

**MCOM DISSERTATION**

**A SIMULATION-BASED APPROACH TO ASSESSING THE  
RELATIONSHIP BETWEEN MUTUAL FUND SIZE AND  
PERFORMANCE**

by

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## **ABSTRACT**

This study examines how mutual fund size affects performance. Academic literature on this topic is extensive but has yielded conflicting results. Some studies find a distinct relationship between fund size and risk-adjusted returns while others do not; some studies also posit that an optimal fund size exists where risk-adjusted returns are maximised. The size of equity mutual funds in South Africa and the market dynamics of the Johannesburg Stock Exchange provide an interesting context within which to analyse the relationship between size and performance. In this study, hypothetical portfolios are created, and an allocation procedure is used to distribute capital to these hypothetical portfolios. The allocation procedure distributes capital to the portfolio stocks by controlling for each stock's yearly volume traded. This method works to distribute capital up until a certain fund size; beyond that size, the hypothetical portfolio might no longer be fully invested in the random portfolio. To control for this, the simulation model engages in a routine to discard the stock with the lowest volume-traded level from the portfolio and reselect another stock from the investable universe with a higher volume-traded level. This process is repeated until the portfolio is fully invested. Stock selection and investment dates are randomised and variance reduction techniques are used to improve the efficiency of the simulation, and 10 000 simulation runs are performed. The results of the simulation found a non-monotonic relationship between mutual fund size and performance over a one-year holding period, consistent with some research internationally and in South Africa. Over a two- and three-year holding period, mutual fund size and returns, however, seem to be negatively correlated. Over the three holding periods, the study suggests that the optimal equity mutual fund size in South Africa is approximately ZAR 2bn. Portfolios with assets under management greater than ZAR 2bn see their returns decrease noticeably as fund size continues to increase. These findings are supported by comparing simulated returns to actual benchmark returns over the same random periods. The results of this study suggest that mutual funds should be aware that consistent increases in assets under management could negatively affect performance and that all funds should ensure that total assets under management do not exceed ZAR 2bn.

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## **LIST OF ABBREVIATIONS AND ACRONYMS**

|          |   |
|----------|---|
| AUM      | Assets Under Management                                 |
| ASISA    | The Association for Savings and Investment South Africa |
| CIS      | Collective Investment Scheme                            |
| CRN      | Common Random Numbers                                   |
| CRSP     | Centre for Research into Security Prices                |
| DEA      | Data Envelopment Analysis                               |
| DEF      | Domestic Equity Fund                                    |
| JALSH    | FTSE/JSE All-Share Index                                |
| JSE      | Johannesburg Stock Exchange                             |
| JSE SWIX | Johannesburg Stock Exchange Shareholders Weighted Index |
| NAV      | Net Asset Value   |

## CHAPTER ONE: INTRODUCTION

The advent of passive investment vehicles called for an emphasis on the role of active mutual funds in South Africa. Passive investments such as exchange-traded funds now allow investors to realise market returns on a variety of asset classes at a fraction of the active cost. The primary reason for the rise in popularity of these products was the inability of active investment managers to consistently outperform their benchmarks (French, 2008). Research into why mutual fund managers struggle to outperform or even meet their benchmark returns is critical and has far-reaching implications for the asset management industry. One factor that could affect the ability of managers to outperform their benchmarks is mutual fund size, as measured by assets under management (AUM).

Mutual funds are a popular type of collective investment scheme (CIS). A CIS is a pooled investment vehicle built to invest in either a single or diverse range of asset classes (ASISA, 2017). Mutual funds are managed by an investment manager and aim to generate returns more than a certain benchmark return. Typically, South African equity benchmarks include the Johannesburg Stock Exchange Shareholders Weighted Index (JSE SWIX) and the FTSE JSE Top40 Index. The fundamentals of how these indices are calculated and constructed are less important than establishing that mutual fund managers add value when they generate returns more than their benchmark returns or positive differential returns. Jensen (1968) defines positive differential returns or alpha ( $\alpha$ ) as follows, where  $E(R_{jt})$  represents the one-period return on a single security or portfolio  $j$ :

$$E(R_{jt}) - R_{Ft} = \alpha_j + \beta_j[R_{Mt} - R_{Ft}] + u_{jt}, \quad (1)$$

where,

$R_{Ft}$  is the one-period risk-free rate at time  $t$ ,

$\beta_j$  is the measure of systematic risk used in the asset pricing model,

$R_{Mt}$  is the expected one-period return on the market portfolio,

$\alpha_j$  is the expected excess return on a single security or portfolio  $j$ , and

$u_{jt}$  is the uncorrelated error term at time  $t$ .

Thus, when  $\alpha_j$  is positive, the return to portfolio  $j$ ,  $E(R_{jt})$ , exceeds the return on the market portfolio  $R_{Mt}$ , and the portfolio manager has generated positive outperformance. The ability of managers to consistently generate a positive  $\alpha_j$  was called into question (Malkiel, 2003). Moreover, the cost of active management has further pushed investors into looking at other ways to generate consistent investment returns. Many investors have turned to passive investment products to realise investment returns at a lower cost than active investments. Advocates of passive or index investing often cite efficient markets, tax considerations, and the inability of managers to beat the market as reasons to pursue passive rather than active investment strategies (Raubenheimer, 2012).

Malkiel (2003) noted that index investing is often preferred rather than active investing because markets are largely efficient. Debate persists over whether active or passive strategies are more optimal for investors, and these debates often hinge on two factors, namely the efficiency of markets and the constraints that hinder active management. This dissertation will focus on the latter and, specifically, on how mutual fund size, as a constraint, could contribute to or impede the generation of  $\alpha_j$ . The effect of mutual fund size on performance is well documented in academic literature (Berk & Green, 2004; Chen et al., 2004; Pillay, Millar & Ward, 2010; Yan, 2008). In South Africa, the effect of domestic equity fund (DEF) size on performance is particularly important for two reasons. First, the number of DEFs in South Africa has grown considerably over the past 10 years (ASISA, 2017), and second, because the JSE is highly concentrated among large capitalisation stocks (Majapa & Gossel, 2016).

Over 85% of the JSE's total market capitalisation is represented by the 40 largest stocks listed on the exchange (Majapa & Gossel, 2016). Moreover, Majapa and Gossel (2016) noted that the JSE is characterised by a high degree of sectoral and liquidity concentration among resources and industrials stocks, and this is supported by Kruger and Van Rensburg (2008). Towards the end of 2017, Allan Gray, Coronation, and Alexander Forbes, South Africa's largest

DEF managers, held a DEF AUM of more than ZAR 80bn. Given the size of their portfolios, one might ask how managers can find a comprehensive set of stocks in which to invest when the JSE is so highly concentrated. Another question one might ask is should managers outperform their benchmarks. To some extent, they would need to invest in assets in which the benchmark does not have significant holdings or small capitalisation stocks. Large-cap stocks tend to trade liquidly and could be easily bought and sold, while small-cap stocks often do not trade at all (Kruger & Van Rensburg, 2008). This condition has led to what is now known as the small-cap premium (Fama & French, 2012).

Data and research show how concentration and the small-cap premium hamper the ability of active managers to generate positive differential returns. Furthermore, the burgeoning demand for CIS products in South Africa resulted in a greater need for investable securities. ASISA data show that the CIS industry in South Africa attracted a tremendous amount of capital over the past ten years (ASISA, 2017). Specifically, an increasing number of equity unit trusts need an increasing number of equity securities in which to invest. Asset managers, however, are constrained in their ability to invest freely because of concentration risk. This phenomenon is pertinent in South Africa where many DEFs compete for a share of a relatively small equity market. Moreover, from January 2000 to December 2018, equity managers in South Africa have struggled to generate alpha (Khuzwayo & Tsotetsi, 2019).

## **1.1 AIMS AND OBJECTIVES**

---

This study aims to determine whether a relationship exists between mutual fund size and performance, and how mutual fund returns will react to changes in fund size. If a relationship does exist between mutual fund size and risk-adjusted-performance, what is the optimal size for a unit trust within a South African context? Prior studies on the topic have either approached the problem without using a simulation framework (Kopke, 2015) or the simulation method used is fundamentally different to the one used here (Pillay et al., 2010). This study's objective is to expand on the work of Pillay et al. (2010) to assess the relationship between mutual fund size and performance through a simulation framework using a selection of real-world constraints.

## **1.2 PROBLEM STATEMENT**

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This study seeks to examine two factors relating to mutual fund size and performance. The first factor is whether a relationship exists between mutual fund size and performance and the second factor is determining whether an optimal fund size exists. These two factors can be split out into a series of research questions:

Question 1: Does a relationship exist between mutual fund size and performance in South Africa over the period 2008 to 2017?

Question 2: If a relationship does exist between mutual fund size and performance in South Africa over the period 2008 to 2017, is the relationship monotonic or non-monotonic?

Question 3: If a relationship does exist between mutual fund size and performance in South Africa over the period 2008 to 2017, does an optimal fund size exist?

Question 4: If an optimal fund size exists between mutual fund size and performance what is the ZAR value of that size in terms of assets under management?

### **1.3 STRUCTURE OF THE DISSERTATION**

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The rest of this dissertation is structured as follows: Chapter 2 presents a review of the literature related to mutual fund size and performance. This is broken up into four distinct categories of research where both foreign and domestic studies are assessed. Chapter 3 reviews the research methodology and data used in the study. The simulation model and allocation procedure used in the study are described in detail, and practical considerations related to the portfolio construction process and the simulation are described. Chapter 4 details the empirical results of the dissertation, and Chapter 6 concludes the study. Limitations of the study and areas for further research are also discussed in Chapter 6.

## **CHAPTER TWO: LITERATURE REVIEW**

### **2.1 INTRODUCTION**

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Mutual fund performance analysis has attracted significant academic interest over time. Collective investment schemes, mutual funds, or unit trusts have become popular investment vehicles for both retail and institutional investors and understanding the factors that drive their performance has become important to researchers and investors. Mutual fund research typically focuses on external and internal factors that drive performance (Sharpe, 1966; Berk & Green, 2004; Ferreira et al., 2013). Internal factors focus on how managers use their skills to generate alpha (Grinold, 1989; Grinold & Titman, 1989), while external factors evaluate how regulation, expenses, liquidity and other constraints, including mutual fund size, affect performance (Chen et al., 2004; Yan, 2008; Pillay et al., 2010).

The dominant view is that managers cannot consistently generate alpha due either to their lack of skill, or the constraints placed on their portfolios (Reuter & Zitzewitz, 2011). While this paper focuses on the effect that one specific constraint, mutual fund size, has on the performance of mutual funds, it is important to briefly discuss what other factors constrain investment managers in their ability to generate excess returns.

Sharpe (1966) established a link between the level of risk that managers undertake and their pursuit of excess returns. By building on the work of Tobin (1958), he noted that a measure of performance evaluation could be derived from the Tobin effect known as the reward to variability ( $R/V$ ) ratio. Following on from this, Sharpe (1994) and Tonks (2001) found that managers do not consistently outperform their benchmarks. Subsequent studies focused on what drives the inability of investment managers to generate positive outperformance (Malkiel, 1995; French, 2008). Whether underperformance is attributable to a lack of skill among managers or due to the constraints imposed upon them by regulation, a lack of investable opportunities and the liquidity of financial markets is still being debated.

Several research papers focused on how one external factor, namely fund size, affects mutual fund performance. While research on the topic is extensive, no consensus has been reached

on how the fund size influences the ability of managers to generate excess returns, although four distinct categories of research have formed.

The first category posits that no correlation exists between fund size and performance (Milburne-Pyle, 1984). The second category finds that a negative correlation between size and performance exists (Chen et al., 2004; Yan, 2008; Pillay et al., 2010). Conversely, the third category of research finds that a positive correlation exists between fund size and performance (Chen et al., 1992; Dahlquist, Engstrom & Soderland, 2000), while the final category advocates that a u-shaped relationship exists between fund size and performance (Indro et al., 1999). The final category of research further posits that it could be possible to determine an optimal mutual fund size (Indro et al., 1999).

Recent literature supports the second and fourth categories of research that finds that mutual fund performance is negatively related to the size of the fund and that it is possible to find an optimal fund size (Chen et al., 2004; Yan, 2008; Shawky & Li, 2005; Pillay et al., 2010; Kopke, 2015). Increases in transaction costs (Perold & Salmon, 1991), operational inefficiencies (Chen et al., 2004) and liquidity concerns (Pillay et al., 2010) were all cited as reasons for the negative relationship between mutual fund size and performance. Each of these four segments of the research will be examined separately, both internationally and in South Africa.

## **2.2 NO CORRELATION BETWEEN MUTUAL FUND SIZE AND PERFORMANCE**

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### **2.2.1 FOREIGN**

Berk and Green's (2004) study was the first to analyse the persistence of the United States (US) mutual fund returns based on past performance. The study was developed on the basis that fund flows are related to past performance. Berk and Green (2004) argued that continued investment-flows into performing funds, hamper managers' ability to generate outperformance due to diseconomies of scale. Active managers do not consistently outperform passive benchmarks because of competition in the market for the capital provision and decreasing returns to scale in active management. Furthermore, when

managers do outperform their benchmarks, excess returns are set off by diseconomies of scale that managers face as mutual fund size increases. These diseconomies of scale include higher expenses associated with gathering information and higher transaction costs associated with trading large block sizes (Berk & Green, 2004). The costs associated with diseconomies of scale are funded by outperformance generated by skilled managers. As mutual fund size increases, diseconomies of scale increase and higher costs associated with portfolio management are then cancelled by excess returns generated by skilled managers, and mutual fund size does not affect performance.

Drawing on Berk and Green (2004), Reuter and Zitzewitz (2011) assessed the relationship between fund size and diseconomies of scale. While Berk and Green (2004) used past performance to determine manager skill, Reuter and Zitzewitz (2011) assumed that investors infer a manager's skills based on Morningstar ratings. They studied a sample of US mutual funds from 1996 to 2009. Using a regression discontinuity design, they showed that fund size has no effect on performance and thus, no diseconomies of scale are observed. Due to the highly competitive nature of the mutual fund market, almost all excess returns are diminished, except to the most highly performing funds (Reuter & Zitzewitz, 2011).

Elton, Gruber and Blake (2012) assessed the relationship between fund size and performance. Their sample consisted of all mutual funds listed on the Centre for Research into Security Prices (CRSP) database from 1999 to 2009. They initially noted a positive relationship between fund size and performance. Funds experience economies of scale associated with decreasing expenses as a percentage of total AUM (Blake et al., 2012). They then assessed whether fund size influences the future performance of funds. Consistent with Berk and Green (2004), they found that size is not a critical factor in determining the future performance of mutual funds. Although management fees decline with size, diseconomies of scale offset these expense savings (Blake et al., 2012). Large funds that experience high transaction costs due to taking substantial positions in stocks minimise these costs by access to more experienced traders and analysts (Blake et al., 2012).

Berk and Green (2004), Reuter and Zitzewitz (2011), and Blake et al. (2012) studied the effect of size on the performance of general equity mutual funds and not style-specific funds. Daraio and Simar (2004) used a non-parametric approach to measure the performance of US mutual funds that vary by style, and fund size was used as an external variable within the model. They found no evidence of economies of scale among balanced, growth, and growth-income style funds. Various other style categories, however, experienced some level of scale effect among smaller firms, including equity income and asset allocation style funds (Daraio & Simar, 2004). These results show that although asset growth might be accompanied by non-equivalent expenditure growth, asset managers struggle to adapt to a larger set of investment opportunities being made available to them. Thus, scale effects are mitigated by operational complexities that include learning how to process and select securities from a larger group of investment opportunities. Similarly, Phillips, Pukthuanthong and Rau (2018) study the effect that mutual fund size has on performance, they study diseconomies of scale in the mutual fund industry and find that size is not an important factor that influences mutual fund performance.

### **2.2.2 DOMESTIC**

Studying unit trusts in South Africa from 1966 to 1975, Moles (1981) found that fund size did not influence risk-adjusted-performance. Milburne-Pyle (1984) documented comparable results to Moles (1981) when analysing fund size and pension fund returns in South Africa from 1975 to 1982. By comparing the investment yield to the size of each pension scheme's mean asset base, Milburne-Pyle (1984) found no relationship between fund size and performance.

Kopke (2015) used data from 100 South African CISs, classified as general equity funds by ASISA to analyse if a relationship exists between fund size and risk-adjusted-returns. Using both regression and ranking analysis to analyse the data over 10 years, Kopke (2015) found no statistically significant correlation between fund size and risk-adjusted-returns. Kopke (2015), however, the ranking analysis showed that an inverted u-shape relationship existed between fund size and returns. These findings support the findings of Chen et al. (2004) and

Shawky and Li (2004), although the regression analysis found no statistically significant relationship between fund size and performance, consistent with Berk and Green (2004) and Reuter and Zitzewitz (2011).

Academic literature from Category 1 suggests that no relationship exists between mutual fund size and performance, largely because diseconomies of scale associated with increasing fund size offset excess returns generated by skilled managers (Berk & Green, 2004). The next category of research suggests that a negative correlation exists between mutual fund size and performance.

## **2.3 NEGATIVE CORRELATION BETWEEN MUTUAL FUND SIZE AND PERFORMANCE**

---

### **2.3.1 FOREIGN**

Academic literature from Category 2 posits that a negative correlation exists between fund size and performance. Many studies drew on the diseconomies of scale that affect fund performance as size increases (Perold & Salomon, 1991; Indro et al., 1999). Chen et al. (2004) and Pollet and Wilson (2008) studied these diseconomies of scale while incorporating a style element into their research, highlighting that funds with specific style biases might be more prone to diseconomies of scale following increases in fund size. Lastly, some research theorised that as fund size increases, funds experience diseconomies of scale because portfolio managers increase their holdings in companies, forgoing diversification and forming concentrated portfolios (Kruger & Van Rensburg, 2008; Yan, 2008; Pillay et al., 2010; Petajisto, 2013).

Grinblatt and Titman (1989) analysed quarterly US mutual fund holdings from 1975 to 1984. Forming five different mutual fund portfolios they rank the portfolios according to their net asset value (NAV) and found that small NAV portfolios perform better than large NAV portfolios (Grinblatt & Titman, 1989). Given high transaction costs, small funds, however, did not offer investors an opportunity to realise alpha (Grinblatt & Titman, 1989). They highlighted that outperformance among mutual funds could be related to the fund style, as many of the sample funds had a growth style bias. In contrast to Daraio and Simar (2004), they found that small funds with specific style biases (growth and aggressive growth) performed better than large funds.

Perold (1988) highlighted that as portfolio size increases, paper returns tend to be higher than actual returns. Paper returns are those calculated by analysts and managers if securities could be bought and sold at stipulated market prices. Actual returns consider transaction and other costs associated with buying and selling securities in capital markets (Perold, 1988). Perold and Salomon (1991) drew on Perold (1988) and noticed that some diseconomies of scale are present in active management. These diseconomies of scale result from higher transaction costs associated with larger transactions. As fund size increases, asset positions increase and transaction costs increase, resulting in a decline in portfolio return. Although marginal returns become negative, managers continue to add wealth up to a point. This point is reached when the marginal cost of trading is greater than the opportunity cost of choosing not to trade (Perold & Salmon, 1991).

Ciccotello and Grant (1996) noted that based on historical analysis, large funds outperform small funds and investors invest in funds that have performed well in the past. They argued that growth in fund size is based on effective communication with potential investors regarding superior return-generating capability. When Ciccotello and Grant (1996) used fund size as a predictor of future fund performance they, however, found that large funds underperform small funds, mainly because of investors having overly positive expectations regarding the future performance of the fund.

Initially, Indro et al. (1999) studied the relationship between AUM and mutual fund performance and the effect of operational inefficiencies on performance. Their sample consisted of 683 none-indexed US equity funds, covering the period 1993 to 1995. Similar to Ciccotello and Grant (1996), they posited that mutual funds should attain a minimum fund size to justify their expense ratios, while funds operating above a certain NAV threshold would see performance diminish, as they spend capital on acquiring information and trading large market positions. Prior studies analysing mutual fund performance fail to recognise the diseconomies of scale in active investment management (Indro et al., 1999; Berk & Green, 2004). While Berk and Green (2004) found similar diseconomies of scale in active management, Indro et al. (1999) posited that these diseconomies of scale are not offset by superior portfolio management and that as fund size increases, performance decreases.

Indro (2004) noted that diseconomies of scale affect the ability of larger funds to generate superior returns. Chen et al. (2004) build on this work by studying the effect of organisational diseconomies of scale on funds that are negatively affected by increasing AUM. Using CRSP mutual fund data from 1962 to 1999, they found that fund performance decreases as fund size increases, even after controlling for turnover and fund age, and size effects are most pronounced for funds with a small-cap style bias (Chen et al., 2004). Moreover, they found that small funds tend to be better at selecting local stocks than large funds.

Large funds struggle to process soft information (information that cannot be verified by more than one party) experiencing organisational diseconomies, suggesting that large funds struggle to adapt their operations to increasing AUM (Chen et al., 2004). A minimum fund size, however, could exist because the study excluded funds with AUM of less than 15 million US dollars. Chen et al.'s (2004) study were one of the first to find a negative correlation between fund size and performance while controlling for investment style. The study notions that investment strategy could be a principal factor in determining whether the correlation between fund size and performance is affected by investment style.

Like Chen et al. (2004), Pollet and Wilson (2008) noted that diminishing returns to scale negatively affect the performance of actively managed US funds. Using CRSP data for the period 1975 to 2000, they removed funds from the smallest percentile with a total NAV less than 100 million US dollars to account for survivorship bias. While the study found that asset growth does not typically alter the behaviour of mutual funds, large- and small-cap funds diversify their portfolios in response to asset growth (Pollett & Wilson, 2008). They associated higher levels of diversification among small-cap funds with higher levels of investment performance. As fund size increases, portfolio managers tend to increase their existing holdings, diverging from their investment strategy. Thus, as fund size increases and managers increase their holdings, diminishing returns tend to increase. Increases in fund size lead to lower levels of diversification, which negatively affects returns.

While Pollet and Wilson (2008) found that a lack of diversification among larger funds leads to diminishing returns, Beckers and Vaughn (2001) noted that large funds struggle to implement investment ideas, as they have less flexibility than smaller funds. Their sample

consisted of 250 stocks that constituted the Australian All Ordinaries Index from 1997 to 1999. Given the dynamic nature of financial markets, large funds failed to capitalise on their investment ideas (Beckers & Vaughn, 2001). They noted that it becomes difficult for managers to commit to their investment style as AUM grows, specifically for momentum style managers. Managers with increasing AUM will ultimately have to improve their ability to generate alpha from stock selection and decrease their tracking error to maintain outperformance (Beckers & Vaughn, 2001). They further noted that large funds do not benefit from economies of scale related to decreasing expense ratios as AUM increases. Small managers that transact optimally will incur the same proportion of transaction costs that large managers will incur (Beckers & Vaughn, 2001).

Yan (2008) studied a sample of actively managed US mutual funds from 1993 to 2002 and showed that a negative correlation exists between fund size and risk-adjusted performance. This relationship is particularly pronounced for concentrated portfolios, consistent with Pollet and Wilson (2008). The study further found that the performance of high turnover and growth funds is particularly sensitive to changes in fund size and liquidity is an important consideration when addressing the effects of fund size on performance.

Edelen, Evans and Kadlec (2006) argued that the diseconomies of scale observed by Berk and Greene (2004) arose from unproportioned increases in trading costs relative to fund size. They used a sample of 3 799 open-ended US equity funds from 1995 to 2005. They found that annual trading costs for large equity funds are comparable to their percentage of total expenses, and there is a higher cross-sectional variation related to fund-specific trade size. Moreover, trading is positively related to the returns of funds with small trading size, and negatively related to the returns of funds with relatively large trading size. They noted that the primary source of diseconomies of scale, as observed by Berk and Greene (2004), is higher trading costs associated with larger fund size.

Cremers and Petajisto (2009) developed a metric designed to measure the extent of active management among unit trusts namely, Active Share. This measure represents the difference between the fund's holdings and its benchmark index holdings (Cremers & Petajisto, 2009). They computed the Active Share for US equity mutual funds from 1980 to 2003 and found

that Active Share decreases with fund size. This is not because managers select new stocks when they receive more funding but because they allocate more capital to existing positions, consistent with Pollet and Wilson (2008).

Petajisto (2013) extended on Cremers and Petajisto (2009) and computed the Active Share for US mutual funds from 2008 to 2009. By subdividing his sample of actively managed unit trusts into five separate kinds of funds, namely closet indexers, moderately active, factor bets, concentrated and stock pickers, he noted a weak negative relationship between fund size and performance. Closet indexers are defined as those funds that generate low levels of positive differential performance, staying relatively close to their benchmark returns (Petajisto, 2013). Stock pickers, on the other hand, are those funds that differ significantly from their benchmarks and tend to generate large absolute differential performance. These five categories of funds are ordered from least active (closet indexers) to most active (stock pickers). He noted that among these five categories, small stock-picking funds tend to generate the highest levels of outperformance, while closet indexers are relatively large and perform poorly. Ultimately, he noted a correlation between fund size and the type of active management or style used, consistent with other style-based studies such as Indro et al. (1999) and Chen et al. (2004).

Turning to non-US markets, Malaquias, Duarte de Sarvas and Oliveira (2017) studied the effect of size on the performance of Brazilian multimarket funds. Using a sample of 231 funds from 2009 to 2014, they found that size is a principal factor to consider when addressing the performance of Brazilian investment funds. Their results were consistent with the findings of Indro et al. (1999), suggesting that both transaction costs and liquidity are critical factors to consider when AUM is increasing and that smaller funds outperform larger funds. Urdahl and Vasset (2019) study the relationship between mutual fund size and performance for 67 equity mutual funds in Norway while controlling for survivorship bias. By constructing three portfolios based on fund size they find a statistically significant negative relationship between mutual fund size and performance.

### **2.3.2 DOMESTIC**

Kruger and Van Rensburg (2008) drew on the effects of fund size and concentration on liquidity in South Africa. They noted that liquidity is an increasingly critical factor to consider in the stock selection process for large funds. Funds that actively try to reduce the level of concentration in their portfolios will be constrained because of liquidity concerns with smaller funds (Kruger & Van Rensburg, 2008). Funds are capped in their ability to invest in less liquid shares and are forced to commit more capital to more liquid shares. Given the heavy weighting of resources-focused shares on the JSE, a notable shift from financial industrials to resources stocks is noted (Kruger & Van Rensburg, 2008).

Pillay et al. (2010) studied the effects of fund size on performance in South Africa. Their work is based on that of Clarke, de Silva and Thorley (2002). They constructed a range of different portfolios from 1991 to 2008, with portfolios consisting of 40 stocks randomly selected from a possible universe of 160 JSE listed stocks sorted by market capitalisation. Certain restrictions were applied to each portfolio to ensure realistic trading volumes and limited concentration, and each portfolio was then randomly simulated annually 17 years. They found that fund size influences performance due to liquidity, consistent with Yan (2008). Large funds underperformed small funds, and as portfolio managers increase their holdings, the weights of the stocks in their portfolios tended towards market capitalisation weights, negatively influencing performance and resulting in a concentration in resource stocks, consistent with Kruger and Van Rensburg (2008).

Research from Category 2 finds that mutual fund size is negatively correlated to performance for several reasons that focus largely on the diseconomies of scale that portfolio managers face when fund size increases. The third cluster of literature theorises that fund size is positively correlated to performance. This synthesis of research deals with four overarching topics, including economies of scale, survivorship bias, stock selection and transaction costs.

## 2.4 POSITIVE CORRELATION BETWEEN SIZE AND PERFORMANCE

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### 2.4.1 FOREIGN

Category 3 research posits that mutual fund size is positively correlated to investment performance, either because larger funds can devote more resources to investment strategies (Chan et al., 2009), or because previous studies that found a negative relationship between fund size and performance did not account for survivorship bias (Elton, Grueber & Blake, 1996b). Some research moved away from equity funds and focused on how fund size affects the performance of bond and money market funds, finding a positive correlation between AUM and performance (see Dahlquist et al., 2000).

Carter (1950) discussed the effects of fund size on the performance of US mutual funds and found that larger funds have more capital to spend on investment supervision. Larger funds have a greater bargaining power to negotiate lower brokerage costs with investment banks than small funds and have significant influence over security prices. Consequently, the study posited that mutual fund size is positively correlated to performance. Using a similar methodology over a different period, Chan, Chen and Lakonishok (2002) studied the returns to US mutual funds from 1976 to 1997 while considering investment style. They distinguished between managers with a fundamental stock selection strategy and other style biases. Managers with a stock selection bias and a large asset base performed better than managers with the same bias and a small asset base (Chan et al., 2002). Large funds could spend greater amounts of capital on resources to generate stock selection ideas, giving them a comparative advantage over small funds. Several studies found a positive correlation between size and the performance of bond and money market funds.

Philpot, Hearth, Rimbey and Schulman (1998) analysed a range of asset classes and used time-series cross-sectional analysis to study the relationship between risk-adjusted returns to bonds and a range of fund factors, including size. Analysing 27 fixed income mutual funds, they found a direct correlation between the reward to variability ( $R/V$ ) ratio of the fund and the AUM (Philpot et al., 1998). Bond fund managers tend to benefit from economies of scale largely because bonds are more efficient and easily substituted than equities (Philpot et al.,

1998). That is, it is relatively easy to trade in and out of large, relatively liquid bond issues, and larger bond issues tend to be more liquid than smaller bond issues.

Dahlquist et al. (2000) reached similar conclusions as Carter (1950), but only among bond and money market funds consistent with Philpot et al. (1998). Their sample consisted of Swedish mutual funds that existed between 1992 to 1997. By subdividing the sample of Swedish equity funds into three categories ranging in size from smallest to largest regarding AUM, they found no significant relationship between fund size and the performance of small to medium-sized equity funds. They, however, found a subtle positive relationship between fund size and the performance of bond and money market funds. By adopting a trading strategy that buys large money market funds and sells small money markets funds would not have generated outperformance. On the contrary, the same strategy applied to bond funds would have generated outperformance over the sample period (Dahlquist et al., 2000).

Early studies examining the effects of fund size on the performance of mutual funds, add significant value to the current stream of literature, although many of the samples used by researchers do not adjust for survivorship bias. Elton et al. (1996b) drew on the effects of survivorship bias on fund size and performance studies. They noted that mutual fund attrition could create sample problems, as underperforming funds disappear over time or are absorbed by better performing funds. By tracking 361 US mutual funds that existed at the end of 1976 they attempted to estimate the size of the bias, adjusting for mergers. When analysing the effects of size on performance, they found two starkly contrasting results. By analysing the largest 10% of funds regarding total AUM, and the smallest 10% of funds from the biased sample, they found no relationship between fund size and performance. When the unbiased sample was analysed, they, however, found that smaller funds do not perform better than larger funds, and significantly so. Small funds also find it more difficult to survive than large funds.

Dahlquist et al. (2000) evaluated for survivorship bias within their sample, finding evidence of survivorship bias for the entire market, although most pronounced for equity funds, consistent with Elton et al. (1996b). They noted a return differential between surviving and

non-surviving funds of 0.6% to 0.7% per year, slightly lower than the return differentials found by Elton et al. (1996).

Moving away from survivorship bias studies, Annaert, Van den Broeck and Vennet (2003) used a Bayesian stochastic frontier approach to study the determinants of mutual fund performance. Studying a sample of 179 European equity unit trusts from 1995 to 1998, differential performance is separated into a noise component and an efficiency score. This methodology is consistent with Van den Broeck et al. (1994) who developed a Bayesian approach to modelling stochastic frontiers. Grinblatt and Titman (1989) suggested that a differential portfolio return could be decomposed into stock selection and market timing components, where outperformance due to stock selection was regarded as manager skill and outperformance because market timing is regarded as sporadic in nature.

Annaert et al. (2003) noted that a fund exhibiting an efficiency score of 100% indicates that the fund's assets were used efficiently and there is no underperformance within the fund. They found a positive relationship between the fund size of European equity funds and performance. They, however, noted that their sample could be influenced by flow effects because they rely on ex-post fund statistics referring to total assets managed. Investors could base their fund allocation decisions on the historical performance of equity funds (Annaert et al., 2003). When they examined fund statistics on an ex-ante basis, they found that the same result holds, although the correlation between the variables is weaker.

#### **2.4.2 DOMESTIC**

Hibbert (2003) investigated the effect of fund size on the risk-adjusted-performance of South African equity funds. Using regression and ranking analysis to study the performance of South African equity funds from 1989 to 1999, he found no statistically significant relationship between fund size and total risk-adjusted-performance. Thus, he posited that there seems to exist no optimal range in which portfolio returns are maximised. Hibbert (2003) notions that these results show that the JSE is efficient because fund managers cannot earn excess returns by controlling the size of their portfolios. Given this, the fourth cluster of literature notions

that fund size is both positively and negatively correlated to performance and that it is possible to determine an optimal fund size that maximises returns.

## **2.5 CONCAVE RELATIONSHIP BETWEEN MUTUAL FUND SIZE AND PERFORMANCE**

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### **2.5.1 FOREIGN**

Category 4 finds that a non-monotonic relationship exists between mutual fund size and performance. That is, at first, funds experience economies of scale as fund size increases and then, diseconomies of scale beyond a certain point (Tang, Wang & Xu, 2010). The result of this research is that it is possible to find an optimal fund size where performance is maximised. Some studies incorporated style elements into the research and posited that the optimal fund size differs between funds with different investment styles (Shawky & Li, 2004). Research also focused on hedge funds, finding that an inverted u-shaped relationship exists between AUM and performance (Getmansky, 2005).

Tang et al. (2010) studied how economies of scale and liquidity influence the relationship between fund size and performance. Using a sample of Chinese open-ended equity mutual funds and a ranking analysis, they found a non-monotonic relationship between performance and mutual fund size. Initially, funds benefit from an increase in their AUM, but beyond a certain point, funds start to experience diseconomies of scale. They found that the optimal fund size range, where performance is maximised, is between RMB 2–3 billion. Basso (2017) used data envelopment analysis (DEA) models to study the effects of fund size on performance. Although finding no initial relationship between size and performance, he noted that a non-linear relationship might exist between size and performance due to large funds exhibiting higher performance scores in the DEA model than small funds. Thus, suggesting an optimal fund size could exist. Tuzca and Ertugay (2020), use DEA analysis to study the relationship between Turkish mutual fund performance and size. They also use linear correlation, Kendall and Spearman rank correlation coefficients to determine that mutual fund size is positively related to performance, similar to Basso (2017).

Shawky and Li (2004) wanted to determine the optimal size of US mutual funds using data from 1997 to 2003 while incorporating different investment styles into their analysis. They

found that the optimal fund size for small-cap funds with either a value or growth bias to be either \$1 008m or \$1 245m, respectively. They further noted that there is a significant

relationship between a fund's performance and the growth in the fund's asset base during the corresponding period.

Getmansky (2005) studied the effect of fund size on the performance of hedge funds. Using data from the TASS database on the performance evaluation of hedge funds, he found that there is a concave relationship between hedge fund returns and NAV. The concavity of the relationship suggests that it is possible to obtain an optimal size. The hypothesis behind this relationship is that as hedge funds grow, they have greater flexibility to invest in a larger range of assets with uncorrelated returns; thus, they can reduce the variance of the entire portfolio more aggressively than mutual funds, given the long constraints imposed on mutual funds (Getmansky, 2005). These results are consistent with the findings of Goetzmann, Ingersoll and Ross (2003) and Agarwal, Daniel and Naik (2004) who found positive concave relationships between US hedge fund returns and risk-adjusted-performance.

## **2.5.2 DOMESTIC**

Kopke (2015) used data from 100 South African collective investment schemes to analyse whether performance is influenced by fund size. Although Kopke (2015) found no initial relationship between fund size and performance, the results of the ranking analysis suggested that a non-monotonic relationship could exist between size and performance. Kopke (2015) thus calculated the optimal fund size for South African equity unit trusts as between R1–2bn. Pillay et al. (2010) wanted to find an optimal equity fund size for the South African market. Finding that the point at which AUM influence performance is a fund size of R5bn (Pillay et al., 2010). They suggested that large funds should shift their holdings to cheaper passive investment products. Small and medium-sized managers must be aware of size influences and not let AUM exceed a certain level, in this case, the R5bn.

## **2.6 SUMMARY**

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Academic literature shows that debate persists over the relationship between fund size and performance. Over time, four categories of research emerged on the topic. The most popular view, however, was that a negative relationship exists between fund size and performance.

Research from Category 1 suggests that no relationship exists between mutual fund size and performance (Berk & Green, 2004; Blake et al., 2011). Category two research finds that there is a negative correlation between mutual fund size and performance (Chen et al., 2004; Yan, 2008); while Category 3 posits that a positive relationship exists between mutual fund size and performance (Chan et al., 2009). The fourth category of research suggests that an inverted non-monotonic relationship exists between fund size and performance and thus, it is possible to calculate an optimal fund size (Tang et al., 2010; Pillay et al., 2010).

In South Africa, the relatively illiquid nature of the JSE compared to more developed stock-exchanges added impetus to the argument that fund size is negatively related to performance (Pillay et al., 2010). Although the literature does exist for the South African market (Milburne-Pyle, 1984; Pillay et al., 2010; Kopke, 2015), it does not use a simulation procedure or the period being analysed is outdated. Further research on the topic that studies how mutual fund size is related to performance within a simulation framework would provide meaningful insight that could be used by a wide-ranging group of financial market participants across the CIS industry. Furthermore, the structure of the South African equity market and the CIS industry provides a particularly interesting context within which to study the relationship between mutual fund size and performance. The next chapter will review some important characteristics of the JSE and the CIS industry that make the South African case an interesting one to study the relationship between mutual fund size and performance.

## **CHAPTER THREE: DATA AND METHOD**

### **3.1 INTRODUCTION**

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Pillay et al.'s (2010) study was one of the first and only academic studies to examine how mutual fund size affects portfolio performance in South Africa using a simulation procedure. Most academic research on the subject used actual mutual fund data to assess the relationship between size and performance (Kopke, 2015). Moreover, studies on the topic often evaluated whether a range of independent variables (size, investment style, and age) affect mutual fund performance (Chen et al., 2004; Yan, 2008). As Kothari and Warner (2001) noted, large standard errors from multifactor excess return regressions limit the researcher's ability to detect abnormal performance. Using a simulation procedure allows the researcher to employ real-world constraints to simulated portfolios while examining the effect that one independent variable (size) has on the performance of a hypothetical set of mutual funds.

The analysis and the results presented in this study are based on daily price, market capitalisation, and volume-traded data by value (measured in ZAR) sourced from *DataStream* for all companies listed on the JSE between 1 January 2008 – 31 December 2017, including shares that could have been delisted over the period. The same ordered list of shares was used for all three data sets to ensure that accurate returns, market capitalisation, and volume-traded data were being used for each stock selected in the hypothetical portfolios. Daily price data were used to calculate stock returns over one-, two-, and three-year holding periods assuming companies pay no dividends. The researcher then constructed a simulation model that randomly selects 40 stocks for a hypothetical portfolio and allocates capital to those stocks based on portfolio size and yearly volume-traded data for the underlying stocks. Once the capital was fully allocated to the different portfolio sizes, returns were calculated and assessed.

This section will proceed by reviewing the mutual fund industry in South Africa, specifically referencing mutual fund size and market liquidity. The practical considerations in the portfolio

construction process will then be reviewed, and the allocation and simulation procedures applied in the study will be discussed in detail.

### **3.2 MUTUAL FUNDS IN SOUTH AFRICA: SIZE AND LIQUIDITY**

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Before assessing the relationship between mutual fund size and performance within a simulation framework, it is critical to understand some characteristics of DEFs in South Africa, and how liquidity on the JSE has changed over time. The latter is a particularly critical element of the allocation procedure because stocks with greater volume-traded levels have more capacity to take on investment than stocks with lower volume-traded levels. The allocation procedure refers to the process used to allocate capital to the stocks in the hypothetical portfolios. An overview of DEF size in South Africa is followed by a discussion on liquidity in the country.

In its CIS Statistics Report on 31 December 2017, ASISA noted that the average DEF in South Africa has AUM of R1.2bn and the majority of DEFs in South Africa are classified as general funds (ASISA, 2017). In this study, the size of the hypothetical mutual funds was selected to include the average DEF size as reported by ASISA at the end of 2017. Referring to Table 1, ASISA classified 265 funds as having a general style bias at the end of 2017, while the second-largest style bias was large-cap. While it is safe to assume that most large-cap funds are invested in large-cap equities, it is also safe to assume that most general funds are significantly invested in large-cap equities; therefore, DEFs in South Africa have a large-cap bias (De Vries, Erasmus & Gerber, 2017).

In South Africa, large-cap companies typically comprise the top 40 companies by market capitalisation listed on the JSE. Furthermore, not only do DEFs have a large-cap bias, but the number of DEFs in South Africa has steadily been increasing over time. The general rise in the number of DEFs in South Africa has absorbed some of the increase in liquidity on the JSE over the same period. Here, liquidity is measured by trading volumes and following the 2008–2009 global financial crisis, trading volumes on the JSE increased significantly (JSE, 2017). This increase in liquidity was partly due to an influx of capital into the country and broadened the set of investment opportunities available to portfolio managers. While trading volumes might

have increased, most DEFs, however, remain heavily invested in the top 40 stocks by market capitalisation listed on the JSE.

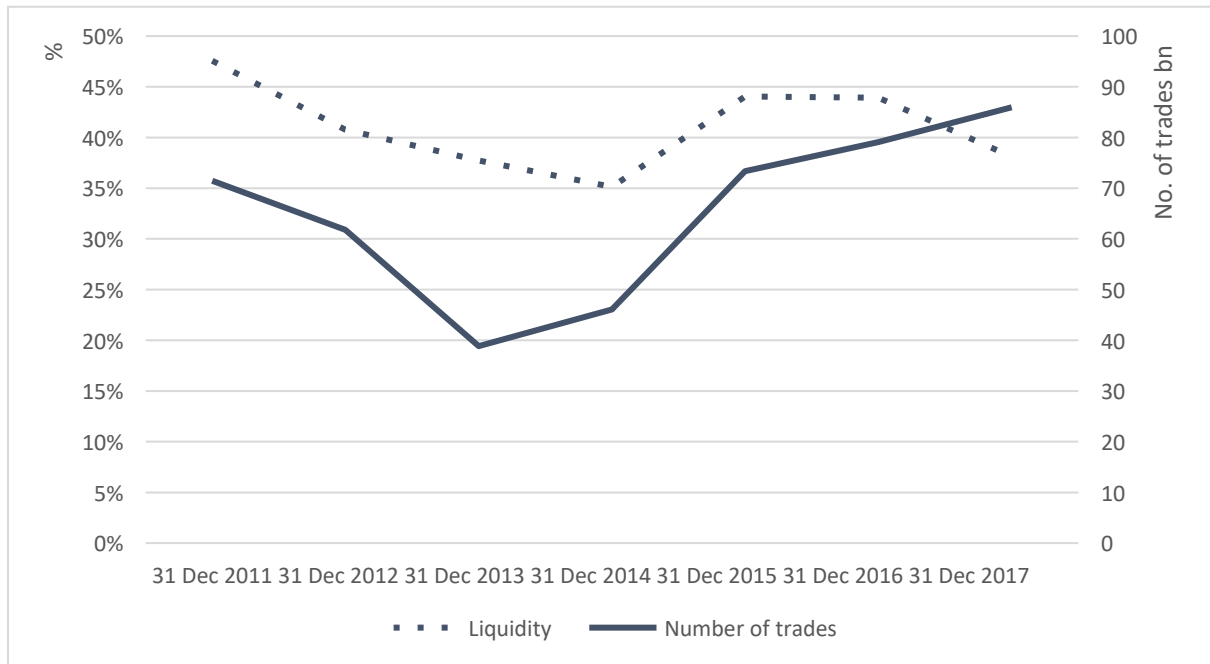
As fund size increases, managers either must find new investment opportunities or increase investment in the top40. Moreover, while over the past 25 years, liquidity on the JSE improved greatly, from 2011 to 2017, liquidity remained relatively constant while the size and number of DEFs in the country increased. Figure 1 defines liquidity as the average value of traded equity as a percentage of market capitalisation on the JSE. Liquidity remained relatively constant over the past six years, while the total number of trades has been increasing from 2013 (JSE, 2017).

Figure 2 shows the growth in the total number of DEFs in South Africa over the past seven years. From this information, one could conclude that the total number of DEFs in South Africa has been steadily increasing, and this has not been met by an increase in liquidity. This is an important conclusion because it shows that a larger number of portfolio managers are looking to invest in a limited number of liquid listed securities. Next, we review key constraints and considerations in the portfolio construction process.

**Table 1: Holding information: DEFs in South Africa (31 December 2017)**

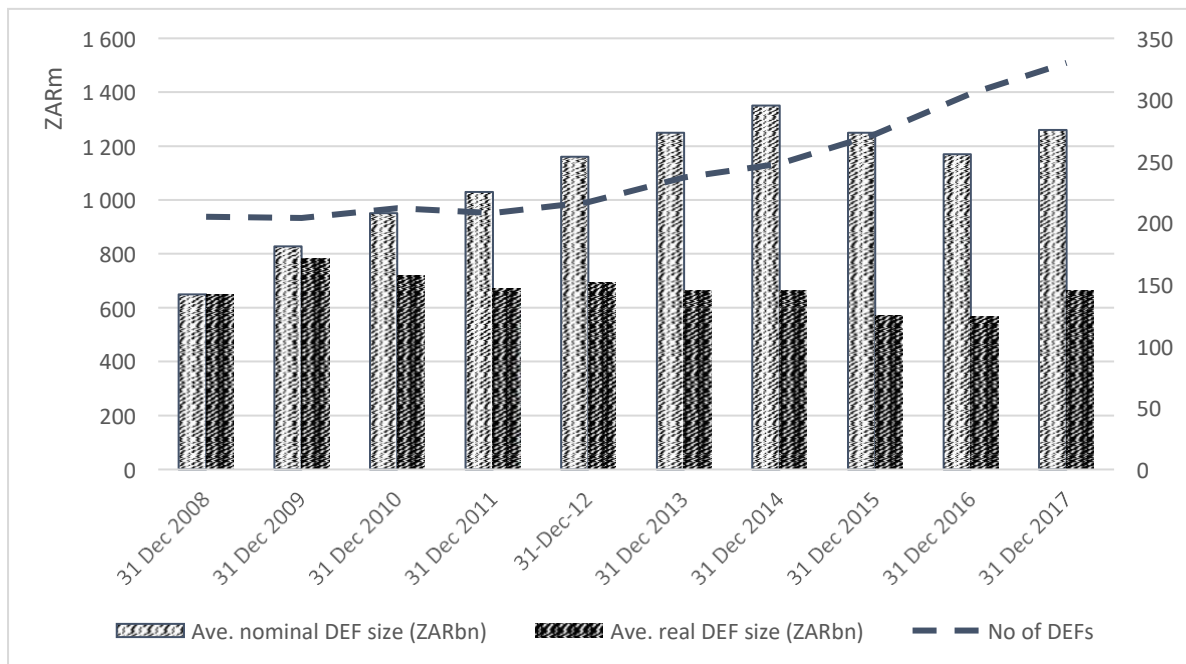
| <b>DEFs</b>                       | <b>Total Assets (ZARm)</b> | <b>Total Sales (ZARm)</b> | <b>No. of Accounts</b> | <b>No. of Funds</b> |
|-----------------------------------|----------------------------|---------------------------|------------------------|---------------------|
| <b>General funds</b>              | 364 456                    | 44 135                    | 800 040                | 265                 |
| <b>Large-cap funds</b>            | 27 476                     | 2 324                     | 62 690                 | 25                  |
| <b>Mid- &amp; Small-cap funds</b> | 6 484                      | 347                       | 72 025                 | 10                  |
| <b>Unclassified funds</b>         | 973                        | 48                        | 359                    | 3                   |
| <b>Resources funds</b>            | 3 820                      | 733                       | 30 644                 | 10                  |
| <b>Industrial funds</b>           | 7 631                      | 203                       | 56 502                 | 7                   |
| <b>Financial funds</b>            | 3 660                      | 454                       | 11 654                 | 10                  |

**Source: ASISA (2017)**



**Figure 1: Liquidity and trading on the JSE**

*Source: JSE (2017)*



**Figure 2: DEF growth in South Africa and DEF size**

### 3.3 PORTFOLIO CONSTRUCTION: PRACTICAL CONSIDERATIONS

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To construct hypothetical mutual fund portfolios, certain assumptions and practical considerations were applied, and these will be discussed in detail. They include assumptions regarding fund size, the investable universe of stocks, the total number of stocks held in the portfolios, the weighting of those stocks in the portfolios, the investment date, the holding period of the investments, and corporate governance constraints. Furthermore, survivorship bias in the sample was also controlled and will be discussed separately.

Portfolios sizes in ZAR of 100mn, 500mn, 1bn, 2bn, 5bn, 10bn, 20bn, 50bn and 100bn were used. These portfolio sizes were assumed so that all major fund sizes of 1bn, 5bn, and 20bn were included in the study. Although at the end of 2017, the largest DEF in South Africa had AUM of 60bn, a fund size of 100bn was also used. Pillay et al. (2010) created a set of funds increasing in size by 25%, starting with an initial fund size of R10mn in 2008. Here, the minimum fund size was increased to R100mn. The reason for this, as is shown in Figure 2, is that the average size of DEFs in South Africa has nominally increased over the last 10 years (ASISA, 2017).

Before stocks can be randomly sampled to portfolios, the total investable universe of stocks must be determined. The investable universe of stocks available to DEF managers in South Africa is best represented by the FTSE/JSE All-Share Index (JALSH). The JALSH represents 99% of the full market capital value of all ordinary shares listed on the main board of the JSE and is made up of 160 stocks (JSE, 2017). This study assumes that the set of stocks in the investable universe,  $m$ , or the universe of tradeable stocks, is the top 160 stocks, ordered by market capitalisation, listed on the JSE at investment date,  $t$ . That is to say, 40 stocks are randomly sampled from  $m$  on date  $t$ . Once the universe of tradeable stocks was determined, volume- traded data by value (in ZAR) for all the stocks in  $m$  is determined.

Once the investable universe was determined, the total number of stocks to be held in the hypothetical portfolios had to be established. The researcher reviewed the literature on the topic to determine the optimal number of stocks in the random portfolios with specific reference to the South African case. Statman (1987) noted that a well-diversified equity

portfolio should include between 30 and 40 stocks. Bradfield and Munro (2017) found that in South Africa, at least 20 stocks are needed to effectively diversify a portfolio. They studied both equally weighted and market capitalisation-weighted portfolios and found that equally weighted portfolios require less diversification than market capitalisation-weighted portfolios. Using the JSE SWIX as a proxy, they noted that at least 33 stocks are required to effectively diversify a capitalisation-weighted portfolio, while an equal-weighted portfolio requires between 15–29 stocks to be adequately diversified (Bradfield & Munro, 2017). Here, a 40-stock portfolio is used to sample random equally weighted portfolios, in line with Pillay et al. (2010) who also used a 40-stock portfolio. An equally weighted portfolio is assumed at the initial investment date  $t$ . Once the allocation procedure is applied and capital is allocated to the portfolio, the portfolio, however, might not be equally weighted. The portfolios will be constrained by the one-third value-traded rule, which will now be discussed.

Pillay et al. (2010) noted that corporate governance constraints exist that restrict large share purchases. To accurately account for these constraints, stock purchases were limited to one-third of the total annual volume traded by value,  $vt_x$ , for any given stock at time  $t$ .  $vt_x$ , for all constituents in  $m$ , calculated from daily volume-traded data as *DataStream* does not provide annual volume-traded data. Following on from Pillay et al. (2010), two hundred and sixty (260) trading days are assumed in the calculation of  $vt_x$ . One-third of  $vt_x$  is then calculated and this is assumed to be the maximum ZAR amount that could be invested in the  $n$ th stock in the portfolio at time  $t$ . This is the only constraint that is applied to the model, and it considerably impacts the allocation of capital to the hypothetical portfolios. Larger stocks by market capitalisation typically have larger volume-traded levels than medium and small capitalisation stocks. As fund size increases, the portfolios, therefore, must invest more capital in large capitalisation stocks than in medium and small capitalisation stocks.

Another important consideration is the investment date,  $t$ . Portfolios constructed on different investment dates might yield significantly different returns based on the investment date of the underlying stocks. Market timing effects that distort equity returns have been well documented internationally and in South Africa. One such market timing phenomenon is the January effect, although in South Africa the existence of the January effect remains debatable

among researchers. For example, two notable studies on the January effect in South Africa include Robbins et al. (1999) and Auret and Cline (2011). The former found a significant January effect on the JSE using a two-period sample from January 1988 to December 1995, and January 1996 to December 2006. The latter, however, found no significant January effect on the JSE. To avoid any possible time-period-specific market effects, 10 000 random dates between 1 January 2008 and 31 December 2014 were used in the model. December 2014 is selected as the end date for the random sampling window to allow for the calculation of three-year returns on the portfolio to 31 December 2017.

To control for survivorship bias in the sampling process, all stocks listed on the JSE from 1 January 2008 – 31 December 2017 were included in the sample. Pillay et al. (2010) used the same method to control for survivorship bias in their study. When stocks are delisted, they are still included in the sample and their holdings are converted into a cash amount equal to their last traded share price. If delisted stocks are included in the portfolios, their returns are calculated on their last traded share price.

Last, it is important to note that the model randomly samples two variables. The first being the investment date  $t$ , and the second being the 40 stocks in the portfolio. Specific assumptions and considerations discussed here include the various portfolio sizes used, the investable universe, corporate governance constraints, the investment date, and survivorship bias controls. Based on the volume-traded constraints, it is important to review the allocation procedure that the model applies to allocate capital to portfolio stocks.

### **3.4 THE ALLOCATION PROCEDURE**

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The allocation procedure describes the process used to allocate capital to the randomly sampled stocks in the hypothetical portfolios and forms part of the simulation model. This part of the model is necessary because the portfolio is constrained by the one-third volume-traded rule. That is, because of corporate governance constraints, the maximum amount that can be invested in any stock is one-third of the annual volume traded in that stock. If portfolio managers were not constrained in their ability to allocate capital among stocks, the allocation procedure would equally rand weight capital among all 40 stocks in the portfolio as follows:

$$w_i = \frac{ps}{40} \quad (2)$$

where  $w_i$  is the ZAR weight of the  $i^{\text{th}}$  stock in the portfolio on date  $t$ , and  $ps$  is the initial portfolio size. In this scenario, all stocks in the portfolio are assumed to have sufficient volume traded to allow for an equal distribution of capital among all securities. One-third of the total volume traded in the  $i^{\text{th}}$  stock in the portfolio on date  $t$ ,  $vt_x$ , could be defined as follows:

$$vt_x = \left(\frac{1}{3}\right)(vt_i), \quad (3)$$

where  $vt_x$  is equal to one-third of the total yearly value-traded,  $vt_i$ , in the  $i^{\text{th}}$  stock in the portfolio. The portfolio is constrained in its ability to allocate capital to stocks where  $w_i > vt_x$ ; therefore, the following function applies:

$$w_x = \mathbf{min}(w_i; vt_x). \quad (4)$$

Using an equal-weighted portfolio ensures that each stock is weighted equally at the beginning of the simulation, where  $w_x$  is the ZAR value allocated to the  $i^{\text{th}}$  stock in the portfolio. Where  $w_i > vt_x$ , there will be capital remaining in the portfolio once the first allocation of capital has been completed. If  $w_i > vt_x$ , there will always be capital remaining in the portfolio to be allocated. Once the allocation procedure has completed the first allocation iteration, and  $w_i > vt_x$ , the amount of capital to still be allocated will be:

$$rc_i = \{ps_i - (\sum w_x)\}, \quad (5)$$

where  $rc_i$  represents the unallocated capital remaining in the portfolio that must be allocated to the stocks in the portfolio that can still take on capital. Once the first allocation iteration is completed, some stocks will have been allocated  $vt_x$ . At this point, it is again possible to calculate the equal-weighted amount of capital to be allocated to the remaining stocks in the portfolio, using the following function, where  $s_x$  represents the remaining number of stocks in the portfolio that can still take on additional capital:

$$w_{ii} = \left(\frac{rc_i}{s_x}\right), \quad (6)$$

where  $w_{ii}$  is the rand weight of additional capital to be allocated to  $s_x$ . At this point, the allocation procedure engages in the next iteration, allocating the minimum of the volume traded,  $vt_x$ , or the equal-weighted ZAR value,  $w_i$ , to the remaining stocks in the portfolio,  $s_x$ . It is also important to note that the process will repeat itself until the model can equally allocate capital to the remaining stocks in the portfolio. At this point, the portfolio will be fully allocated. Table 2 shows how the allocation procedure works using a step-by-step process.

**Table 2: Allocation procedure: Process**

| Steps | Process   |
|-------|---|
| 1     | Using Equation (2), calculate the rand weight of capital to be allocated equally to all 40 stocks in the portfolio. This equal-weighted amount will depend on the initial size of the portfolio.  |
| 2     | Calculate the annual volume traded for all 40 stocks in the portfolio from daily data sourced from <i>DataStream</i> , $vt_i$ .   |
| 3     | Using Equation (3), calculate one-third of the annual volume traded for all 40 stocks in the portfolio, $vt_x$ .  |
| 4     | Since the portfolio is constrained by the one-third volume-traded rule, allocate the minimum of the equal-weighted amount, $w_i$ , or one-third of the volume traded in that specific stock, $vt_x$ , to that specific stock, using Equation (4). |
| 5     | Using Equation (5), calculate the remaining amount of capital to be allocated, $rc_i$ . This amount will be the difference between the original portfolio size and the amount of capital that has already been allocated to the portfolio.        |
| 6     | Calculate the number of stocks that can still take on more capital, $s_x$ . If the total one-third of volume traded has been allocated to a specific stock, then it cannot take on additional capital.  |
| 7     | Calculate the new equal-weighted amount of capital to be allocated to the remaining stocks in the portfolio, $w_{ii}$ , using Equation (6).   |
| 8     | Repeat from step 4 to step 7, allocating the minimum of the new equal-weighted amount of capital and the remaining amount of volume traded to each of the stocks that can take on more capital.   |
| 9     | Repeat this process until the portfolio is fully allocated.   |

One problem that arises during the allocation procedure is that on the larger end of the fund size spectrum, the portfolio might not be fully invested in a 40-stock portfolio. At this point, the model engages in an additional procedure to allocate the remaining amount of capital. The model will then discard the stock with the lowest amount of volume traded from the portfolio and reselect another stock from the investable universe, this process might need to be repeated until the portfolio is fully allocated.

### 3.5 VARIANCE REDUCTION TECHNIQUES

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Before the simulation procedure is described in detail, the researcher discusses variance reduction techniques and how they were used in this study. Variance reduction is a procedure used in the Monte Carlo simulation to increase the precision of estimates obtained from a simulation (McGeoch, 1992). The Monte Carlo method used in this study has an error variance of the form  $\sigma^2/n$ , sampling with a larger value for  $n$  (in this case  $n = 10\,000$ ), resulting in a reduction in the error variance. While increasing the size of the sample will reduce the error variance, reducing  $\sigma$ , however, will also reduce the error term. Here, this is achieved by reconstructing the Monte Carlo problem more efficiently. That is, the outcome of the simulation will be the same as the original outcome, but it will be achieved with a lower  $\sigma$ .

The specific variance reduction procedure used here is common random numbers (CRN). CRN is used to estimate the difference between expected performance measures for two or more systems (L'Ecuyer, 1994). CRN is one of the simplest most widely used methods used to compare the efficiency of comparisons through simulations (Glasserman & Yao, 1992). The only requirement of CRN is that two or more systems in need of comparison are studied using the same set of random numbers. Essentially, each fund size is a different simulation or system where the outcome or final portfolio allocation depends on the initial size of the portfolio and volume-traded levels on the JSE.

#### 3.5.1 VARIANCE REDUCTION: PORTFOLIO ALLOCATION EXAMPLE

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The research presents an example of the allocation procedure used in the simulation model and how variance reduction, specifically CRN, is incorporated into the portfolio construction process. For simplicity, the researcher assumes that the total investable universe comprises 15 stocks and each random portfolio will consist of five stocks. In the simulation model, the investable universe comprises 160 stocks (consistent with the FTSE/JSE All-Share Index) and each random portfolio consists of 40 stocks. For illustrative purposes, however, a 15-stock

investable universe and 5-stock random portfolio are assumed. The investable universe in this example will thus take on the following form:

$$m = \begin{pmatrix} y_1 \\ \mathbf{1} \cdot y_2 \\ \cdot \\ \cdot \\ (y_{15}) \end{pmatrix}, \quad (7)$$

where  $m$  is a vector that represents the investable universe of stocks  $y_1$  to  $y_{15}$ . Assuming the allocation procedure described in Section 3.4 is applied to a random portfolio,  $z$ , a certain initial fund size is also assumed, and no volume-traded constraints are applied. The fully allocated portfolio could take on the following form:

$$z = \begin{pmatrix} y_3 \\ \mathbf{1} \cdot y_2 \\ y_7 \\ y_{11} \\ (y_4) \end{pmatrix}, \quad (8)$$

where portfolio  $z$  is a vector that consists of five stocks that were randomly selected from the investable universe,  $m$ . Furthermore, no volume-traded constraints were applied so one iteration of the allocation procedure has produced a fully and equally weighted 5-stock portfolio, as shown in Equation 8. That is, if the initial portfolio size was ZAR 100mn, ZAR 20mn is invested in each stock that was randomly sampled to the portfolio. Assuming now that volume-traded constraints are applied and the portfolio size, as measured by AUM, increases, the allocation procedure runs through several iterations to arrive at a new hypothetical portfolio that is different from the portfolio specified in Equation 8:

$$z_x = \begin{pmatrix} y_3 \\ \mathbf{1} \cdot y_5 \\ y_7 \\ y_{11} \\ (y_4) \end{pmatrix}, \quad (9)$$

where  $z_x$  is a fully allocated hypothetical portfolio that differs from portfolio  $z$  regarding size, stock selection and stock weighting. First, the size of portfolio  $z_x$ , as measured by AUM is

larger than portfolio  $z$ . Second, because of volume-traded constraints, stock  $y_2$  was replaced with stock  $y_5$  to satisfy the allocation requirements set out in Section 3.4. Because of the increase in fund size, the portfolio can no longer be fully invested in the first iteration of randomly selected stocks. Consequently, the allocation procedure engaged in a routine to discard the stock with the lowest volume-traded level ( $y_2$ ) and replace that stock with another stock from the investable universe with a higher volume-traded level ( $y_5$ ) (see Section 3.4 where the allocation procedure is described in detail). The third difference between  $z_x$  and  $z$  is the stock weightings. Because volume-traded constraints were applied, the portfolio stocks are weighted differently. Each stock in  $z_x$  is not equally weighted.

In the above example, CRN was applied to the initial random selection of stocks for the hypothetical portfolios varying in size. If stock selection is randomised, every time the portfolio size increases, the portfolios will not be directly comparable to one another. As shown above, the only factor that changes the composition of the hypothetical portfolios is a change in fund size. If fund size, however, does increase and all stocks in the portfolio can take on additional capital, there should be no difference in the return between portfolios varying in size and all stocks should be equally weighted. If stock selection, however, is randomised as portfolio size increases, the return to the hypothetical portfolios will differ.

For instance, if  $z$  represents a portfolio of a certain size and size is increased by a certain amount but no volume-traded constraints apply to the allocation procedure, the percentage weights of the stocks in portfolio  $z_x$  should be the same as the percentage weights of the stocks in portfolio  $z$  and the return to the portfolios should be the same. There should be no reason to randomise stock selection as fund size increases. A new random stock should only be selected from the investable universe if the portfolio is constrained in its ability to fully invest in a set of stocks.

CRN forms an essential part of this study because it ensures that the relationship between mutual fund size and performance is analysed and variance in the simulation is reduced. If CRN was not applied to the study, some other factor could contribute to return differentials between mutual funds varying in size. Because CRN is applied, the only time the composition

of the hypothetical portfolio changes, however, is if the portfolio can no longer be fully invested in a 40-stock portfolio.

### **3.5.2 VARIANCE REDUCTION: PRACTICAL IMPLEMENTATION**

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The simulation model used to assess the relationship between mutual fund size and performance is run over nine different fund sizes. For each fund size, random stocks are selected, and allocated capital based on an allocation procedure. The returns to each of these fund sizes are then compared to one another and a benchmark. For the portfolios, however, to be directly comparable to one another, they must be invested in the same random portfolios initially. This is because as size increases, the portfolios will be constrained by the one-third volume-traded rule and stocks will be discarded and added to the portfolios based on their capacity to take on more capital. If the different portfolios that vary in size are initially invested in different stocks, they, however, are not directly comparable to one another, and as fund size increases, it is not certain that fund size alone impacts performance because the stock mix changes completely as fund size increases. Some unidentified factor, and not fund size, might affect performance. This CRN method allows one to compare portfolios of varying sizes and determine whether larger or smaller portfolios perform better as fund size increases. The only factor that will change the composition of the portfolios is a change in fund size. This CRN method was considered when developing the simulation procedure.

CRN was also applied to the initial investment date,  $t$ . For the portfolios varying in fund size to be directly comparable to one another, they must be invested in the same stocks initially and on the same dates to allow for accurate return calculations. The initial investment date used in the simulation considerably affects the return calculations as stock prices fluctuate over time. If different random dates were being used to compare funds varying in size the results would be meaningless because stock performance fluctuates over time. It, therefore, is important to ensure that the same investment dates are being used across the different fund sizes.

In summary, two variables were randomised in the simulation model and then standardised across the different fund sizes: portfolio mix or stock selection and investment date. This

allows the simulated portfolios to be directly comparable to one another, and the effect of that fund size on performance can be assessed within that context. Variance in the simulation results is reduced by using these two CRN techniques so that the relationship between fund size and performance can be assessed in isolation.

### 3.6 THE SIMULATION PROCEDURE

Table 3 details the simulation procedure used in the model. The model was built in Matlab (2017b).

**Table 3: Simulation procedure**

| No. | Instruction   |
|-----|---|
| 1   | Define the investable universe, the number of stocks in the portfolio, the length of the simulation, and the portfolio sizes.<br><i>Investable universe = <math>m</math></i><br><i>number of portfolio stocks = 40</i><br><i>length of the simulation (no. of iterations) = 10 000</i><br><i>portfolio sizes (mn)</i><br><i>= 500, 1 000, 2 000, 5 000, 10 000, 20 000, 50 000, 100 000</i> |
| 2   | Read the market capitalisation, price, and volume data into Matlab.   |
| 3   | Convert the market capitalisation, price, and volume data into numeric matrices; strip out the dates.   |
| 4   | Define the index dates used to calculate the one-, two-, and three-year returns to the portfolios, assuming 260 trading days in a year.   |
| 5   | Randomly sample an initial investment date, $t$ , between 1 Jan 2008 and 31 Dec 2014.   |
| 6   | Sort the market capitalisation data in descending order on the initial investment date.   |
| 9   | Select the top 160 stocks by market capitalisation from the sorted market capitalisation data on date $t$ .   |
| 10  | Randomise the top 160 stocks by market capitalisation on date $t$ , and select the first 40 stocks as the initial portfolio.  |
| 11  | Apply the allocation procedure discussed in Section 3.4 and discussed again here.   |
| 12  | Using Equation (2), calculate the rand weight of capital to be allocated equally to all 40 stocks in the portfolio. This equal-weighted amount will depend on the initial size of the portfolio.  |
| 13  | Calculate the annual volume traded for all 40 stocks in the portfolio from daily data sourced from <i>DataStream</i> , $vt_i$ .   |
| 14  | Using Equation (3), calculate one-third of the annual volume traded for all 40 stocks in the portfolio, $vt_x$ .  |

| No. | Instruction   |
|-----|---|
| 15  | Since the portfolio is constrained by the one-third volume-traded rule, allocate the minimum of the equal-weighted amount, $w_i$ , or one-third of the volume traded in that specific stock, $vt_x$ , to that specific stock, using Equation (4). |
| 16  | Using Equation (5), calculate the remaining amount of capital to be allocated, $rc_i$ . This amount will be the difference between the original portfolio size and the amount of capital that has already been allocated to the portfolio.        |
| 17  | Calculate the number of stocks that can still take on more capital, $s_x$ . If the total one-third of volume traded has been allocated to a specific stock, then it cannot take on additional capital.  |
| 18  | Calculate the new equal-weighted amount of capital to be allocated to the remaining stocks in the portfolio, $w_{ii}$ , using Equation (6).   |
| 19  | Repeat from step 4 to step 7, allocating the minimum of the new equal-weighted amount of capital and the remaining amount of volume traded to each of the stocks that can take on more capital.   |
| 20  | Repeat this process until the portfolio is fully allocated.   |
| 21  | Once the portfolio is fully allocated, calculate the one-, two-, and three-year returns to the portfolio.   |
| 22  | Repeat from step 5, 10 000 times.   |

### 3.7 SUMMARY

This section described the simulation procedure used to assess the relationship between mutual fund size and performance. The liquidity features of the JSE and characteristics related to CISs in South Africa were first reviewed to effectively model the market dynamics of the JSE. Next, important considerations to consider when constructing the system used to assess mutual fund size and performance are discussed.

The allocation procedure describes a sub-system of the broader simulation model that is used to distribute capital to the portfolio stocks. Variance reduction techniques were also used to improve the efficiency of the simulation and ensure that the portfolios differ only in defined areas. Last, an overview of the simulation framework applied in this study is provided.

## **CHAPTER FOUR: RESULTS**

### **4.1 INTRODUCTION**

---

The previous chapter discussed the research methodology employed in this study. This chapter discusses the relationship that the portfolio simulation results infer between fund size and performance. As discussed previously, the simulation model randomises two variables, stock selection and investment date. Ten thousand (10 000) random portfolios were created on random dates between 01 January 2008 and 31 December 2014 for each of the different fund sizes, and their returns were assessed over different holding periods. To accurately determine whether the simulated portfolio returns are influenced by a change in fund size, returns were studied across fund sizes and compared to an equity benchmark in South Africa. The most recent date in the date sampling window, 31 December 2014, is three years before the end of the sample period, 31 December 2017, to allow for the calculation of three-year holding period returns to the simulated portfolios constructed on 31 December 2014.

The initial portfolio sizes were separated into nine different fund sizes, where the smallest fund size is ZAR 100m, and the largest fund size is ZAR 100bn. Table 4 shows the different fund sizes used. All major fund sizes of ZAR 1bn, 2bn, 5bn and 10bn were included in the study.

**Table 4: Different fund sizes used in the simulation**

| <b>Fund Size</b>   | <b>1</b> | <b>2</b> | <b>3</b> | <b>4</b> | <b>5</b> | <b>6</b> | <b>7</b> | <b>8</b> | <b>9</b> |
|--------------------|----------|----------|----------|----------|----------|----------|----------|----------|----------|
| <b>Size (ZARm)</b> | 100      | 500      | 1 000    | 2 000    | 5 000    | 10 000   | 20 000   | 50 000   | 100 000  |

The simulation study finds that over a one-year investment horizon, as DEF size increases, returns increase before decreasing sharply beyond a certain fund size. Over two- and three-year investment horizons, increases in fund size negatively affect performance. Over the three, time horizons, the optimal fund size is approximately ZAR 2bn.

The allocation procedure that forms part of the broader simulation procedure is constructed so that as fund size increases, the simulated portfolios become more heavily invested in stocks with higher volume-traded levels. These stocks are assumed to have larger market capitalisations than stocks with lower volume-traded levels. As portfolio sizes increase, the simulated portfolios become more heavily invested in large capitalisation stocks. To assess how the market capitalisation bias of the simulated portfolios changes as fund size increases, the returns to the different fund sizes are compared to the FTSE/JSE Top40 Index. One critical factor contributing to the results is the level of liquidity on the JSE because of the one-third volume-traded constraint that is imposed on the portfolios.

This section will proceed by discussing how liquidity on the JSE has changed over time. The general statistical properties of the return data will then be discussed and proceeded by an analysis of the mean portfolio returns calculated across the various fund sizes. The simulated results will be compared to the returns to the FTSE/JSE Top40 Index.

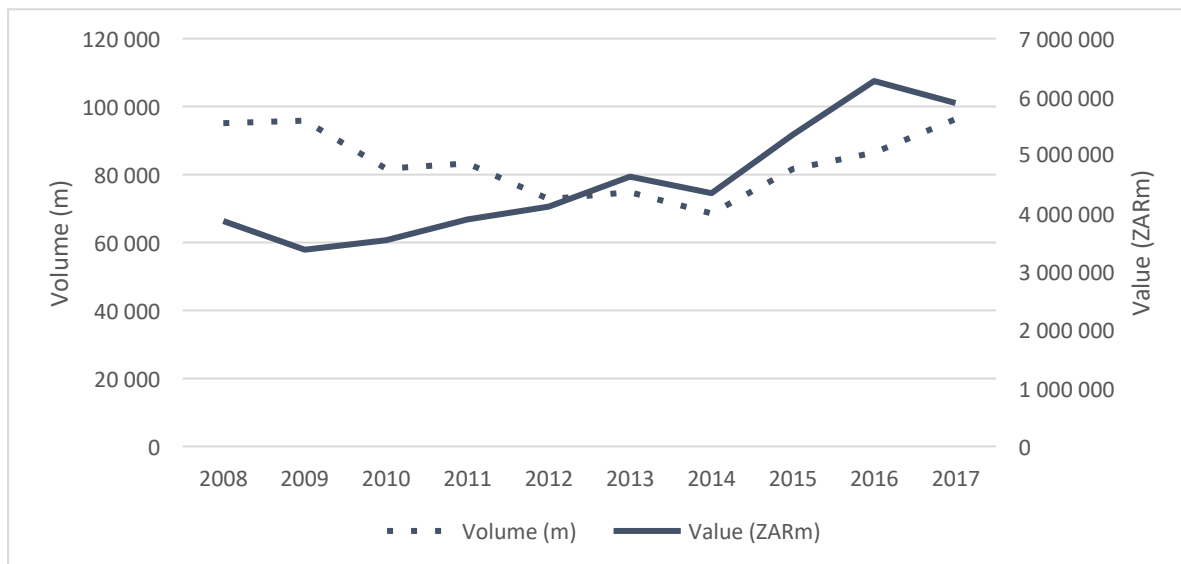
## **4.2 LIQUIDITY DYNAMICS ON THE JSE**

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Pillay et al. (2010) noted that from 1991 to 2008, liquidity on the JSE improved greatly following the introduction of the STRATE electronic trading system in 1999, the relaxation of exchange controls, and an improving economy. Auret and Young (2018) explained that higher trading volumes, more local and foreign investment, greater information dissemination, and improvements in the JSE's trading system all contributed to greater liquidity. Over the past 25 years, increased levels of volume traded largely resulted from changes in tax rules and methods to encourage the disclosure of information by companies (Auret & Young, 2018).

From December 2008 to December 2017, yearly volume-traded levels continued to increase in nominal terms but not in real terms. Figure 3 reports market statistics for the JSE over the period of analysis. In contrast to the findings of Pillay et al. (2010), liquidity on the JSE, as measured by volume traded, has not changed significantly from 2008–2017. The value of total trades, however, nominally increased from ZAR 4tn to ZAR 6tn from 2008–2017.

As can be seen in Figure 2, over the same period, the number of DEFs in the country increased significantly from 180 in December 2008 to 330 in December 2017. This has important implications for the simulation results because the increase in the amount of capital earmarked for investment into listed equity in South Africa, as measured by the number of DEFs in the country, was not met by a concomitant increase in liquidity on the JSE. More portfolio managers are competing to invest capital in a relatively smaller investment universe, and as fund size increases, managers become more constrained in their ability to invest in liquid stocks.



**Figure 3: Total volume and value-traded on the JSE (2008 – 2017)**

Liquidity on the JSE is a critical factor to consider in the real-world portfolio construction process, especially in South Africa. While the level of liquidity on the JSE is positively correlated to the size of the investable universe, we will next discuss the results of the baseline simulation and the relationship they infer between DEF size and performance.

### 4.3 SIMULATION RESULTS

**Table 5: Descriptive statistics: One-year holding period simulation results**

| Fund Size          | 1      | 2      | 3      | 4      | 5      | 6      | 7      | 8      | 9      |
|--------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| Mean               | 0.1232 | 0.1233 | 0.1240 | 0.1243 | 0.1211 | 0.1158 | 0.1065 | 0.0845 | 0.0714 |
| Standard Error     | 0.1234 | 0.1251 | 0.1247 | 0.1237 | 0.1200 | 0.1148 | 0.1046 | 0.0803 | 0.0677 |
| Median             | 0.0763 | 0.0760 | 0.0769 | 0.0772 | 0.0750 | 0.0787 | 0.0700 | 0.0696 | 0.0654 |
| Standard Deviation | 0.0058 | 0.0058 | 0.0059 | 0.0060 | 0.0056 | 0.0062 | 0.0068 | 0.0077 | 0.0076 |
| Sample Variance    | 3.0814 | 2.7404 | 2.7225 | 2.8264 | 3.0710 | 3.1055 | 3.2372 | 3.3799 | 3.4740 |
| Kurtosis           | 0.0757 | 0.0284 | 0.0252 | 0.1236 | 0.2101 | 0.2278 | 0.2105 | 0.2669 | 0.3574 |
| Skewness           | 0.5510 | 0.5203 | 0.5236 | 0.5393 | 0.5826 | 0.6418 | 0.6612 | 0.6755 | 0.6160 |
| Range              | 0.1349 | 0.1307 | 0.1197 | 0.1148 | 0.1388 | 0.1887 | 0.2161 | 0.2731 | 0.2290 |
| Minimum            | 0.4161 | 0.3895 | 0.4039 | 0.4245 | 0.4437 | 0.4531 | 0.4452 | 0.4024 | 0.3870 |
| Maximum            | 0.1234 | 0.1251 | 0.1247 | 0.1237 | 0.1200 | 0.1148 | 0.1046 | 0.0803 | 0.0677 |

**Table 6: Descriptive statistics: Two-year holding period simulation results**

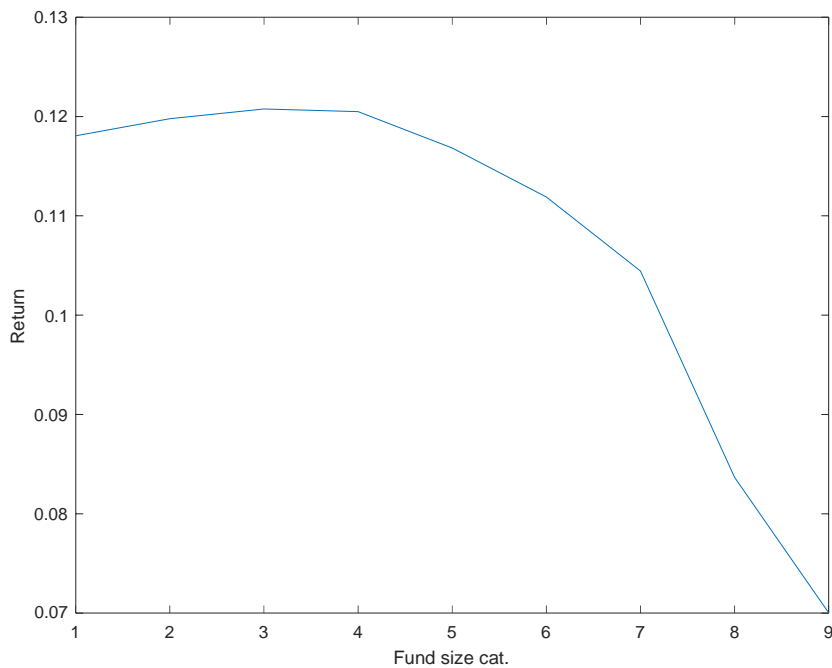
| Fund Size          | 1      | 2      | 3      | 4      | 5      | 6      | 7      | 8      | 9      |
|--------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| Mean               | 0.1190 | 0.1203 | 0.1209 | 0.1220 | 0.1169 | 0.1125 | 0.1056 | 0.0857 | 0.0710 |
| Standard Error     | 0.1379 | 0.1394 | 0.1399 | 0.1370 | 0.1309 | 0.1258 | 0.1178 | 0.0957 | 0.0782 |
| Median             | 0.1466 | 0.1458 | 0.1470 | 0.1470 | 0.1451 | 0.1431 | 0.1400 | 0.1100 | 0.1000 |
| Standard Deviation | 0.0215 | 0.0213 | 0.0216 | 0.0216 | 0.0211 | 0.0221 | 0.0236 | 0.0260 | 0.0264 |
| Sample Variance    | 4.7654 | 4.7223 | 4.6520 | 4.6384 | 4.6910 | 4.7249 | 4.7994 | 4.7200 | 4.6091 |
| Kurtosis           | 0.7651 | 0.7593 | 0.6662 | 0.5220 | 0.5031 | 0.5144 | 0.4797 | 0.3815 | 0.3152 |
| Skewness           | 1.2033 | 1.1528 | 1.1682 | 1.1817 | 1.1617 | 1.2048 | 1.2451 | 1.3119 | 1.2904 |
| Range              | 0.4476 | 0.4379 | 0.4326 | 0.4263 | 0.4174 | 0.4646 | 0.4723 | 0.5893 | 0.6100 |
| Minimum            | 0.7558 | 0.7150 | 0.7356 | 0.7553 | 0.7443 | 0.7402 | 0.7729 | 0.7226 | 0.6804 |
| Maximum            | 0.1379 | 0.1394 | 0.1399 | 0.1370 | 0.1309 | 0.1258 | 0.1178 | 0.0957 | 0.0782 |

**Table 7: Descriptive statistics: Three-year holding period simulation results**

| <b>Fund Size</b>          | <b>1</b> | <b>2</b> | <b>3</b> | <b>4</b> | <b>5</b> | <b>6</b> | <b>7</b> | <b>8</b> | <b>9</b> |
|---------------------------|----------|----------|----------|----------|----------|----------|----------|----------|----------|
| <b>Mean</b>               | 0.1158   | 0.1153   | 0.1161   | 0.1160   | 0.1120   | 0.1079   | 0.0980   | 0.0759   | 0.0650   |
| <b>Standard Error</b>     | 0.1219   | 0.1228   | 0.1229   | 0.1209   | 0.1143   | 0.1087   | 0.0960   | 0.0735   | 0.0636   |
| <b>Median</b>             | 0.1125   | 0.1130   | 0.1131   | 0.1132   | 0.1100   | 0.1050   | 0.0950   | 0.0811   | 0.0718   |
| <b>Standard Deviation</b> | 0.0034   | 0.0037   | 0.0038   | 0.0037   | 0.0035   | 0.0038   | 0.0040   | 0.0042   | 0.0038   |
| <b>Sample Variance</b>    | 2.3484   | 2.2840   | 2.3515   | 2.4737   | 2.5505   | 2.5627   | 2.7602   | 2.9653   | 3.0602   |
| <b>Kurtosis</b>           | 0.1842   | 0.2138   | 0.1970   | 0.1541   | 0.0494   | 0.0548   | 0.1155   | 0.0744   | 0.1087   |
| <b>Skewness</b>           | 0.3577   | 0.3654   | 0.3826   | 0.4066   | 0.4230   | 0.4552   | 0.4682   | 0.5097   | 0.4757   |
| <b>Range</b>              | 0.0472   | 0.0476   | 0.0520   | 0.0593   | 0.0653   | 0.0937   | 0.1274   | 0.1991   | 0.1800   |
| <b>Minimum</b>            | 0.3105   | 0.3178   | 0.3307   | 0.3473   | 0.3577   | 0.3615   | 0.3409   | 0.3106   | 0.2958   |
| <b>Maximum</b>            | 0.1219   | 0.1228   | 0.1229   | 0.1209   | 0.1143   | 0.1087   | 0.0960   | 0.0735   | 0.0636   |

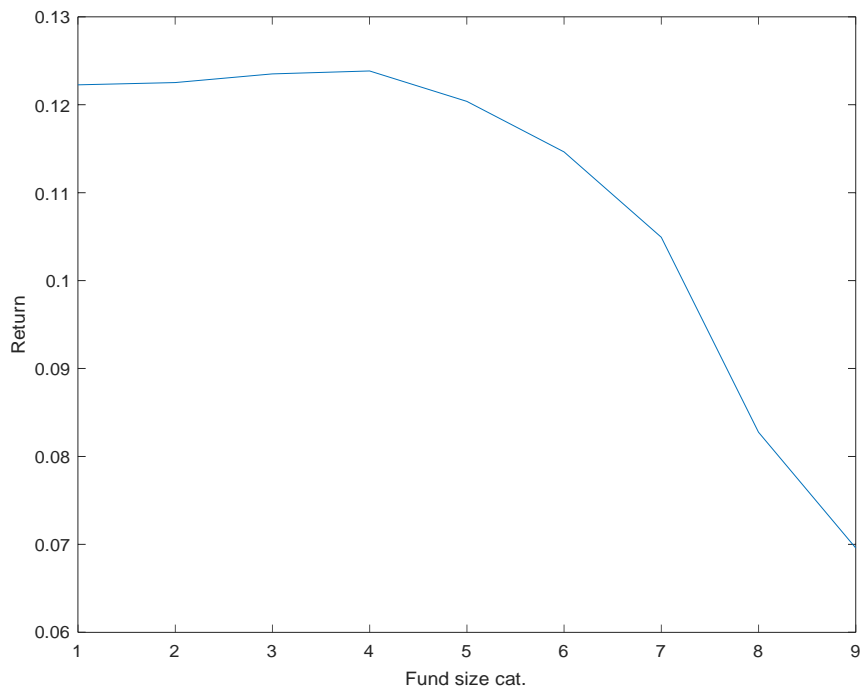
The mean returns across all fund sizes and all three holding periods indicate that as DEF fund size increases, returns increase until a fund size of ZAR 2bn is reached. Beyond a fund size of ZAR 2bn, further increases in fund size start to negatively affect performance. Incremental increases in performance because of increases in fund size, however, are minor compared to the decreases in performance that funds with AUM greater than ZAR 2bn experience. That is, DEF performance seems to be more negatively related to fund size than it is positively related to fund size.

Across all three holding periods, the ZAR 100bn funds experienced the worst performance, and considerably so. Comparing the performance of the Category 1 funds to the performance of the Category 9 funds across all three portfolios shows that returns decreased by more than 3% from the smallest to the largest fund size category. Simulated returns across all nine fund sizes and all three holding periods range from negative to over 50%, annually. Figures 4 to 6 illustrate how the mean return across all three holding periods changes as fund size increases.



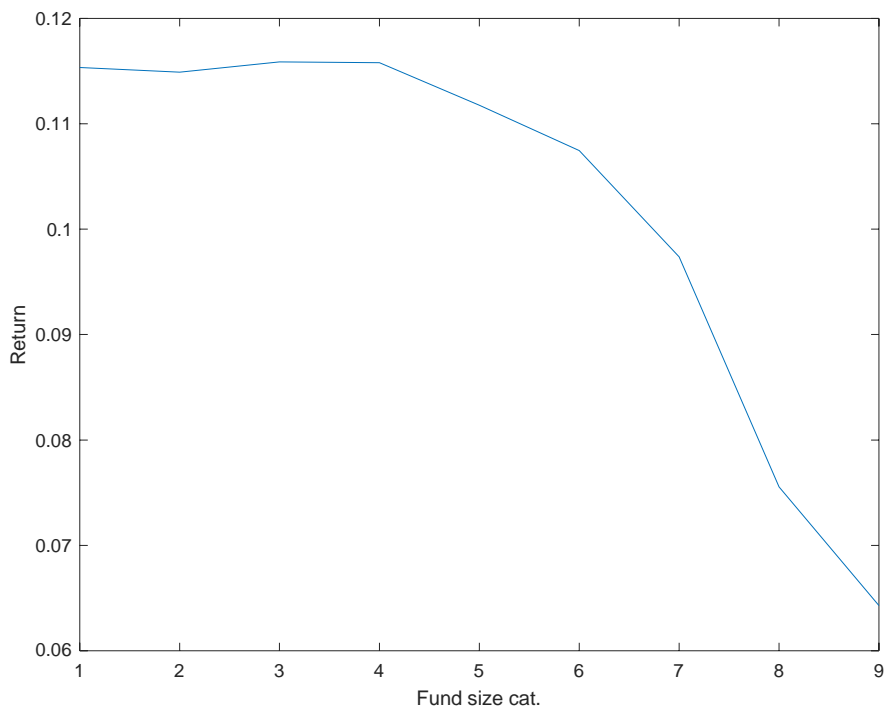
**Figure 4: Annual mean returns for simulated portfolios of increasing fund size over a one-year holding period**

Figure 4 shows that from fund sizes of ZAR 100mn to ZAR 2bn, increases in fund size lead to small increases in returns. ZAR 2bn funds performed the best, with a mean return of 11.90% over a one-year holding period. ZAR 5bn funds, however, seemed to perform considerably worse than ZAR 2bn funds when mutual fund size increased, with mean returns for these funds decreasing to 11.69% over a one-year holding period. ZAR10bn to ZAR 50bn funds perform even worse, with ZAR 100bn funds returning just over 7.10% over a one-year holding period. The results presented in Figure 4 suggest that as fund size increases, performance improves only slightly, but beyond a certain fund size, performance starts to decline noticeably.



**Figure 5: Average annual return for simulated portfolios across all fund sizes over a two-year holding period**

Figure 5 shows that from fund sizes of ZAR 100mn to ZAR 2bn, mean returns for funds varying in size were roughly constant at approximately 12.35% over a two-year holding period. Consistent with the one-year holding period results, mean returns, however, decline notably from ZAR 2bn to ZAR 5bn funds, with average returns for ZAR 5bn funds declining to just over 12.00% over a two-year holding period. ZAR 10bn to ZAR 100bn funds' performance continues to decline considerably with ZAR 100bn funds returning 7.10% on average over a two-year holding period. The results presented in Figure 5 suggest that increases in fund size do not initially lead to increases in returns, and beyond a certain fund size, further increases in size lead to noticeable decreases in performance.



**Figure 6: Average annual return for simulated portfolios across all fund sizes over a three-year holding period**

The results presented in Figure 6 are similar to the results presented in Figure 5. From fund sizes of ZAR 100mn to ZAR 2bn, increases in fund size do not lead to significant changes in performance, and the funds returned on average 11.55% over a three-year holding period. From ZAR 2bn to ZAR 5bn, fund performance starts to decline notably to just over 11.00. ZAR 10bn to ZAR 100bn funds perform considerably worse than Category 1 to 5 funds, with ZAR 100bn funds returning approximately 6.5% over the three-year holding period. The results presented in Figure 6 suggest that increases in fund size do not initially lead to increases in returns, and beyond a certain fund size, further increases in size lead to decreases in performance.

The baseline simulation results over the one-year holding period presented in Figure 4 suggest that as mutual fund size increases, returns increase up to a fund size of ZAR 2bn. As fund size increases beyond ZAR 2bn, funds, however, start to experience considerable declines in performance, with ZAR 100bn portfolios performing the worst out of all nine fund

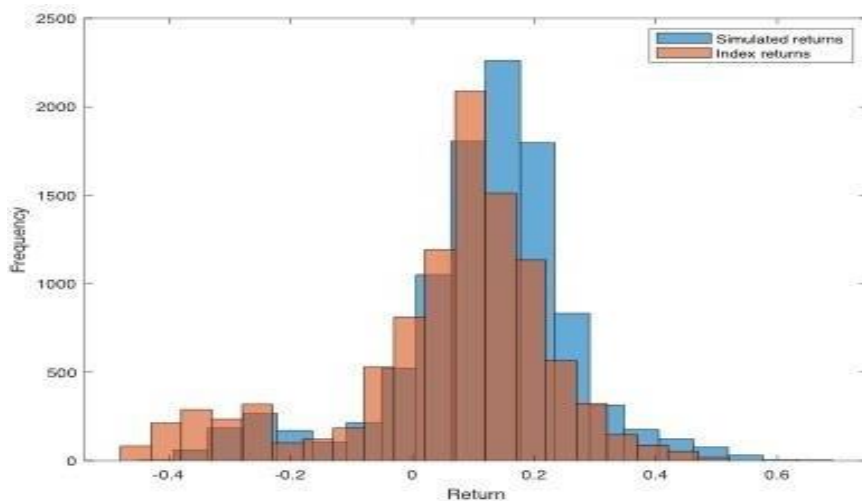
sizes. These findings are largely consistent with the findings over the two- and three-year holding periods presented in Figures 5 and 6 with one small difference. The results presented in Figures 5 and 6 suggest that as fund size increases to ZAR 2bn, performance is not noticeably affected, as average returns to the simulated portfolios remain relatively constant. Consistent with the results presented in Figure 4, beyond a fund size of ZAR 2bn, the simulated funds, however, start to experience a notable decline in performance.

The results presented in Figure 4 are consistent with several studies discussed in the literature review that suggest that a non-monotonic relationship exists between mutual fund size and performance. These include Indro et al. (1999), Tang et al. (2010), and in South Africa, Pillay et al. (2010). Tang et al. (2010) used a sample of Chinese mutual funds and found that funds tend to benefit from an increase in their AUM, but beyond a certain point, they start to experience diseconomies of scale. Similarly, using DEA models, Basso (2017) and Tuzca and Ertugay (2020) noted that a non-linear relationship might exist between mutual fund size and performance because large funds exhibit higher performance scores than smaller funds. Shawky and Li (2004) also found that there seems to be an optimal fund size where performance is maximised.

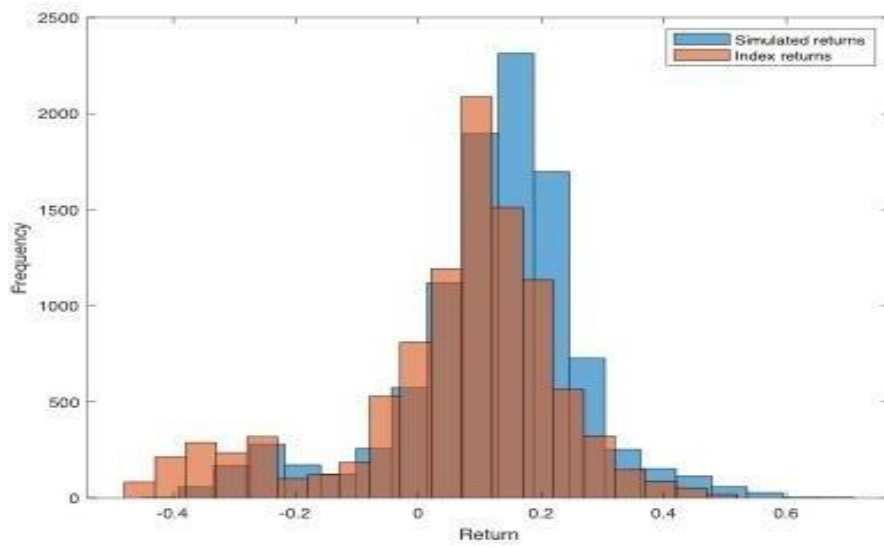
In South Africa, Pillay et al. (2010) used a simulation procedure to study the effect of fund size on performance. Their methodology is fundamentally similar to the methodology used here. The results found in this study, however, suggest that the optimal fund size in South Africa is approximately ZAR 2bn.

The two- and three-year holding period results presented in Figures 5 and 6 are more consistent with the academic literature that suggests that mutual fund size is negatively related to performance (Perold & Salomon, 1991 and Urdahl and Vasset, 2019). This strand of research posits that diseconomies of scale and liquidity effects outweigh skills that managers from larger funds might possess, leading to lower returns among large funds. While the results in Figure 4 might contrast with the results in Figures 5 and 6, one consistent finding across all three holding periods is that performance starts to decline considerably when fund size increases beyond ZAR 2bn.

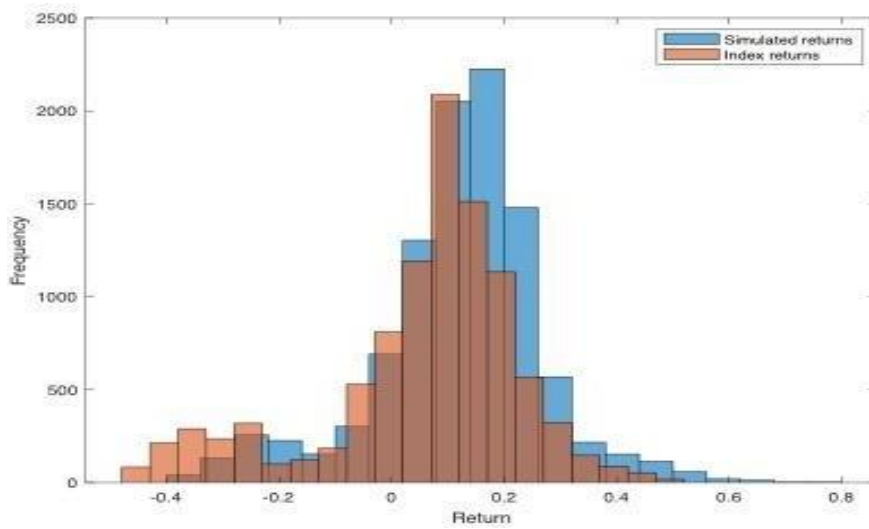
Simulated results were compared to an equity benchmark to holistically assess whether smaller DEFs perform better than larger DEFs in South Africa. The benchmark used for comparison was the JSE FTSE Top 40 Index, a market capitalisation-weighted index. Benchmark comparisons are important for two reasons. First, they aid in assessing whether the returns generated across different fund sizes were higher or lower than the stipulated benchmark returns. Second, by comparing the returns between the benchmarks and the simulated returns, one can assess how the style bias of the hypothetical portfolios changes as fund size increases. That is, as fund size increases, the hypothetical portfolios become more heavily invested in large capitalisation stocks, and the return between the benchmark and the hypothetical portfolios starts to converge. Figures 7 to 15 compare the simulated portfolio returns to the benchmark returns across all fund sizes over a one-year holding period. Figures 1 to 18 in the appendix compare the simulated portfolio returns to the benchmark portfolio returns across all fund sizes over two-year and three-year holding periods.



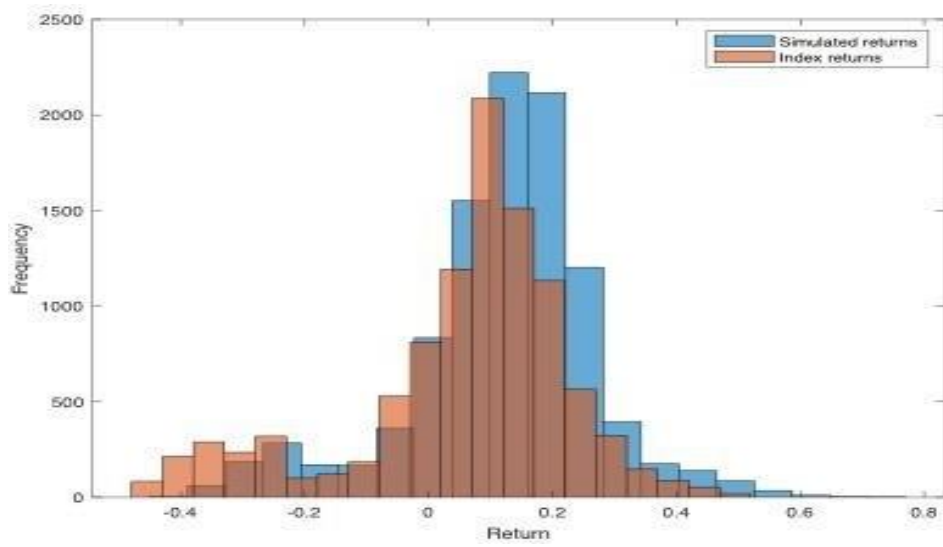
**Figure 7: Distributions of simulated vs index returns: ZAR 100mn fund size – One-year holding period**



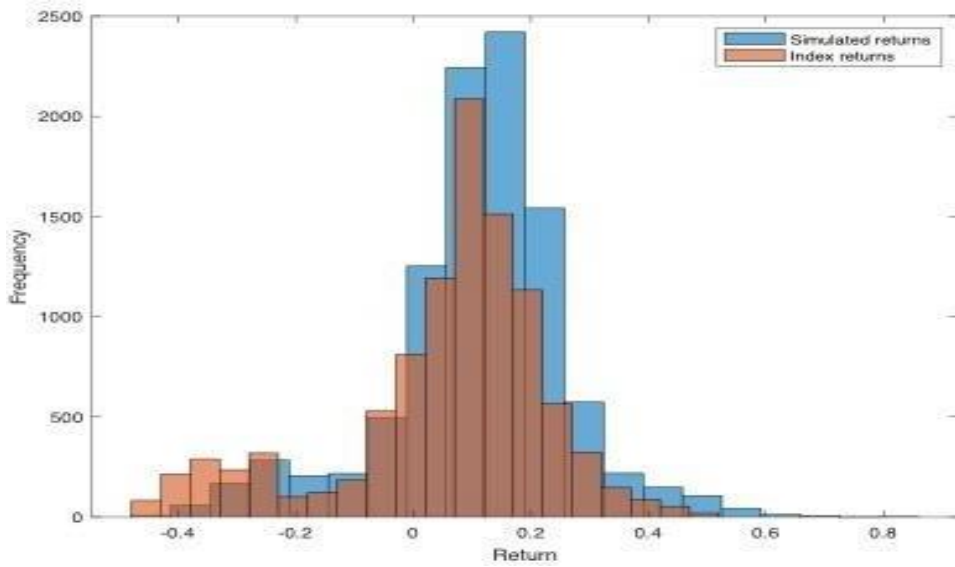
**Figure 8: Distributions of simulated vs index returns: ZAR 500mn fund size – One-year holding period**



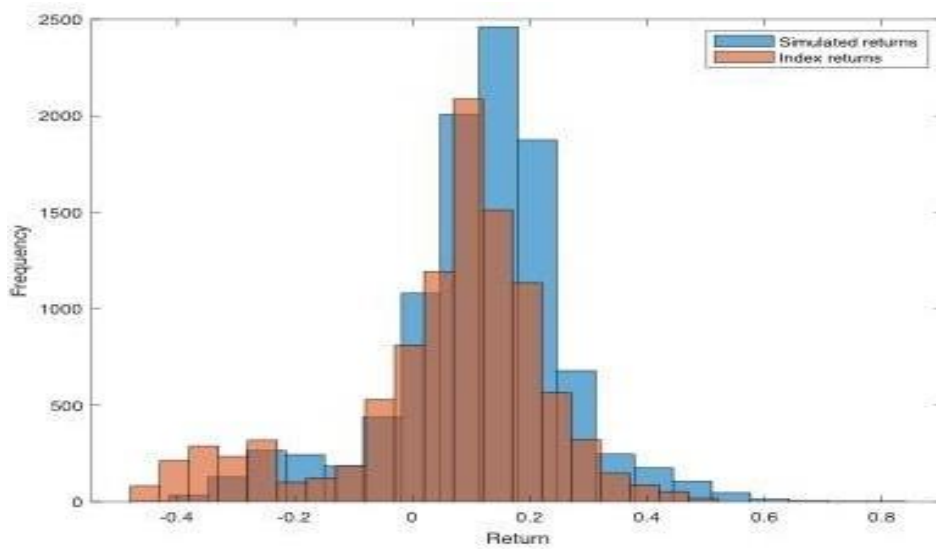
**Figure 9: Distributions of simulated vs index returns: ZAR 1bn fund size – One-year holding period**



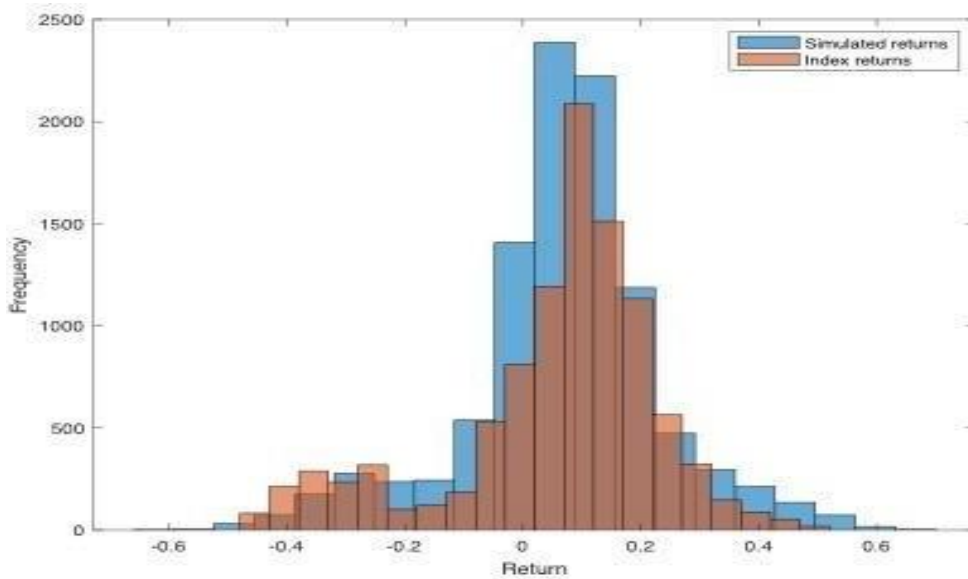
**Figure 10: Distributions of simulated vs index returns: ZAR 2bn fund size – One-year holding period**



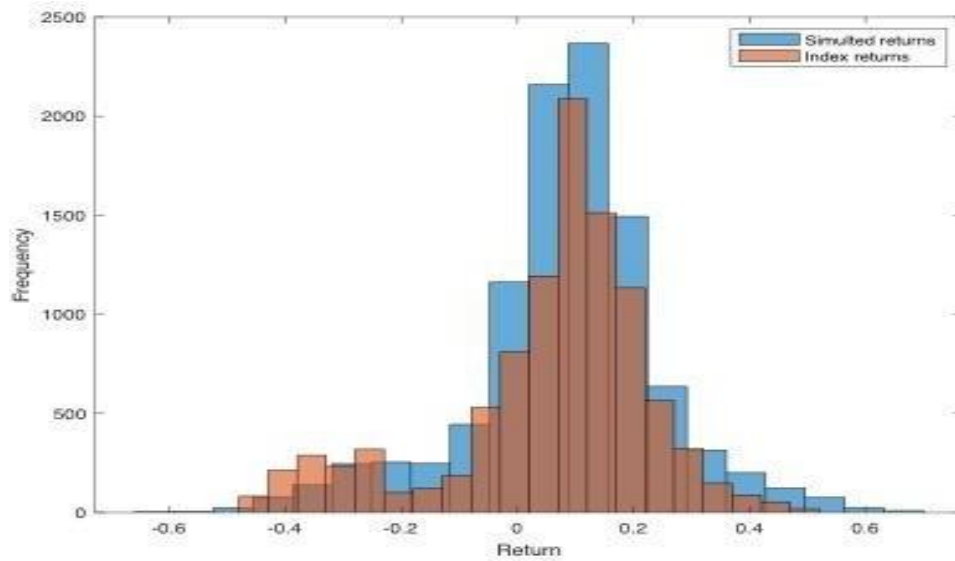
**Figure 11: Distributions of simulated vs index returns: ZAR 5bn fund size – One-year holding period**



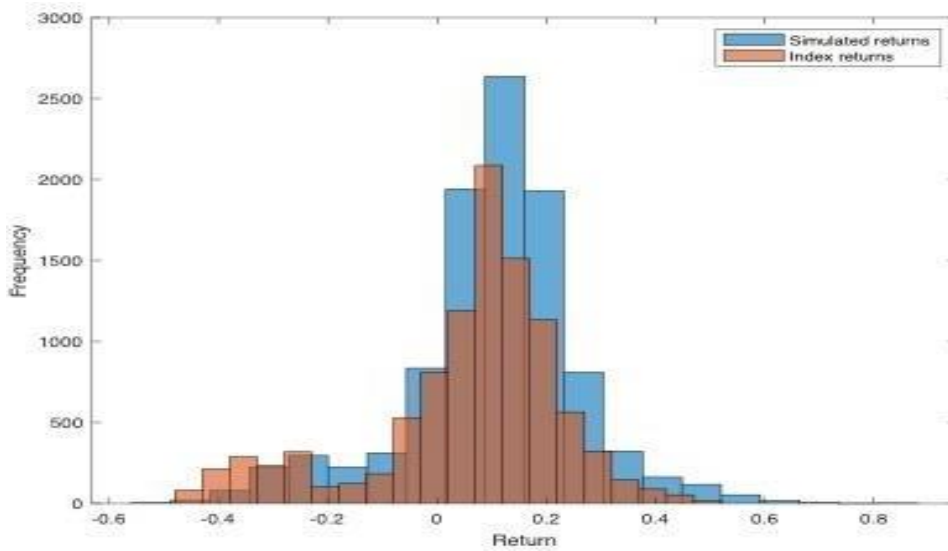
**Figure 12: Distributions of simulated vs index returns: ZAR 10bn fund size – One-year holding period**



**Figure 13: Distributions of simulated vs index returns: ZAR 20bn fund size – One-year holding period**

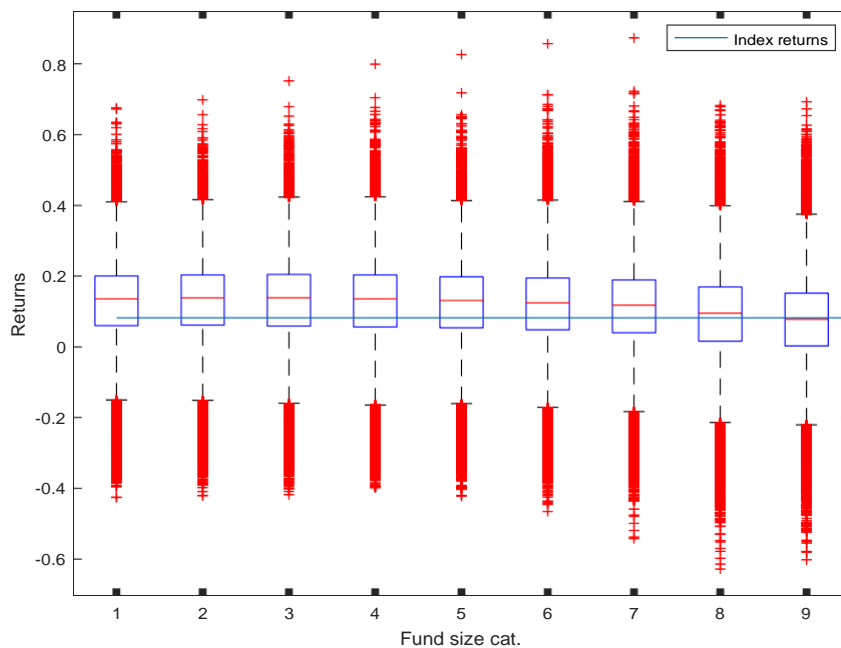


**Figure 14: Distributions of simulated vs index returns: ZAR 50bn fund size – One-year holding period**



**Figure 15: Distributions of simulated vs index returns: ZAR 100bn fund size – One-year holding period**

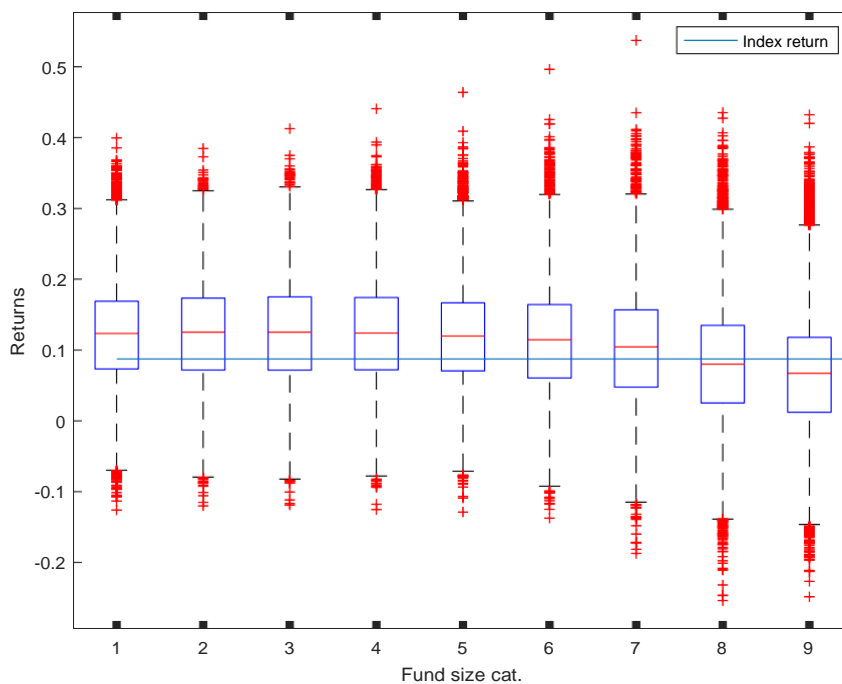
Figures 7 to 15 show how the distribution of returns to the simulated portfolios changes as fund size increases compared to the FTSE JSE Top 40 Index. The distribution of returns to the hypothetical portfolios changes as fund size increases, highlighting that the style bias of the portfolios changes as fund size increases. Notably, by comparing the ZAR 100mn funds distribution to the ZAR 100bn funds distribution, the mean return is closer to zero for the ZAR 100bn distribution than it is for the ZAR 100mn distribution, indicating that as fund size increases, returns decrease. Across all nine fund sizes, simulated return distributions track the return distribution of the index relatively well.



**Figure 16: Distributional properties of simulated returns vs benchmark average return (one-year holding period)**

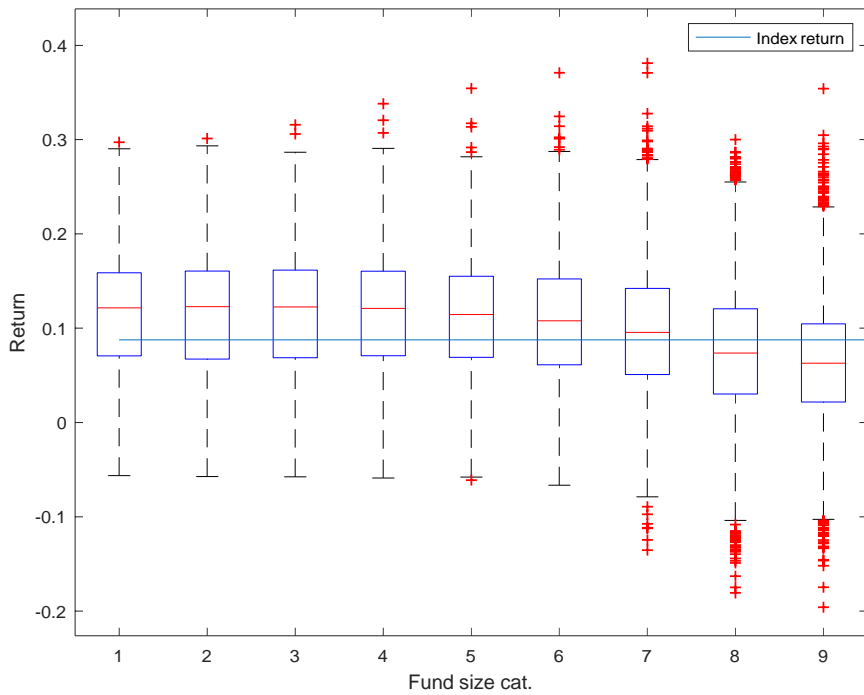
Some of the distributional properties, including the median and range of the simulated portfolios across all nine fund sizes across all three holding periods are presented in Figures 16 to 18. The returns to the index over the same holding periods, are also presented here for comparison.

The boxes shown in Figure 10 indicate the 25<sup>th</sup> and 75<sup>th</sup> percentiles of the simulated data, while the red line represents the median returns to the index. From ZAR 100mn to ZAR 20bn the median return to the simulated portfolios is higher than the index return. ZAR 20bn and ZAR 50bn funds, however, have a similar median return to the index return. This observation is important because it shows that as fund size increases, the returns to the simulated portfolios tend towards the returns of the FTSE JSE Top 40 Index, and the portfolios start to hold larger capitalisation stocks.



**Figure 17: Distributional properties of simulated returns vs benchmark average return (two-year holding period)**

The results presented in Figure 16 are similar to the results presented in Figure 17. There, however, seems to be a larger dispersion between the index returns and the median returns to the simulated portfolios. From ZAR 100mn to ZAR 20bn, the median return to the simulated portfolios is significantly higher than the index returns. The ZAR 50bn and 100bn funds' median returns, however, are less than the returns of the index.



**Figure 18: Distributional properties of simulated returns vs benchmark average return (three-year holding period)**

The dispersion between the median returns and index returns increases even more over the three-year holding period, as can be seen in Figure 18. From ZAR 100mn to ZAR 10bn median, the simulated returns are considerably higher than the index returns. The ZAR 20bn median returns, however, are similar to the index returns. The ZAR 50bn and ZAR 100bn results are similar to the results presented in Figure 17, where the median returns to the hypothetical portfolios are less than the index.

## **CHAPTER FIVE: CONCLUSION, STUDY LIMITATIONS AND AREAS FOR FURTHER RESEARCH**

### **5.1 CONCLUSION**

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This study investigates how mutual fund size affects performance in South Africa using a simulation model. Random hypothetical portfolios were constructed on random dates and capital was allocated to the underlying stocks using an allocation procedure that incorporates constraints. Returns over one-, two-, and three-year holding periods were then assessed independently and compared to an equity benchmark to ascertain whether changes in fund size affect returns.

The simulation model used in this study is similar to the model used by Pillay et al. (2010) with a few modifications. In this model, two variables, namely stock selection and investment date, are randomised, and 10 000 simulation runs were performed. Each hypothetical portfolio created consists of 40 stocks and an allocation procedure was used to allocate capital to the randomly selected 40 stocks. The allocation procedure allocates capital to the portfolio stocks by controlling for each stock's yearly volume traded.

Like Pillay et al. (2010), the maximum amount of capital that can be invested in any stock is one-third of that stock's prior year volume traded. This method works to allocate capital up until a certain fund size. Beyond that size, the possibility arises that the hypothetical portfolio might no longer be fully invested in a 40-stock portfolio. To control for this, the model engages in a routine to discard the stock with the lowest volume-traded level from the portfolio and reselect another stock from the investable universe with a higher volume-traded level. This process is repeated until the portfolio is fully invested in a 40-stock portfolio.

The results of the simulation found that a non-monotonic relationship exists between mutual fund size and performance over a one-year holding period, consistent with some research internationally and in South Africa (Shawky & Li, 2004; Pillay et al., 2010). Over a two- and three-year holding period, mutual fund size and returns, however, seem to be negatively

correlated, consistent with Malaquias et al. (2017). Over all three holding periods, the study suggests that the optimal fund size is approximately ZAR 2bn.

Portfolios with AUM greater than ZAR 2bn see their returns decrease noticeably as fund size continues to increase. These findings are supported by comparing simulated returns to actual benchmark returns over the same random periods. The results of this study suggest that mutual funds should be aware that consistent increases in AUM could negatively impact performance and that all funds should ensure that total AUM does not exceed ZAR 2bn.

## **5.2 LIMITATIONS**

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Several limitations of this study must be addressed. The first is that the model is a simulation model, and certain assumptions were applied to assess a real-world problem. That is, the model does not consider many of the practical limitations associated with real-world portfolio construction. These include rebalancing, transaction costs associated with trading stocks, taxes, and, to a certain extent, liquidity.

Second, most mutual fund research does not study how fund size affects performance in isolation. Often, fund size is studied as one of several factors that affect mutual fund returns. It, therefore, is possible that although fund size seems to affect performance, it might not be the most critical factor contributing to mutual fund returns. Assessing fund size and its relationship with returns in isolation could lead researchers to believe that it is the most critical factor that affects mutual fund returns. These, however, are hypothetical portfolios, and there might be real-world factors that are more important in the determination of returns. Berk and Green (2004) noted that while mutual fund size might negatively affect performance, increasing skills among investment managers as fund size grows might offset these diseconomies of scale. This study does not assess how changes in portfolio manager skills affect mutual fund performance and might thus be limited in that respect.

### 5.3 AREAS FOR FURTHER RESEARCH

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The scope of this study and, more broadly, mutual fund research, provides several areas for further research. These include the period over which the study was conducted, a closer analysis of investment style, and incorporating more real-world constraints into the simulation model.

The study was conducted over 10 years from 01 January 2008 to 31 December 2017. As was shown in the Results Section, compared to the period used by Pillay et al. (2010), liquidity on the JSE between the period that the two studies were conducted changed. Using a longer period to include more recent trading data might yield different results. The study also only analyses the returns over one-, two-, and three-year holding periods, and does not consider longer or shorter holding periods.

The study does not use an exhaustive set of methods to assess how the composition and style bias of the portfolios changes as fund size increases. Using more different techniques to assess how fund size changes the weighting of certain stocks in the portfolios and whether portfolios develop sectoral biases because of changes in fund size might add significant value to the research.

The only constraint applied to the hypothetical portfolios throughout the simulation model is that the total investment into any stock cannot exceed one-third of that stock's total volume traded for the prior year. The model, however, does not consider other factors that might affect the fund's ability to generate returns, including trading costs, rebalancing, and tax considerations.

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## APPENDIX

### APPENDIX 1: MATLAB CODE

---

```
clear all

%Define variables, investablue universe, number of portfolio stocks,
simulation length and portfolio sizes
usable_universe =160;
max_nr_stocks=40;
simulationlength = 10000;
portfoliosizes =
[100000000;500000000;1000000000;2000000000;5000000000;10000000000;20
000000000;50000000000;100000000000]'

%*****
%*****
%THIS IS TO UPLOAD THE EXCEL FILE AND CLEAN DATA
%*****
%*****

%load market caps, prices and trading volumes
[mcaps,~,~] = xlsread('Dummy.xlsx','Dailymc');
[prices,dates_stocknames,x] = xlsread('Dummy.xlsx','Dailyprices');
[Voltraded,stock_namesvol,~] = xlsread('Dummy.xlsx','AVT1');
[indexvalues,~,~] = xlsread('Indexvalues.xlsx','Sheet9');

%stripping out dates, converting to numeric matrices
mcaps = mcaps(2:end,:);
prices = prices(2:end,:);
Voltraded = Voltraded(2:end,:);

%clean NaNs from matrices
prices(isnan(prices)) = 0;
mcaps(isnan(mcaps)) = 0;
Voltraded(isnan(Voltraded)) = 0;
[universe_size,nr_dates]=size(prices);

%*****
%*****
%INITIAL VARIABLES
%*****
%*****

[dum,dif_portfoliosizes]=size(portfoliosizes);

%Index date used to calculate 3-year return - assumed 260 trading
days in a
```

```

%year
indexdate = [0; 260; 260*2; 260*3];

%Do this simulationlength times
for j=1:simulationlength

    %get initial date
    clear Initialdate
    Initialdate=randsample(nr_dates-260*3,1);

    clear universe_ordered;
    clear index_160;
    clear index_40;
    [~,universe_ordered] = sort(mcaps(:,Initialdate),'descend');
    index_160=universe_ordered(1:usable_universe);

    randomVector =randsample(usable_universe,usable_universe);
    index_40=index_160(randomVector(1:max_nr_stocks));

    for simulation = 1:dif_portfoliosizes

        total_Vol=(sum(Voltraded(index_40(1:max_nr_stocks),Initialdate)))/3;

        num=1;

        while total_Vol<portfoliosizes(simulation)

            [M,I]=min(Voltraded(index_40));
            index_40(I)=universe_ordered(randomVector(max_nr_stocks+num));

            total_Vol=(sum(Voltraded(index_40(1:max_nr_stocks),Initialdate)))/3;
            num=num+1;

            if max_nr_stocks+num>usable_universe
                break
            end

        end
        portfolio(1:max_nr_stocks,simulation)=index_40;
    end

    for simulation =1:dif_portfoliosizes
        index_40=portfolio(1:max_nr_stocks,simulation);
        num1=max_nr_stocks;
        portfolio_rem=portfoliosizes(simulation);
    end

```

```

portfoliovoltraded = Voltraded(index_40,Initialdate);
portfoliovoltraded=portfoliovoltraded/3;
[~,sortedvolind] = sort(portfoliovoltraded,'descend');
port_desc=index_40(sortedvolind);
portfoliovoltraded = Voltraded(port_desc,Initialdate);

for i=1:max_nr_stocks
    if(portfoliovoltraded(num1)>=portfolio_rem/num1)
        for jk=1:num1
            portfolio_allocate(jk)=portfolio_rem/num1;
        end
    else
        portfolio_allocate(num1)=portfoliovoltraded(num1);
        portfolio_rem=portfolio_rem-portfoliovoltraded(num1);
        num1=num1-1;
    end
end

%Return calculations

indexreturns(j,:) =
indexvalues(Initialdate+260,:)./indexvalues(Initialdate,:)-1;
indexreturns2(j,:) =
(indexvalues(Initialdate+(260*2),:)./indexvalues(Initialdate,:)).^(1/2)-1;
indexreturns3(j,:) =
(indexvalues(Initialdate+(260*3),:)./indexvalues(Initialdate,:)).^(1/3)-1;

pricesreturns =
prices(port_desc,Initialdate+260)./prices(port_desc,Initialdate);
pricesreturns(isnan(pricesreturns)) = 1;
pricesreturns(isinf(pricesreturns)) = 1;
yeportfolioval = pricesreturns'*portfolio_allocate';
pricesreturns2 =
prices(port_desc,Initialdate+(260*2))./prices(port_desc,Initialdate)
;
pricesreturns2(isnan(pricesreturns2)) = 1;
pricesreturns2(isinf(pricesreturns2)) = 1;
yeportfolioval2 = pricesreturns2'*portfolio_allocate';
pricesreturns3 =
prices(port_desc,Initialdate+(260*3))./prices(port_desc,Initialdate)
;
pricesreturns3(isnan(pricesreturns3)) = 1;
pricesreturns3(isinf(pricesreturns3)) = 1;
yeportfolioval3 = pricesreturns3'*portfolio_allocate';

portfolioreturn(j,simulation) =
sum(yeportfolioval)/portfoliosizes(simulation)-1;
portfolioreturn2(j,simulation) =
(sum(yeportfolioval2)/portfoliosizes(simulation))^(1/2)-1;

```

```

    portfolioreturn3(j,simulation) =
    (sum(yeportfolioval3)/portfoliosizes(simulation))^(1/3)-1;

    end
end

%Results and plots

mean1 = mean(portfolioreturn);
mean2 = mean(portfolioreturn2);
mean3 = mean(portfolioreturn3);

results1 = [ mean(portfolioreturn) ' median(portfolioreturn) '
std(portfolioreturn) ' nanvar(portfolioreturn) '
kurtosis(portfolioreturn) ' skewness(portfolioreturn) '
range(portfolioreturn) ' min(portfolioreturn) ' max(portfolioreturn) ' ]

results2 = [ mean(portfolioreturn2) ' median(portfolioreturn2) '
std(portfolioreturn2) ' nanvar(portfolioreturn2) '
kurtosis(portfolioreturn2) ' skewness(portfolioreturn2) '
range(portfolioreturn2) ' min(portfolioreturn2) '
max(portfolioreturn2) ' ]

results3 = [ mean(portfolioreturn3) ' median(portfolioreturn3) '
std(portfolioreturn3) ' nanvar(portfolioreturn3) '
kurtosis(portfolioreturn3) ' skewness(portfolioreturn3) '
range(portfolioreturn3) ' min(portfolioreturn3) '
max(portfolioreturn3) ' ]

index40ave1 = mean(indexreturns(:,2));
repind401 = repmat(index40ave1,10000);
repind401 = repind401(:,1);

index40ave2 = mean(indexreturns2(:,2));
repind402 = repmat(index40ave2,10000);
repind402 = repind402(:,1);

index40ave3 = mean(indexreturns3(:,2));
repind403 = repmat(index40ave3,10000);
repind403 = repind403(:,1);

figure(1)
plot(mean1);

figure(2)
plot(mean2);

figure(3)
plot(mean3);

```

```
figure(4)
histogram(portfolioreturn(:,1),20);
hold on
histogram(indexreturns(:,2),20);
hold off

figure(5)
histogram(portfolioreturn(:,2),20);
hold on
histogram(indexreturns(:,2),20);
hold off

figure(6)
histogram(portfolioreturn(:,3),20);
hold on
histogram(indexreturns(:,2),20);
hold off

figure(7)
histogram(portfolioreturn(:,4),20);
hold on
histogram(indexreturns(:,2),20);
hold off

figure(8)
histogram(portfolioreturn(:,5),20);
hold on
histogram(indexreturns(:,2),20);
hold off

figure(9)
histogram(portfolioreturn(:,6),20);
hold on
histogram(indexreturns(:,2),20);
hold off

figure(10)
histogram(portfolioreturn(:,7),20);
hold on
histogram(indexreturns(:,2),20);
hold off

figure(11)
histogram(portfolioreturn(:,8),20);
hold on
histogram(indexreturns(:,2),20);
hold off

figure(12)
histogram(portfolioreturn(:,9),20);
hold on
```

```
histogram(indexreturns(:,2),20);  
hold off
```

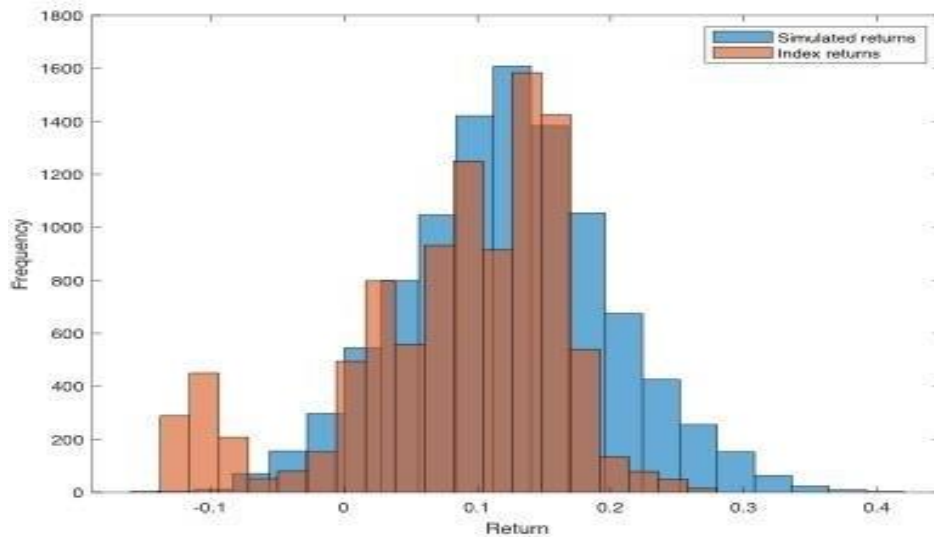
```
figure(13)  
boxplot(portfolioreturn);  
hold on  
plot(repind401);  
hold off
```

```
figure(14)  
boxplot(portfolioreturn2);  
hold on  
plot(repind402);  
hold off
```

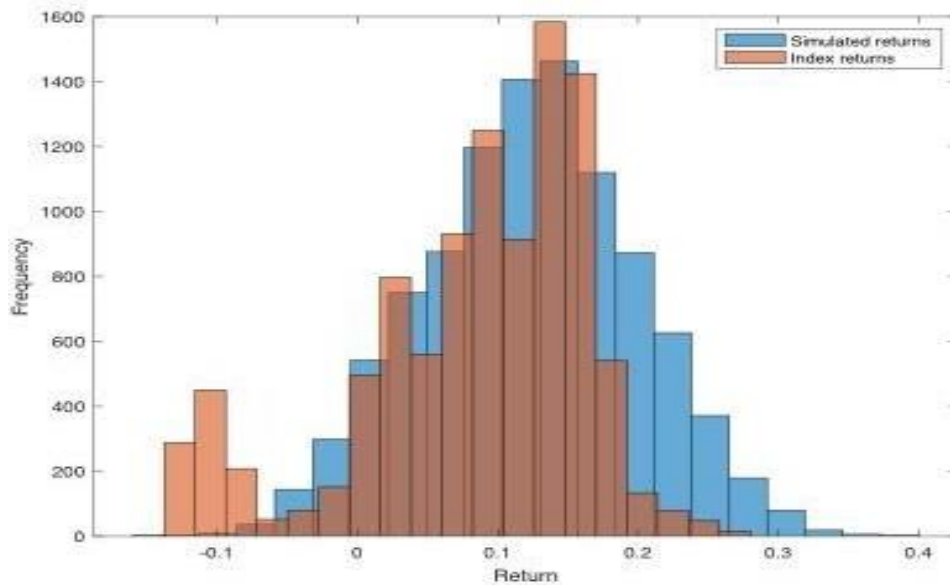
```
figure(15)  
boxplot(portfolioreturn3);  
hold on  
plot(repind403);  
hold off
```

## APPENDIX 2: DISTRIBUTIONS – SIMULATED VS INDEX RETURNS

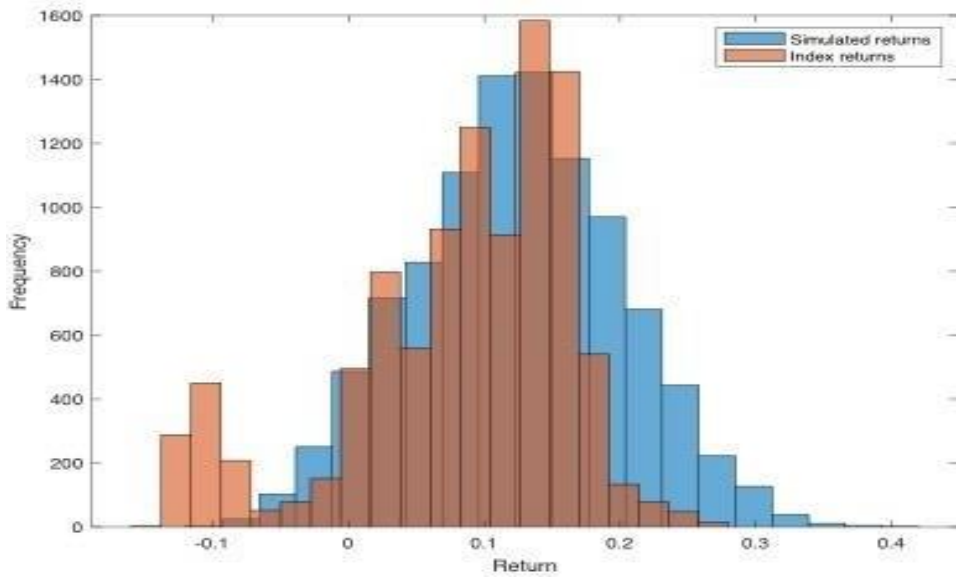
---



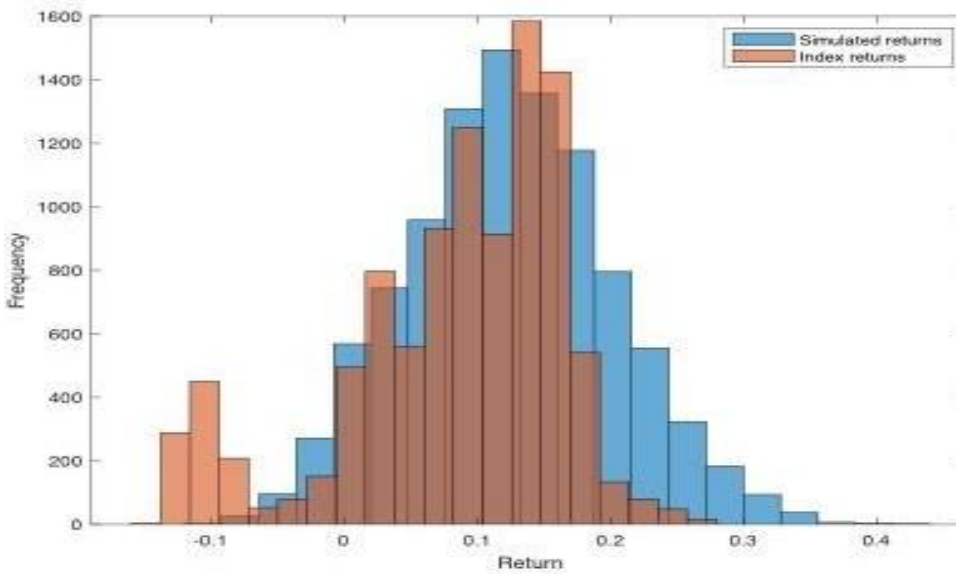
**Figure 19: Distributions of simulated vs index returns: ZAR 100mn fund size – two-year holding period**



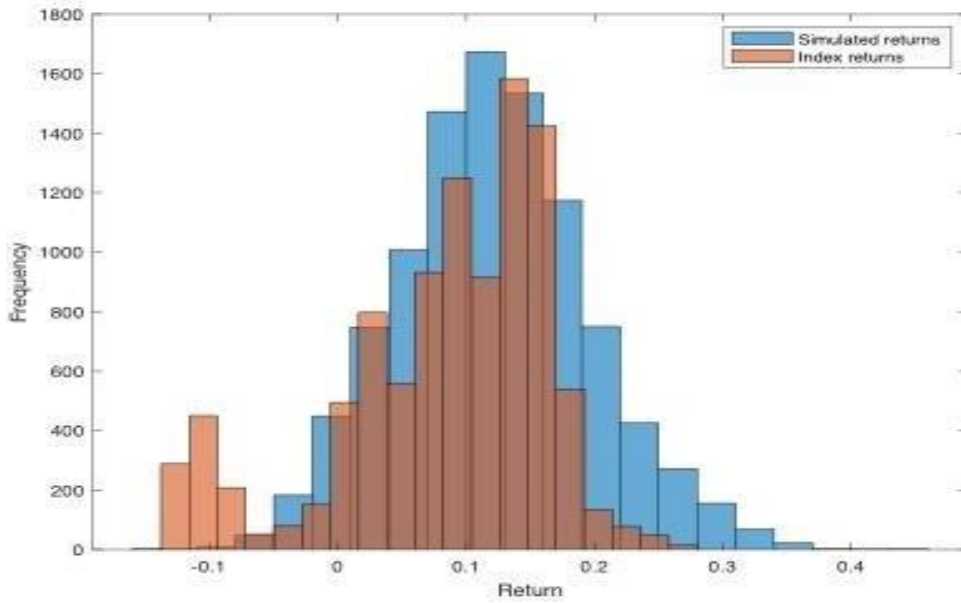
**Figure 20: Distributions of simulated vs index returns: ZAR 500mn fund size – two-year holding period**



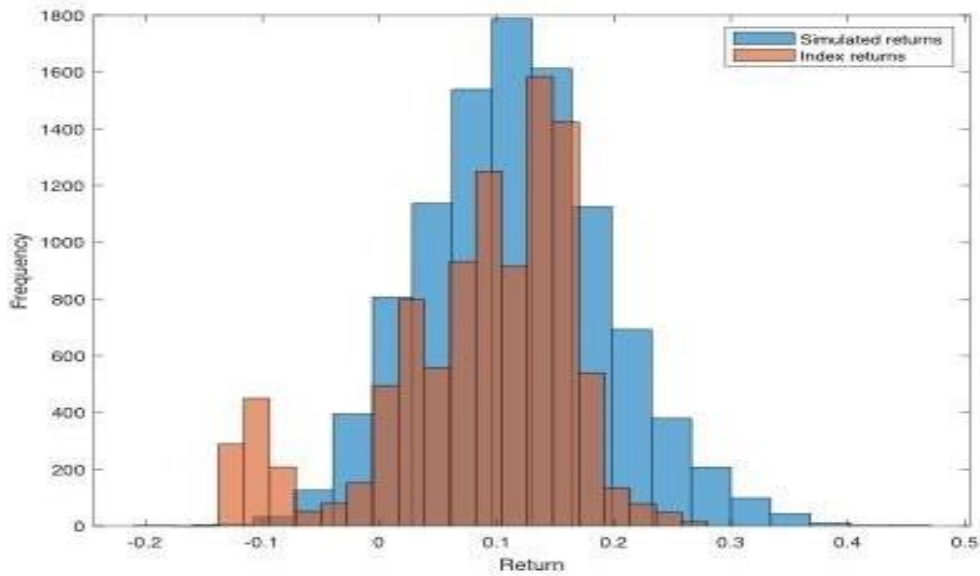
**Figure 21: Distributions of simulated vs index returns: ZAR 2bn fund size – two-year holding period**



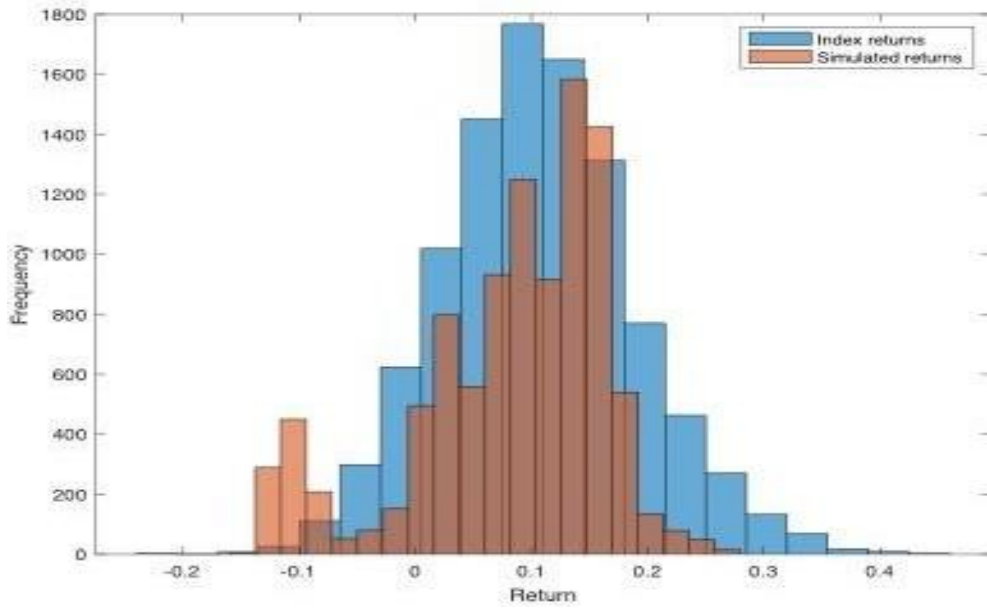
**Figure 22: Distributions of simulated vs index returns: ZAR 5bn fund size – two-year holding period**



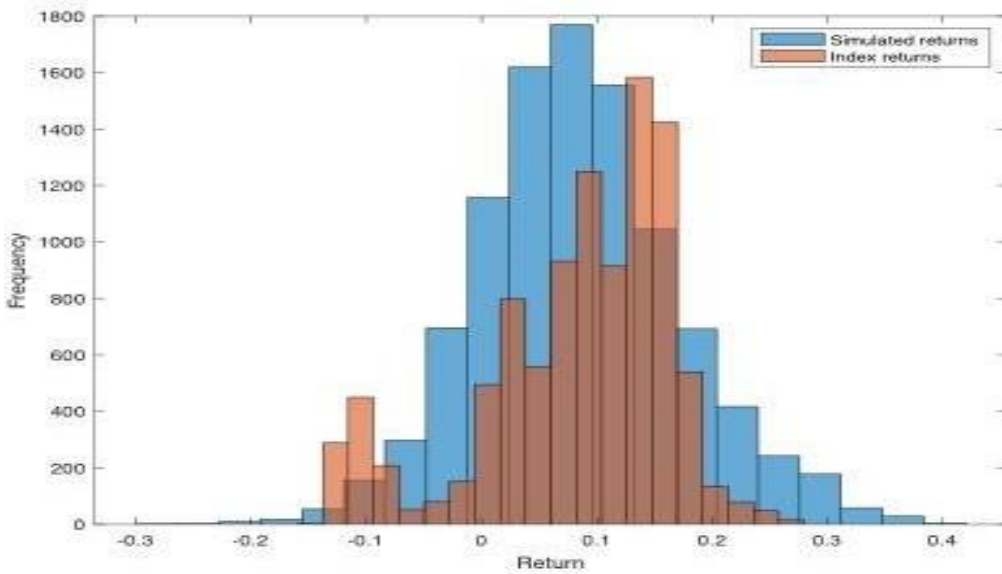
**Figure 23: Distributions of simulated vs index returns: ZAR 10bn fund size – two-year holding period**



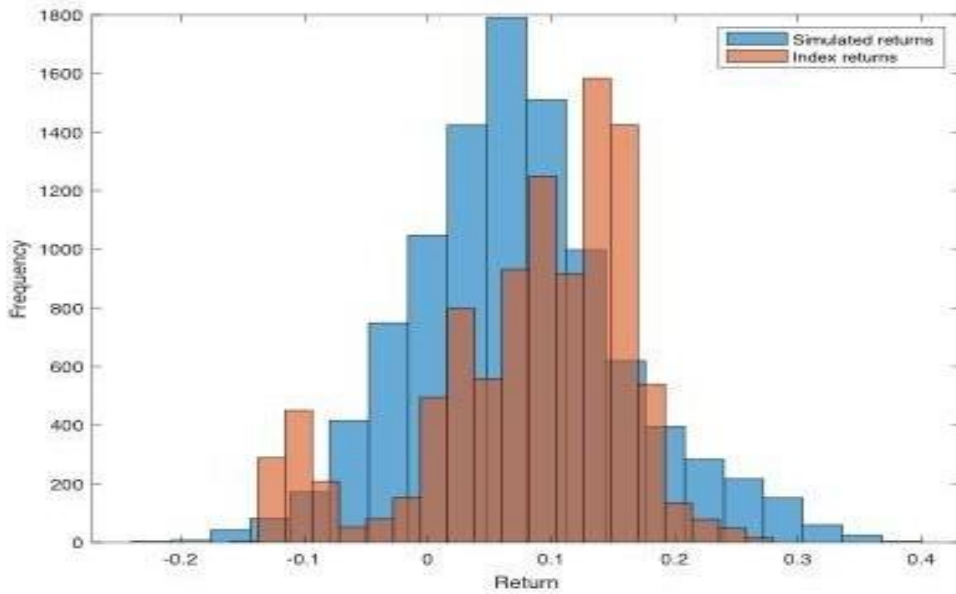
**Figure 24: Distributions of simulated vs index returns: ZAR 20bn fund size – two-year holding period**



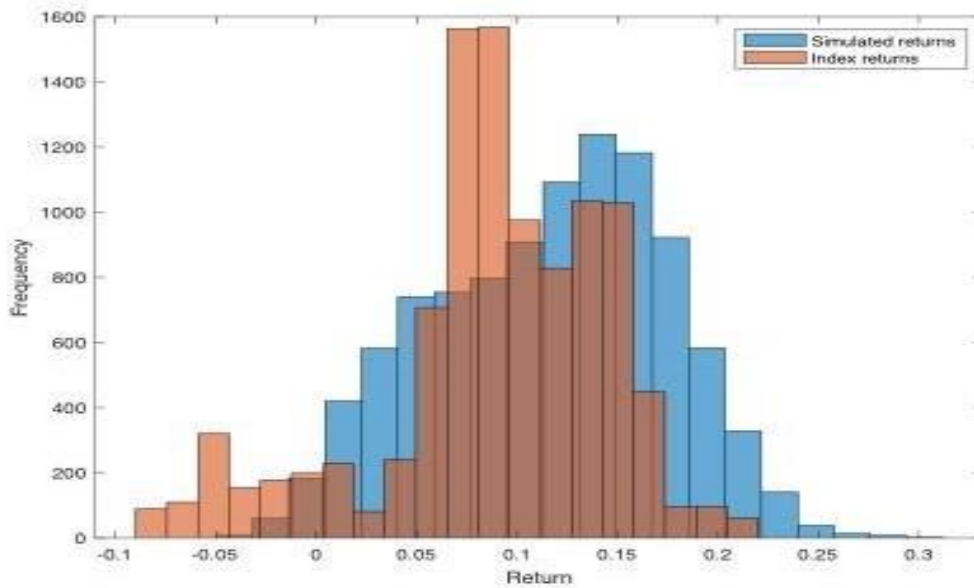
**Figure 25: Distributions of simulated vs index returns: ZAR 50bn fund size – two-year holding period**



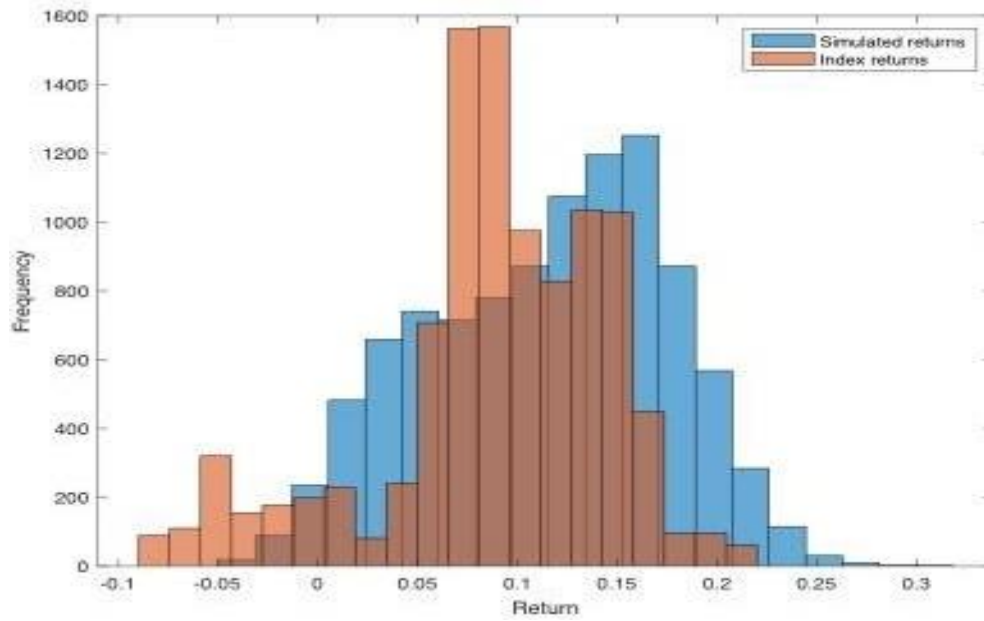
**Figure 26: Distributions of simulated vs index returns: ZAR 100bn fund size – two-year holding period**



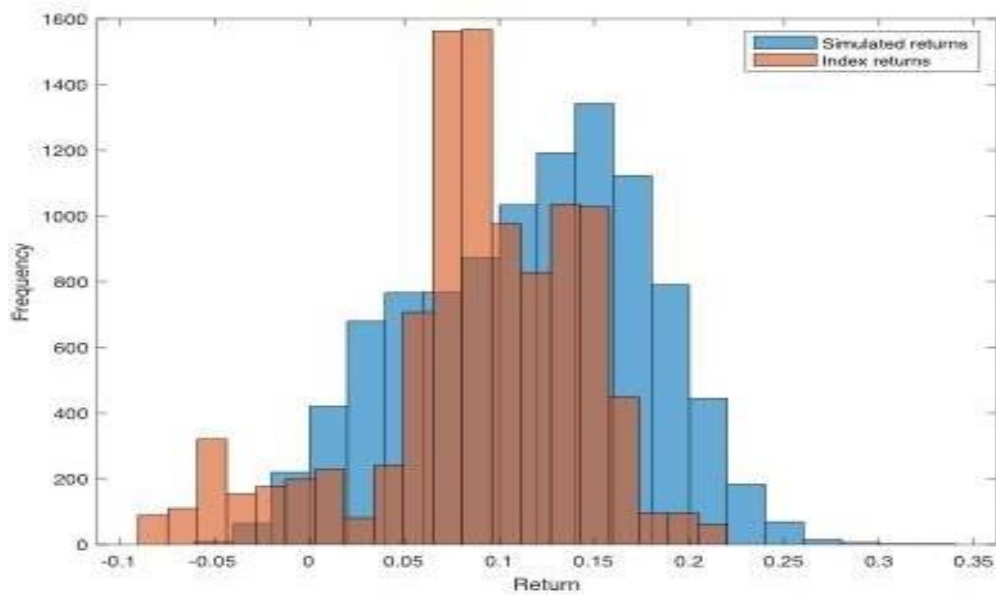
**Figure 27: Distributions of simulated vs index returns: ZAR 100mn fund size – three-year holding period**



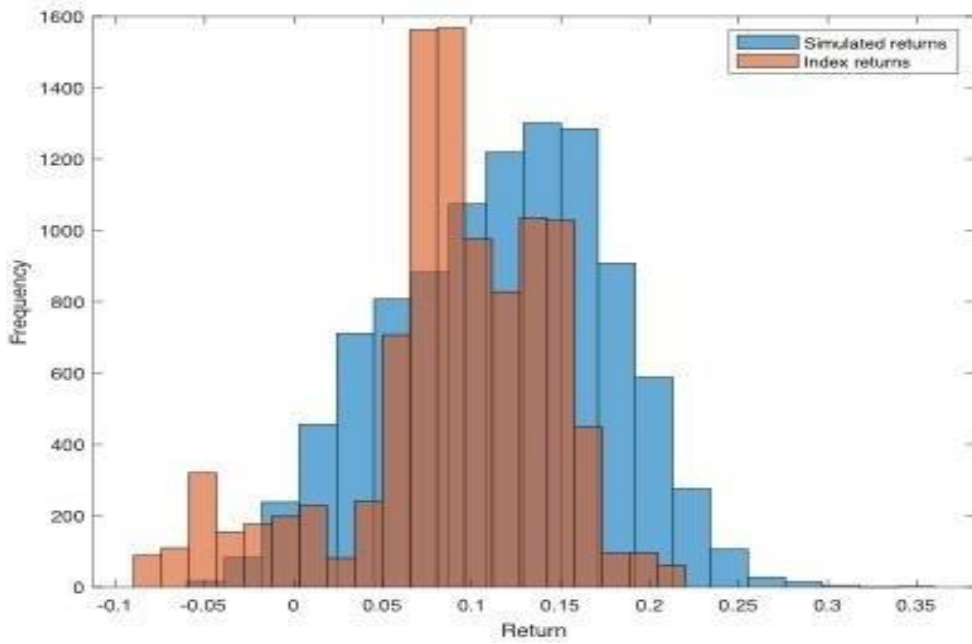
**Figure 28: Distributions of simulated vs index returns: ZAR 500mn fund size – three-year holding period**



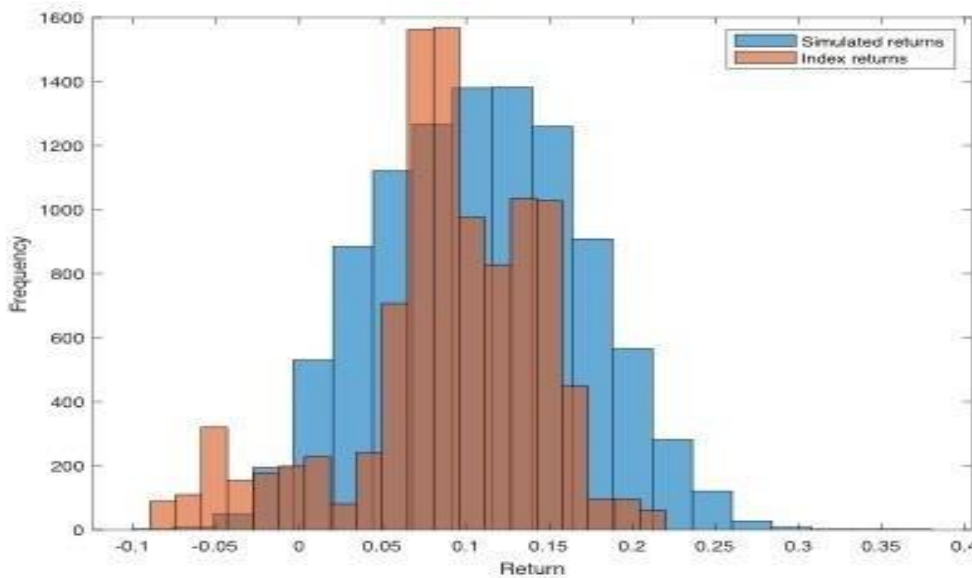
**Figure 29: Distributions of simulated vs index returns: ZAR 1bn fund size – three-year holding period**



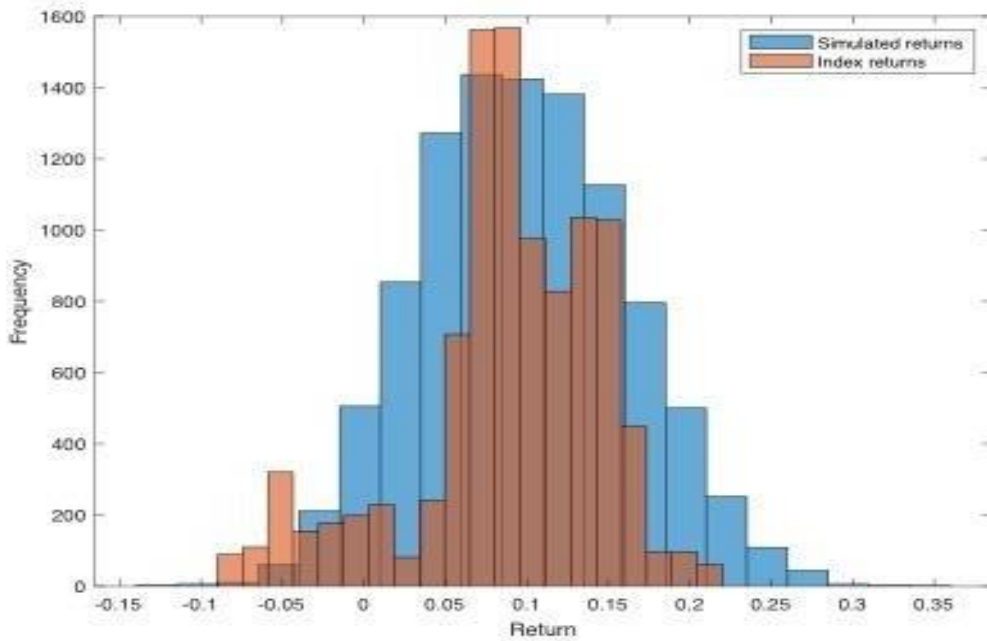
**Figure 30: Distributions of simulated vs index returns: ZAR 2bn fund size – three-year holding period**



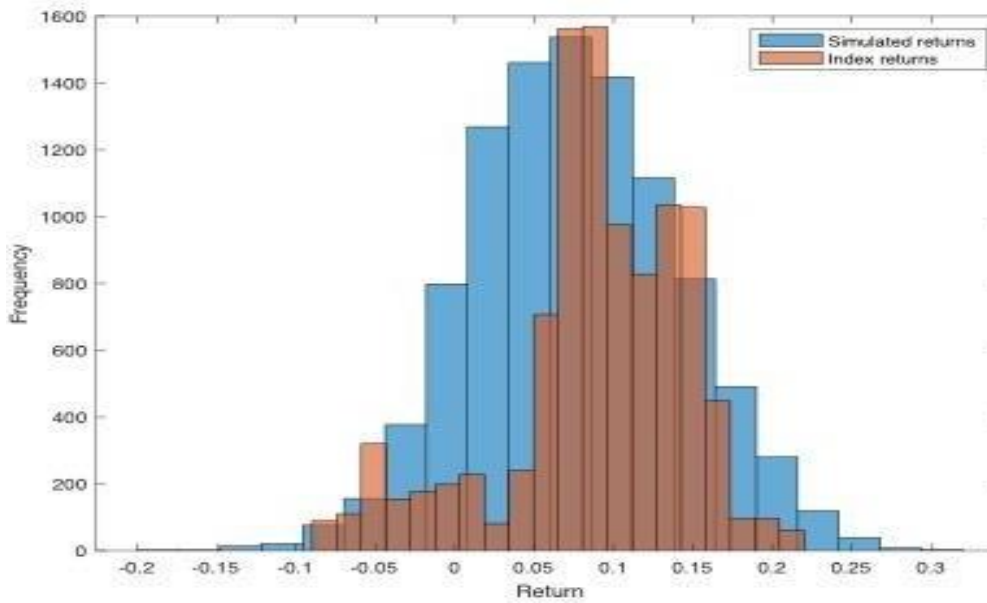
**Figure 31: Distributions of simulated vs index returns: ZAR 5bn fund size – three-year holding period**



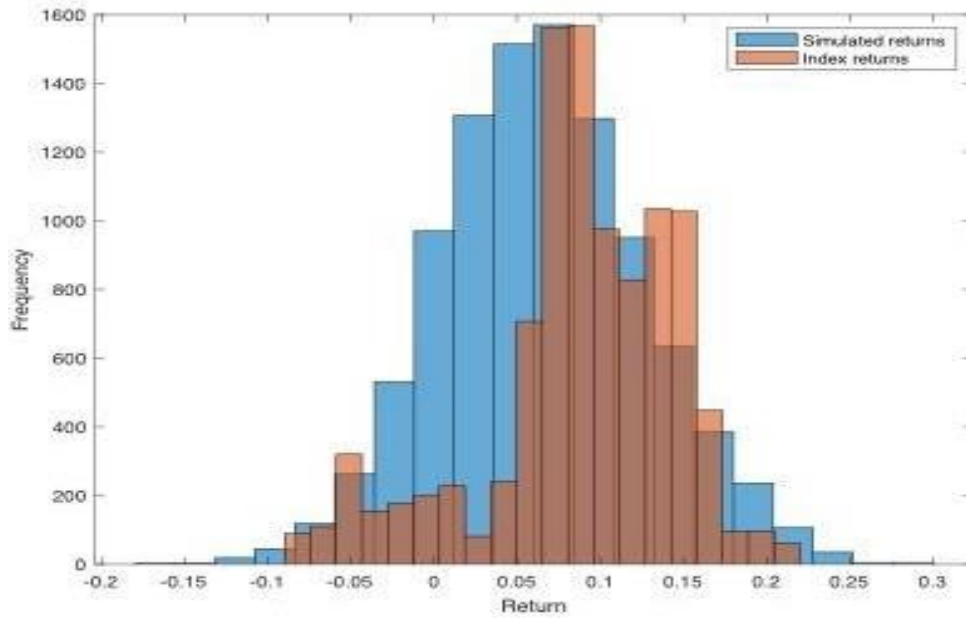
**Figure 32: Distributions of simulated vs index returns: ZAR 10bn fund size – three-year holding period**



**Figure 33: Distributions of simulated vs index returns: ZAR 20bn fund size – three-year holding period**



**Figure 34: Distributions of simulated vs index returns: ZAR 50bn fund size – three-year holding period**



**Figure 35: Distributions of simulated vs index returns: ZAR 100bn fund size – three-year holding period**

### APPENDIX 3: INDEX DESCRIPTIONS

|                        |   |
|------------------------|---|
| Name                   | FTSE/JSE All-Share Index  |
| Description            | The FTSE/JSE All-Share Index is a market capitalisation-weighted index that represents 99% of the market capitalisation of all stocks listed on the main board of the JSE. The index can further be split into small, medium, and large capitalisation indexes. |
| Number of constituents | 160   |
| Ticker symbol          | JALSH:JNB   |
| Weighting method       | Market capitalisation weighted  |

|                        |   |
|------------------------|---|
| Name                   | FTSE/JSE Top 40 Index   |
| Description            | The FTSE/JSE Top 40 Index is a market capitalisation-weighted index that consists of the 40 most investable companies ranked by market capitalisation in the FTSE/JSE All-Share Index. There are a set number of constituents in the index. |
| Number of constituents | 40  |
| Ticker symbol          | TOP40:IND   |
| Weighting method       | Market capitalisation weighted  |

|                        |  |
|------------------------|--|
| Name                   | FTSE/JSE Shareholder Weighted (SWIX) All-Share Index   |
| Description            | The FTSE/JSE SWIX index is a SWIX index where all constituents are independently ranked and then selected by their respective SWIX net market capitalisation. All the constituents in the index are downweighted by using an alternate free float that is called the SWIX free float. The SWIX free float is the proportion of the share capital held in dematerialised form and registered in the South African share register. |
| Number of constituents | -  |
| Ticker symbol          | JSESWIX:IND  |
| Weighting method       | SWIX weighted  |