables were found insignificant.

The Adaptive Markets Hypothesis suggests that these findings should be expected, as an investment strategy's performance varies with its environment.

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Table 6. 1 Fundamentals Relative to Share Price

Table 6.1 displays the results for the *t*-statistics of the mean factor payoffs to each of the style attributes in the fundamental values relative to share price category for both sub-periods as well as the entire examination period. The style attributes under examination are BVTP, SALESTP, DY, and HEY. Values that are statistically significant attributes significant at the 5% significance level are highlighted in bold.

Characteristics of Factor Payoffs to Style Attributes				
Fundamentals to Price	**BVTP**	**SALESTP**	**DY**	**HEY**
Sub Period 1 (1 Jan 98 - 31 Dec 07)				
Factor Payoffs	0.007197564	0.006634969	-6.34822E-06	0.004004113
Mean Test				
T-Stat	**2.159537381**	**1.9907169**	-0.002943911	1.543603083
Median Tests				
Sign (normal approx)	1.949801051	**3.1433011**	0.554700196	**3.328201177**
No of Observations > 0	69	76	55	77
No of Observations < 0	47	41	62	40
Sub Period 2 (1 Jan 08 - 31 Dec 17)				
Factor Payoffs	-0.001957157	-0.0012746	0.001452379	0.00025036
Mean Test				
T-Stat	-1.806410454	-1.38570375	1.361182752	0.364535409
Median Tests				
Sign (normal approx)	**2.143303525**	**2.1433035**	0.306186218	**2.551551815**
No of Observations > 0	37	59	46	61
No of Observations < 0	59	37	50	35
Entire Period (1 Jan 98 - 31 Dec 17)				
Factor Payoffs	0.002530234	0.002597247	0.000723095	0.002077185
Mean Test				
T-Stat	1.459010878	1.524101297	0.614227594	1.581849088
Median Tests				
Sign (normal approx)	0.325472277	1.818795447	0.389741881	**3.117935052**
No of Observations > 0	115	133	122	143
No of Observations < 0	121	104	115	94

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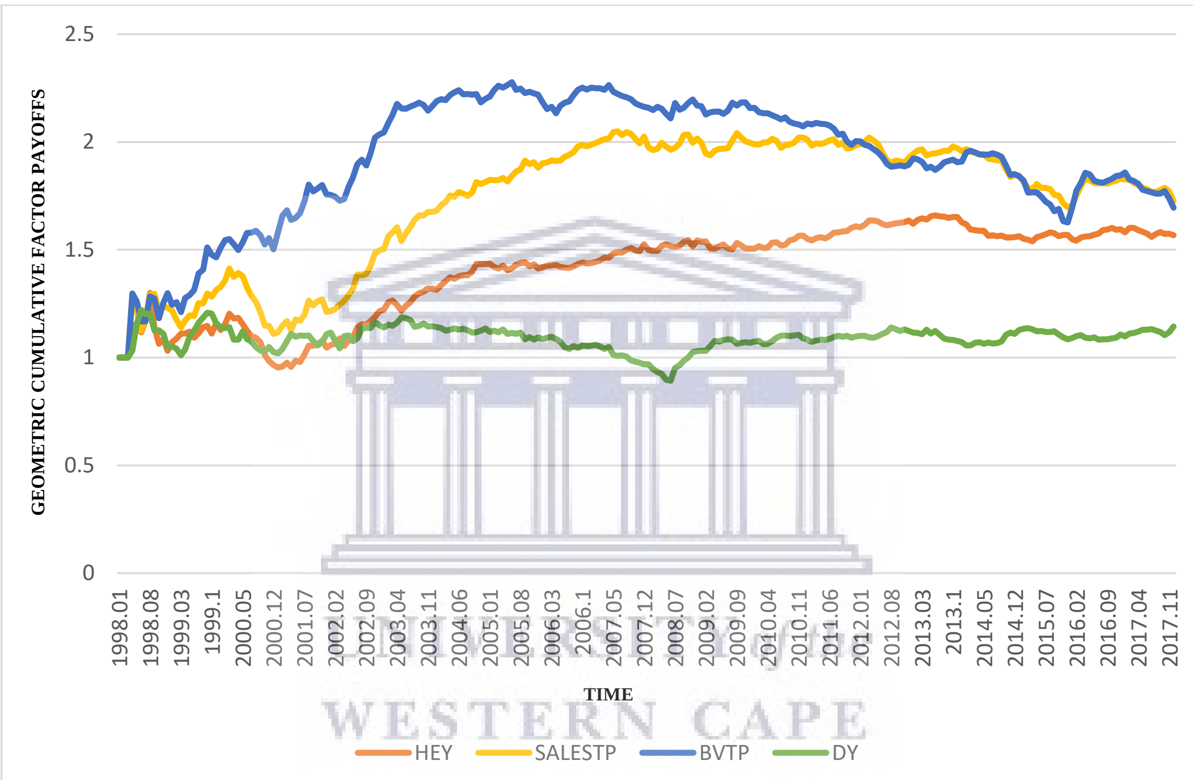
Figure 6. 1 Fundamentals Relative to Share Price

Figure 6.1 displays the cumulative payoff to each style attribute in the fundamental values relative to share price category (HEY, SALESTP, BVTP, and DY) over the entire examination period (01 January 1998 to 31 December 2017).



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6.3.2. Size and Return Momentum

Table 6.2 shows the results for the *t*-statistics of the mean factor payoffs to each of the style attributes in the size and return category. For the first sub-period (1 Jan 98 – 31 Dec 2007), the MOM12, MOM24, and LSIZE possess significant mean payoffs, while in the second sub-period (1 Jan 08 – 31 Dec 17), MOM6, MOM12, and MOM24 possess significant mean payoffs. When calculated over the entire period (1 Jan 98 – 31 Dec 13), the t-statistics of the mean factor payoffs to the MOM6, MOM12, and MOM24 style attributes are shown to be significant. Additionally, the attributes with statistically significant payoffs also possess significant positive signs.

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From the cumulative payoff to the style attributes in this category, illustrated in Figure 6.2, it is evident that the payoffs to MOM6, MOM12 and MOM24 have accelerated at a superior rate when compared to the rest of the attributes in this category. With the exception of MOM1, the cumulative payoffs to the momentum attributes are similarly shaped.

While the mean payoff to MOM6, MOM12, and MOM24 attributes have accumulated for the majority of the examination period, there are two, relatively short, time periods where a sharp downward trend is evident, taking place in August 2008 – August 2009 and December 2015 – April 2017.

These results are similar to those documented in prior literature. Both the existence of a size effect on the JSE (Van Rensburg, 2003; Van Rensburg and Robertson, 2004; Hodnett, Hsieh and van Rensbug, 2012) and its diminishing strength (Strugnell, Gilbert and Kruger, 2011) are evident in the findings presented here.

With respect to the momentum attributes, the findings of this thesis are in accordance with those of Hodnett and Hsieh (2009, 2012). During the early 2000s, the reward to MOM1 has disappeared while MOM6 prospers. Rewards to MOM12 and MOM24 exist over both periods however, conversely to Hodnett and Hsieh (2011), the results suggest that there is no prior 36-month or 60-month price-reversal effect.

The time-varying performance of MOM6 and LSIZE at explaining returns supports the idea of cyclical profitability of investment strategies, however, it should be noted that MOM12 and MOM24 provide significant and superior payoffs over the entire examination period. Despite this, the cumulative payoff graphs indicate that there are short periods of underperformance of MOM12 and MOM24 (amongst other attributes). Thus, it could be argued that while the reward to momentum strategies has yet to be exhausted over longer periods of time, an adaptive model may be able to detect or defend against possible downturn during shorter periods.

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Table 6. 2 Return Momentum and Size

Table 6.2 displays the results for the *t*-statistics of the mean factor payoffs to each of the style attributes in the return momentum and size category for both sub-periods as well as the entire examination period. The style attributes under examination are MOM1, MOM3, MOM12, MOM36, MOM48, MOM60 and LSIZE. Values that are statistically significant attributes significant at the 5% significance level are highlighted in bold.

Characteristics of Factor Payoffs to Style Attributes

Return Momentum and Size	MOM1	MOM3	MOM6	MOM12	MOM24	MOM36	MOM48	MOM60	LSIZE
Sub Period 1 (1 Jan 98 - 31 Dec 07)									
Factor Payoffs	-0.002562203	0.001221649	0.003303146	0.005988997	0.005739298	0.00188692	0.000644143	-0.0003	-0.0039
Mean Test									
T-Stat	-1.665276128	0.695718537	1.852239236	**4.154749993**	**3.6492**	1.04485843526	0.388024584	-0.1724	**-2.328**
Median Tests									
Sign (normal approx)	**2.016736693**	0.924500327	**2.528781691**	**3.56032666**	**2.9598**	0.545544726	1.060660172	1.1619	2.93344
No of Observations > 0	48	64	71	73	63.0000	45	41	35	43
No of Observations < 0	71	53	43	35	33.0000	39	31	25	76
Sub Period 2 (1 Jan 08 - 31 Dec 17)									
Factor Payoffs	-0.000178912	0.001493398	0.002695542	0.00322342	0.002705808	0.001739856	0.001913393	0.00163	0.00081
Mean Test									
T-Stat	-0.14870078	1.280161017	**2.007209778**	**2.323079694**	**2.0072**	1.15535633	1.350688207	1.25367	0.72687
Median Tests									
Sign (normal approx)	0.510310363	1.93917938	**3.163924251**	**3.572172542**	**3.1639**	1.735055234	**3.163924251**	**3.1639**	1.12268
No of Observations > 0	45	58	64	66	64.0000	57	64	64	42
No of Observations < 0	51	38	32	30	32.0000	39	32	32	54
Entire Period (1 Jan 98 - 31 Dec 17)									
Factor Payoffs	-0.001359882	0.001357524	0.002916765	0.004306759	0.003648623	0.00153035	0.001149939	0.00075	-0.0015
Mean Test									
T-Stat	-1.398253714	1.301883691	**2.702918553**	**4.507551503**	**3.9334**	1.559699955	1.329751233	0.99711	-1.5242
Median Tests									
Sign (normal approx)	1.034953964	**2.0786234**	**4.118438838**	**4.966996339**	**4.2866**	1.610322097	**2.670244995**	**2.4597**	1.94054
No of Observations > 0	111	135	149	152	140.0000	114	115	107	104
No of Observations < 0	128	102	85	76	76.0000	90	77	73	135

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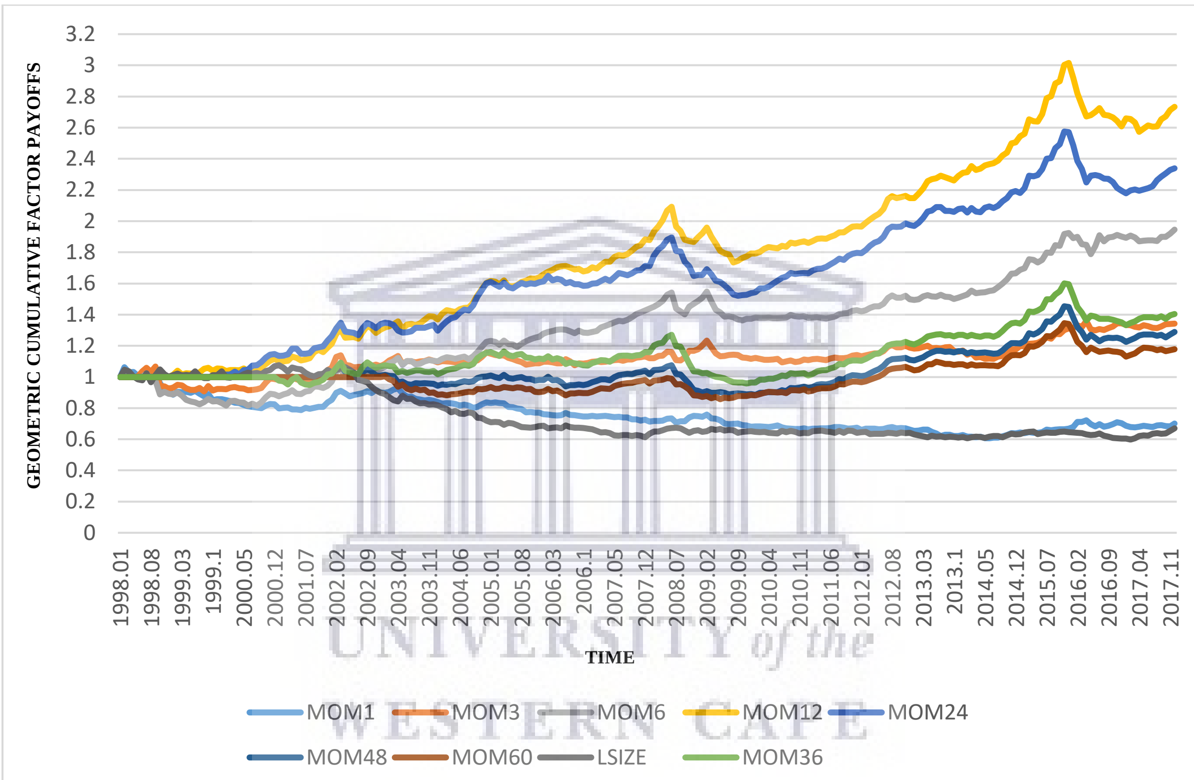
Figure 6. 2 Return Momentum and Size

Figure 6.2 displays the cumulative payoff to each style attribute in the return momentum and size category (MOM1, MOM3, MOM6, MOM12, MOM24, MOM36, MOM48, MOM60, and LSIZE) over the entire examination period (01 January 1998 to 31 December 2017).



6.3.3. Fundamental Growth

Table 6.3 shows the results for the *t*-statistics of the mean factor payoffs to each of the style attributes in the fundamental growth category. None of the attributes in this category show an ability to explain the returns on the JSE in either examination period. These results are somewhat consistent with Hodnett, Hsieh and van Rensburg (2012), finding similar attributes as insignificant for the period January 1997 – December 2001 but report 5 attributes in this category (none of which are included in this thesis) with significant payoffs between January 2002 and December 2007.

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For the first sub-period, the cumulative payoffs to the style attributes in this category, depicted in Figure 6.3, are moderately volatile and do not exhibit any particular trend. In the second sub-period, the payoffs to each attribute are less volatile and remain relatively unchanged for the duration of the examination period. At this stage, the results in this category do not provide any useful information.

Table 6. 3 Fundamental Growth

Table 6.3 displays the results for the *t*-statistics of the mean factor payoffs to each of the style attributes in the fundamental values relative to share price category for both sub-periods as well as the entire examination period. The style attributes under examination are YOYHE, YOYSALES, and PEG. Values that are statistically significant attributes significant at the 5% significance level are highlighted in bold.

Characteristics of Factor Payoffs to Style Attributes			
Fundamental Growth	YOYSALES	YOYHE	PEG
Sub Period 1 (1 Jan 98 - 31 Dec 07)			
Factor Payoffs	-0.00111482	-0.000767389	-0.00287254
Mean Test			
T-Stat	-0.478573704	-0.254355593	-0.91782692
Median Tests			
Sign (normal approx)	0.390360029	1.287191806	0.099014754
No of Observations > 0	55	58	52
No of Observations < 0	50	44	50
Sub Period 1 (1 Jan 08 - 31 Dec 17)			
Factor Payoffs	-2.3573E-05	-0.000729088	0.00079166
Mean Test			
T-Stat	-0.030718148	-1.1396976	1.251412035
Median Tests			
Sign (normal approx)	0.510310363	0.714434508	0.306186218
No of Observations > 0	51	52	50
No of Observations < 0	45	44	46
Entire Period (1 Jan 98 - 31 Dec 17)			
Factor Payoffs	-0.00049952	-0.000690684	-0.000825
Mean Test			
T-Stat	-0.454031281	-0.510151172	-0.58697172
Median Tests			
Sign (normal approx)	0.8	0.067115606	0.469809239
No of Observations > 0	119	112	115
No of Observations < 0	106	110	107

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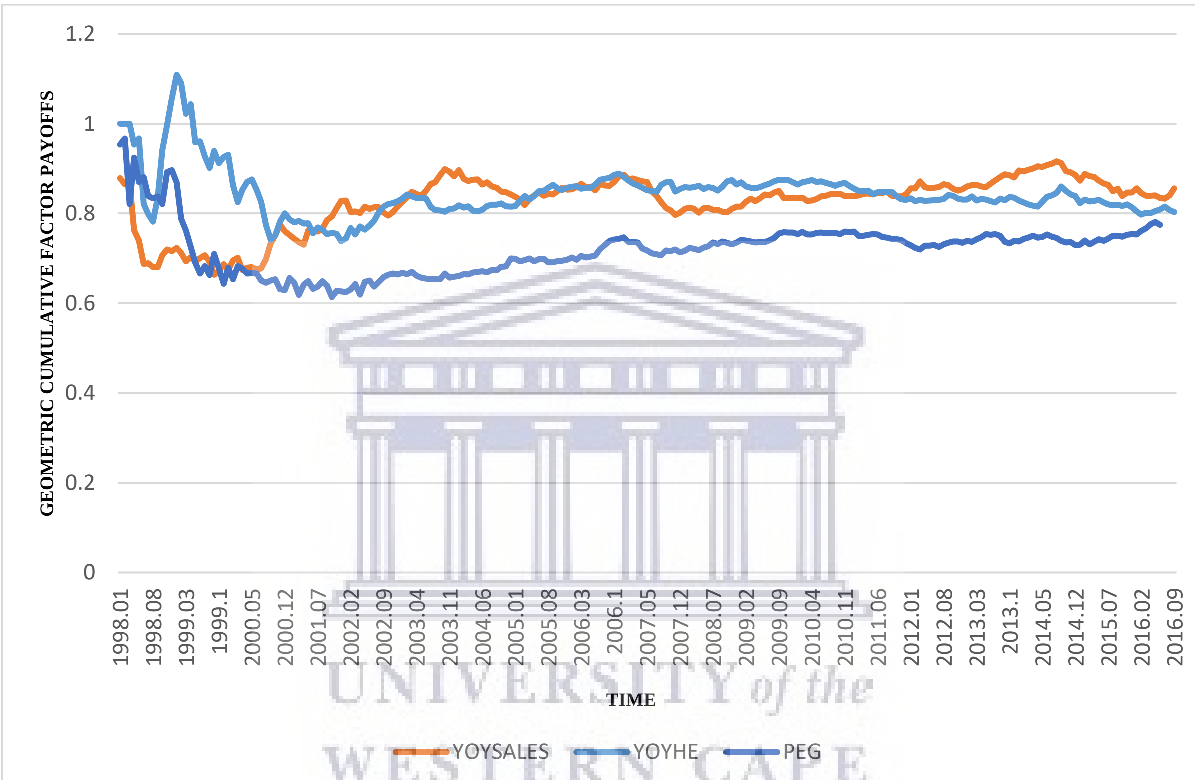
Figure 6. 3 Fundamental Growth

Figure 6.3 displays the cumulative payoff to each style attribute in the fundamental growth category (YOYSALES, YOYHE, PEG) over the entire examination period (01 January 1998 to 31 December 2017).



6.3.4. Operating Performance

Table 6.4 shows the results for the *t*-statistics of the mean factor payoffs to each of the style attributes in the operating performance category. Most of the attributes produced weak results in this category. For the first sub-period, ROE was the only attribute of the 4 to possess a significant payoff and consistent negative sign, while TAT only passed the sign test. With the exception of a consistent positive sign in the TAT attribute, none of the attributes exhibited statistical significance in the second sub-period.

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In line with this result, the cumulative payoff to ROE has mild volatility until 2002, from which it exhibits a strong negative trend that extends to 2007, remaining relatively unchanged thereafter. While TAT did not possess a significant mean payoff during the examination period, its cumulative payoff is greatest amongst the attributes in this category. Interestingly, neither the cumulative payoffs to ROE or TAT show any recognisable pattern until 2002, from which the direction of the two attributes diverges.

The lackluster ability of attributes in this category to explain returns is also found in Hodnett (2010), where none of the operating attributes tested (including NPM, ROE, and TAT) were found statistically significant.

With ROE being the only attribute in this category showing any significance and the disappearance of the significant payoff to ROE in the second sub-period suggests that the reward to operating performance measures is minimal and on the decline.

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Table 6. 4 Operating Performance

Table 6.4 displays the results for the *t*-statistics of the mean factor payoffs to each of the style attributes in the operating performance category for both sub-periods as well as the entire examination period. The style attributes under examination are NPM, TAT, ROE and ROIC. Values that are statistically significant attributes significant at the 5% significance level are highlighted in bold.

Characteristics of Factor Payoffs to Style Attributes					
Operating Performance		NPM	TAT	ROE	ROIC
Sub Period 1 (1 Jan 98 - 31 Dec 07)					
Factor Payoffs		-0.00609487	0.004004113	-0.003897904	-0.0051636
Mean Test					
T-Stat		-1.611237137	1.543603083	**-2.32772105**	-1.42172893
Median Tests					
Sign (normal approx)		**2.528781691**	**3.328201177**	**2.93343519**	0.655610068
No of Observations > 0		43	77	43	53
No of Observations < 0		71	40	76	61
Sub Period 1 (1 Jan 08 - 31 Dec 17)					
Factor Payoffs		0.00084611	0.00025036	0.000806982	0.000570793
Mean Test					
T-Stat		1.417893145	0.364535409	0.726874827	1.022231085
Median Tests					
Sign (normal approx)		0.714434508	**2.551551815**	1.122682799	1.326806944
No of Observations > 0		52	61	42	55
No of Observations < 0		44	35	54	41
Entire Period (1 Jan 98 - 31 Dec 17)					
Factor Payoffs		-0.00262438	0.002077185	-0.001545461	-0.0022964
Mean Test					
T-Stat		-1.364104415	1.581849088	-1.52418791	-1.24614707
Median Tests					
Sign (normal approx)		0.326860225	**3.117935052**	1.940538682	0.065372045
No of Observations > 0		114	143	104	116
No of Observations < 0		120	94	135	118

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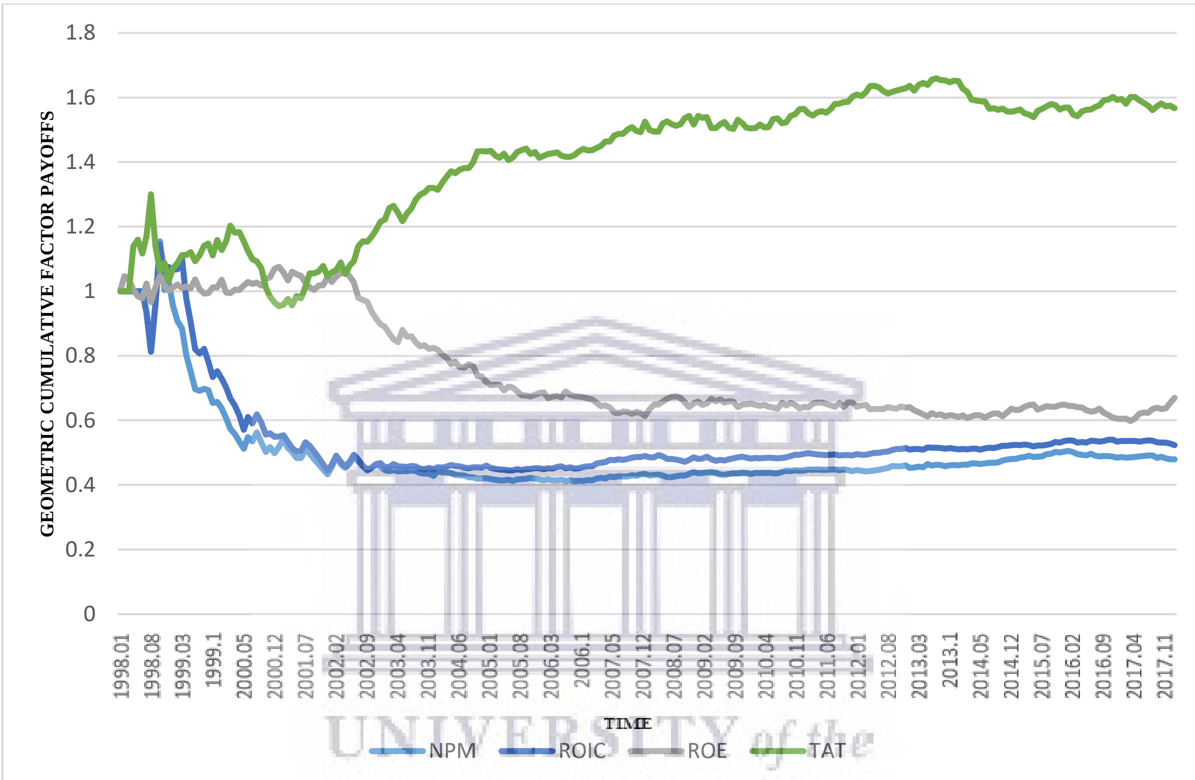
Figure 6. 4 Operating Performance

Figure 6.4 displays the cumulative payoff to each style attribute in the operating performance category (NPM, TAT, ROE, ROIC) over the entire examination period (01 January 1998 to 31 December 2017).



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6.3.5. Solvency

Table 6.5 shows the results for the *t*-statistics of the mean factor payoffs to each of the style attributes in the solvency category. None of the attributes in this category possessed statistically significant payoffs or signs in either sub-period. These results are in accordance with prior literature, which suggests that the reward to attributes in the solvency category is generally insignificant (Hodnett, Hsieh and Van Rensburg, 2012).

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Table 6. 5 Solvency

Table 6.5 displays the results for the *t*-statistics of the mean factor payoffs to each of the style attributes in the solvency category for both sub-periods as well as the entire examination period. The style attributes under examination are DtE, DtE, and DebtRatio. Values that are statistically significant attributes significant at the 5% significance level are highlighted in bold.

Characteristics of Factor Payoffs to Style Attributes			
Solvency and Liquidity	DtE	DtM	DebtRatio
Sub Period 1 (1 Jan 98 - 31 Dec 07)			
Factor Payoffs	-0.00487863	-0.000741742	-0.00238802
Mean Test			
T-Stat	-1.895635671	-0.274950541	-1.037101843
Median Tests			
Sign (normal approx)	1.849000654	0.924500327	0
No of Observations > 0	48	53	59
No of Observations < 0	69	64	58
Sub Period 1 (1 Jan 08 - 31 Dec 17)			
Factor Payoffs	0.000554344	0.000151867	0.000845683
Mean Test			
T-Stat	0.65882761	0.184393388	1.013239416
Median Tests			
Sign (normal approx)	0.306186218	0.714434508	1.93917938
No of Observations > 0	50	44	58
No of Observations < 0	46	52	38
Entire Period (1 Jan 98 - 31 Dec 17)			
Factor Payoffs	-0.00216214	-0.000294938	-0.000771168
Mean Test			
T-Stat	-1.587038369	-0.209522095	-0.628756538
Median Tests			
Sign (normal approx)	0.649569802	1.169225644	1.299139605
No of Observations > 0	113	109	129
No of Observations < 0	124	128	108

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Figure 6. 5 Solvency

Figure 6.5 displays the cumulative payoff to each style attribute in the solvency category (DtE, DtM and DebtRatio) over the entire examination period (01 January 1998 to 31 December 2017).

6.4. Conclusion

The univariate tests include tests of the mean and median of the time-series factor payoffs to the style attributes for the duration of the two sub-periods and entire examination period. The cumulative factor payoff to each style attribute is then graphed for the entire examination period. The results from these tests would provide insight on the ability of these factors to explain returns in the cross-section and to what extent their predictive power is time-varying, in an attempt to identify possible periods of adaptation.

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The results of the univariate regression tests indicate that attributes in the fundamental to price, operating performance, and return momentum and size categories possess the ability to explain returns. The strong momentum effect observed in prior studies is once again prevalent in this study for the entire examination period while the value and size effect has disappeared in the second sub-period.

The shapes of the cumulative geometric payoff graphs accentuate these results and provide insight into the time-varying predictive power of the attributes. While the significant momentum attributes accumulate for the majority of the examination period, there are two, relatively short, periods where the payoffs exhibit a consistent negative trend. The fundamental to price, the SALESTP and BVTP attributes show a more noticeable change, gradually shifting from an increasing payoff in the first sub-period to a decreasing payoff in the second sub-period.

These findings provide support for the Adaptive Markets Hypothesis, with particular respect to the idea of varying efficiency of financial strategies and the requirement for innovation. The payoff to the statistically significant style attributes in the fundamental to price and operating performance categories have become progressively weaker, suggesting a shift from trade decisions based on these attributes.

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7

Conclusion

This research attempts to discover whether the Adaptive Market Hypothesis theory is applicable in the South African financial market and explores the innovation and cyclical profitability implications of the Adaptive Market Hypothesis theory. This is explored first by determining if returns follow a random walk or not and secondly, by analysing the consistency of technical and fundamental factors to explain the cross-section of equity returns between 1 January 1998 to 31 December 2017. The findings from this paper are consistent with the findings of prior research in related fields and where this thesis finds contrary evidence, it supports the research objective.

The tests of stock return dependency include a total of five tests on the average monthly returns for each stock in the ALSI covering normality and random walk theory for the duration of the two sub-periods and entire examination period. The results of these tests would provide some insight into the level of market efficiency of the JSE and to what extent this efficiency is cyclical. The results for the Jarque-Bera test and Q-Q plots are in agreement, with both tests presenting a strong case for non-normally distributed returns. By contrast, the results of the random walk tests are rather mixed. The results of the Ljung-Box and runs tests suggest that very few stocks in the sample have returns that are randomly generated while the results from the three different variance ratio tests convey quite the opposite in that all stocks in the sample have non-randomly generated returns. Mixed findings for this section are not an unexpected result given that this is the case in the literature as well. The results in support of the Adaptive Markets Hypothesis are present, albeit feint. A larger number of stock returns switch between being normally distributed and non-normally distributed during the two sub-periods, however, with respect to predictability, as few as 30 stocks possessed returns that were found to switch between a state of predictability and non-predictability.

The univariate tests include tests of the mean and median of the time-series factor payoffs to the style attributes for the duration of the two sub-periods and entire examination period. The cumulative factor payoff to each style attribute is then graphed for the entire examination period. The results from these tests would provide insight on the ability of these factors to explain returns

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in the cross-section and to what extent their predictive power is time-varying, in an attempt to identify possible periods of adaptation.

The results of the univariate regression tests indicate that attributes in the fundamental to price, operating performance, and return momentum and size categories possess the ability to explain returns. The strong momentum effect observed in prior studies is once again prevalent in this study for the entire examination period while the value and size effect has disappeared in the second sub-period.

The findings of the univariate test provide support for the Adaptive Markets Hypothesis, with particular respect to the idea of varying efficiency of financial strategies and the requirement for innovation. The payoff to the statistically significant style attributes in the fundamental to price and operating performance categories have become progressively weaker, suggesting a shift from trade decisions based on these attributes.

The combined results of this research violate the assumptions of the efficient market hypothesis which suggests that price movements are unpredictable. The findings also suggest that markets go through periods of efficiency and inefficiency and that in an effort to maintain a profitable position, investors are required to be more innovative.

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The test results are limited by the number of included tests and the frequency of the data. An increased number of tests of greater power and variety may have produced more conclusive results. There are also only two lengthy sub-periods comprised of monthly data. An increased number of sub-periods or additional data at different frequencies may capture more short-term return predictability, however, it should be noted that data at higher frequencies tend to be noisier than those at lower frequencies. Additionally, it would be worth exploring how the factors identified in the univariate test could be used in quantitative models for comparison between adaptive and non-adaptive active strategies. This demands further research into the Adaptive Markets Hypothesis and how constant innovation is key in the pursuit of profitable strategies. A promising direction for this would be the exploration into using machine-learning techniques to create dynamic or adaptive portfolios and compare the performance of their non-adaptive counter-parts. One such

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technique is the genetic algorithm, which is based on the same evolutionary principles that inspires the Adaptive Markets Hypothesis.

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