Does Pairs Trading Work On The Johannesburg Stock Exchange?

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Abstract

In this study it was examined whether Pairs trading is a potentially profitable trading strategy on the Johannesburg Stock Exchange. Pairs trading is a quantitative based trading strategy, in which shares are paired up based on a historic price relationship and traded accordingly, in a contrarian manner, when they diverge from said historical relationship. The essence of Pairs trading is to take advantage of perceived market inefficiencies, which is a direct contradiction of the Efficient Markets Hypothesis (even in its weak form).

This study tested Pairs trading on both an unrestricted (any two shares can be paired), as well as a sector-restricted (only pairs within the RESI and the FINDI sectors could be paired), sample of shares (the JSE Top80 – based on market capitalization). Furthermore, a number of different signals (which are based on standard deviations) to open and close pairs were tested, on both the unrestricted and sector-restricted samples. The aim of using different samples of shares, as well as different trading signals, was to determine whether or not different strategies could serve to bolster the performance of a Pairs trading strategy.

It was concluded that all tested strategies outperformed the ALSI in terms of cumulative before-fee returns. However, the high frequency of trading required to execute a Pairs trading strategy substantially eroded before-fee returns. Despite the high transaction costs incurred by Pairs trading, with the exception of one strategy, all of the strategies tested outperformed the ALSI on a net of brokerage fee returns basis. It, however, remains to be tested whether the strategy continues to outperform when scrip borrow costs, as well as higher levels of brokerage, are included. In addition to the more significant before- and after-fee returns yielded by Pairs trading (in comparison to the ALSI), Pairs Trading also resulted in lower standard deviations than the ALSI. Therefore engaging in a Pairs trading strategy appears to carry less risk than investing in the ALSI. Furthermore, it was concluded that applying sector

restrictions resulted in both decreased returns, as well as risk (as evidenced by lower standard deviations). However, the decreased returns were relatively greater than the decreased standard deviations, and thus led to lower Sharpe Ratios.

Significantly, a decline in the performance of Pairs trading over time was observed – as documented in prior literature on foreign stock markets. Furthermore, Pairs trading appears to have relatively outperformed in periods of increased market stress (volatility) around 2008.

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List of Acronyms and Abbreviations

R	Return
SD	Standard Deviation
SR	Sharpe Ratio
ASSD	Average Sum of the Squared Distances
ANOP	Average Number of Open Pairs
NoT	Number of Trades
ATL	Average Trade Length
RPT	Return per Trade
R(CC)	Return on Committed Capital
R(FI)	Fully Invested Return
JSE	Johannesburg Stock Exchange
ALSI	All Share Index
(2;0)	Strategy notation – a strategy using an opening parameter of 2 standard deviations, and a closing parameter of 0 standard deviations.
TP	Trading Period

1 Introduction

Pairs trading became a popular investment strategy in the early 80's when the Wall Street quant Nunzio Tartaglia (Gatev, Goetzman and Rouwenhorst, 2006) brought together a group of scientists from a number of different disciplines (mathematics, computer sciences etc). Tartaglia's objective was to develop computer based trading platforms in which human subjectivity had no influence on investment decisions. For some time the team enjoyed positive outperformance, before dismantling after a period of sustained underperformance (Perlin, 2007).

The theory behind Pairs trading is based on the assumption that when the prices of two shares have historically tended to trade with a constant price relationship, they can be viewed as economic substitutes. Any deviations from the observed historical price relationship are expected to re-converge to the historic mean. A deviation from the historic mean is seen as a market inefficiency, as economic substitutes are not trading at parity, which should be exploitable to earn profits. When the spread between the prices of two paired shares widens (with the assumption of future convergence), an investor engaging in a Pairs trading strategy will enter into a long position in the relative loser stock (expecting future relative gains) and a short position in the relative winner stock (expecting future relative loses). Pairs trading is thus of a contrarian nature, as humans tend to buy shares when they are increasing in price and sell them when they are decreasing in price.

Pairs trading is a violation of market efficiency theory. Fama (1970) elaborated on the Efficient Market Hypothesis, which, even in its weak form, postulates that the past trading information of a stock is already reflected in its price and therefore an investor cannot earn excessive returns using only historical market data. However, there are a number of papers that demonstrate, at least to some extent, that past information is able to predict future movements in stock prices, such as Pietranico and Riepe (2004) and Bouman and Jacobsen (2002).

This study follows a similar methodology to the works carried out by Gatev, Goetzmann & Rouwenhorst (2006) and Do and Faff (2009) on the S&P500, Perlin (2007) on the Brazilian stock exchange and Bolgun, Kurun & Guven (2009) on the Turkish stock exchange. To this extent, pairs were formed through a process of minimizing the sum of the squared distances between the normalized prices of shares within the Top80 on the Johannesburg Stock Exchange (JSE). Once pairs were formed, trading was simulated when the spread between the shares widened to a predetermined degree from the rolling historic mean, and closed upon subsequent convergence to a predetermined degree from the rolling mean. A number of strategies with differing opening and closing parameters have been simulated in order to determine whether predictable outperformance is possible. Furthermore, pair formation has been conducted on both an Unrestricted (any two shares within the Top80 can form a pair) and a Sector Restricted (only shares from within the Resi or Findi sectors can form a pair) basis.

This study concludes that, between January 1998 and May 2012, Pairs trading strategies outperformed the All Share Index (ALSI) in terms of both return and risk (as evidenced by lower standard deviations). The outperformance was robust to a level of brokerage costs that an institutional investor could expect to pay, while the costs associated with scrip borrow were not included in this study. Outperformance was also noted on an Unrestricted basis, when compared to the Sector Restricted strategies. As concluded in Gatev *et al.* (2006) and Do and Faff (2009), returns yielded by Pairs trading appear to have drastically declined over time.

According to Chng (2007), there are a number of reasons for the popularity of Pairs trading. Firstly, the investment process is easy to understand as well as execute. Secondly, it does not require valuation models, which are subject to wide error margins. The lack of the necessity of valuation models stems from the fact that positions opened when engaging in Pairs trading are generally relatively close to market neutral, and trade signals are generated on relative valuations. Thirdly, the investment style is sufficiently flexible to accommodate various investment styles. Furthermore, the positions rarely require intraday re-balancing, and thus making Pairs trading a feasibly profitable strategy as transaction costs are substantially lower than an intraday trading strategy would incur, however, transaction costs remain relatively high in comparison to a more fundamental based investment approach. And lastly, trading can be automated. Due to Pairs trading generally being a relatively market neutral investment strategy, underperformance relative to the market is expected in a bull market, where net long positions should outperform. Conversely, Pairs trading is expected to outperform in both bear and static markets (as long as realized volatility is relatively high).

Section 2 of this study provides an analysis of previously published literature on the EMH and Pairs trading, which is followed by a brief description of the raw data used in this study in Section 3. The Methodology of the study is then described in Section 4. Section 5 is a report on the Empirical Results of the study, while Section 6 suggests potential topics for future research. The conclusion of the study is drawn up in Section 7, which is followed by the Bibliography and Appendix in Sections 8 and 9 respectively.

2 Literature Review

There is limited prior research on Pairs trading due its proprietary nature. To the best of my knowledge this is the first study to test whether or not Pairs trading is a profitable trading strategy on the Equity Market of the Johannesburg Stock Exchange (JSE).

The most widely cited study on Pairs trading is by Gatev, Goetzman and Rouwenhorst (1999) and (2006), which had a follow up study by Do and Faff (2009), both studies tested a Pairs trading strategy on the S&P500. Gatev *et al.* (1999) found that Pairs trading was able to generate statistically significant after-fee returns on the S&P500. However, in a follow up paper, Gatev *et al.* (2006) concluded that, while Pairs trading remained profitable on the S&P500, the profitability was declining over time. It was still concluded that suitably paired shares were able to generate statistically significant excess returns. Do and Faff (2009) further concluded that the trend in declining profitability had persisted, and at an increasing rate.

There are three proposed manners in which shares can be paired, namely the minimum squared distance methodology as used in Gatev *et al.* (2006), Do and Faff (2009) and Nath (2003). The cointegration method as proposed by Vidyamurthy (2004) and lastly the Stochastic Spread application as proposed by Elliot, van der Hoek and Malcom (2004). This study will focus on the most widely cited minimum squared distance methodology, as used in Gatev *et al.* (2006) and Do and Faff (2009).

2.1 The Efficient Market Hypothesis

The Efficient Market Hypothesis (EMH) was first hypothesized in Fama (1965), and then elaborated upon in Fama (1970), when it was separated into three forms of efficiency. The three forms of market efficiency, in ascending order of strictness, are Weak Form, Semi-strong Form and Strong Form. Weak Form efficiency states that market prices correctly represent all past publically available information. Semi-strong Form efficiency states that market prices reflect all publically available information – both past and current. Strong Form efficiency takes it further, stating that all information is reflected in market prices, including insider information and future information.

Pairs trading aims to generate statistical outperformance based on observed historical price relationships, and the subsequent divergence from and convergence to the said relationship. Thus, should positive outperformance of Pairs trading be possible, it will prove a violation of the EMH, even in its weak form.

A number of pieces of prior literature have already disproved the EMH, particularly in its stricter forms. Seasonal effects on stock prices were demonstrated in Pietranico and Riepe (2004), who concluded that a phenomenon dubbed the January Effect exists, and that small-cap shares tend to outperform on the first few trading days of a new year. Bouman and Jacobsen (2002) found evidence of lower market returns between May and October.

Fama (1998) postulated that investors tend to both over- and under-react to information, while Hirschleifer (2001) discussed investor conservatism.

2.2 Returns of Pairs Trading

2.2.1 American Studies

2.2.1.1 Unrestricted Pairing

Gatev *et al.* (2006) tested a Pairs trading strategy on the S&P500. The signal for opening a position was a spread of 2 historic standard deviations (from a 125 day rolling mean) between the paired shares. Positions were closed when the two shares returned to their historic price equilibrium (a 0 standard deviation spread). It was concluded that excess returns yielded by a Pairs trading strategy were both positive and statistically significant, even after reasonable estimates of transaction costs. This finding held true for both the sample period, as well as a 4-year out of sample period (to reduce data snooping error). However, over time a decline in profitability was noted, which was observed by splitting the sample at the end of 1988. In a later study, Do and Faff (2009) noted the decline in profitability of Pairs trading to have continued, and the excess returns yielded by Pairs trading to have become statistically insignificant as a whole. However, Do and Faff (2009) concluded that, with better methods of stock picking, significant excess returns could still be achieved – with more than 50% of the top pairs (pairs with the smallest sum of squared differences between their normalized price series') still having been profitable, or highly profitable.

Gatev *et al.* (2006) measured excess returns in two manners, firstly on a fully invested portfolio and secondly on a more conservative manner of measuring returns on committed capital. The committed capital return measure is based on the number of pairs selected for trading – whether or not a pair trades during the period, it is included in the excess return calculation (and should it not have traded, it would result in a drag on the return of the strategy). The fully invested portfolio only includes pairs that trade during the period in the excess return calculation.

In addition, two different portfolios were tested. The first included the top 5 pairs and the second included the top 20 pairs (the top pair being defined as the pair with the smallest sum of its squared distances, and thus the closest historical relationship). Without a sector pairing constraint, the excess return to the 5 pair portfolio was 1.31% per month (t-stat of 8.74) for the fully invested portfolio and 0.78% per month for the committed capital approach. The 20 pair portfolio yielded excess returns of 1.44% (t-stat of 11.56) and 0.81% per month respectively. Excess returns were found to be significant in both an economic and statistical sense. In addition, it was observed that the standard deviation of returns decreased as the number of shares increased, leading to a larger positive skewness coefficient. The observation period contained 464 months of data, of these, the 5 pair portfolio had 124 months of negative return, while the 20 pair portfolio only had 71 months of negative returns.

Do and Faff (2009) replicated the Gatev *et al.* (1999) and Gatev *et al.* (2006) papers, their findings were roughly consistent with the 1999 paper and there were some marginal differences in comparison to the 2006 paper.

Do and Faff (2009) reported an average monthly return of 0.34% (for the top 20 pair portfolio) for the 1989-2002 period, which is roughly consistent with Gatev *et al.* (2006) who reported a return of 0.38%. This figure was already a 60% decline on the earlier 1962-1988 sub-period. Furthermore, Do and Faff (2009) concluded that the average monthly return declined to only 0.06% in the latest 2003-2008 period and the corresponding t-statistic suggests that this was not significantly different from 0.

The probability of achieving a negative monthly return increased from 19% in the 1962-1988 period to 31% in the 1989-2002 period, and finally to 53% in the most recent 2003-2008 period, according to Do and Faff (2009).

Gatev *et al.* (2006) noted a number of observations in the composition of portfolios when pairing was Unrestricted. Positions generally opened and closed a number of times over a long period, with neither stock being a 'leader' (moves away from the median tended to happen in both directions, requiring that both long and short positions were entered into on both shares at different times during the period of study). The average duration of an open position was 3.75 months, making Pairs trading a medium term investment horizon. Two thirds of pairs were from different size deciles and significantly, 71% of pairs were within the utility sector (utility shares historically have tended to have lower volatilities).

2.2.1.2 Restricted Pairing

Both Do and Faff (2009) and Gatev *et al.* (2006) found benefits to restricting the pairing of shares to within the same sector (the four sectors in both papers were the Utilities, Financials, Transportation and Industrials sectors). Under a strategy with no restrictions on the pairing of shares, Gatev *et al.* (2006) noted that well below 50% of paired shares were mixed pairs (from different sectors) due to shares within sectors being influenced by similar exogenous factors (for example, Financial shares are more exposed to a change in the repo rate than shares from different sectors).

Both Gatev *et al.* (2006) and Do and Faff (2009) concluded that pairs formed from the Utilities and Financial sectors tended to outperform pairs formed from the Industrials and Transportation sectors.

Gatev *et al.* (2006) concluded that all 4 sectors showed statistically significant positive excessive returns. Using the top 20 pairs (based on a minimum value of the sum of the squared distances between the shares' normalized price series') in each sector, Gatev *et al.* (2006) found that Utilities yielded 1.08% per month (t-stat of 10.26), Financials yielded 0.78% per month (t-stat of 7.6), Industrials yielded 0.61% (t-stat of 6.93) and Transportation yielded 0.58% (t-stat of 4.26). These returns were generally skewed to the right and showed positive kurtosis.

Do and Faff (2009) tested whether Utilities and Financials remained profitable in the later period (2003-2008). They concluded that pairs from the Utilities sector averaged returns that were 9bps/month higher than an unconditional portfolio for the entire sample and significantly, in the 2003-2008 period they yielded returns that were 12bps/month higher and were statistically significant. Pairs from within the Financials sector averaged 16bps/month higher returns than pairs from the unconditional portfolio for both the entire sample and the 2003-2008 period. However, the outperformance of the Financial pairs was statistically insignificant. Pairs from within the Utilities sector yielded the lowest non-convergence risk, despite the fact that the sector contained the highest number of non-convergent pairs. This was due to the non-convergent pairs in the utilities sector having yielded a smaller average loss of -4.88%, compared to financials losing on average -7.54% (unconditional: -6.39%).

Both Do and Faff (2009) and Gatev *et al.* (2006) postulate that pairs from within the Utilities sector tend to perform well under a Pairs trading strategy because the companies face stable demands and products within the sector are fairly homogenous. Thus, shares within the Utilities sector are more likely to be economic substitutes than shares in other sectors. Similarly, the outperformance of the Financials sector is pinned on the fact that the companies in the Financials sector are sensitive to common factors (interest rate risk, levels of unemployment etc.) and thus prices are more likely to be cointegrated. Industrial companies however, can be fundamentally very different from one another (for example, a healthcare company and a supermarket chain are not likely to be influenced by similar exogenous factors, and are thus likely to perform relatively poorly under a Pairs trading strategy).

2.2.1.3 Recent Pair Profitability

Do and Faff (2009) tested whether both the decline in profitability and the increased risk of continued pair divergence applied to the wider market, or just the previously tested 20 pairs. To do so, they conducted an analysis of the top 50 pairs on the S&P500. The average monthly excess return yielded by the top 50 pair portfolio was very similar to that of the top 20 pair portfolio, proving that excess returns were not merely restricted to the top 20 pairs. In addition, the standard deviation of the top 50 pairs was lower than that of the top 20 pairs, highlighting benefits of diversification in a Pairs trading strategy. It was noted that, in the most recent period, 55% (17%) of the top 20 pairs were still profitable, which is comparable to the 56% (22%) of the top 50 pairs still being profitable. Do and Faff (2009) concluded that increasing the pairs from 20 to 50,Pairs trading remained profitable in the later period through more opportunities of pair formation.

2.2.1.4 Robustness of Short Selling Costs

Gatev *et al.* (2006) questioned why the prices of economic substitutes (in this case, paired shares) ever diverge, and they postulated that it is due to random liquidity shocks that aren't able to be exploited due to the costs associated with short selling securities. There are two types of costs associated with short selling. Firstly, specials, which are the explicit costs that arise from short selling. Secondly, as concluded by D'Avolio (2002) there are further costs associated with short recalls, which are potentially costly because they may deprive arbitrageurs of their profits.

Gatev *et al.* (2006) concluded that specials have minimal effects on large shares, which is a similar conclusion to D'Avolio (2002) and Getczy *et al.* (2002). The test was done by restricting pairs of shares to the top three size deciles, the resultant returns yielded by the top 20 portfolio declined by 2 bps per month, while the top 5 portfolio's returns increased slightly. After factoring in liquidity, returns changed little and remained statistically significant, hence Gatev *et al.* (2006) concluded that illiquid shares trading on special have little effect on Pairs trading returns.

Chen, Hong and Stein (2002) and D'Avolio (2002) concluded that short recalls are driven by dispersion of opinion. Gatev *et al.* (2006) used high trade volume as a proxy for divergence of opinion (an increased number of both buyers and sellers), and concluded that profits remained large and positive, thus Pairs trading profits persisted even when shorts were recalled.

Gatev *et al.* (2006) concluded that profits of Pairs trading are robust with regards to short selling costs and persist when trading large shares (that aren't trading on special) as well as when shorts are recalled. Furthermore, for better-positioned investors such as large institutions or hedge funds, Pairs trading profits are likely to remain essentially unaffected due to relatively favourable costs associated with short selling.

2.2.2 International Studies

2.2.2.1 Turkey

Bolgun *et al.* (2009) tested whether Pairs trading is a feasible investment strategy on the Istanbul Stock Exchange, using the ISE-30 index. Shares were paired through the use of the minimum squared distance methodology as was done in Gatev *et al.* (2006) and were not Sector Restricted, leaving potential room for future study. The period of the study was 2002-2008.

The signal used to open a position was a 2.5 historical standard deviation spread from the historic rolling mean. Open positions were closed when the spread reverted to a 0.5 historic standard deviation move from the rolling historic mean. It is noted that the spreads to open and close positions in pairs are different to those utilized in Gatev *et al.* (2006) and Do and Faff (2009), and thus direct comparisons are potentially misleading. A take profit was in place at 3% of the initial position and a stop loss at 2% of the position value.

According to Bolgun *et al.* (2009), the Turkish stock market provides a number of challenges with regards to the short sale of stock, due to market inefficiencies and institutions being acutely aware of counterparty risk (and thus pricing default risk into scrip borrowing costs or not offering scrip borrow at all). This makes the transaction costs of Pairs trading more costly on the Turkish stock market than in other countries with more liquid markets for scrip borrow, such as the S&P500.

Bolgun *et al.* (2009) undertook an analysis of Value-at-Risk (VaR) measures of Pairs trading, as VaR can be used as a gauge as to the level of potential leverage that an investor can (relatively safely) apply when engaging in a Pairs trading strategy. It is also noted that one should not rely too heavily on historic VaR measures, however, the results suggest that Pairs trading is exposed to relatively little risk. The three mean measures of VaR were analyzed, namely the Variance Covariance method (VCV), the Historical Simulation Method (HS) and the Monte Carlo methodology. The HS method underestimated the loss of the portfolio for only 8 out of 1627 days as opposed to 15 for the VCV method and 28 for the Monte Carlo simulation; thus it is suggested that the HS method is used in practice to minimize error.

Pairs trading appears to have outperformed the ISE-30 index before fees, with Bolgun *et al.* (2009) having documented annualized before-fee excess returns of

3.32% when compared to a naïve buy and hold strategy of the index. The average daily return on the IMKB-30 for the period of study was 0.06% with a daily volatility of 2.20%, while the Pairs trading portfolio yielded 0.12% with a volatility of 1.67%. The higher return, coupled with a lower standard deviation, resulted in the Pairs trading strategy having a substantially higher Sharpe Ratio in comparison to the naïve buy and hold strategy of the index. However, Bolgun *et al.* (2009) noted that trading commissions and scrip borrowing costs are generally greater than the excess before-fee returns generated by a Pairs trading strategy on the Istanbul Stock Exchange.

It is suggested that a follow up paper is done on the ISE, as adding constraints in the stock pairings (such as sector limitations etc) will potentially yield more favourable results.

2.2.2.2 Brazil

In his working paper, Perlin (2007) tested whether a Pairs trading strategy is a feasible investment strategy on the Brazilian stock exchange. He used the 100 most liquid shares on the exchange and the period of study was 2000-2006. He concluded that Pairs trading was a profitable and possibly market neutral (due to equal long and short positions invested in shares that have historically traded at a constant price relationship) investment strategy. Data was tested from three different frequencies (daily, weekly and monthly), and was compared to a naïve buy and hold strategy of the index, as well as a bootstrap method of random stock pairing. Shares were paired using the minimum squared distance rule of normalized prices, which is the same methodology that was applied in Gatev *et al.* (2006), Do and Faff (2009) and Bolgun *et al.* (2009). Perlin (2007) allowed a stock to be paired to more than one other stock, and thus a stock could generate both a buy and a sell signal at the same time (against two different shares).

With regards to raw return (clean return yielded by the strategy minus transaction costs), Perlin (2007) found that the long positions tended to be substantially more profitable than the short positions for all frequencies. He concluded that this is due to the upward trend of the stock market for the period of study.

When excess returns were analyzed, it was found that the Pairs trading strategy was able to outperform the properly weighted naïve portfolio under the majority of cases – predominantly for a daily frequency (for the interval of d between 1.5 and 2) and the monthly frequency (for all values of d).[1] Pairs trading outperformed the bootstrapped method of pair formation in just a few cases, primarily daily data with d between 1.5 and 2. It also appeared that there was positive outperformance for monthly data with d between 2.6 and 3, but the low frequency of trades made this observation statistically insignificant.

The superiority of the higher frequencies (daily) is logically consistent with the objective of Pairs trading, namely, taking advantage of the corrections that follow market inefficiencies. Market inefficiencies are likely to be corrected quickly due to the number of informed investors in the market – the Efficient Market Hypothesis even hypothesizes that one cannot profit from market inefficiencies.

Perlin (2007) also examined the resultant Jensen's Alphas of their Pairs trading strategy.[2] Most of the Jensen's Alphas were found to be positive but statistically insignificant. The Beta's of the portfolios were all very close to zero, and, barring one, they were statistically insignificant.

It was concluded by Perlin (2007) that Pairs trading on the Brazilian stock exchange was a moderately profitable strategy in the past and, furthermore, an almost market neutral strategy. Similarly to Bolgun *et al.* (2009), Perlin (2007) didn't add constraints such as Sector Restriction into their pairing, and thus there is room for future improvement in the results of this study.

2.3 Risks of Pairs Trading

2.3.1 American Studies

Gatev *et al.* (2006) found that, for the period spanning from 1963 to 2002, the standard deviation of a Pairs trading portfolio was between a half and a third of the

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[1] Perlin (2007) used the variable d, making it arbitrary and used it as a filter for creating a trading signal. The value cannot be very high; otherwise too few trades will be opened, and similarly, can't be too small, as too many trades will be opened, which will lead to very high transaction costs. The variable is essentially a measure of the standard deviation spread required to open a trade.

[2] Jensen's Alpha is a risk-adjusted performance measure; it measures a portfolios excess return on the market after adjusting for the portfolios Beta.

standard deviation of the S&P500. Furthermore, individual pairs tended to be near market neutral, with their market exposures small and generally statistically insignificant (particularly when applying Sector Restrictions to the formation of pairs). It was tested whether or not a difference between large and small shares, as well as between value and growth shares changed the risk/return payoffs yielded by a Pairs trading strategy, and it was concluded that the difference was statistically insignificant. With regards to VaR, the portfolio of 20 pairs of shares tended to have a smaller VaR than a portfolio of 5 pairs of shares (a worst day VaR of 6.72% vs 10.08% respectively). Thus, the benefits of diversification when engaging in a Pairs trading strategy are evident.

It was postulated by Gatev *et al.* (2006) that there is a dormant risk factor inherent in a Pairs trading strategy that isn't captured by conventional risk measures. This dormant risk factor (or dormant risk factors) became apparent during the sub period analysis, when the sample period was split at the end of 1988. Significantly, the later period yielded a substantially lower return, marked by a decrease from 118bps to 38bps per month. However, the risk adjusted return decreased substantially less drastically, from 67bps to 42bps per month (with t-stats of 4.41 and 3.77 respectively). A change in factor exposures and factor volatilities were thus only able to explain part of the lower returns, but not the risk adjusted returns. The dormant risk factor was tested through stock correlations in the different sub-periods, as well as the entire sample (between the top 20 shares and the 101-120 shares). The full sample correlations were 0.48, while the sub-periods' correlations were 0.51 and 0.18 for the pre- and post-1988 periods respectively. In addition the correlation between Fama-French-Momentum-Reversion residuals was tested, and 0.41, 0.42 and 0.20 were the correlations for the full sample, pre-1988 and post-1988 respectively. Clearly returns were higher in the earlier period, where both correlations and rolling correlations, were higher. Gatev *et al.* (2006) concluded that the substantial difference in the correlations between the sub periods highlights the fact that there was a dormant risk factor that was more prevalent in the earlier period. Therefore, the higher returns in the earlier sub-period were the reward for taking on additional unmeasured risk.

Do and Faff (2009) documented the increased trend with which pairs continue to diverge from their historic mean instead of re-converging, resulting in an increase in the fundamental risks of Pairs trading. This increase in pairs' diversion causes the Law of One Price to not hold for sufficiently long investment horizons, increasing the risk of losses to a Pairs trading strategy. A number of possible reasons were postulated and tested by Do and Faff (2009), which will be covered in a later section (2.5) of the literature review (namely 'Potential Drivers Of Diminishing Returns'). It was concluded that the divergence problem is not caused by higher market volatility, but by a gradual change in the markets' perception of the relative values of paired securities. The Law of One Price was defined in Ingersoll (1987) and expanded upon in Chen and Knez (1995). It suggests that two similar shares should trade at the same price. Therefore, two shares that have historically traded at similar prices should continue to trade at similar prices, unless there is a fundamental shift in either share.

Herlemont (2004) suggested a number of rules that an investor can use to reduce their risk exposure. Firstly, he suggests a way for an investor to avoid the further divergence of the spread between two shares after opening a position. The investor should wait for the signal generation band to be breached a second time before opening the position, in other words; the position should only be opened when the spread has already begun to converge. Secondly, it is suggested that an investor should stipulate a maximum holding period for an open position, and Herlemont (2004) suggested a period of 50 days, as the average reversion period was found to be around 35 days. The assumption behind this is that the spread should, based on past observations, have reverted to the historical mean in this time period if it is going to converge, it also avoids losing the time value of money. Furthermore, Herlemont (2004) suggests that systematic market risk can be avoided by pairing shares with similar Beta's (ensuring that the pair is essentially, barring the fact that a shares beta can change over time, perfectly market neutral) to the market. However matching pairs based on their Beta's will severely restrict the number of pairs that can be formed. Herlemont (2004) suggests that the analysis of Beta spreads should be conducted and a maximum spread enforced (a spread of 0.2 was suggested). Lastly, Herlemont (2004) suggested that a stop-loss trigger should be added to any Pairs trading strategy.

2.3.2 International Studies

Perlin (2007), in his study of Pairs trading on the Brazilian stock exchange, examined the Jensen's Alphas that were yielded by a Pairs trading strategy. The majority of Jensen's Alphas for the daily frequency were found to be positive, although not statistically significant. These findings highlight that Pairs trading (for a daily frequency) tended to have a positive constant return after filtering for market conditions and risks, however, these findings weren't statistically significant. The analysis of portfolio Beta's (for all 3 frequencies – daily, weekly and monthly) shows that they were all very close to zero, but only one was significant, and only at the 10% level. The low values of portfolio's Beta's generated by a Pairs trading strategy highlights that the strategy was close to market neutrality.

Bolgun *et al.* (2009) hypothesized that factors of market incompleteness (ex-dividend date jumps etc.) and market frictions (transaction costs, financing costs, immediacy etc.) make Pairs trading a more difficult strategy to implement, and result in lower returns. Both Bolgun *et al.* (2009) and Do and Faff (2009) suggest that noise trader risk is prevalent in a Pairs trading strategy. Bolgun *et al.* (2009) defines noise trader risk as "…where the fundamental economic values of the two securities, based on ultimate payoffs, are exactly the same, but the aggregate of informed and uninformed investors trades them at even more disparate prices than when the spread was opened." Thus, both Bolgun *et al.* (2009) and Do and Faff (2009) highlighted the risk of further divergence of the shares in an open pair. Pairs trading portfolios on the Istanbul Stock Exchange outperformed the ISE-30 in terms of both return, as well as volatility (a daily volatility of 1.67% compared to the markets daily volatility of 2.20%).

2.4 Other Potential Drivers of Pairs Trading Returns

2.4.1 Bid-Ask Bounce

Jegadeesh (1990), Jegadeesh and Titman (1995) and Conrad and Kaul (1989) postulated that contrarian trading strategies' excess returns contain an upward bias due to a Bid-Ask Bounce. Due to Pairs trading being a contrarian investment strategy, the investor is likely to be able to take the long positions at prices close to bid quotes and take the short positions at prices close to the ask quotes. Bid-Ask Bounce is based on the theory that an investor can buy cheap (due to, on average, the market trying to exit positions on the way down) and sell expensive (due to, on average, the market wanting to enter positions on the way up) due to the contrarian nature of selling the winner and buying the loser, which is likely to cause an upward bias in the reported returns.

Gatev *et al.* (2006) tested whether Bid-Ask Bounce was a driving force behind the returns generated by Pairs trading's by only opening and closing positions the day after the signal was generated. The price on the following day is equally likely to be at the prior day's bid or ask price, and therefore Bid-Ask Bounce bias will be halved. Gatev *et al.* (2006) found that average monthly excess returns on fully invested portfolios and on committed capital portfolios dropped by 30-55bps and 20-35bps respectively. It was noted that part of the reduction in returns was from true mean reversion in prices and part was due to Bid-Ask Bounce bias. The portion attributable to each is difficult to quantify.

2.4.2 Short-Term Mean Reversals

Both Lehmann (1990) and Jegadeesh (1990) documented that contrarian investment strategies, including Pairs trading, benefit from short-term mean reversals. Gatev *et al.* (2006) examined whether reversals are the main driving force behind Pairs trading's excess returns and concluded that, while the returns of the two strategies are positively correlated, price reversals are not an explanatory factor for Pairs trading's outperformance.

Gatev *et al.* (2006) conducted this test through a bootstrap methodology comparing the returns of the paired shares to returns of randomly selected pairs. Randomly paired shares were chosen with similar one-month prior returns on the shares as the actual pair. It was found that the excess returns yielded by the random pairs were slightly negative, and the standard deviations were larger in comparison to the pairs formed based on a historical relationship. Thus, it was concluded that simple mean reversion could not be the explanatory force behind Pairs trading's outperformance.

Furthermore, Gatev *et al.* (2006) hypothesized that, should Pairs trading's excess returns be driven by mean reversion, the abnormal returns yielded by the strategy should be equal from both the long and the short positions (the opening of the position is equally likely to be triggered by a move in the price of either of the shares). However, it was found that the majority of the excess returns were due to the short position, with the returns yielded by the long position insignificantly different from zero. Should part of the study have occurred during a bull market, it would be feasible that the majority of the excess return yielded by the strategy should have been generated through the long position. Thus, short-term mean reversion is unlikely to be the main driver behind Pairs trading outperformance.

2.5 Potential drivers of diminishing returns

Do and Faff (2009) concluded that the increased rate of persistent divergence of shares in open pairs is the main driving force behind the decreased profitability of Pairs trading over time. Furthermore, it was concluded that this divergence is more likely to be a gradual, sustainable, shift in the market perception of relative values, as opposed to sudden fundamental changes.

2.5.1 Increased number of hedge funds

A common hypothesis for the diminishing, and ultimately statistically insignificant, returns yielded by Pairs trading has often been pinned on an increasing number of hedge funds. The hypothesis states that the increased numbers of hedge funds are all competing for the same price discrepancies, and therefore the discrepancies are likely to be eliminated more rapidly, leaving lower potential profits available to the funds. Do and Faff (2009) found evidence that disproves this argument.

Do and Faff (2009) split pairs into four groups, the first for pairs that never opened, the second for pairs that opened and never converged, the third group was pairs that completed one round trip (a trade was opened and closed) and the fourth group was for pairs that completed more than one round trip. Group 2 are the pairs that generate the most risk for a portfolio of paired shares, while group 4 is the most profitable set of pairs. Do and Faff (2009) postulated that increased competition between hedge funds would cause a reduction in pairs belonging to group 4 and an increase in groups 1 and 3. The theory is that the prices of paired shares wouldn't diverge as much (or as frequently) due to an increased number of funds attempting to profit from the potential arbitrage opportunity. Pairs in group 2 made up 26% of the population in the 1962-1988 period, which increased to 39% in the 1989-2002 period and then 42% in the latest 2003-2008 period. A decline in the number of pairs in group 4 was observed, from 42% to 24% and furthermore to 21%, while the percentage of pairs in groups 1 and 3 remained fairly constant.

Do and Faff (2009) also noted that the increased number of pairs in group 2 highlights an increased risk, over time, to investors. This increased risk would be likely push rational investors out of the market, and thus competition between hedge funds should have decreased over time.

Two further observations that served to disprove the increased competition argument were; firstly, in the presence of increased competition, the spread should narrow on the trading day following the opening of a pair (assuming that investors are using the same information, and trading according to the same signals). Do and Faff (2009) observed that the spread in fact tended to widen on the day following the opening of a pair, however, this was not statistically significant. Secondly, it was hypothesized that should there be increased competition in the Pairs trading market, divergences in the spread should correct more quickly, and Do and Faff (2009) noted the opposite effect. Pairs in group 3 (assuming a 2 standard deviation in the spread) took on average 34 days to converge in the 1962-1988 sub period, increasing to 36.75 and 38.79 days in the 1989-2002 and 2003-2008 sub periods respectively. Group 4 pairs initially took on average 19.25 days, increasing to 20.94 days and 23.72 days respectively.

2.5.2 Market Volatility

Do and Faff (2009) suggested that increased volatility of the market could possibly be the driving force behind the increasing trend in non-convergent pairs. Increased market volatility could lead to increased levels of noise trading, which can drive further divergence.

By regressing the divergence rate of pairs to the relevant six-month standard deviation of the return on the S&P500 index, Do and Faff (2009) tested the relationship of increased market volatility and the continued divergence in pairs' spreads. If a positive relationship is found, it can be concluded that increased market volatility drives divergence in pairs. The findings, however, for the entire sample, as well as the pre 1989 sub period, were of a negative relationship. The relationship was found to be statistically insignificant in the later periods, and therefore, Do and Faff (2009) concluded that, at most, increased market volatility played a small part in increasing the frequency of pairs divergence.

2.5.3 Earnings Events

Papadakis and Wysocki (2007) concluded that accounting events (such as earnings announcements and analysts forecasts) can cause a drift in the relative prices of paired shares due to investor under-reaction. A drift in relative prices around these events could cause Pairs trading to be less profitable. However, this study was limited to a small number of paired shares and results weren't examined for the possibility of a strategy that avoids these events.

Significantly, earnings events occur more frequently in recent years, and therefore it was hypothesized that they could be a driving force behind the diminishing returns of Pairs trading.

Do and Faff (2009) concluded that earnings announcements were not a driving force behind pairs continuing to diverge. The Gatev *et al.* (2006) algorithm was modified by Do and Faff (2009) so that if a signal to open a position occurred within 5 days after an earnings announcement the position would not be opened. The overall excess return was not different from the unconditional algorithm, but the later sub period of 2002-2008 yielded marginally higher returns. Pairs in groups 3 and 4 experienced a greater number of event induced divergences than pairs in group 2, which further suggests that an increased rate of divergence is driven primarily by gradual shifts in market perception rather than by market shocks.

3 Data

The daily total return, adjusted for reinvested dividends and corporate actions, for the Top 80 securities listed on the Johannesburg Stock Exchange ranked by market capitalization as at 2012/04/26 – was collected from DataStream. The period of study runs from 1998/01/21, through until 2012/04/26. A list of the shares in the sample and their relevant sectors is available in the Appendix.

Selecting shares on the basis of a static market cap has the potential to lead to look-ahead bias in the results, due to including a relatively large number of shares that previously outperformed. However, a Pairs trading strategy is market neutral as it requires that equal long and short positions are taken in paired shares when opening a position. Thus, while the look-ahead bias would positively affect the long position, it would equally have a negative effect on the short position. Thus, look-ahead bias in a Pairs trading strategy is not likely to be material. Furthermore, a benefit of a static market cap is a constant investment horizon in which no shares delist during the period of study.

Having selected the shares in the study at the end date will cause the study to include a higher proportion of previous winners than a constantly rebalanced ranking. This is likely to cause a disproportionate percentage of profits to be generated from the long positions in each pair. It should also be noted that due Pairs trading being almost market neutral (equal long and short positions are opened concurrently) a higher proportion of past winners would cause the trading strategy to appear to either underperform the market by a larger degree or to be less profitable with respect to the market.

For returns comparisons, daily returns to the All Share Index (ALSI) for the period 11/06/2002 to 26/04/2012 were collected off INET BFA. The collected returns are before associated trading costs for the ALSI, however, investing in an index generally incurs comparably low fees – particularly in comparison to a quantitative strategy.

The data is analyzed using Microsoft Excel 2011 for Apple Macintosh to both form and trade the pairs.

4 Methodology

Implementing a Pairs trading strategy requires two stages of application. Firstly, pairs need to be formed. In this study, the formation period for pairs is a 6-month period. For consistency in the length of the formation periods, this is equated to 125 trading days, which is marginally shorter than 6 months. The pairs then need to be traded, and each trading period was the 125 trading days following its relevant formation period. Thus, the trading of pairs was tested out of sample of pairs' formation. Each trading period lagged its formation period by 125 days and therefore the second formation period is over the same time frame as the first trading period. The periods are chosen to be similar to comparable to prior papers, most notably Do and Faff (2009) and Gatev *et al.* (2006).

4.1 Pairs Formation

The first step in the formation of pairs is to normalize the price series' (inclusive of reinvested dividends) for each of the 80 shares over the corresponding 125-day formation period. A stock's normalized price is based on its expected price (in this case the average price over the period), the actual price and the standard deviation of the price over the period.

Equation 1

$$P^{*}{}_{it} = \frac{P_{it} - E(P_{it})}{\sigma_i}$$

Where:

P^{*} is the normalized price

E(P) is the expected price, or the average price over the 125-day formation period

σ is the standard deviation of the price over the 125-day period

'After the normalization, all shares are brought to the same standard unit and this permits a quantitatively fair formation of pairs' Bolgun *et al*. (2009).

After a normalized price series has been constructed for each of the 80 shares, the relationship of each stock to every other stock needs to be tested for the duration of the formation period. The closeness of the relationship between two shares is tested by a summation of the daily differences between the normalized price series' of the shares. However, the sum of the differences would equate to zero. To ensure that real numbers are returned for accurate pair formation, the daily differences between the normalized price series' are squared prior to their summation. This results in a measure called the Sum of the Squared Differences (SSD), which is calculated as follows:

<u>Equation 2</u>

$$SSD = \sum_{i=1}^{125} (P^*A_i - P^*B_i)^2$$

Where:

P^*A is the normalized price of Stock A

P^*B is the normalized price of Stock B

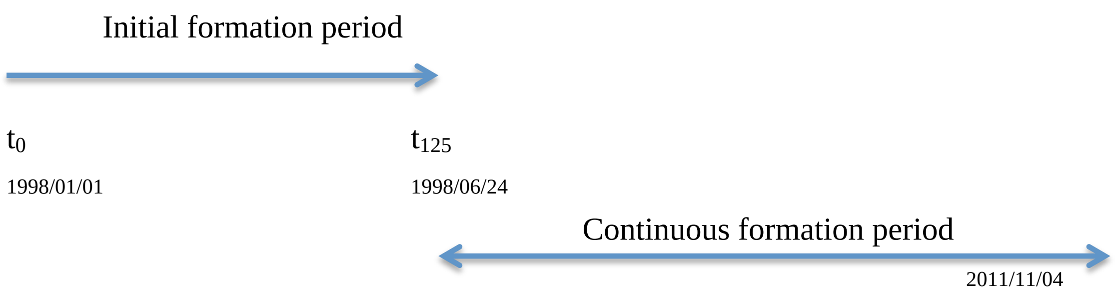
A matrix of the Sum of the Squared Differences between the normalized price series' was constructed for each formation period, and from that, a portfolio of 20 pairs was created (the 20 pairs with the lowest SSD, which reflects the closest historical relationship between the shares' prices). Within the portfolio of 20 pairs, two further portfolios were constructed – one using the 5 pairs with the lowest SSD and another using the 5 pairs with the highest SSD. A portion of the SSD matrix is available in the Appendix, the entire matrix is omitted due to its size and the limited amount of value it would add to this research report.

This process of pair formation was repeated every 125 days to create the required portfolios of pairs for every 125-day trading period. On the 126^{th} day, the first trading period began using the portfolios selected in the first formation period, and concurrently, the second formation period began.

Pairing was also carried out twice for every formation period, the first with no restriction (Unrestricted) on the paired shares and the second only allowing for pairs within the Resources (RESI) sector or within the Financials and Industrials (FINDI) sectors (Sector Restricted).

The lack of any restrictions under the Unrestricted pairing is likely to result in a number of pairs that don’t make practical sense, such as a retailer and a property company. However, it is expected that, due to expected inter-Sector correlations, the majority of the pairs will still be from the same sector.

Figure A.1: Formation Period



4.2 Trading Period

After the shares were paired in the formation period, portfolios of shares were constructed, and trading was simulated in the following 125-day trading period. This was done for both the unrestricted portfolio of pairs as well as the Sector Restricted portfolio of pairs.

Pairs from the matrix were ranked and the top 20 with the smallest SSD measure were used for the formation of 3 different portfolios. Firstly, a portfolio of all 20 (Top20) pairs was tested. In addition a portfolio of the top 5 (Top5) as well as the pairs ranked between 15 and 20 (Bottom5) were tested. The portfolio construction differs from that of Do and Faff (2009) as well as Gatev *et al*. (2006) due to the smaller universe of shares (particularly those that are shortable, due to limited scrip borrow) on the JSE than on the S&P500.

Trading of the pairs in the portfolios starts on the day following the last day of the corresponding formation period, and is carried out according to certain predetermined rules. When the spread between the prices of paired shares widens by more than a predetermined amount a position is opened. A long position is taken in the stock that has relatively decreased in price and a short position is taken in the stock that has relatively increased in price, assuming a reversion to the historic price relationship will occur. When, and if, the price relationship reverts, again to a predefined metric, the position is closed. Signals are generated based on the 125-day rolling standard deviation around a 125-day rolling mean of the shares' normalized price relative.

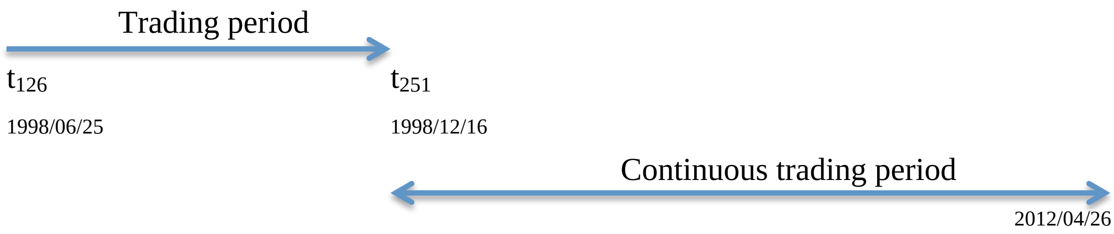
In an attempt to be comparable to previous studies, the basic strategy of this study entails a spread of two standard deviations to open a position, and the subsequent reversion to a zero standard deviation spread generates the signal to close the pair. In addition to the basic trading rules, a number of other sets of trading rules have been tested to determine whether a particular set leads to relative outperformance.

The signal creation for trading pairs is generated by using the rolling 125-day average of the difference between the normalized prices of the paired shares, as well as the rolling 125-day standard deviation of the difference between the normalized prices of the paired shares. Using a 2 standard deviation opening signal, a pair is opened when a daily difference between two paired shares' returns is greater than the rolling 125-day average plus two times the rolling 125-day standard deviation.

When a pair is opened, an equal position is taken in both the long and the short positions. For ease of interpretation in this study, a value of R1 is used for both the long and the short positions. Any positions that are open at the end of the trading period will be closed on that date and the corresponding profits or losses will be taken into account.

As no shares can delist during the trading period, as they were selected based on their market capitalizations at the end date, this can lead to a potential for survivorship bias. However, it must be noted that due to Pairs Trading deriving fifty percent of its returns from a long position (which would benefit from a higher portion of shares that previously performed well) as well as fifty percent of its returns from a short position (conversely, survivorship bias would have a negative effect on these returns), the effect of survivorship bias will be limited.

Figure A.2: Trading Period



4.3 Excess Return Computation

During the trading period, pairs can either; open and close once, open and close a number of times, never open or open and never close. Thus, calculating excess return is not an easy process. A pair that opens and converges has a positive cash flow (however, drastic movements in the stock prices can change both the rolling mean and rolling standard deviation, which could result in a pair that completes a round trip yielding a negative cash flow), while a pair that opens and hasn't closed by the end of the period will have a cash flow on the last day of the period when it is closed out (this cash flow can be positive or negative depending on the relative performances of the shares). Due to the fact that a pair can open and close a number of times over the period, a pair can be made up of multiple cash flows. A Pairs trading strategy yields a number of randomly distributed cash flows over the trading period and a set of cash flows at the end of the final day that can be positive or negative due to positions being closed out.

The excess returns are calculated as the reinvested payoffs during the trading interval which is a, a conservative approach, assuming that cash earns a zero percent interest rate when not invested in an open pair, thus understating excess returns. The daily returns on the long and short positions (when they are marked-to-market) are calculated as follows;

<u>Equation 3</u>

$$r_{P,t} = \frac{\sum_{i \epsilon P} w_{i,t} r_{i,t}}{\sum_{i \epsilon P} w_{i,t}}$$

Where $w_{i,t}$ is:

$$w_{i,t} = w_{i,t-1}(1 + r_{i,t-1}) = (1 + r_{i,1}) \dots (1 + r_{i,t-1})$$

With *r* defining returns and *w* defining weights. Monthly returns can be calculated by compounding daily returns.

As in the Do and Faff (2009) and Gatev *et al.* (2006) studies, two measures of excess return on a portfolio are analyzed, namely, return on Committed Capital and the Fully-Invested Return (return on employed capital). The first measure scales the portfolio's performance by the number of pairs that are available to be traded (20 pairs in each period), while the latter scales performance by the number of pairs that open during the period. The Return on Committed Capital is a more conservative approach of return calculation. If a pair doesn't open for a trading period, the return for the period will be calculated as if a portion of funds was held in cash (on which no interest is earned).

4.4 Performance Comparisons

The performance of the Pairs trading strategy has been tested against a passive trading strategy. The passive strategy chosen is simply the daily return yielded by the ALSI, which was taken directly off INET BFA.

Comparisons were made on a cumulative returns basis for the period 2002/06/11 until 2012/04/26. Comparisons were also drawn between the daily returns of the strategies, which allows for a comparison of the volatility of returns yielded by the different strategies.

In addition, return comparisons were conducted over 4 sub periods of equal length, being 875 trading days or roughly 3,5 years. Each sub period spanned 7 trading periods. This was in order to test whether the performance of Pairs trading has changed over time.

4.5 Scrip Borrow and Fees

Due to the high frequency of trading expected under a quantitative strategy, it is important to examine the after-fee returns, particularly in comparison to a passive strategy of holding an index.

To this degree, a trading (brokerage) fee of 10 basis points (bips) was used per trade. Fees of this size could realistically be expected to be incurred by large institutional investors, while individuals would be likely to incur comparably higher trading costs.

As a caveat to this research report, the costs of scrip lending have not been included. This is due to the vast differences in both the availability and cost of borrowing scrip between different shares on the JSE. For example, a number of particularly large counters in the Top40 have no available (or prohibitively expensive) scrip available due to being tightly held, while a number of smaller counters have comparably readily available cheap scrip on offer. The unpredictable nature of scrip on the Top40 is even more pronounced when extended to the Top80 universe.

Furthermore, the potential costs associated with a short recall have not been taken into account in this study. A short recall occurs when the lender of scrip requires that the borrower returns borrowed scrip any time prior to when they were aiming to. This forces the borrower to purchase the stock back in the market, potentially at unfavourable rates. Furthermore, the investor would be forced to close an open pair prematurely should he be unable to locate alternative scrip.

The lack of available scrip on the JSE could potentially be a limiting factor on the ability of an investor to trade a Pairs trading strategy in practice. Should scrip be unavailable in the counter that an investor wishes to short, under a Pairs trading strategy, the investor could not take a long position in the paired counter.

4.6 Sharpe Ratios

The formula for calculating a Sharpe Ratio is as follows;

$$SR = \frac{R_p - R_f}{\sigma}$$

Where;

SR is the Sharpe Ratio

R_p is the return on the portfolio

R_f is the risk free rate

σ is the standard deviation of the strategy

However, due to each pair being self-funded (the short sale funds the long purchase every time a pair is opened), funds committed to the strategy can earn the risk free rate. Thus, the following equation holds true;

$$R_p = R_{LS} + R_f$$

Where;

R_{LS} is the Return of the Long/Short postition

Therefore, the Sharpe Ratio is calculated as follows in this research report;

$$SR = \frac{R_{LS}}{\sigma}$$

However, a caveat to this section is that the committed funds may not quite earn the risk free rate. This is due to the associated trading costs, particularly scrip borrow costs, which would be required to be paid on the strategy eroding the committed capital.

5 Empirical Results

5.1 Strategy Profits

5.1.1 Unrestricted

5.1.1.1 Unrestricted (2;0)

Gatev *et al.* (2006) as well as Do and Faff (2009) both tested a Pairs trading strategy using a 2 standard deviation spread to open a position and a subsequent 0 standard deviation spread to close the position. It is because these studies are both so widely respected and cited that this study employs *their* basic set of trading rules i.e. 2 and 0 standard deviation trade execution triggers.

Trading Period	Date	R	SD	SR	ASSD	ANOP	NoT	ATL	RPT	T-Stat
1	98/06/25 - 98/12/16	180,26%	0,18	10,00	16,31	6,72	132	6,36	0,51%	**5,33**
2	98/12/17 - 99/06/09	79,70%	0,11	7,47	14,12	9,75	134	9,10	0,25%	**4,55**
3	99/06/10 - 99/12/01	91,48%	0,10	8,91	11,92	9,42	160	7,36	0,24%	**5,33**
4	99/12/02 - 00/05/04	96,17%	0,13	7,46	22,65	10,03	148	8,47	0,27%	**4,43**
5	00/05/05 - 00/10/26	58,91%	0,07	7,92	18,72	8,74	130	8,40	0,20%	**4,99**
6	00/10/27 - 01/04/19	60,16%	0,11	5,57	22,24	9,71	122	9,95	0,22%	**3,50**
7	01/04/20 - 01/10/11	61,31%	0,09	6,82	16,79	11,30	122	11,58	0,22%	**4,28**
8	01/10/12 - 02/04/04	68,70%	0,08	8,22	21,23	8,95	142	7,88	0,21%	**5,10**
9	02/04/05 - 02/09/26	86,83%	0,14	6,26	8,18	11,34	138	10,27	0,27%	**3,77**
10	02/09/27 - 03/03/20	65,12%	0,07	8,93	15,07	8,42	150	7,01	0,19%	**5,57**
11	03/03/21 - 03/09/11	61,54%	0,07	9,28	14,14	7,42	138	6,72	0,20%	**5,82**
12	03/09/12 - 04/03/04	58,51%	0,06	10,11	8,82	8,02	166	6,04	0,16%	**6,38**
13	04/03/05 - 04/08/26	50,54%	0,06	7,83	8,25	10,52	198	6,64	0,11%	**5,01**
14	04/08/27 - 05/02/17	31,62%	0,09	3,72	17,40	9,33	110	10,60	0,13%	**2,47**
15	05/02/18 - 05/08/11	49,13%	0,05	10,21	6,38	8,46	168	6,30	0,13%	**6,55**
16	05/08/12 - 06/02/02	56,69%	0,07	8,68	10,04	7,80	158	6,17	0,16%	**5,50**
17	06/02/03 - 06/07/27	63,71%	0,07	8,97	8,05	8,52	146	7,29	0,19%	**5,61**
18	06/07/28 - 07/01/18	42,90%	0,05	9,40	10,99	5,25	118	5,56	0,17%	**6,10**
19	07/01/19 - 07/07/12	47,43%	0,06	8,19	6,33	9,23	196	5,89	0,11%	**5,27**
20	07/07/13 - 08/01/03	53,19%	0,08	6,69	11,96	7,56	102	9,26	0,23%	**4,26**
21	08/01/04 - 08/06/26	93,96%	0,09	10,28	14,87	8,12	148	6,86	0,27%	**6,13**
22	08/06/27 - 08/12/18	95,31%	0,11	8,47	10,97	8,17	186	5,49	0,21%	**5,04**
23	08/12/19 - 09/06/11	86,22%	0,13	6,65	7,23	9,53	142	8,39	0,26%	**4,01**
24	09/06/12 - 09/12/03	42,22%	0,05	9,36	21,32	5,70	96	7,43	0,20%	**6,08**
25	09/12/04 - 10/05/27	39,49%	0,05	8,71	9,31	8,18	158	6,47	0,11%	**5,70**
26	10/05/28 - 10/11/18	24,10%	0,04	6,03	11,67	7,68	114	8,42	0,10%	**4,07**
27	10/11/19 - 11/05/12	38,30%	0,06	6,24	7,96	10,34	164	7,88	0,11%	**4,09**
28	11/05/13 - 11/11/03	25,78%	0,07	3,82	19,14	10,30	114	11,29	0,11%	**2,57**
29	11/11/04 - 12/04/26	37,74%	0,05	7,09	13,74	9,02	118	9,56	0,15%	**4,65**
Average		63,69%	0,08	7,84	13,30	8,74	142	7,88	0,20%	

Table 1.1 – Returns Analysis – Unrestricted (2;0)

Where:
R = Return SD = Standard Deviation SR = Sharpe Ratio RPT = Return Per Trade
ASSD = Average Sum of Squared Distances ANOP = Average Number of Open Pairs
MR = Monthly Return NoT = Number of Trades ATL = Average Trade Length
(A more detailed explanation is available in the Appendix)

Initially a 20 pair portfolio, constructed with the closest fitting 20 pairs, was tested using the basic trading rules of a 2 and 0 standard deviation spread. The before fee results are summarized in *Table 1.1*.

The annualized return for each 125 day trading period was, on average, 63,69% before trading costs were taken into account, and no period had an annualized before-fee return of less than 24,10%. All returns had a significant t-stat at the 2% level and, notably, 27 of the 29 sub periods were statistically significant at the 1% level. The average trading period before-fee standard deviation was 0,08, which reflects the low risk nature of the trading strategy. Sharpe Ratio's have been calculated in excess of cash due to the particularly low risk nature of the strategy, as well as the equal long and short positions entered into under each pair, and were high across all 29 sub-periods. Returns before trading costs were clearly both statistically as well as economically significant. However, as with many quantitative trading strategies, profits may not have been resilient to the high level of trading costs incurred.

The average number of open pairs was generally fairly close to 10 (8,74 pairs), such that at any point in time roughly fifty percent of the funds allocated to the strategy were invested. If only fifty percent of the portfolio is invested, the remaining fifty percent would remain in cash (so as to remain immediately investible, should an open signal be triggered) and not yield a return. On average, the portfolio would be under-invested. The low average level of investment was driven both by the high number of trades (142), as well as low average trade length (7,88 days). The high number of trades executed is a result of 2 trades being executed simultaneously every time a position opens and closes, 1 long and another short. Thus, for every round trip (open and close) that a pair completes, 4 trades in total are required to be executed. The Return Per Trade (which averaged 20 bips, and ranged from 10 to 51 bips) is essentially the maximum possible transaction costs that the strategy would have been able to endure before the high frequency of trading diminished positive returns. Therefore the basic strategy would have been resilient to low levels of brokerage costs (such as the costs an institutional investor would enjoy) in the majority of the trading periods. Should an investor be able to open (and close) a pair (funding both the long and the short trade) at less then 40 bips (20 bips for each trade), the strategy on average would have yielded after-fee positive returns. Conversely, should the investor be unable to trade for under 40 bips, on average a negative after-fee return would have been yielded. These breakeven costs are inclusive of both brokerage as well as scrip lending. It is expected that an institutional investor should be able to yield profitable returns from Pairs trading (particularly if scrip borrow is excluded), while an individual investor could have his positive before-fee returns more than eroded by trading costs.

Trading Period	R(125Day)	NoT	Instutional Fee (Per Trade)	Profit After Fees	Anualized PAF	Sharpe Ratio
1	67,41%	132	0,1%	54,21%	137,80%	7,64
2	34,05%	134	0,1%	20,65%	45,57%	4,27
3	38,37%	160	0,1%	22,37%	49,76%	4,85
4	40,06%	148	0,1%	25,26%	56,90%	4,41
5	26,06%	130	0,1%	13,06%	27,82%	3,74
6	26,56%	122	0,1%	14,36%	30,77%	2,85
7	27,01%	122	0,1%	14,81%	31,81%	3,54
8	29,88%	142	0,1%	15,68%	33,82%	4,05
9	36,69%	138	0,1%	22,89%	51,01%	3,68
10	28,50%	150	0,1%	13,50%	28,82%	3,95
11	27,10%	138	0,1%	13,30%	28,36%	4,27
12	25,90%	166	0,1%	9,30%	19,47%	3,36
13	22,70%	198	0,1%	2,90%	5,88%	0,91
14	14,73%	110	0,1%	3,73%	7,59%	0,89
15	22,12%	168	0,1%	5,32%	10,92%	2,27
16	25,17%	158	0,1%	9,37%	19,63%	3,01
17	27,95%	146	0,1%	13,35%	28,48%	4,01
18	19,54%	118	0,1%	7,74%	16,08%	3,52
19	21,42%	196	0,1%	1,82%	3,68%	0,63
20	23,77%	102	0,1%	13,57%	28,98%	3,64
21	39,27%	148	0,1%	24,47%	54,93%	6,01
22	39,75%	186	0,1%	21,15%	46,78%	4,16
23	36,46%	142	0,1%	22,26%	49,48%	3,81
24	19,26%	96	0,1%	9,66%	20,24%	4,49
25	18,10%	158	0,1%	2,30%	4,66%	1,03
26	11,40%	114	0,1%	0,00%	0,00%	0,00
27	17,60%	164	0,1%	1,20%	2,41%	0,39
28	12,15%	114	0,1%	0,75%	1,51%	0,22
29	17,36%	118	0,1%	5,56%	11,44%	2,15
Average	27,46%	142		13,26%	29,47%	3,16

Table 1.2 - After-fee Analysis – Unrestricted (2;0)

Table 1.2 highlights the after-fee (brokerage) return that an institutional investor would have yielded. Notably *Table 1.2* presents an after-fee return analysis, relating only to institutional investors. This is because Pairs trading is a strategy that is more likely to be employed by an institutional investor, and institutional fees don't tend to vary as substantially, nor be as large, as the fees incurred by an individual investor.

The assumption of a fee in the region of 10 bips (for brokerage) per trade is both realistic and conservative in terms of the transaction costs institutional investors can expect to pay when trading on the Johannesburg Stock Exchange (JSE). The after fee returns were calculated by taking the 125 day return in each period and subtracting 0,1% (10 bips) multiplied by the number of trades (which are weighted to reflect their portion of the portfolio weight – multiplied by 5%, for both the long and the short trade required to open and close a pair) executed in the period. The results show that positive after-fee returns were yielded in every trading period. After-fee returns ranged between 0% (0% annualized) and 54,21% (137,80% annualized). The resultant after-fee Sharpe Ratio's of the strategy ranged between 0 and 7.64, and averaged 3.16.

The average 125-day after-fee return for the strategy over the 29 Trading Periods was 13,26% (29,47% annualized), a substantial figure. A number of the more substantial returns occurred earlier in the period of study, with 4 of the last 5 periods yielding sub 3% after-fee 125-day returns.

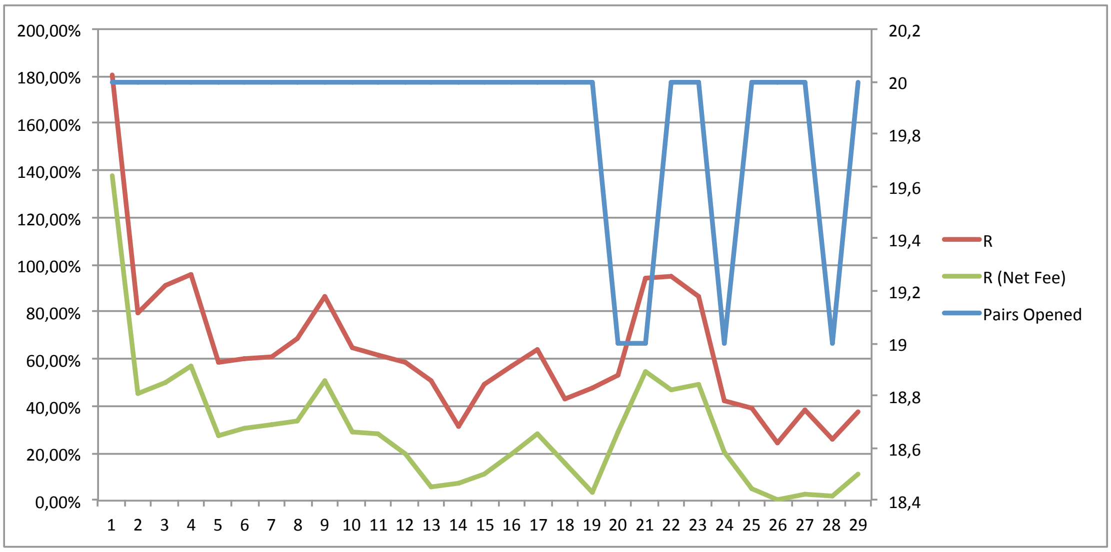


Figure 1 – Before- and After-fee Returns – Unrestricted (2;0)

Figure 1 graphs the before- and after-fee returns yielded by the (2;0) trading strategy. Clearly, with the exception of the period beginning in the middle of 2007 and ending in the middle of 2009 (a period highlighted by substantial market stress and elevated levels of market volatility), before- and after-fee returns yielded by Pairs Trading were (as Gatev *et al.* (2006) and Do and Faff (2009) concluded) on a downward trend. The strategy yielded higher than normal returns in both periods of *in-sample* market stress – namely, 1998 as well as the previously mentioned period.

The reason underlying these findings is the market neutral nature of the trading strategy benefiting from the substantially increased market volatility. Increased market volatility is expected to both increase the number of pairs that trade, as well as increase the return per trade. Increased market volatility is likely to result in larger standard deviations as well as means of the SSD's of paired shares. Therefore a larger relative share price move (an increase of the long position, and/or a decrease in the short position) of the paired shares is required to trigger a close signal, which would result in larger returns.

Trading Period	R(Top20)	R(Top5)	R(15-20)	SD(Top20)	SD(Top5)	SD(15-20)	SR(Top20)	SR(Top5)	SR(15-20)	T-Stat(Top20)	T-Stat(Top5)	T-Stat(15-20)
1	180,26%	174,16%	133,67%	0,18	0,43	0,21	10,00	4,01	6,44	5,33	2,15	3,63
2	79,70%	81,21%	103,43%	0,11	0,20	0,18	7,47	3,98	5,79	4,55	2,42	3,40
3	91,48%	120,02%	71,61%	0,10	0,16	0,17	8,91	7,60	4,10	5,33	4,36	2,53
4	96,17%	89,65%	98,08%	0,13	0,30	0,24	7,46	3,00	4,14	4,43	1,80	2,45
5	58,91%	46,85%	29,63%	0,07	0,13	0,14	7,92	3,61	2,07	4,99	2,33	1,38
6	60,16%	33,27%	59,61%	0,11	0,11	0,16	5,57	3,03	3,67	3,50	2,01	2,31
7	61,31%	54,78%	43,10%	0,09	0,14	0,14	6,82	3,88	3,00	4,28	2,47	1,95
8	68,70%	65,93%	37,00%	0,08	0,14	0,14	8,22	4,75	2,65	5,10	2,96	1,74
9	86,83%	88,84%	83,58%	0,14	0,16	0,19	6,26	5,49	4,36	3,77	3,30	2,64
10	65,12%	31,30%	51,62%	0,07	0,15	0,12	8,93	2,05	4,20	5,57	1,36	2,68
11	61,54%	47,87%	71,64%	0,07	0,12	0,10	9,28	3,97	7,14	5,82	2,55	4,41
12	58,51%	50,91%	64,81%	0,06	0,09	0,10	10,11	5,90	6,71	6,38	3,78	4,19
13	50,54%	38,24%	65,69%	0,06	0,07	0,10	7,83	5,36	6,62	5,01	3,51	4,13
14	31,62%	28,38%	39,70%	0,09	0,11	0,10	3,72	2,59	4,10	2,47	1,73	2,68
15	49,13%	33,40%	62,43%	0,05	0,08	0,09	10,21	4,18	6,89	6,55	2,77	4,32
16	56,69%	18,00%	63,30%	0,07	0,06	0,13	8,68	3,09	4,93	5,50	2,11	3,08
17	63,71%	113,28%	54,16%	0,07	0,16	0,17	8,97	7,00	3,11	5,61	4,06	1,98
18	42,90%	27,90%	42,83%	0,05	0,06	0,07	9,40	4,33	6,57	6,10	2,90	4,27
19	47,43%	61,19%	36,66%	0,06	0,06	0,10	8,19	9,56	3,51	5,27	6,00	2,31
20	53,19%	54,33%	33,31%	0,08	0,13	0,13	6,69	4,33	2,52	4,26	2,75	1,67
21	93,96%	92,74%	55,69%	0,09	0,15	0,12	10,28	6,31	4,69	6,13	3,77	2,97
22	95,31%	69,22%	142,59%	0,11	0,12	0,17	8,47	5,65	8,17	5,04	3,50	4,56
23	86,22%	45,27%	113,00%	0,13	0,18	0,22	6,65	2,49	5,23	4,01	1,61	3,03
24	42,22%	36,07%	34,76%	0,05	0,08	0,08	9,36	4,35	4,59	6,08	2,86	3,03
25	39,49%	29,19%	42,26%	0,05	0,07	0,08	8,71	4,33	4,98	5,70	2,89	3,24
26	24,10%	27,75%	19,17%	0,04	0,07	0,06	6,03	4,04	3,48	4,07	2,71	2,37
27	38,30%	37,60%	34,13%	0,06	0,09	0,08	6,24	4,35	4,15	4,09	2,85	2,74
28	25,78%	26,59%	22,93%	0,07	0,09	0,11	3,82	2,90	2,16	2,57	1,94	1,46
29	37,74%	37,08%	36,57%	0,05	0,09	0,09	7,09	4,33	3,94	4,65	2,84	2,59
Average	63,69%	57,28%	60,24%	0,08	0,13	0,13	7,84	4,50	4,62			

Table 1.3 – Top20 Portfolio Risk and Return Drivers – Unrestricted (2;0)

Table 1.3 highlights the breakdown of those pairs in the Top20 portfolio (*Table 1.1*) that contributed towards the overall portfolio performance. For the purposes of analysis, the Top20 portfolio is included, together with another portfolio constructed of only the 5 pairs in the portfolio with the smallest sum of the squared distances between their normalized prices (Top5). A third portfolio is also included (Bottom5), which includes the five pairs in the Top20 portfolio that have the largest sum of their normalized squared differences. The Top5 portfolio consists of the pairs with the closest observed price relationships, while the Bottom5 portfolio consists of the 5 pairs that have shown the weakest observed price relationships in the Top20 portfolio. The returns yielded by all three of the portfolios were calculated through the Return on Committed Capital (the more conservative return metric) approach.

Trading Period	Date	R(CC)	R(FI)	Pairs Opened	Min R	Max R	% Days <0	% Pairs <0
1	98/06/25 - 98/12/16	180,26%	180,26%	20	-2,37%	9,10%	20,8	0
2	98/12/17 - 99/06/09	79,70%	79,70%	20	-1,57%	2,15%	33,6	0
3	99/06/10 - 99/12/01	91,48%	91,48%	20	-1,44%	3,17%	27,2	10
4	99/12/02 - 00/05/04	96,17%	96,17%	20	-1,61%	2,93%	28	5
5	00/05/05 - 00/10/26	58,91%	58,91%	20	-1,25%	1,33%	28,8	5
6	00/10/27 - 01/04/19	60,16%	60,16%	20	-2,25%	2,11%	28	15
7	01/04/20 - 01/10/11	61,31%	61,31%	20	-1,23%	1,74%	36	0
8	01/10/12 - 02/04/04	68,70%	68,70%	20	-0,95%	2,11%	27,2	5
9	02/04/05 - 02/09/26	86,83%	86,83%	20	-2,30%	3,24%	35,2	0
10	02/09/27 - 03/03/20	65,12%	65,12%	20	-0,85%	1,70%	32	10
11	03/03/21 - 03/09/11	61,54%	61,54%	20	-0,85%	1,54%	30,4	0
12	03/09/12 - 04/03/04	58,51%	58,51%	20	-0,68%	1,88%	24,8	0
13	04/03/05 - 04/08/26	50,54%	50,54%	20	-1,23%	1,40%	32	0
14	04/08/27 - 05/02/17	31,62%	31,62%	20	-0,98%	2,28%	40,8	15
15	05/02/18 - 05/08/11	49,13%	49,13%	20	-0,58%	1,17%	25,6	0
16	05/08/12 - 06/02/02	56,69%	56,69%	20	-0,81%	1,60%	28	0
17	06/02/03 - 06/07/27	63,71%	63,71%	20	-1,04%	1,75%	28,8	0
18	06/07/28 - 07/01/18	42,90%	42,90%	20	-0,64%	1,22%	26,4	0
19	07/01/19 - 07/07/12	47,43%	47,43%	20	-0,94%	1,39%	25,6	10
20	07/07/13 - 08/01/03	53,19%	56,30%	19	-0,78%	3,50%	35,2	0
21	08/01/04 - 08/06/26	93,96%	99,76%	19	-1,21%	2,17%	28	0
22	08/06/27 - 08/12/18	95,31%	95,31%	20	-1,97%	2,86%	31,2	5
23	08/12/19 - 09/06/11	86,22%	86,22%	20	-1,87%	2,91%	32	0
24	09/06/12 - 09/12/03	42,22%	44,65%	19	-0,51%	1,02%	28,8	0
25	09/12/04 - 10/05/27	39,49%	39,49%	20	-0,57%	0,94%	31,2	0
26	10/05/28 - 10/11/18	24,10%	24,10%	20	-0,57%	0,83%	33,6	0
27	10/11/19 - 11/05/12	38,30%	38,30%	20	-1,13%	1,08%	34,4	5
28	11/05/13 - 11/11/03	25,78%	27,22%	19	-1,18%	1,12%	34,4	15
29	11/11/04 - 12/04/26	37,74%	37,74%	20	-0,74%	1,47%	28,8	0
Average		63,69%	64,13%	19,86	-1,18%	2,13%	30,23	3,45

Table 1.4 – Profitability Analysis – Unrestricted (2;0)

The Top20 portfolio realized the highest average annualized before-fee return of 63,69%, compared to 57,28% and 60,24% for the Top5 and Bottom5 portfolios respectively. Furthermore, the Top20 portfolio yielded the highest returns in 11 of the 29 sub periods and the lowest return in only 1. The Bottom5 portfolio, on average, yielded a 2,96% higher return than the Top5 portfolio. As expected, increasing the number of pairs in a portfolio from 5 to 20 contributed diversification benefits, which was evident in the substantially lower standard deviation of the Top20 portfolio (when compared to the Top5 or Bottom5 portfolios). The standard deviation of the Top20 portfolio was on average 0.08, while the 5 pair portfolios were both substantially higher, at 0.13. The higher return and lower risk associated with the Top20 portfolio led to a substantially larger Sharpe Ratio then both of the 5 pair portfolios. The T-statistics for the Top20 portfolio were all significant at the 2% level, and 27 out of the 29 sub periods were significant at the 1% level. The T-Statistics for both the Top5 and Bottom5 portfolios were significant at the 5% level in the majority of the trading periods, with insignificant t-stats in 5 and 4 sub periods respectively.

Table 1.4 comprises of a returns analysis of the Top20 portfolio, and illustrates that opening pairs at a 2 standard deviation spread resulted in almost every of the 20 pairs opening in every trading period. This was however, with the exception of 4 sub periods – all of which occurred post 2007, and in which only 19 out of 20 pairs opened. A decrease in the number of traded pairs in the later periods could be a driving force behind the declining returns yielded by Pairs trading, as concluded by Gatev *et al.* (2006), Do and Faff (2009). All 20 pairs opening in a period will lead to a larger number of trades being executed than if fewer of the pairs were to open. A large number of trades, assuming re-convergence for the majority, will boost before-fee returns. Of note, an increased number of trades will also serve to increase the net trading costs incurred.

The difference between the Return on Committed Capital and the Fully Invested Return in this instance was negligible. This is due to all 20 of the pairs having opened in the majority of the sub periods. Where 20 pairs didn't open, 19 pairs still traded.

The second half of *Table 1.4* represents a break- down of the profitability of the Top20 portfolio. The majority of pairs selected were profitable before trading costs and an average of only 3,45% of pairs yielded a negative before-fee return in each sub period. This figure indicates that, on average, less than 1 pair yielded negative before-fee returns per sub period. A figure of 5% would highlight a negative pair per trading period. No sub periods had more than 15% (3 pairs) of the pairs yielding a negative return. It must be noted that these return metrics are gross of trading costs, and therefore a larger number of pairs could potentially have yielded negative net of fee returns (however, the frequency of positive 125-day after-fee returns suggests that this wasn't the case). Daily before-fee returns were more often than not positive for every sub period, and ranged from 20,8% to 40,8% of days yielding negative returns, with an average of 30,23%. In all but 3 sub periods, the absolute value of the maximum daily return was larger than the absolute value of the minimum daily return. The average maximum daily return was 2,13%, while the average minimum daily return was -1,18%. Again, the daily profitability analysis is gross of fees.

It appears that the Top20 portfolio (using 2 and 0 standard deviation trading signals) yielded positive before-fee returns more frequently than not, both in terms of days as well as pairs. Significantly, also, positive returns tended to be larger than negative returns. Of further significance, Pairs trading, using the (2;0) set of trading parameters, appears to have been resilient to a conservative measure of trading costs (broking costs, but still being gross of scrip borrowing costs) that an institutional investor could expect to pay. However, it must be noted that both before- and after-fee returns appear to be on a downward trend, a finding that has been noted in a number of prior papers including Gatev *et al.* (2006) and Do and Faff (2009).

While the basic (2;0) strategy appears to produce positive outperformance on the JSE, there is potential scope for further improvements to be yielded from different trading parameters, as well as sector restrictions.

5.1.1.2 Unrestricted (2;-0.5)

A second set of trading rules was imposed on the Unrestricted pairs sample, namely, opening a position at a 2 standard deviation spread and closing the position only when the pairs had crossed by a further half standard deviation (a subsequent half standard deviation spread from the mean in the opposite direction to the opening signal).

The theoretical rationale underlying this strategy is that the longer holding period (in terms of a required relative price shift required to trigger the closing signal) will serve to increase the return generated per round trip completed, when compared to the basic (2;0) set of trading parameters. The (2;-0,5) trading strategy requires a 2,5 standard deviation relative move in the paired shares prices, while the (2;0) strategy only required a 2 standard deviation move. In addition, the longer holding period is expected to decrease the number of trades that are executed. This is due to the fact that should a pair open (at a 2 standard deviation spread), return to a 0 standard deviation spread, and then subsequently to a 2 standard deviation spread, the pair will only open once under the (2;-0,5) set of trading parameters. The same pair would open twice under the (2;0) set of trading parameters. This will have the effect of reducing the number of sources of return generation of the strategy, which will cause a drag on performance. However, it will also serve to decrease the net trading costs of the strategy. Therefore, changing the trading parameters could serve to increase the returns generated (resulting in outperformance) as a result of more significant returns per round trip completed, coupled with a decreased net trading cost. However, the reduced number of trades executed could serve to decrease the yielded returns to a larger degree than the increased return per trade bolsters them.

Table 2.1 summarizes the results of the Top20 portfolio when traded according to the (2;-0,5) set of trading parameters. The average annualized before-fee return was substantially higher when compared to the (2;0) strategy, at 70,54% (compared to 63,69%) and, notably, the annualized before-fee returns were higher in all but 2 of the 29 sub periods. The lowest before-fee trading period return was 23,62%, marginally lower than the 24,10% minimum trading period return that the basic (2;0) strategy yielded. As observed under the basic strategy, all t-statistics were significant at the 2% level, and 27 out of the 29 sub periods were significant at the 1% level. The associated standard deviation of the strategy (0,09) was marginally higher than that of the basic strategy (0,08). A standard deviation of 0,09 reflects a notably un-volatile (low risk) set of returns. Following the reasoning used with the basic strategy, Sharpe Ratios were calculated above cash and were, moreover, all substantial. Again, before-fee returns were significant in both a statistical as well as an economic sense in all 29 Trading Periods.

The basic (2;0) strategy proved to be resilient to conservative brokerage costs (for institutional investors) in all 29 Trading Periods. Higher before-fee returns, coupled with an expected lower number of trades, leads to the expectation of positive after-fee returns that could be yielded by an institutional investor.

The average trade length (10,31 days) was, as expected, longer than that of the basic strategy (7,88 days). It stands to reason that an open pair will be held for a longer period, when compared to the (2;0) strategy, due to the greater relative price change that is required to trigger the close signal. The increased trade length led to a larger average number of open pairs, 10.63 pairs relative to 8.74 pairs. On average, marginally more than 50% of the allocated funds would have been invested at any point. Despite a slight improvement when compared to the basic strategy, the strategy was still substantially under-invested.

As expected, there were fewer trades in all 29 sub-periods. The average number of trades declined by 7% (i.e. from 142 to 132). Increased returns as well as a decrease in the number of trades executed, resulted in a higher average before-fee return per trade of 0,23% (the minimum return per trade was 0,11% in a single period) when compared to 0,20%. Therefore, it is still expected that, on average, an institutional investor would yield positive after-fee returns. An individual investor is still expected to have their before-fee return more than eroded by trading costs, particularly when scrip borrow costs are included.

Trading Period	Date	R	SD	SR	ASSD	ANOP	NoT	ATL	RPT	T-Stat
1	98/06/25 - 98/12/16	204,02%	0,19	10,52	16,31	8,67	130	8,34	0,57%	**5,47**
2	98/12/17 - 99/06/09	92,73%	0,12	7,96	14,12	11,78	126	11,68	0,31%	**4,75**
3	99/06/10 - 99/12/01	100,65%	0,11	9,52	11,92	11,02	154	8,95	0,27%	**5,62**
4	99/12/02 - 00/05/04	116,38%	0,15	7,90	22,65	12,03	140	10,74	0,34%	**4,56**
5	00/05/05 - 00/10/26	70,76%	0,08	8,49	18,72	10,73	118	11,36	0,26%	**5,25**
6	00/10/27 - 01/04/19	71,26%	0,11	6,50	22,24	11,59	114	12,71	0,27%	**4,01**
7	01/04/20 - 01/10/11	68,13%	0,10	6,99	16,79	13,46	114	14,76	0,26%	**4,34**
8	01/10/12 - 02/04/04	79,43%	0,09	8,86	21,23	11,12	136	10,22	0,25%	**5,40**
9	02/04/05 - 02/09/26	90,44%	0,14	6,40	8,18	12,78	124	12,89	0,31%	**3,83**
10	02/09/27 - 03/03/20	69,50%	0,08	8,99	15,07	10,25	140	9,15	0,22%	**5,57**
11	03/03/21 - 03/09/11	76,10%	0,07	10,53	14,14	9,00	134	8,40	0,24%	**6,45**
12	03/09/12 - 04/03/04	63,51%	0,06	10,18	8,82	9,83	152	8,09	0,18%	**6,37**
13	04/03/05 - 04/08/26	55,58%	0,07	8,22	8,25	12,98	182	8,91	0,14%	**5,22**
14	04/08/27 - 05/02/17	33,28%	0,09	3,70	17,40	10,53	104	12,65	0,15%	**2,45**
15	05/02/18 - 05/08/11	55,39%	0,05	10,58	6,38	10,30	158	8,15	0,16%	**6,71**
16	05/08/12 - 06/02/02	56,10%	0,07	7,86	10,04	9,72	144	8,44	0,17%	**4,98**
17	06/02/03 - 06/07/27	74,18%	0,07	9,92	8,05	11,09	132	10,50	0,24%	**6,10**
18	06/07/28 - 07/01/18	49,37%	0,05	9,16	10,99	6,89	112	7,69	0,20%	**5,88**
19	07/01/19 - 07/07/12	51,94%	0,06	8,51	6,33	10,78	186	7,25	0,13%	**5,43**
20	07/07/13 - 08/01/03	54,16%	0,09	6,33	11,96	10,04	94	13,35	0,26%	**4,03**
21	08/01/04 - 08/06/26	95,42%	0,10	9,54	14,87	10,06	138	9,11	0,29%	**5,67**
22	08/06/27 - 08/12/18	87,14%	0,12	7,09	10,97	9,35	160	7,31	0,23%	**4,27**
23	08/12/19 - 09/06/11	104,99%	0,15	7,19	7,23	12,30	132	11,64	0,33%	**4,22**
24	09/06/12 - 09/12/03	45,10%	0,05	8,80	21,32	7,04	90	9,78	0,23%	**5,69**
25	09/12/04 - 10/05/27	41,06%	0,05	8,37	9,31	10,14	146	8,68	0,13%	**5,45**
26	10/05/28 - 10/11/18	23,62%	0,05	5,01	11,67	10,18	98	12,98	0,11%	**3,38**
27	10/11/19 - 11/05/12	41,38%	0,06	6,49	7,96	12,16	152	10,00	0,12%	**4,23**
28	11/05/13 - 11/11/03	29,11%	0,07	4,10	19,14	11,78	106	13,89	0,13%	**2,74**
29	11/11/04 - 12/04/26	45,02%	0,06	7,91	13,74	10,60	116	11,42	0,18%	**5,12**
Average		70,54%	0,09	7,99	13,30	10,63	132	10,31	0,23%	

Table 2.1 – Returns Analysis – Unrestricted (2;-0,5)

Table 2.2 presents a breakdown of the after-fee returns that an institutional investor would have earned. (Again, a brokerage cost per portfolio turnover of 10 bips has been employed and individual investors have been excluded.)

All 29 of the sub-periods can be seen to have yielded positive after-fee returns (125-day after-fee returns ranged from 1,38% to 61,36%), and the average after-fee return was 16,80% (37,88% annualized). Significantly, the (2;-0,5) strategy outperformed the (2;0) trading strategy with regard to after-fee returns in 28 out of the 29 sub periods. The average trading period after-fee return was 16,80% (37,88% annualized), a substantial increase from the after-fee return of 13,26% (29,47% annualized) yielded by the (2;0) strategy. The returns were again realized at a low level of risk, resulting in an average after-fee Sharpe Ratio of 3.88, higher than the after-fee Sharpe Ratio (3.16) yielded by the (2;0) strategy.

Trading Period	R(125Day)	NoT	Instutional Fee (Per Trade)	Profit After Fees	Anualized PAF	Sharpe Ratio
1	74,36%	130	0,1%	61,36%	160,38%	8,27
2	38,83%	126	0,1%	26,23%	59,34%	5,10
3	41,65%	154	0,1%	26,25%	59,40%	5,62
4	47,10%	140	0,1%	33,10%	77,15%	5,24
5	30,67%	118	0,1%	18,87%	41,31%	4,96
6	30,87%	114	0,1%	19,47%	42,73%	3,90
7	29,67%	114	0,1%	18,27%	39,87%	4,09
8	33,95%	136	0,1%	20,35%	44,85%	5,00
9	38,00%	124	0,1%	25,60%	57,75%	4,09
10	30,19%	140	0,1%	16,19%	35,00%	4,53
11	32,70%	134	0,1%	19,30%	42,33%	5,86
12	27,87%	152	0,1%	12,67%	26,95%	4,32
13	24,73%	182	0,1%	6,53%	13,49%	2,00
14	15,45%	104	0,1%	5,05%	10,35%	1,15
15	24,66%	158	0,1%	8,86%	18,50%	3,53
16	24,94%	144	0,1%	10,54%	22,19%	3,11
17	31,98%	132	0,1%	18,78%	41,08%	5,50
18	22,22%	112	0,1%	11,02%	23,24%	4,31
19	23,26%	186	0,1%	4,66%	9,54%	1,56
20	24,16%	94	0,1%	14,76%	31,70%	3,71
21	39,79%	138	0,1%	25,99%	58,74%	5,88
22	36,80%	160	0,1%	20,80%	45,92%	3,74
23	43,17%	132	0,1%	29,97%	68,93%	4,72
24	20,46%	90	0,1%	11,46%	24,23%	4,73
25	18,77%	146	0,1%	4,17%	8,51%	1,74
26	11,18%	98	0,1%	1,38%	2,79%	0,59
27	18,90%	152	0,1%	3,70%	7,54%	1,18
28	13,63%	106	0,1%	3,03%	6,15%	0,87
29	20,42%	116	0,1%	8,82%	18,42%	3,24
Average	30,01%	132		16,80%	37,88%	3,88

Table 2.2 – After-fee Analysis – Unrestricted (2;-0,5)

The payoff trend, highlighted in *Figure 2* is clearly an upward shift of the basic trading strategy's payoff trend. Pertinently, as can be observed, the trend of both strategies' before- and after-fee returns is downward. This, again, excludes the period of market stress (beginning mid 2007 and ending mid 2009).

The descriptive data highlighted in *Table 2.3* can be compared to that in *Table 1.3*. Both of these represent breakdowns of which of the 5 pair portfolios (Top5 and Bottom5), within the Top20 portfolio, contributed most towards risk and returns. Like observed under the basic strategy, the average before fee return yielded by the Top20 portfolio was highest, at 70,54%, compared to 65,87% and 65,60% for the Top5 and Bottom5 portfolios respectively. All three (2;-0,5) portfolios yielded higher before-fee returns when compared to the best performing (Top20) portfolio for the basic (2;0) trading rule (63,69%). The associated standard deviations for all three portfolios were marginally higher than their comparative standard deviations under the basic strategy. Diversification benefits of a 20 pair portfolio, in comparison to a 5 pair portfolio, were still evident. The standard deviations were 0.09, 0.14 and 0.14 for the Top20, Top5 and Bottom5 portfolios respectively – compared with 0.08, 0.13 and 0.13 for the basic strategy portfolios. T-statistics for the returns of the Top20 portfolio were all significant at the 2% level, with 27 out of the 29 sub-periods having been significant at the 1% level. The Top5 and Bottom5 portfolios were significant at the 5% level in the majority of the sub-periods, with the exception of 4 and 5 periods respectively (which were statistically insignificant). As would be expected, the Top20 portfolio Sharpe Ratio's were substantially larger than those of the 5 pair portfolios. This was a result of the higher returns coupled with the lower associated standard deviations.

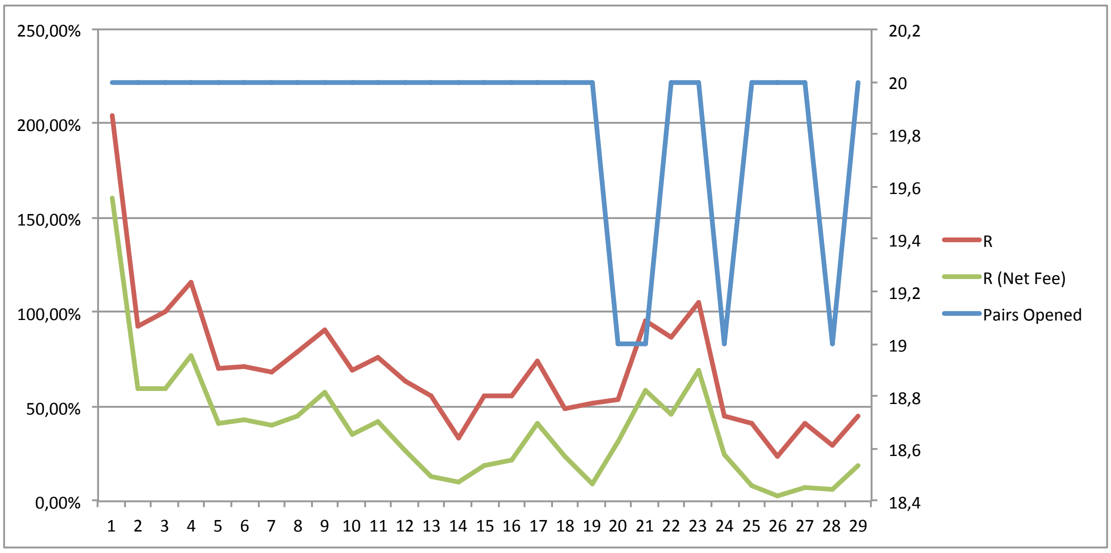


Figure 2 – Before- and After-fee Returns – Unrestricted (2;-0,5)

The number of pairs that opened in each trading period for the (2;-0,5) strategy was equal to that of the basic strategy, as is shown in *Table 2.4.* This was expected due to the same opening parameter resulting in the same pairs opening under both strategies. It must be noted that this is not the number of trades that were executed (a figure that is lower than that of the basic strategy), but merely a reflection on how many of the 20 pairs did, or didn't, trade during a specific period. Again, the difference between the Return on Committed Capital and the Fully Invested Return was negligible.

Trading Period	R(Top20)	R(Top5)	R(15-20)	SD(Top20)	SD(Top5)	SD(15-20)	SR(Top20)	SR(Top5)	SR(15-20)	T-Stat(Top20)	T-Stat(Top5)	T-Stat(15-20)
1	204,02%	224,71%	140,55%	0,19	0,47	0,24	10,52	4,81	5,80	**5,47**	**2,45**	**3,24**
2	92,73%	105,29%	107,91%	0,12	0,22	0,19	7,96	4,74	5,58	**4,75**	**2,78**	**3,26**
3	100,65%	139,64%	54,39%	0,11	0,16	0,19	9,52	8,68	2,84	**5,62**	**4,86**	**1,80**
4	116,38%	131,33%	94,21%	0,15	0,32	0,25	7,90	4,14	3,76	**4,56**	2,34	**2,24**
5	70,76%	57,13%	42,55%	0,08	0,15	0,15	8,49	3,73	2,86	**5,25**	**2,36**	1,86
6	71,26%	39,63%	67,74%	0,11	0,11	0,18	6,50	3,51	3,76	**4,01**	**2,29**	**2,34**
7	68,13%	68,77%	56,96%	0,10	0,14	0,17	6,99	4,84	3,32	**4,34**	**3,00**	2,10
8	79,43%	83,20%	42,46%	0,09	0,15	0,15	8,86	5,37	2,90	**5,40**	**3,26**	1,88
9	90,44%	93,58%	74,69%	0,14	0,16	0,20	6,40	5,69	3,82	**3,83**	**3,39**	**2,35**
10	69,50%	32,99%	60,14%	0,08	0,16	0,14	8,99	2,12	4,25	**5,57**	1,41	**2,67**
11	76,10%	68,97%	90,61%	0,07	0,14	0,10	10,53	4,97	8,63	**6,45**	**3,08**	**5,17**
12	63,51%	56,61%	70,69%	0,06	0,09	0,12	10,18	6,49	6,10	**6,37**	**4,11**	**3,77**
13	55,58%	35,05%	72,08%	0,07	0,08	0,10	8,22	4,20	7,29	**5,22**	**2,77**	**4,49**
14	33,28%	26,64%	38,66%	0,09	0,12	0,10	3,70	2,30	3,91	**2,45**	1,54	**2,56**
15	55,39%	37,97%	75,06%	0,05	0,09	0,10	10,58	4,35	7,49	**6,71**	**2,85**	**4,60**
16	56,10%	22,58%	58,21%	0,07	0,06	0,13	7,86	3,53	4,32	**4,98**	**2,39**	**2,73**
17	74,18%	117,57%	66,32%	0,07	0,18	0,19	9,92	6,58	3,58	**6,10**	**3,79**	2,23
18	49,37%	34,28%	50,14%	0,05	0,07	0,08	9,16	4,68	5,96	**5,88**	**3,09**	**3,82**
19	51,94%	64,30%	39,76%	0,06	0,07	0,11	8,51	9,35	3,53	**5,43**	**5,84**	**2,31**
20	54,16%	60,81%	33,82%	0,09	0,14	0,14	6,33	4,29	2,39	**4,03**	**2,69**	1,58
21	95,42%	91,37%	70,26%	0,10	0,17	0,14	9,54	5,53	5,04	**5,67**	**3,31**	**3,12**
22	87,14%	73,27%	127,68%	0,12	0,14	0,18	7,09	5,23	7,14	**4,27**	**3,22**	**4,06**
23	104,99%	49,93%	152,56%	0,15	0,21	0,25	7,19	2,40	6,11	**4,22**	1,54	**3,37**
24	45,10%	30,97%	35,78%	0,05	0,09	0,09	8,80	3,44	3,96	**5,69**	**2,29**	**2,61**
25	41,06%	31,47%	43,25%	0,05	0,07	0,09	8,37	4,34	4,65	**5,45**	**2,88**	**3,01**
26	23,62%	26,02%	24,14%	0,05	0,08	0,07	5,01	3,25	3,58	**3,38**	**2,18**	**2,41**
27	41,38%	40,53%	40,18%	0,06	0,09	0,09	6,49	4,40	4,38	**4,23**	**2,87**	**2,86**
28	29,11%	24,13%	28,89%	0,07	0,11	0,11	4,10	2,29	2,58	**2,74**	1,55	1,72
29	45,02%	41,59%	42,64%	0,06	0,09	0,10	7,91	4,58	4,24	**5,12**	**2,98**	**2,76**
Average	70,54%	65,87%	65,60%	0,09	0,14	0,14	7,99	4,62	4,61			

Table 2.3 – Top20 Portfolio Risk and Return Drivers – Unrestricted (2;-0,5)

The second half of *Table 2.4* also illustrates the returns analysis of the trading strategy. The percentage of pairs that yielded negative before-fee trading costs was slightly lower, averaging 3.10%, compared to 3.45% under the basic strategy. However, the (2;-0,5) strategy included trading periods that had a larger number of pairs yielding negative before-fee returns when compared to that of the basic trading strategy. The maximum number of pairs yielding a negative return in a trading period increased from 15% (3 pairs) to 20% (4 pairs). As previously noted with respect to the basic strategy, daily before-fee portfolio returns were more often than not positive. Negative daily returns ranged from 22,4% to 38,4% of days (in each individual trading period). The average percentage of negative trading days was marginally higher than the (2,0) strategy at 30.51% (30,23%). In all but one of the trading periods, the absolute value of the maximum daily portfolio return was larger then the absolute value of the portfolio daily minimum return. The average maximum daily return was 2,20% and the minimum average daily return was -1,20%. All of these statistics highlight the marginally increased volatility of the (2;-0,5) strategy, in comparison to the (2;0) trading strategy.

As with the (2,0) strategy, before-fee returns were more often than not positive, both in terms of pairs as well as days, and, moreover, positive returns tended to be more significant than the negative returns.

Trading Period	Date	R(CC)	R(FI)	Pairs Opened	Min R	Max R	% Days <0	% Pairs <0
1	98/06/25 - 98/12/16	204,02%	204,02%	20	-2,37%	9,68%	24	0
2	98/12/17 - 99/06/09	92,73%	92,73%	20	-1,71%	2,90%	32	0
3	99/06/10 - 99/12/01	100,65%	100,65%	20	-1,37%	3,17%	28,8	10
4	99/12/02 - 00/05/04	116,38%	116,38%	20	-1,96%	2,93%	29,6	0
5	00/05/05 - 00/10/26	70,76%	70,76%	20	-1,25%	1,97%	32,8	5
6	00/10/27 - 01/04/19	71,26%	71,26%	20	-1,95%	2,04%	28,8	10
7	01/04/20 - 01/10/11	68,13%	68,13%	20	-1,37%	2,28%	32	0
8	01/10/12 - 02/04/04	79,43%	79,43%	20	-1,13%	2,06%	25,6	5
9	02/04/05 - 02/09/26	90,44%	90,44%	20	-2,26%	3,24%	33,6	0
10	02/09/27 - 03/03/20	69,50%	69,50%	20	-0,85%	1,70%	30,4	5
11	03/03/21 - 03/09/11	76,10%	76,10%	20	-0,85%	1,82%	30,4	0
12	03/09/12 - 04/03/04	63,51%	63,51%	20	-0,66%	1,70%	22,4	0
13	04/03/05 - 04/08/26	55,58%	55,58%	20	-1,23%	1,48%	28	0
14	04/08/27 - 05/02/17	33,28%	33,28%	20	-1,26%	2,28%	38,4	20
15	05/02/18 - 05/08/11	55,39%	55,39%	20	-0,58%	1,13%	24,8	0
16	05/08/12 - 06/02/02	56,10%	56,10%	20	-0,81%	1,50%	30,4	0
17	06/02/03 - 06/07/27	74,18%	74,18%	20	-0,88%	1,45%	28	0
18	06/07/28 - 07/01/18	49,37%	49,37%	20	-0,68%	1,38%	26,4	0
19	07/01/19 - 07/07/12	51,94%	51,94%	20	-0,84%	1,41%	28,8	10
20	07/07/13 - 08/01/03	54,16%	57,33%	19	-1,07%	3,48%	32,8	5
21	08/01/04 - 08/06/26	95,42%	101,31%	19	-1,11%	1,76%	32,8	0
22	08/06/27 - 08/12/18	87,14%	87,14%	20	-1,78%	2,86%	34,4	5
23	08/12/19 - 09/06/11	104,99%	104,99%	20	-1,87%	2,54%	35,2	0
24	09/06/12 - 09/12/03	45,10%	47,71%	19	-0,51%	1,12%	32,8	0
25	09/12/04 - 10/05/27	41,06%	41,06%	20	-0,66%	0,99%	28,8	0
26	10/05/28 - 10/11/18	23,62%	23,62%	20	-0,62%	0,88%	37,6	0
27	10/11/19 - 11/05/12	41,38%	41,38%	20	-1,23%	1,15%	32,8	5
28	11/05/13 - 11/11/03	29,11%	30,75%	19	-1,22%	1,28%	34,4	10
29	11/11/04 - 12/04/26	45,02%	45,02%	20	-0,77%	1,50%	28	0
Average		70,54%	71,00%	19,86	-1,20%	2,20%	30,51	3,10

Table 2.4 – Profitability Analysis – Unrestricted (2;-0,5)

Evidently, changing the closing parameter from 0 standard deviations to -0,5 standard deviations served to improve before- and after-fee returns, while marginally increasing the associated levels of risk (as evidenced by higher standard deviations).

Significantly, despite the increased standard deviations, the (2;-0,5) strategy outperformed the (2;0) strategy in terms of risk adjusted returns, as measured by the larger Sharpe Ratio.

Of further significance is the persistence of the observation of declining before- and after-fee returns, again, with the exception of the period of increased market stress and in-line with prior research.

5.1.1.3 Unrestricted (3;-0.5)

In addition to the (2;0) and (2;-0,5) sets of trading rules, a third set of trading parameters was tested on the Unrestricted sample. The signal to open a position was generated at a 3 standard deviation spread, and the close signal was generated when the spread reverted to a 0,5 standard deviation spread in the opposite direction – the (3;-0.5) strategy.

The theoretical rationale behind testing the (3;-0,5) strategy is along a similar vein to that of the (2;-0,5) strategy. Firstly, due to the improved results that arose from shifting the closing parameter to -0,5 standard deviations, that closing parameter is retained. In addition, having noted relative out-performance, (as previously hypothesized) due to a longer holding spread, the opening parameter was shifted to 3 standard deviations. The required relative move of the prices to close an open pair under the (3;-0,5) strategy is 3,5 historical standard deviations, substantially larger than the 2 and 2,5 standard deviation relative moves required under the (2;0) and (2;-0,5) strategies respectively. The (3;-0,5) strategy is hypothesized to further reduce the number of trades executed, as well as increase the returns generated by each round trip that a pair completed.

An opening parameter of 3 standard deviations is expected to substantially reduce the number of pairs that open, a larger opening parameter requires a greater movement in the relative prices before an open signal is generated. The basic theoretical rationale behind Pairs trading is that the paired shares exhibited a stable historical price relationship. A 3 standard deviation spread in the relative prices of the paired shares is therefore less likely than a 2 standard deviation spread. This led to the hypothesis that a lower number of 20 pairs would be likely to open in the average trading period, which would serve to drastically decrease the number of trades that would be required to be executed. In addition, a longer holding period increases the probability of a pair having not closed when it returns to a 3 standard deviation spread, and thus further decreasing the number of executed trades. It must be noted that, as for the (2;-0,5) strategy, despite the increased return per completed round trip coupled with expected decreased trading costs, relative underperformance could occur. This relative underperformance could be expected, should the number of trades be substantially decreased, resulting in too few sources of return generation.

Trading Period	Date	R	SD	SR	ASSD	ANOP	NoT	ATL	RPT	T-Stat
1	98/06/25 - 98/12/16	78,61%	0,14	5,81	16,31	3,15	46	8,57	0,73%	**3,54**
2	98/12/17 - 99/06/09	71,18%	0,09	8,06	14,12	5,78	64	11,30	0,48%	**4,98**
3	99/06/10 - 99/12/01	59,07%	0,09	6,52	11,92	5,50	76	9,04	0,34%	**4,11**
4	99/12/02 - 00/05/04	58,56%	0,11	5,52	22,65	6,18	62	12,45	0,42%	**3,49**
5	00/05/05 - 00/10/26	49,15%	0,06	7,57	18,72	5,58	62	11,26	0,36%	**4,86**
6	00/10/27 - 01/04/19	42,48%	0,08	5,08	22,24	5,94	56	13,25	0,35%	**3,30**
7	01/04/20 - 01/10/11	49,03%	0,06	7,60	16,79	6,89	64	13,45	0,34%	**4,88**
8	01/10/12 - 02/04/04	43,25%	0,06	7,70	21,23	4,21	56	9,39	0,35%	**4,99**
9	02/04/05 - 02/09/26	68,66%	0,08	8,12	8,18	6,94	64	13,56	0,47%	**5,04**
10	02/09/27 - 03/03/20	38,02%	0,06	6,78	15,07	4,08	58	8,79	0,30%	**4,45**
11	03/03/21 - 03/09/11	50,24%	0,05	9,45	14,14	3,90	62	7,85	0,36%	**6,05**
12	03/09/12 - 04/03/04	34,37%	0,05	7,38	8,82	4,62	60	9,62	0,27%	**4,87**
13	04/03/05 - 04/08/26	41,85%	0,06	7,18	8,25	7,74	104	9,30	0,18%	**4,67**
14	04/08/27 - 05/02/17	14,16%	0,05	2,65	17,40	4,33	36	15,03	0,19%	**1,83**
15	05/02/18 - 05/08/11	25,20%	0,03	8,01	6,38	3,85	52	9,25	0,23%	**5,39**
16	05/08/12 - 06/02/02	27,98%	0,05	5,34	10,04	2,99	52	7,19	0,25%	**3,57**
17	06/02/03 - 06/07/27	47,99%	0,06	7,81	8,05	6,78	74	11,45	0,29%	**5,02**
18	06/07/28 - 07/01/18	14,12%	0,02	6,87	10,99	1,70	28	7,61	0,24%	**4,73**
19	07/01/19 - 07/07/12	35,35%	0,04	8,18	6,33	5,36	98	6,84	0,17%	**5,39**
20	07/07/13 - 08/01/03	44,12%	0,07	6,04	11,96	5,10	50	12,74	0,40%	**3,91**
21	08/01/04 - 08/06/26	57,63%	0,08	7,57	14,87	4,74	68	8,72	0,38%	**4,78**
22	08/06/27 - 08/12/18	40,59%	0,08	4,91	10,97	4,39	68	8,07	0,27%	**3,20**
23	08/12/19 - 09/06/11	82,73%	0,11	7,31	7,23	7,38	76	12,13	0,46%	**4,43**
24	09/06/12 - 09/12/03	13,80%	0,02	5,96	21,32	2,23	22	12,68	0,30%	**4,11**
25	09/12/04 - 10/05/27	24,28%	0,04	6,93	9,31	4,69	68	8,62	0,17%	**4,67**
26	10/05/28 - 10/11/18	19,37%	0,03	6,33	11,67	4,56	54	10,56	0,17%	**4,31**
27	10/11/19 - 11/05/12	32,06%	0,05	6,55	7,96	7,35	84	10,94	0,18%	**4,34**
28	11/05/13 - 11/11/03	24,73%	0,06	4,46	19,14	7,48	60	15,58	0,19%	**3,00**
29	11/11/04 - 12/04/26	34,99%	0,05	7,60	13,74	5,47	62	11,03	0,26%	**5,01**
Average		42,19%	0,06	6,73	13,30	5,13	62	10,56	0,31%	

Table 3.1 – Returns Analysis – Unrestricted (3;-0,5)

A summary of the Top20 portfolio's before-fee returns, when traded according to the (3;-0.5) trading parameters, is presented in *Table 3.1*. The before-fee returns were lower than those of both the (2;0) and (2;-0.5) strategies in all of the 29 periods. The average annualized before-fee return was 42,19% and ranged between 13,80% and 82,73%, which is substantially lower than the 63,69% and 70,54% yielded under the (2;0) and (2;-0.5) strategies respectively. With the exception of one sub period (which was only significant at the 10% level), all returns were statistically significant at the 1% level. In addition to the lower returns, the strategy also had a substantially lower average level of risk (as evidenced by a standard deviation of 0,06) than both of the other strategies (0,08 and 0,09 under the (2;0) and (2;-0,5) strategies respectively). Despite the lower standard deviations, the substantially reduced returns led to an average before-fee Sharpe Ratio (6,73) that lagged both the (2;0) (7,84) and (2;-0.5) (7,99) strategies. The substantially reduced returns, however, remained significant in both an economic as well as a statistical sense.

Trading Period	R(Top20)	R(Top5)	R(15-20)	SD(Top20)	SD(Top5)	SD(15-20)	SR(Top20)	SR(Top5)	SR(15-20)	T-Stat(Top20)	T-Stat(Top5)	T-Stat(15-20)
1	78,61%	138,87%	25,32%	0,14	0,45	0,10	5,81	3,08	2,56	**3,54**	**1,73**	**1,72**
2	71,18%	90,92%	70,66%	0,09	0,19	0,16	8,06	4,87	4,54	**4,98**	**2,92**	**2,80**
3	59,07%	66,17%	54,32%	0,09	0,13	0,17	6,52	5,27	3,22	**4,11**	**3,29**	**2,05**
4	58,56%	116,09%	30,31%	0,11	0,27	0,15	5,52	4,22	2,06	**3,49**	2,44	**1,37**
5	49,15%	48,78%	34,40%	0,06	0,11	0,13	7,57	4,30	2,65	**4,86**	**2,76**	1,75
6	42,48%	21,23%	43,02%	0,08	0,10	0,14	5,08	2,11	3,08	**3,30**	**1,43**	**2,00**
7	49,03%	41,45%	56,01%	0,06	0,11	0,12	7,60	3,69	4,67	**4,88**	**2,40**	2,96
8	43,25%	50,42%	35,10%	0,06	0,10	0,12	7,70	5,19	2,95	**4,99**	**3,33**	1,95
9	68,66%	53,66%	75,35%	0,08	0,09	0,13	8,12	6,02	5,66	**5,04**	**3,83**	**3,47**
10	38,02%	29,84%	41,17%	0,06	0,11	0,11	6,78	2,71	3,86	**4,45**	1,81	**2,51**
11	50,24%	68,32%	33,01%	0,05	0,11	0,07	9,45	6,08	5,04	**6,05**	**3,78**	**3,33**
12	34,37%	36,85%	39,50%	0,05	0,07	0,08	7,38	5,13	5,11	**4,87**	**3,37**	**3,34**
13	41,85%	36,12%	43,03%	0,06	0,07	0,08	7,18	4,99	5,62	**4,67**	**3,28**	**3,65**
14	14,16%	9,86%	12,57%	0,05	0,08	0,06	2,65	1,17	2,04	**1,83**	0,81	**1,41**
15	25,20%	22,36%	38,30%	0,03	0,06	0,06	8,01	3,63	6,05	**5,39**	**2,45**	**3,97**
16	27,98%	1,51%	36,79%	0,05	0,01	0,11	5,34	1,26	3,35	**3,57**	**0,89**	**2,20**
17	47,99%	80,07%	52,96%	0,06	0,15	0,15	7,81	5,48	3,59	**5,02**	**3,33**	2,29
18	14,12%	15,42%	10,21%	0,02	0,05	0,04	6,87	3,25	2,58	**4,73**	**2,23**	**1,79**
19	35,35%	26,55%	32,16%	0,04	0,04	0,09	8,18	6,19	3,64	**5,39**	**4,15**	**2,41**
20	44,12%	45,54%	34,81%	0,07	0,11	0,11	6,04	4,17	3,25	**3,91**	**2,70**	2,14
21	57,63%	73,90%	32,71%	0,08	0,14	0,10	7,57	5,35	3,34	**4,78**	**3,29**	**2,21**
22	40,59%	2,50%	61,93%	0,08	0,06	0,11	4,91	0,43	5,62	**3,20**	**0,30**	**3,53**
23	82,73%	31,03%	127,53%	0,11	0,15	0,23	7,31	2,07	5,61	**4,43**	1,38	**3,19**
24	13,80%	15,78%	8,21%	0,02	0,06	0,03	5,96	2,49	2,50	**4,11**	**1,71**	**1,75**
25	24,28%	17,35%	21,58%	0,04	0,04	0,07	6,93	4,16	2,92	**4,67**	**2,85**	**1,98**
26	19,37%	27,95%	4,10%	0,03	0,06	0,03	6,33	5,07	1,31	**4,31**	**3,39**	**0,93**
27	32,06%	26,29%	32,23%	0,05	0,07	0,08	6,55	3,77	4,30	**4,34**	**2,53**	**2,85**
28	24,73%	10,65%	34,51%	0,06	0,07	0,11	4,46	1,49	3,23	**3,00**	1,03	2,13
29	34,99%	32,68%	38,77%	0,05	0,06	0,09	7,60	5,24	4,16	**5,01**	**3,47**	**2,73**
Average	42,19%	42,69%	40,02%	0,06	0,11	0,10	6,73	3,89	3,74			

Table 3.3 – Top 20 Portfolio Risk and Return Drivers – Unrestricted (3;-0,5)

As hypothesized, the average trade length of the (3;-0,5) strategy was longer when compared to the two strategies that have been previously tested. Once a pair opened, there was a larger relative movement required to trigger the close signal. The average trade length was 10,56 days, an increase from 7,88 days and 10,31 days under the (2;0) and (2;-0.5) strategies respectively. The comparatively similar average trade length when compared to the (2;-0,5) strategy, despite the substantially larger price movement required to trigger the close signal, suggests that the larger degree to which a pair deviates from its historical relationship the quicker it is likely to converge. Furthermore, as hypothesized, the average number of open pairs was significantly lower, averaging only 5.13, compared to 8.74 and 10.63 for the comparable strategies.

Only 25,65% of funds allocated to the Pairs trading portfolio were likely to have been invested at any point, thus, the (3;-0,5) strategy was substantially under-invested. A potential topic for further research is whether or not it would be feasible to apply leverage to any of the substantially under-invested strategies tested in this study.

As hypothesized, the number of executed trades was substantially lower, and averaged only 62 trades per period. A figure that is less than 50% of the 142 and 132 trades averaged under both the (2;0) and (2;-0.5) strategies. Based on the substantially reduced number of executed trades, the before-fee Return per Trade increased to 0.31%, compared to 0.20% and 0.23% under the (2;0) and (2;-0,5) strategies.

Table 3.3 decomposes the Top20 portfolio to determine which pairs within it contributed most towards the strategy’s risk and return. In stark contrast with both previously tested strategies, the Top5 portfolio generated the highest before-fee returns (42,69%), with the Top20 portfolio (42,19%) ranking second and the Bottom5 portfolio (40,02%) having yielding the lowest of the returns. A possible explanation for this observation is that when paired shares diverge by such a large degree, a closer historical relationship is more likely to drive future convergence, or convergence at a more rapid rate. All 3 portfolios underperformed (before-fees) all 6 of the portfolios tested under both the (2;0) and (2;-0.5) sets of trading rules.

Diversification benefits were once again apparent, with the Top20 portfolio’s (0.06) standard deviation substantially lower than that of the Top5 (0.11) and Bottom5 (0.10) portfolios. These standard deviations were lower than their comparable portfolios under the other strategies, in line with the lower the before-fee returns. However, due to the diversification benefits of a 20 pair portfolio, when compared to the 5 pair portfolios, the Top20 portfolio for both the (2;0) and (2;-0,5) strategies yielded a lower standard deviation than either of the (3;-0,5) 5 pair portfolios.

The Top20 portfolio before-fee returns were significant at the 1% level in 28 of the 29 sub periods, and significant at the 10% level in the remaining period. The 5 pair portfolios didn’t fare as well, significantly, as the Top20 portfolios or the comparable 5 pair portfolios tested in the other strategies. The Top5 portfolio was insignificant (above the 10% level) in 6 of the 29 sub periods and only 15 of the periods were significant at the 1% level. Furthermore, the Bottom5 portfolio had only three insignificant periods, but only 11 periods were significant at the 1% level. Before-fee returns yielded by the (3;-0,5) strategy were considerably less significant than for the comparative portfolios under the (2;0) and (2;-0,5) strategies.

The before-fee Sharpe Ratios of all three portfolios were lower than their respective portfolios under the other strategies, due to their lower returns, and in spite of their lower associated standard deviations. Once again, the Top20 (6.73) portfolio had a higher Sharpe Ratio than both the Top5 (3.89) and Bottom5 (3,74) portfolios due to the diversification benefits yielding a substantially lower standard deviation.

Trading Period	R(125Day)	NoT	Instutional Fee (Per Trade)	Profit After Fees	Anualized PAF	Sharpe Ratio
1	33,64%	46	0,1%	29,04%	66,52%	4,91
2	30,83%	64	0,1%	24,43%	54,84%	6,21
3	26,12%	76	0,1%	18,52%	40,47%	4,47
4	25,92%	62	0,1%	19,72%	43,33%	4,09
5	22,13%	62	0,1%	15,93%	34,39%	5,30
6	19,36%	56	0,1%	13,76%	29,42%	3,52
7	22,08%	64	0,1%	15,68%	33,82%	5,24
8	19,69%	56	0,1%	14,09%	30,15%	5,37
9	29,87%	64	0,1%	23,47%	52,45%	6,20
10	17,48%	58	0,1%	11,68%	24,73%	4,41
11	22,57%	62	0,1%	16,37%	35,43%	6,66
12	15,92%	60	0,1%	9,92%	20,82%	4,47
13	19,10%	104	0,1%	8,70%	18,16%	3,12
14	6,85%	36	0,1%	3,25%	6,60%	1,24
15	11,89%	52	0,1%	6,69%	13,83%	4,40
16	13,13%	52	0,1%	7,93%	16,49%	3,15
17	21,65%	74	0,1%	14,25%	30,53%	4,97
18	6,83%	28	0,1%	4,03%	8,22%	4,00
19	16,34%	98	0,1%	6,54%	13,51%	3,12
20	20,05%	50	0,1%	15,05%	32,37%	4,43
21	25,55%	68	0,1%	18,75%	41,01%	5,39
22	18,57%	68	0,1%	11,77%	24,93%	3,01
23	35,18%	76	0,1%	27,58%	62,76%	5,55
24	6,68%	22	0,1%	4,48%	9,15%	3,96
25	11,48%	68	0,1%	4,68%	9,58%	2,74
26	9,26%	54	0,1%	3,86%	7,86%	2,57
27	14,92%	84	0,1%	6,52%	13,46%	2,75
28	11,68%	60	0,1%	5,68%	11,69%	2,11
29	16,19%	62	0,1%	9,99%	20,97%	4,55
Average	19,00%	62		12,84%	27,84%	4,20

Table 3.2 – After-fee Returns – Unrestricted (3;-0,5)

After-fee (scrip borrowing costs excluded) returns are presented in *Table 3.2* and again, only for an institutional investor (10 bips per trade). Positive after-fee returns were realized in all 29 sub periods tested, and averaged 12,84% (27,84% annualized). After-fee returns ranged from 3,25% to 29,04%. This return is substantially lower than both the 13,26% (29,47% annualized) and 16,80% (37,88%

annualized) after-fee returns of the (2;0) and (2;-0.5) strategies respectively. However, the return of 12,84% had a lower associated standard deviation, and the after-fee Sharpe Ratio (4.20) was larger then that of both the (2;0) (3.16) and (2;-0,5) (3.88) strategies.

Figure 3 highlights the payoff trend, as well as the number of pairs that opened in a particular period. Again, the clear downward trend in returns that was evident under both the (2;0) and (2;-0,5) strategies is clear under the (3;-0,5) strategy (again, with the exceptions of the period of pronounced market stress). However, the payoff pattern was substantially more volatile than for comparative strategies. Significantly, the figure illustrates that returns and the number of pairs that open in a period appear to be positively correlated. This affirms the earlier hypothesis that fewer pairs opening in a period leads to fewer sources of returns, and therefore lower overall returns.

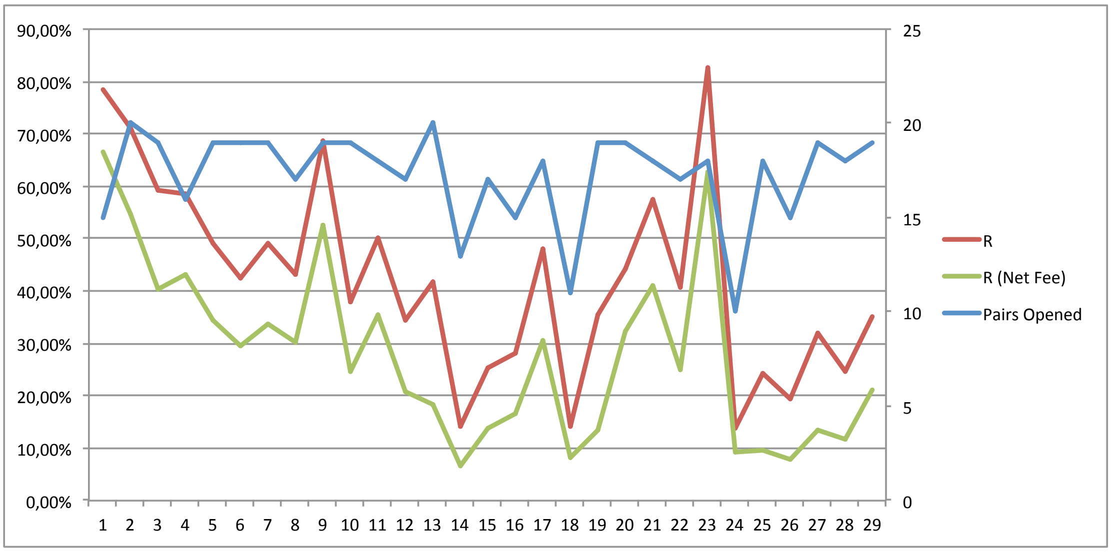


Figure 3 – Before- and After-fee Returns – Unrestricted (3;-0,5)

Table 3.4 highlights that substantially fewer pairs traded under the (3;-0.5) strategy. This is as a result of a larger relative price move being required to trigger the opening of a position. There is less likelihood of a pair moving to a 3 standard deviation spread than there is of a pair moving to a 2 standard deviation spread. Any pair that opens for the (3;-0,5) strategy will, by definition, have to have opened under the (2;0) and (2;-0,5) strategies as the spread will have to breach the 2 standard deviation open signal to reach the 3 standard deviation open signal.

An average of 17.28 (86.4%) of the 20 pairs opened per period, compared to 19.86 (99,3%) under both of the other strategies, with individual periods dropping as low as only having had 13 of the 20 pairs open (compared to a previous low of 19). The decreased number of pairs that traded in the periods led to a discrepancy between the Return on Committed Capital and the Fully Invested Return, with before-fee returns of 42,19% and 48,73% on average respectively. However, using a Fully Invested Return measure is unrealistic, due to a potential requirement to breach a fund's risk limits in order to invest an overly large portion of the fund in a reduced number of pairs. Essentially, if only 1 pair was to open, a Fully Invested Return would require that 100% of the funds allocated to the strategy to be invested in that particular pair. An investor would be highly unlikely to be willing to take on the substantially higher risk of investing the entire sum of allocated capital in only one pair. Being fully invested would mean that, should an open signal on a closed pair be triggered, a portion of the pairs currently being held would need to be liquidated (potentially at unfavorable valuations should the shares have continued to diverge) in order to open the new pair, this would involve unnecessary trading costs (which are already particularly high in a number of strategies). It must, however, be noted that due to the lower average number of open positions, the full amount of capital allocated to the trading strategy need not to have been held. Improved performance could potentially be achieved by investing a slightly larger portion (greater than 5% per pair in a 20 pair portfolio) of the allocated funds in each of the open pairs. In addition, the investment horizon could potentially be slightly increased (more then 20 pairs included in the portfolio, while keeping a maximum investment of 5% per pair). Both of these potential areas of improvement are out of the scope of this study, and are potential topics for future research.

An analysis of the strategy returns is laid out in the second half of *Table 3.4*. The number of unprofitable pairs, on average, was less than half of either of the previously tested strategies; only 1.21% of pairs, compared to 3.45% and 3.10% under the (2;0) and (2;-0,5) strategies respectively. The maximum unprofitable pairs in a period based on the (3;-0.5) strategy was 10% (2 pairs), compared to 15% (3 pairs) and 20% (4 pairs) of pairs for the (2;0) and (2;-0.5) strategies respectively. It appears that a stronger opening signal (of 3 standard deviations as opposed to 2) increased the probability of the individual pairs' before-fee returns being positive.

This makes intuitive sense based on the assumption that the formed pairs have a relative pricing relationship (and the positive before-fee returns thus far suggest so), a larger spread would be more likely to drive convergence more rapidly, due to a larger breakdown in the equilibrium price relationship. Furthermore, as mentioned earlier, the wider spread of 3 standard deviations will yield a larger return per round trip than an opening position of 2 standard deviations. Pairs converging to a rolling mean and using a rolling standard deviation make it plausible that a round trip could potentially yield a slightly negative return. This could occur should there be a drastic change in either (or both of) the rolling mean or standard deviation. A larger opening relative price differential is less likely to result in a negative return yielded by a round trip, as the rolling measures will need to change by a larger degree to result in negative returns.

As expected, based on the observations of other strategies, daily returns were more often than not positive. The percentage of negative daily returns ranged between 23.2% and 38.4% of days, and averaged 30.73%. This was marginally higher than the 30,23% and 30,51% of negative days under the (2;0) and (2;-0,5) strategies respectively. While the deterioration in the number of positive trading days was not statistically significant, it could be expected. A substantially lower average number of open pairs results in each pair having a larger impact on the portfolio’s return. One pair yielding a substantial negative daily return is more likely to result in a negative portfolio return should there only be 5, as opposed to 13, open pairs. In 27 of the 29 sub periods the absolute value of the maximum daily return was larger than the absolute value of the minimum daily return, averaging 1.71% and -0.93% respectively. Once again, positive before-fee returns were both larger and more frequent (both in terms of days as well as pairs) than negative returns.

As observed under both the (2;0) and (2;-0,5) strategies, the returns yielded by the (3;-0,5) strategy appear to be on a downward trend with the exception of periods of increased market volatility.

Increasing the opening parameter to 3 standard deviations served to decrease both the before- and after-fee returns yielded by Pairs trading, when compared to strategies using a 2 standard deviation opening spread. However, the lower returns appear to have been yielded at a lower level of risk, as evidenced by a lower standard deviation. Significantly, while the (3;-0,5) strategy underperformed strategies with a 2 standard deviation opening parameter with regards to before-fee Sharpe Ratios, it outperformed them on an after-fee Sharpe Ratio metric. However, due to Pairs trading being a relatively low risk strategy, an investor would be likely to prefer taking on marginally more risk under one of the trading strategies with a 2 standard deviation opening parameter in order to potentially yield larger returns.

Trading Period	Date	R(CC)	R(FI)	Pairs Opened	Min R	Max R	% Days <0	% Pairs <0
1	98/06/25 - 98/12/16	78,61%	109,84%	15	-1,82%	6,52%	34,4	5
2	98/12/17 - 99/06/09	71,18%	71,18%	20	-1,54%	2,24%	28	0
3	99/06/10 - 99/12/01	59,07%	62,55%	19	-1,39%	3,27%	33,6	5
4	99/12/02 - 00/05/04	58,56%	75,29%	16	-1,89%	2,18%	32	0
5	00/05/05 - 00/10/26	49,15%	52,01%	19	-1,10%	1,31%	32,8	0
6	00/10/27 - 01/04/19	42,48%	44,92%	19	-1,30%	1,43%	38,4	0
7	01/04/20 - 01/10/11	49,03%	51,88%	19	-0,93%	1,40%	32	0
8	01/10/12 - 02/04/04	43,25%	51,68%	17	-0,67%	1,56%	28	0
9	02/04/05 - 02/09/26	68,66%	72,77%	19	-0,97%	2,11%	33,6	0
10	02/09/27 - 03/03/20	38,02%	40,19%	19	-0,76%	1,68%	23,2	0
11	03/03/21 - 03/09/11	50,24%	56,46%	18	-0,54%	1,34%	24,8	0
12	03/09/12 - 04/03/04	34,37%	40,96%	17	-1,00%	1,03%	30,4	5
13	04/03/05 - 04/08/26	41,85%	41,85%	20	-0,93%	1,50%	30,4	0
14	04/08/27 - 05/02/17	14,16%	22,18%	13	-1,19%	1,05%	36,8	10
15	05/02/18 - 05/08/11	25,20%	29,94%	17	-0,41%	0,79%	26,4	0
16	05/08/12 - 06/02/02	27,98%	38,08%	15	-0,93%	1,39%	24	0
17	06/02/03 - 06/07/27	47,99%	53,90%	18	-1,01%	1,48%	27,2	0
18	06/07/28 - 07/01/18	14,12%	26,37%	11	-0,20%	0,63%	27,2	0
19	07/01/19 - 07/07/12	35,35%	37,36%	19	-0,66%	1,25%	24,8	0
20	07/07/13 - 08/01/03	44,12%	46,67%	19	-0,89%	3,48%	32,8	0
21	08/01/04 - 08/06/26	57,63%	64,83%	18	-0,64%	1,75%	32,8	0
22	08/06/27 - 08/12/18	40,59%	48,47%	17	-0,98%	2,52%	36	5
23	08/12/19 - 09/06/11	82,73%	93,45%	18	-1,56%	2,18%	34,4	0
24	09/06/12 - 09/12/03	13,80%	28,49%	10	-0,28%	0,52%	38,4	0
25	09/12/04 - 10/05/27	24,28%	27,14%	18	-0,40%	0,86%	29,6	0
26	10/05/28 - 10/11/18	19,37%	26,20%	15	-0,38%	0,73%	30,4	0
27	10/11/19 - 11/05/12	32,06%	33,87%	19	-0,86%	0,99%	28,8	5
28	11/05/13 - 11/11/03	24,73%	27,65%	18	-0,95%	0,92%	35,2	0
29	11/11/04 - 12/04/26	34,99%	36,98%	19	-0,75%	1,53%	24,8	0
Average		42,19%	48,73%	17,28	-0,93%	1,71%	30,73	1,21

Table 3.4 – Profitability Analysis – Unrestricted (3;-0,5)

5.1.1.4 Unrestricted (2;-1)

Changing the closing parameter from 0 standard deviations to -0,5 standard deviations served to improve before- and after-fee returns (it did, however, also increase the associated standard deviation and therefore risk) for an opening parameter of 2 standard deviations. Thus far strategies with an opening parameter of 2 standard deviations have outperformed (before- and after-fees) a strategy with an opening parameter of 3 standard deviations in terms of returns, while outperforming (underperforming) in terms of before-fee (after-fee) Sharpe Ratios. The reason for this was the fact that the increased opening parameters served to substantially decrease the number of trades, and therefore the sources of return generation (and fees). Changing the closing parameter to -1 standard deviation is expected to simultaneously further increase the return per round trip completed (due to the greater move in the relative prices), as well as decrease the number of trades executed, when compared to a closing parameter of both -0,5 and 0.

The effect of changing the closing parameter to -1 standard deviation could either drive outperformance or underperformance relative to the (2;-0,5) trading strategy. This is as a result of both a decreased number of sources of return generation (a lower number of executed trades), as well as an increased return generation per round trip completed.

Table 4.1 presents an analysis of the strategy's performance. The performance of the (2;-1) strategy is compared to the (2;0) and (2;-0,5) sets of trading rules, as they are the two most comparable strategies (the 3 standard deviation strategy doesn't share either the open or the close parameter and yielded inferior performance than the 2 standard deviation strategies). Annualized before-fee returns were more substantial than under both comparative strategies, with an average of 73,63%, compared to 63,69% and 70,54% for the (2;0) and (2;-0,5) strategies respectively. Furthermore, due to the expectation of a decreased number of trades, after-fee returns are expected to further outperform both the (2;0) and (2;-0,5) strategies. However, whilst the average before-fee return was substantially higher than that of the (2;-0.5) strategy, it relatively underperformed in 8 out of the 29 sub periods and, as expected (due to the substantially higher average before-fee return), outperformed the (2;0) strategy in all 29 periods. The periods of underperformance relative to the (2;-0,5) strategy were randomly spread throughout the period of study, and therefore there doesn't appear to be a shifting level of outperformance between the 2 strategies. All returns yielded by the (2;-1) set of trading parameters were significant at the 1% level. In addition to the larger returns, the corresponding standard deviations were higher, averaging 0.10 compared to 0.08 and 0.09 for the (2;0) and (2;-0,5) strategies respectively (the standard deviation in every sub period was either equal to or larger than that of the

(2;-0.5) strategy, and larger than that of the (2;0) strategy). In spite of the higher before-fee returns of the (2;-1) strategy when compared to the (2;0) and (2;-0,5) strategies, the increased standard deviations resulted in a lower average before-fee Sharpe Ratio of 7.68, compared to 7.84 and 7.99 respectively.

Trading Period	Date	R	SD	SR	ASSD	ANOP	NoT	ATL	RPT	T-Stat
1	98/06/25 - 98/12/16	218,47%	0,20	10,66	16,31	11,07	118	11,73	0,66%	**5,46**
2	98/12/17 - 99/06/09	102,39%	0,12	8,39	14,12	13,30	122	13,63	0,35%	**4,94**
3	99/06/10 - 99/12/01	106,14%	0,11	9,38	11,92	12,97	146	11,10	0,30%	**5,49**
4	99/12/02 - 00/05/04	115,16%	0,15	7,67	22,65	14,16	126	14,05	0,37%	**4,43**
5	00/05/05 - 00/10/26	72,17%	0,09	7,67	18,72	13,26	112	14,80	0,28%	**4,73**
6	00/10/27 - 01/04/19	75,41%	0,12	6,31	22,24	13,90	110	15,80	0,29%	**3,87**
7	01/04/20 - 01/10/11	67,91%	0,11	6,33	16,79	15,73	102	19,27	0,29%	**3,93**
8	01/10/12 - 02/04/04	75,28%	0,10	7,39	21,23	13,34	124	13,44	0,26%	**4,53**
9	02/04/05 - 02/09/26	92,98%	0,15	6,32	8,18	14,50	110	16,47	0,35%	**3,77**
10	02/09/27 - 03/03/20	77,88%	0,09	8,78	15,07	13,53	128	13,21	0,26%	**5,36**
11	03/03/21 - 03/09/11	85,39%	0,08	10,90	14,14	10,62	134	9,90	0,27%	**6,58**
12	03/09/12 - 04/03/04	67,28%	0,07	9,20	8,82	12,06	144	10,47	0,20%	**5,72**
13	04/03/05 - 04/08/26	53,58%	0,07	7,22	8,25	14,95	166	11,26	0,14%	**4,60**
14	04/08/27 - 05/02/17	40,27%	0,10	4,20	17,40	12,06	100	15,07	0,18%	**2,74**
15	05/02/18 - 05/08/11	60,21%	0,06	10,04	6,38	12,86	148	10,86	0,18%	**6,32**
16	05/08/12 - 06/02/02	54,34%	0,08	7,00	10,04	11,52	124	11,61	0,20%	**4,45**
17	06/02/03 - 06/07/27	73,50%	0,08	9,58	8,05	12,97	124	13,07	0,26%	**5,89**
18	06/07/28 - 07/01/18	53,81%	0,06	9,45	10,99	8,26	110	9,39	0,22%	**6,02**
19	07/01/19 - 07/07/12	50,86%	0,07	7,50	6,33	14,13	160	11,04	0,14%	**4,80**
20	07/07/13 - 08/01/03	56,46%	0,09	6,29	11,96	12,66	90	17,58	0,28%	**3,99**
21	08/01/04 - 08/06/26	101,53%	0,11	9,25	14,87	12,20	130	11,73	0,32%	**5,45**
22	08/06/27 - 08/12/18	84,90%	0,13	6,53	10,97	11,28	148	9,53	0,24%	**3,95**
23	08/12/19 - 09/06/11	108,36%	0,16	6,85	7,23	15,10	120	15,73	0,37%	**4,00**
24	09/06/12 - 09/12/03	51,60%	0,06	8,55	21,32	9,04	90	12,56	0,26%	**5,46**
25	09/12/04 - 10/05/27	45,36%	0,05	8,92	9,31	11,90	138	10,78	0,15%	**5,77**
26	10/05/28 - 10/11/18	24,81%	0,05	4,56	11,67	12,10	96	15,75	0,12%	**3,07**
27	10/11/19 - 11/05/12	42,46%	0,07	5,82	7,96	14,32	134	13,36	0,14%	**3,78**
28	11/05/13 - 11/11/03	32,82%	0,07	4,50	19,14	13,34	100	16,68	0,15%	**2,98**
29	11/11/04 - 12/04/26	43,81%	0,06	7,31	13,74	12,00	106	14,15	0,19%	**4,74**
Average		73,63%	0,10	7,68	13,30	12,73	123	13,24	0,26%	

Table 4.1 – Returns Analysis – Unrestricted (2;-1)

As noted before, increasing the absolute value of the closing parameters served to increase the average holding period, which resulted in an increased average trade length, as well as average number of open pairs. Holding pairs for increased time periods results in a number of pairs not requiring a subsequent opening, resulting in fewer trades. Fewer trades in turn results in both lower before-fee returns, as well as lower trading costs. This is due to the potential for a pair to have not closed (having returned to a -0,5 standard deviation spread, and not a -1 standard deviation spread) prior to the following return to a 2 standard deviation spread, and thus only requiring to have been opened once, and not having locked in a positive return when closed.

This resulted in fewer executed trades in every period (an average of 123), when compared to the both the (2;0) strategy (142) and the (2;-0,5) strategy (132). The number of trades resulted in a substantial increase in the return per trade, to 0,26%, when compared to both the (2;0) and the (2;-1) strategies – 0,20% and 0,23% respectively.

Trading Period	R(125Day)	NoT	Instutional Fee (Per Trade)	Profit After Fees	Anualized PAF	Sharpe Ratio
1	78,46%	118	0,1%	66,66%	177,74%	8,67
2	42,26%	122	0,1%	30,06%	69,17%	5,67
3	43,58%	146	0,1%	28,98%	66,35%	5,86
4	46,68%	126	0,1%	34,08%	79,78%	5,31
5	31,21%	112	0,1%	20,01%	44,03%	4,68
6	32,44%	110	0,1%	21,44%	47,49%	3,97
7	29,58%	102	0,1%	19,38%	42,51%	3,96
8	32,40%	124	0,1%	20,00%	43,99%	4,32
9	38,92%	110	0,1%	27,92%	63,63%	4,33
10	33,37%	128	0,1%	20,57%	45,37%	5,12
11	36,16%	134	0,1%	22,76%	50,69%	6,47
12	29,34%	144	0,1%	14,94%	32,11%	4,39
13	23,93%	166	0,1%	7,33%	15,19%	2,05
14	18,44%	100	0,1%	8,44%	17,59%	1,84
15	26,58%	148	0,1%	11,78%	24,94%	4,16
16	24,23%	124	0,1%	11,83%	25,07%	3,23
17	31,72%	124	0,1%	19,32%	42,37%	5,52
18	24,02%	110	0,1%	13,02%	27,73%	4,87
19	22,82%	160	0,1%	6,82%	14,11%	2,08
20	25,09%	90	0,1%	16,09%	34,76%	3,87
21	41,96%	130	0,1%	28,96%	66,31%	6,04
22	35,98%	148	0,1%	21,18%	46,84%	3,61
23	44,35%	120	0,1%	32,35%	75,15%	4,75
24	23,12%	90	0,1%	14,12%	30,24%	5,01
25	20,57%	138	0,1%	6,77%	13,99%	2,75
26	11,72%	96	0,1%	2,12%	4,28%	0,79
27	19,36%	134	0,1%	5,96%	12,27%	1,68
28	15,25%	100	0,1%	5,25%	10,77%	1,48
29	19,92%	106	0,1%	9,32%	19,51%	3,25
Average	31,15%	123		18,88%	42,90%	4,13

Table 4.2 – After-fee Analysis – Unrestricted (2;-1)

A breakdown of after-fee returns is summarized in *Table 4.2*. As hypothesized, the (2;-1) strategy outperformed both the (2;0) and (2;-0,5) strategies with respect to after-fee returns. The average after-fee trading period return was 18,88% (42,90% annualized), substantially higher than 13,26% (29,47% annualized) and 16,80% (37,88% annualized) yielded by the (2;0) and (2;-0,5) strategies respectively. Significantly, despite the increased standard deviation of the (2;-1) strategy, it resulted in a higher after-fee Sharpe Ratio of 4.13, when compared to the (2;-0,5) and (2;0) strategies, which were 3.88 and 3.16 respectively.

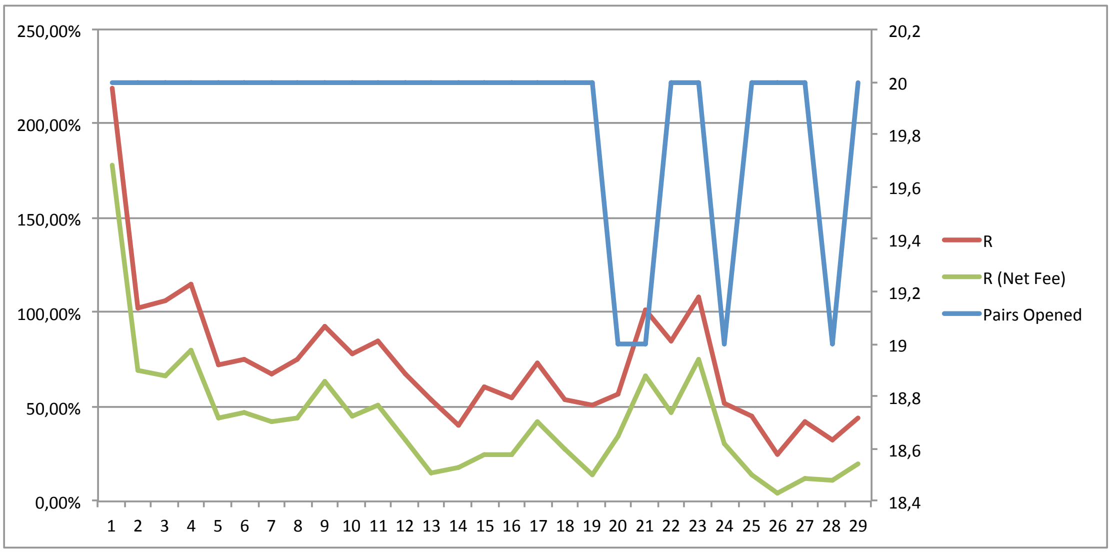


Figure 4 – Before- and After-fee Returns – Unrestricted (2;-1)

Figure 4 displays the before- and after-fee returns yielded by the strategy. It is clear that the strategy (similarly to the earlier tested strategies) performed particularly well in periods of increased market stress, the trading period with highest return was late 1998 and a subsequent period of relative outperformance ran from late 2007 until the end of 2009. Due to the market neutral nature of the strategy, increased market volatility is expected to result in increased returns due to an expected increase in the number of diverging and subsequently converging pairs, should the historic relationship hold. Notably, despite the relative out-performance of the periods of increased market stress, these periods resulted in an increased number of days yielding negative before-fee returns. The 5 periods spanning from late 2007 until the end of 2009 on average had 32,8% of negative days, substantially larger than the 30,90% of negative days yielded by the strategy as a whole. Significantly, the downward trend in before- and after-fee returns (with the exception of the period of market instability) remains evident. This finding confirms the results of the comparative literature on foreign markets, namely Gatev *et al.* (2006) and Do and Faff (2009); however, the decline in performance appears to be less severe and positive after-fee returns appear to have still been achievable on the JSE. A potential reason for the less severe decline in performance, in comparison to foreign markets (most specifically the S&P500), could be the differing maturities of the markets, and the greater likelihood that the EMH doesn't hold on the JSE. This suggests that the downward trend in returns yielded by Pairs trading is likely to continue, until positive returns are no longer possible.

Trading Period	R(Top20)	R(Top5)	R(15-20)	SD(Top20)	SD(Top5)	SD(15-20)	SR(Top20)	SR(Top5)	SR(15-20)	T-Stat(Top20)	T-Stat(Top5)	T-Stat(15-20)
1	218,47%	271,30%	164,27%	0,20	0,48	0,25	10,66	5,60	6,56	**5,46**	**2,73**	**3,56**
2	102,39%	113,52%	117,81%	0,12	0,24	0,21	8,39	4,64	5,69	**4,94**	**2,69**	**3,28**
3	106,14%	150,52%	63,40%	0,11	0,18	0,20	9,38	8,20	3,17	**5,49**	**4,53**	**1,98**
4	115,16%	119,94%	94,97%	0,15	0,32	0,27	7,67	3,71	3,56	**4,43**	2,13	**2,12**
5	72,17%	67,54%	46,33%	0,09	0,16	0,15	7,67	4,25	2,99	**4,73**	**2,64**	1,93
6	75,41%	38,95%	85,09%	0,12	0,13	0,20	6,31	3,01	4,28	**3,87**	**1,97**	**2,59**
7	67,91%	65,69%	66,96%	0,11	0,15	0,18	6,33	4,32	3,63	**3,93**	**2,69**	2,26
8	75,28%	91,59%	32,17%	0,10	0,16	0,17	7,39	5,77	1,89	**4,53**	**3,45**	1,26
9	92,98%	70,25%	91,38%	0,15	0,18	0,20	6,32	3,83	4,48	**3,77**	**2,37**	**2,68**
10	77,88%	45,90%	69,40%	0,09	0,16	0,18	8,78	2,80	3,93	**5,36**	1,81	**2,44**
11	85,39%	73,45%	99,73%	0,08	0,14	0,11	10,90	5,17	9,07	**6,58**	**3,18**	**5,36**
12	67,28%	64,96%	58,59%	0,07	0,09	0,15	9,20	7,10	3,84	**5,72**	**4,43**	**2,42**
13	53,58%	37,32%	57,15%	0,07	0,08	0,11	7,22	4,45	5,14	**4,60**	**2,92**	**3,25**
14	40,27%	30,87%	38,61%	0,10	0,12	0,11	4,20	2,56	3,41	**2,74**	1,70	**2,23**
15	60,21%	43,51%	84,71%	0,06	0,09	0,12	10,04	4,88	7,20	**6,32**	**3,16**	**4,35**
16	54,34%	25,40%	67,07%	0,08	0,07	0,14	7,00	3,62	4,74	**4,45**	**2,43**	**2,95**
17	73,50%	106,47%	73,57%	0,08	0,19	0,20	9,58	5,74	3,76	**5,89**	**3,36**	2,32
18	53,81%	38,53%	52,55%	0,06	0,07	0,09	9,45	5,27	6,04	**6,02**	**3,45**	**3,85**
19	50,86%	52,58%	45,89%	0,07	0,09	0,12	7,50	5,92	3,80	**4,80**	**3,77**	**2,45**
20	56,46%	72,53%	36,58%	0,09	0,16	0,14	6,29	4,57	2,58	**3,99**	**2,81**	1,70
21	101,53%	84,26%	75,52%	0,11	0,17	0,14	9,25	4,84	5,42	**5,45**	**2,93**	**3,32**
22	84,90%	73,18%	144,93%	0,13	0,14	0,18	6,53	5,09	7,85	**3,95**	**3,13**	**4,36**
23	108,36%	58,40%	160,11%	0,16	0,22	0,27	6,85	2,62	5,95	**4,00**	1,65	**3,25**
24	51,60%	38,86%	40,93%	0,06	0,10	0,10	8,55	3,92	3,94	**5,46**	**2,57**	**2,56**
25	45,36%	34,13%	49,73%	0,05	0,09	0,09	8,92	3,77	5,27	**5,77**	**2,49**	**3,38**
26	24,81%	25,09%	25,31%	0,05	0,09	0,07	4,56	2,89	3,57	**3,07**	**1,94**	**2,40**
27	42,46%	38,25%	48,36%	0,07	0,10	0,11	5,82	3,97	4,52	**3,78**	**2,60**	**2,91**
28	32,82%	31,97%	29,70%	0,07	0,11	0,11	4,50	2,94	2,61	**2,98**	1,95	1,74
29	43,81%	35,71%	48,07%	0,06	0,09	0,11	7,31	4,11	4,45	**4,74**	**2,70**	**2,86**
Average	73,63%	68,99%	71,34%	0,10	0,15	0,15	7,68	4,47	4,60			

Table 4.3 – Top 20 Portfolio Risk and Return Drivers – Unrestricted (2;-1)

A closer analysis of those pairs within the Top20 portfolio that generated the risk and return of the strategy is displayed in *Table 4.3*. Returns, as well as standard deviations, increased for all three of the portfolios – namely Top20, Top5 and Bottom5. In addition, diversification benefits were, as expected, still evident. The Top20 portfolio yielded higher returns (when compared to the respective 5 pair portfolios), as well as lower average standard deviations, which resulted in substantially higher Sharpe Ratios, as well as more significant t-statistics.

The second half of *Table 4.4* sets out a profitability breakdown of the (2;-1) set of trading rules. When compared to the (2;-0.5) set of trading rules, both the average percentage of days that yielded a negative return, as well as the average percentage of pairs that yielded a negative return were very similar. The (2;-1) strategy had, on average, 30.90% days yielding negative returns, marginally more then the 30,23% and 30.51% of days in the (2;0) and (2;-0.5) sets of trading rules respectively. However, the number of pairs that yielded a negative return decreased to 2.41% from 3.45% and 3.10% respectively. The decline in the average number of pairs that yielded a negative return was driven both by a larger number of sub-periods in which no pairs yielded negative returns, as well as the maximum number of pairs yielding a negative return in any individual period declining from 15% (3 pairs) and 20% (4 pairs) respectively, to 10% (2 pairs).

Trading Period	Date	R(CC)	R(FI)	Pairs Opened	Min R	Max R	% Days <0	% Pairs <0
1	98/06/25 - 98/12/16	218,47%	218,47%	20	-2,35%	10,07%	28	0
2	98/12/17 - 99/06/09	102,39%	102,39%	20	-1,68%	3,02%	32	0
3	99/06/10 - 99/12/01	106,14%	106,14%	20	-1,53%	3,17%	31,2	10
4	99/12/02 - 00/05/04	115,16%	115,16%	20	-2,34%	2,93%	31,2	0
5	00/05/05 - 00/10/26	72,17%	72,17%	20	-1,27%	1,97%	30,4	0
6	00/10/27 - 01/04/19	75,41%	75,41%	20	-1,73%	2,27%	30,4	10
7	01/04/20 - 01/10/11	67,91%	67,91%	20	-2,58%	1,89%	34,4	0
8	01/10/12 - 02/04/04	75,28%	75,28%	20	-1,16%	2,46%	27,2	10
9	02/04/05 - 02/09/26	92,98%	92,98%	20	-2,35%	3,43%	33,6	0
10	02/09/27 - 03/03/20	77,88%	77,88%	20	-0,97%	1,83%	31,2	10
11	03/03/21 - 03/09/11	85,39%	85,39%	20	-0,85%	1,82%	26,4	0
12	03/09/12 - 04/03/04	67,28%	67,28%	20	-0,76%	1,82%	29,6	0
13	04/03/05 - 04/08/26	53,58%	53,58%	20	-1,40%	1,39%	30,4	0
14	04/08/27 - 05/02/17	40,27%	40,27%	20	-1,26%	2,44%	39,2	10
15	05/02/18 - 05/08/11	60,21%	60,21%	20	-0,60%	1,13%	24,8	0
16	05/08/12 - 06/02/02	54,34%	54,34%	20	-0,89%	1,55%	33,6	0
17	06/02/03 - 06/07/27	73,50%	73,50%	20	-1,12%	1,91%	28	0
18	06/07/28 - 07/01/18	53,81%	53,81%	20	-0,68%	1,33%	25,6	0
19	07/01/19 - 07/07/12	50,86%	50,86%	20	-0,76%	1,41%	28,8	5
20	07/07/13 - 08/01/03	56,46%	59,78%	19	-1,29%	3,38%	32,8	5
21	08/01/04 - 08/06/26	101,53%	107,85%	19	-1,27%	2,24%	30,4	0
22	08/06/27 - 08/12/18	84,90%	84,90%	20	-2,04%	2,74%	31,2	5
23	08/12/19 - 09/06/11	108,36%	108,36%	20	-1,98%	3,57%	36	0
24	09/06/12 - 09/12/03	51,60%	54,61%	19	-0,52%	1,48%	33,6	0
25	09/12/04 - 10/05/27	45,36%	45,36%	20	-0,90%	1,19%	24	0
26	10/05/28 - 10/11/18	24,81%	24,81%	20	-1,08%	1,15%	36,8	0
27	10/11/19 - 11/05/12	42,46%	42,46%	20	-1,48%	1,47%	33,6	0
28	11/05/13 - 11/11/03	32,82%	34,67%	19	-1,17%	1,29%	33,6	5
29	11/11/04 - 12/04/26	43,81%	43,81%	20	-0,69%	1,50%	28	0
Average		73,63%	74,13%	19,86	-1,33%	2,34%	30,90	2,41

Table 4.4 – Profitability Analysis – Unrestricted (2;-1)

As observed under all the other sets of trading rules, for the majority of the sub periods (with the exception of 3), the absolute value of the maximum return was larger than the absolute value of the minimum daily return. The average maximum daily return was 2.34%, while the minimum daily return was only -1.33%. The comparative maximum daily returns for the (2;0) and (2;-0,5) strategies were 2.13% and 2.20% respectively, while the minimum daily returns were -1.18% and -1.20%.

The absolute value of both the maximum and minimum daily returns on the (2;-1) strategy were greater than both of the comparative strategies. The elevated volatility (as evidenced by the higher standard deviation) alluded to this fact.

Clearly, the strategy outperformed both the (2;0) and (2;-0,5) strategies in terms of both before- and after-fee returns. The increase in the return per round trip completed was more substantial than the decrease in returns as a result of the decrease in the number of executed trades. Furthermore, higher returns were yielded at higher standard deviations, however, the resultant Sharpe Ratios were lower before-fees and higher after-fees. It would then be expected to be a preferred strategy for an investor due both to a larger gross return as well as a better after-fee risk adjusted return.

As observed with all of the previously tested strategies, both before- and after-fee returns appear to be on a downward trend. Furthermore, returns appear to have remained positively correlated to the level of market volatility.

5.1.1.5 Unrestricted (2;-2)

Having concluded that an opening parameter of 2 standard deviations resulted in superior before- and after-fee performance relative to an opening parameter of 3 standard deviations, a further strategy using an opening parameter of 2 standard deviations was tested. It is assumed that a larger opening parameter than 3 standard deviations will serve as a further drag on the performance of the trading strategy, due to the same factors that caused returns to decrease when the opening parameter was shifted from 2 to 3, and therefore no larger opening parameters have been tested. With regards to a closing signal, changing the closing parameter from 0 standard deviations, to -0,5 standard deviations, and finally to -1 standard deviations resulted in improved performance with incremental change. Therefore, a larger (negative) closing signal of -2 standard deviations was tested, with an opening parameter of 2 standard deviations (due to its relative outperformance).

It is hypothesized that this strategy will yield higher before- and after-fee returns than the comparative (2;-1) strategy. The expectation arises as a result of the increased return that will be yielded per round trip completed (a 4 standard deviation relative shift in prices, compared to 3 standard deviations), as well as the lower fees as a result of the lower number of trades. Furthermore, similar changes in the closing signal (from 0 to -0,5 and finally to -1) resulted in improved performance. However, it must be noted that the substantially increased closing parameter of 2 standard deviations could potentially result in a marked decline in the number of pairs that open (due to them having not closed), and therefore the sources of return, which could potentially result in poorer returns. Furthermore, the longer holding period is likely to increase the strategy's standard deviation as a result of the increased return per completed round trip. A longer holding period allows for greater return volatility.

Trading Period	Date	R	SD	SR	ASSD	ANOP	NoT	ATL	RPT	T-Stat
1	98/06/25 - 98/12/16	228,25%	0,22	10,39	16,31	17,72	100	22,15	0,81%	**5,27**
2	98/12/17 - 99/06/09	111,97%	0,13	8,43	14,12	19,27	106	22,73	0,43%	**4,89**
3	99/06/10 - 99/12/01	88,78%	0,13	6,92	11,92	18,97	114	20,80	0,33%	**4,16**
4	99/12/02 - 00/05/04	116,28%	0,16	7,24	22,65	19,38	108	22,44	0,44%	**4,18**
5	00/05/05 - 00/10/26	89,45%	0,10	9,30	18,72	18,99	108	21,98	0,35%	**5,58**
6	00/10/27 - 01/04/19	85,93%	0,14	6,15	22,24	18,76	104	22,55	0,35%	**3,71**
7	01/04/20 - 01/10/11	78,69%	0,11	7,08	16,79	19,57	96	25,48	0,35%	**4,32**
8	01/10/12 - 02/04/04	86,08%	0,11	8,01	21,23	18,43	112	20,57	0,33%	**4,83**
9	02/04/05 - 02/09/26	99,64%	0,16	6,22	8,18	19,14	96	24,92	0,43%	**3,67**
10	02/09/27 - 03/03/20	80,74%	0,09	8,56	15,07	19,61	106	23,12	0,32%	**5,21**
11	03/03/21 - 03/09/11	83,48%	0,09	9,13	14,14	18,08	114	19,82	0,31%	**5,53**
12	03/09/12 - 04/03/04	75,33%	0,08	8,97	8,82	17,22	128	16,82	0,25%	**5,50**
13	04/03/05 - 04/08/26	44,13%	0,08	5,32	8,25	19,89	128	19,42	0,16%	**3,45**
14	04/08/27 - 05/02/17	50,87%	0,10	5,04	17,40	15,61	88	22,17	0,26%	**3,22**
15	05/02/18 - 05/08/11	64,26%	0,07	9,39	6,38	18,94	128	18,50	0,22%	**5,86**
16	05/08/12 - 06/02/02	59,07%	0,08	7,29	10,04	18,18	106	21,44	0,25%	**4,59**
17	06/02/03 - 06/07/27	76,63%	0,08	9,43	8,05	19,56	106	23,07	0,31%	**5,77**
18	06/07/28 - 07/01/18	49,36%	0,07	7,12	10,99	15,06	92	20,47	0,24%	**4,57**
19	07/01/19 - 07/07/12	46,11%	0,08	5,93	6,33	19,28	128	18,83	0,16%	**3,83**
20	07/07/13 - 08/01/03	55,50%	0,10	5,72	11,96	18,67	80	29,18	0,31%	**3,63**
21	08/01/04 - 08/06/26	103,75%	0,13	7,87	14,87	18,54	112	20,69	0,38%	**4,62**
22	08/06/27 - 08/12/18	74,67%	0,16	4,76	10,97	17,27	114	18,94	0,28%	**2,92**
23	08/12/19 - 09/06/11	120,97%	0,18	6,90	7,23	19,60	108	22,69	0,45%	**3,96**
24	09/06/12 - 09/12/03	55,43%	0,08	7,31	21,32	12,93	84	19,24	0,29%	**4,64**
25	09/12/04 - 10/05/27	45,58%	0,06	8,22	9,31	18,14	118	19,22	0,18%	**5,31**
26	10/05/28 - 10/11/18	28,43%	0,06	4,41	11,67	15,20	92	20,65	0,14%	**2,95**
27	10/11/19 - 11/05/12	43,62%	0,08	5,21	7,96	19,73	122	20,21	0,16%	**3,38**
28	11/05/13 - 11/11/03	39,91%	0,08	5,06	19,14	18,34	90	25,48	0,20%	**3,31**
29	11/11/04 - 12/04/26	45,18%	0,07	6,30	13,74	19,86	90	27,58	0,23%	**4,08**
Average		76,83%	0,11	7,16	13,30	18,27	106	21,76	0,31%	

Table 5.1 – Returns Analysis – Unrestricted (2;-2)

The before-fee effect of these changes can be determined from the returns analysis that is displayed in *Table 5.1*. Before-fee annualized return increased to 76.83% (all 29 sub periods' returns were significant at the 1% level) from 73.63% for the (2;-1) strategy. The (2;-2) strategy yielded higher returns in all but 7 of the 29 trading periods. The increased returns of the strategy were, however, more volatile than the comparative strategy, resulting in an increased standard deviation of 0,11, compared to 0,10. Despite the increased returns, the higher standard deviations resulted in a substantially lower (yet still substantial) before-fee Sharpe Ratio of 7.16. In comparison, the (2;-1) strategy resulted in an average before-fee Sharpe Ratio of 7.68. The average trade length was substantially longer when compared to the (2;-1) strategy, increasing from 13,24 days to 21.76 days (an increase of 64,35%), as a result of the greater relative price shift required to close the position. Furthermore, the longer average trade length, when compared to the (2;-1) trading strategy, resulted in a higher average number of open pairs, with an average of 18.27 pairs open (the portfolio was, on average, over 90% invested), compared to 12.73 pairs (on average, less then 65% of the portfolio was invested). The particularly high average number of open pairs under the (2;-2) strategy is a result of the absolute value of the open and close parameters being equal, which means that when a pair closes, it is subsequently reopened with opposite positions taken in the underlying shares. An increased average number of open pairs results in a more efficient use of allocated capital, therefore, evidently the (2;-2) strategy had a substantially more efficient use of its capital then the comparative (2;-1) strategy. A drastically increased average trade length, coupled with a larger average number of open pairs, resulted in a substantially lower number of executed trades when compared to any of the strategy's with a 2 standard deviation opening parameter. On average, only 106 trades were executed per trading period, when compared to 123 trades under the (2;-1) strategy and 142 trades under the (2;0) strategy, a reduction of 14% and 25% respectively.

Significantly, the before-fee return per trade of 0.31% was substantially higher than that of the (2;-1) (0.26%) strategy. The increased before-fee return per trade was a result of an increased before-fee return, coupled with a lower number of trades executed.

Table 5.3 displays the profitability and risk breakdown of the set of trading rules. The largest driver of the increased standard deviation of the strategy, similarly to the (2;-1) strategy, was the Bottom5 pair portfolio. The Bottom5 portfolio's standard deviation increased from 0.15 to 0.19, while the Top5 portfolio's standard deviation also increased markedly, but to a lesser degree (from 0.15 to 0.17). In addition to the increased standard deviation, the Bottom5 portfolio realized an increased before-fee return of 77.27%, compared to 71.34%. The Top5 portfolio also realized larger returns, increasing from 68.99% to 70.93%.

Despite the superior before-fee returns, the risk adjusted before-fee returns (Sharpe Ratio) of the Top20 (7.16), Top5 (3.84) and Bottom5 (4.20) portfolios were less significant than their comparatives under the (2;-1) strategy (7.68, 4.47 and 4.60 respectively). The lower Sharpe Ratios were a result of higher standard deviations, and in spite of higher returns. The increased returns were coupled with more substantial increases in the associated standard deviations.

A returns analysis is displayed in *Table 5.4*. The number of pairs that opened in each period was exactly the same as the other strategies tested using a 2 standard deviation opening parameter, due to the strategies sharing an opening parameter. All 20 pairs opened in almost every sub period, with a minimum of 19 pairs having opened in a single period. Thus, the difference between the Return on Committed Capital (76,83%) and the Fully Invested Return (77,36%) was negligibly different.

Trading Period	R(Top20)	R(Top5)	R(15-20)	SD(Top20)	SD(Top5)	SD(15-20)	SR(Top20)	SR(Top5)	SR(15-20)	T-Stat(Top20)	T-Stat(Top5)	T-Stat(15-20)
1	228,25%	374,11%	157,22%	0,22	0,54	0,35	10,39	6,89	4,44	**5,27**	**3,09**	**2,43**
2	111,97%	120,00%	118,24%	0,13	0,30	0,22	8,43	4,07	5,38	**4,89**	**2,33**	**3,09**
3	88,78%	116,03%	59,95%	0,13	0,22	0,24	6,92	5,23	2,46	**4,16**	**3,02**	**1,55**
4	116,28%	96,09%	108,30%	0,16	0,33	0,31	7,24	2,88	3,45	**4,18**	1,71	**2,01**
5	89,45%	76,84%	57,26%	0,10	0,19	0,20	9,30	4,09	2,82	**5,58**	**2,50**	1,79
6	85,93%	52,66%	65,01%	0,14	0,14	0,25	6,15	3,68	2,62	**3,71**	**2,35**	**1,63**
7	78,69%	71,26%	82,67%	0,11	0,15	0,19	7,08	4,77	4,31	**4,32**	**2,94**	2,61
8	86,08%	113,72%	43,47%	0,11	0,17	0,21	8,01	6,73	2,10	**4,83**	**3,90**	1,36
9	99,64%	61,69%	113,84%	0,16	0,23	0,27	6,22	2,71	4,25	**3,67**	**1,70**	**2,46**
10	80,74%	30,77%	69,61%	0,09	0,18	0,19	8,56	1,71	3,75	**5,21**	1,14	**2,32**
11	83,48%	59,88%	98,20%	0,09	0,17	0,15	9,13	3,56	6,54	**5,53**	**2,24**	**3,87**
12	75,33%	67,78%	72,52%	0,08	0,12	0,17	8,97	5,70	4,37	**5,50**	**3,54**	**2,69**
13	44,13%	31,10%	47,31%	0,08	0,11	0,13	5,32	2,96	3,54	**3,45**	**1,97**	**2,28**
14	50,87%	34,21%	46,36%	0,10	0,13	0,13	5,04	2,66	3,64	**3,22**	1,75	**2,35**
15	64,26%	47,10%	101,58%	0,07	0,10	0,13	9,39	4,59	8,10	**5,86**	**2,96**	**4,77**
16	59,07%	19,13%	80,29%	0,08	0,11	0,16	7,29	1,79	4,90	**4,59**	**1,22**	**2,98**
17	76,63%	118,80%	64,14%	0,08	0,20	0,24	9,43	5,91	2,68	**5,77**	**3,40**	1,67
18	49,36%	39,39%	48,92%	0,07	0,08	0,10	7,12	4,67	5,02	**4,57**	**3,05**	**3,22**
19	46,11%	53,29%	49,16%	0,08	0,10	0,15	5,93	5,40	3,18	**3,83**	**3,44**	**2,04**
20	55,50%	75,35%	47,01%	0,10	0,21	0,15	5,72	3,67	3,20	**3,63**	**2,25**	2,06
21	103,75%	94,83%	83,66%	0,13	0,21	0,18	7,87	4,57	4,53	**4,62**	**2,72**	**2,74**
22	74,67%	48,02%	155,07%	0,16	0,25	0,23	4,76	1,95	6,88	**2,92**	**1,25**	**3,77**
23	120,97%	57,15%	186,08%	0,18	0,21	0,29	6,90	2,74	6,48	**3,96**	1,73	**3,43**
24	55,43%	27,65%	48,37%	0,08	0,12	0,12	7,31	2,38	4,02	**4,64**	**1,59**	**2,58**
25	45,58%	35,00%	47,40%	0,06	0,11	0,12	8,22	3,28	3,90	**5,31**	**2,16**	**2,51**
26	28,43%	18,06%	41,62%	0,06	0,09	0,10	4,41	1,91	4,13	**2,95**	**1,31**	**2,69**
27	43,62%	48,93%	48,14%	0,08	0,11	0,13	5,21	4,64	3,76	**3,38**	**2,98**	**2,41**
28	39,91%	35,52%	42,71%	0,08	0,12	0,13	5,06	2,92	3,32	**3,31**	1,92	2,16
29	45,18%	32,67%	56,71%	0,07	0,10	0,14	6,30	3,36	4,19	**4,08**	**2,23**	**2,65**
Average	76,83%	70,93%	77,27%	0,11	0,17	0,19	7,16	3,84	4,20			

Table 5.3 – Top 20 Portfolio Risk and Return Drivers – Unrestricted (2;-2)

The increased standard deviations were evident in the average maximum and minimum daily returns yielded by the strategy. The average maximum daily return of 2.60% was larger than under both the (2;-1) and (2;-0,5) strategies; 2.34% and 2.20% respectively. In addition, the average maximum daily drawdown of -1.59% was more significant when compared to -1.33% and -1.20%. Contrary to expectations, (as increased volatility should lead to a greater relative number of periods in which the maximum daily drawdown is larger than the maximum daily return) the absolute value of the minimum daily return was larger than the maximum daily return in only 2 out of the 29 sub periods, compared to 3 sub periods under the (2;-1) strategy and 1 sub period under the (2;-0,5) strategy. Further highlighting the increased volatility of the strategy, the percentage of days yielding a negative return (32.44%) increased from 30.90% and 30.51%, under the (2;-1) and (2;-0,5) strategies respectively. The average percentage of negative pairs (3.62%) also increased, from 2.41% and 3.10%. Despite the increased negative returns when compared to the (2;-1) and (2;-0,5) strategies, both in terms of frequency and size, the (2;-2) strategy still resulted in more significant before-fee returns. As concluded for previously tested strategies, returns were not only more frequently positive, but on average, positive returns were larger than negative returns.

Trading Period	Date	R(CC)	R(FI)	Pairs Opened	Min R	Max R	% Days <0	% Pairs <0
1	98/06/25 - 98/12/16	228,25%	228,25%	20	-2,60%	9,83%	25,6	0
2	98/12/17 - 99/06/09	111,97%	111,97%	20	-1,80%	3,07%	30,4	0
3	99/06/10 - 99/12/01	88,78%	88,78%	20	-1,45%	3,10%	36	10
4	99/12/02 - 00/05/04	116,28%	116,28%	20	-2,49%	2,93%	32	0
5	00/05/05 - 00/10/26	89,45%	89,45%	20	-1,38%	2,31%	32	0
6	00/10/27 - 01/04/19	85,93%	85,93%	20	-2,10%	3,24%	32,8	10
7	01/04/20 - 01/10/11	78,69%	78,69%	20	-2,02%	1,96%	27,2	0
8	01/10/12 - 02/04/04	86,08%	86,08%	20	-1,31%	2,21%	24,8	10
9	02/04/05 - 02/09/26	99,64%	99,64%	20	-2,69%	4,29%	33,6	0
10	02/09/27 - 03/03/20	80,74%	80,74%	20	-1,36%	2,13%	32	10
11	03/03/21 - 03/09/11	83,48%	83,48%	20	-1,50%	2,26%	29,6	0
12	03/09/12 - 04/03/04	75,33%	75,33%	20	-1,09%	1,99%	33,6	0
13	04/03/05 - 04/08/26	44,13%	44,13%	20	-1,55%	1,64%	34,4	0
14	04/08/27 - 05/02/17	50,87%	50,87%	20	-1,43%	2,00%	40	10
15	05/02/18 - 05/08/11	64,26%	64,26%	20	-1,04%	1,13%	25,6	0
16	05/08/12 - 06/02/02	59,07%	59,07%	20	-0,97%	1,74%	34,4	5
17	06/02/03 - 06/07/27	76,63%	76,63%	20	-1,20%	1,73%	27,2	0
18	06/07/28 - 07/01/18	49,36%	49,36%	20	-0,97%	1,58%	31,2	0
19	07/01/19 - 07/07/12	46,11%	46,11%	20	-0,89%	1,41%	33,6	5
20	07/07/13 - 08/01/03	55,50%	58,75%	19	-1,51%	3,34%	36	15
21	08/01/04 - 08/06/26	103,75%	110,22%	19	-1,84%	3,02%	31,2	0
22	08/06/27 - 08/12/18	74,67%	74,67%	20	-3,15%	4,16%	37,6	10
23	08/12/19 - 09/06/11	120,97%	120,97%	20	-1,89%	5,37%	38,4	0
24	09/06/12 - 09/12/03	55,43%	58,68%	19	-1,01%	1,55%	36,8	0
25	09/12/04 - 10/05/27	45,58%	45,58%	20	-1,02%	1,57%	31,2	0
26	10/05/28 - 10/11/18	28,43%	28,43%	20	-1,49%	1,17%	38,4	5
27	10/11/19 - 11/05/12	43,62%	43,62%	20	-1,76%	1,81%	34,4	5
28	11/05/13 - 11/11/03	39,91%	42,20%	19	-1,33%	1,43%	32,8	10
29	11/11/04 - 12/04/26	45,18%	45,18%	20	-1,11%	1,50%	28	0
Average		76,83%	77,36%	19,86	-1,59%	2,60%	32,44	3,62

Table 5.4 – Profitability Analysis – Unrestricted (2;-2)

An analysis of the after-fee returns is summarized in *Table 5.2*, again only for an institutional investor incurring 10 bips of brokerage costs per trade and ignoring scrip borrowing costs. The average after-fee return was 21,72% per period (49,87% annualized). After-fee returns were greater than the 18,88% (42,90% annualized) and 16,80% (37,88% annualized) yielded by the (2;-1) and (2;-0,5) strategies respectively.

Significantly, the higher after-fee returns yielded by the (2;-2) strategy, despite the increased standard deviations of the strategy, resulted in a higher average after-fee Sharpe Ratio (4.39) than the comparative strategies. The (2;-1) and (2;-0,5) strategies yielded average after-fee Sharpe Ratios of 4.13 and 3.88 respectively. It must be noted once again that Pairs trading appears to be a particularly low risk strategy, and all 3 Sharpe Ratios are significant. The majority of investors would therefore be likely to be willing to take on the marginally higher volatility of the (2;-2) strategy in order to yield the increased returns.

Trading Period	R(125Day)	NoT	Instutional Fee (Per Trade)	Profit After Fees	Anualized PAF	Sharpe Ratio
1	81,18%	100	0,1%	71,18%	193,01%	8,79
2	45,59%	106	0,1%	34,99%	82,23%	6,19
3	37,40%	114	0,1%	26,00%	58,75%	4,58
4	47,07%	108	0,1%	36,27%	85,68%	5,34
5	37,64%	108	0,1%	26,84%	60,88%	6,33
6	36,36%	104	0,1%	25,96%	58,65%	4,20
7	33,68%	96	0,1%	24,08%	53,95%	4,85
8	36,41%	112	0,1%	25,21%	56,78%	5,28
9	41,29%	96	0,1%	31,69%	73,43%	4,58
10	34,44%	106	0,1%	23,84%	53,36%	5,66
11	35,45%	114	0,1%	24,05%	53,90%	5,90
12	32,41%	128	0,1%	19,61%	43,07%	5,13
13	20,06%	128	0,1%	7,26%	15,04%	1,81
14	22,83%	88	0,1%	14,03%	30,02%	2,97
15	28,16%	128	0,1%	15,36%	33,09%	4,83
16	26,12%	106	0,1%	15,52%	33,46%	4,13
17	32,90%	106	0,1%	22,30%	49,57%	6,10
18	22,21%	92	0,1%	13,01%	27,72%	4,00
19	20,88%	128	0,1%	8,08%	16,81%	2,16
20	24,70%	80	0,1%	16,70%	36,18%	3,73
21	42,74%	112	0,1%	31,54%	73,03%	5,54
22	32,16%	114	0,1%	20,76%	45,84%	2,92
23	48,65%	108	0,1%	37,85%	90,03%	5,14
24	24,67%	84	0,1%	16,27%	35,19%	4,64
25	20,66%	118	0,1%	8,86%	18,50%	3,34
26	13,33%	92	0,1%	4,13%	8,43%	1,31
27	19,84%	122	0,1%	7,64%	15,87%	1,90
28	18,28%	90	0,1%	9,28%	19,43%	2,46
29	20,49%	90	0,1%	11,49%	24,30%	3,39
Average	32,33%	106		21,72%	49,87%	4,39

Table 5.2 – After-fee Analysis – Unrestricted (2;-2)

Figure 5 plots the before- and after-fee returns yielded by the strategy. As observed under all of the prior tested trading strategies, with the exclusion of the period of increased market instability (starting mid 2007 and running till late 2009), the before- and after-fee returns appear to be on a downward trend. However, significantly, from the middle of 2010 until the end of the study period (mid 2012), both before- and after-fee returns appear to have been on an upward trend. This upward trend towards the end of the study period is in contrast to the comparative strategies.

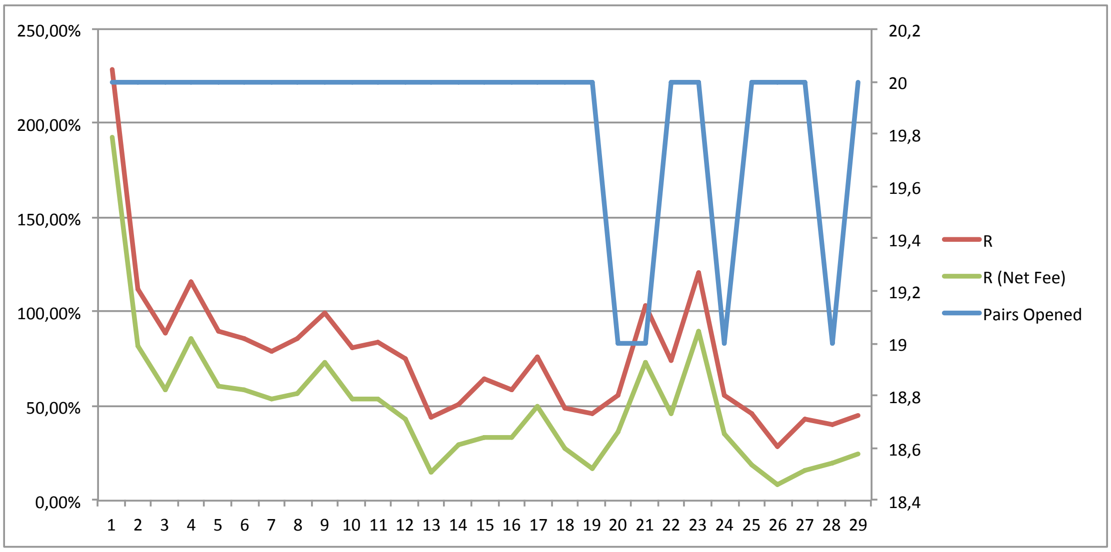


Figure 5 – Before- and After-fee Returns

Thus, for the sample tested, it appears that each incremental shift of the closing parameter from 0 standard deviations to -2 standard deviations served to increase both the before- and after-fee returns of Pairs trading. However, the increased returns came at the expense of increased volatility of the strategy's returns. The increased volatility of the strategy resulted in lower before-fee Sharpe Ratios, while the strategies outperformed on a net of fee Sharpe Ratio metric.

Pairs trading is naturally a low risk trading strategy as a result of the near market neutral (equal long and short positions, which primarily tend to be from the same sector) positions. Therefore, an investor would be more likely to take on the marginally increased levels of risk to bolster their returns.

Due to an opening parameter of 3 standard deviations resulting in poorer before- and after-fee returns, a closing parameter of 3 standard deviations is expected to yield inferior results to a closing parameter of 2 standard deviations, and therefore, was not tested.

5.1.2 Sector Restricted

Both Do and Faff (2009) and Gatev *et al.* (2006) concluded that restricting the pairing of shares to within the same sector served to improve the performance of Pairs trading. Significantly, Do and Faff (2009) concluded that despite the substantially reduced returns yielded, to the point of statistical insignificance, by Pairs trading on the S&P500 over time, applying sector restrictions could still result in statistically significant returns.

The sector restrictions in this study are relatively loosely defined, and therefore leave potential room for further research and possible strategy improvement. Firstly, pairs are only restricted to pairs within the Industrial and Financial (FINDI) and Resources (RESI) sectors. The JSE isn't as diversified an exchange as the S&P500 and has a smaller investible universe, it therefore offers less scope to sector restrict pairs. Furthermore, the utilities sector on the JSE is essentially non-existent, and Utilities shares are therefore not separated from Industrials. One could examine whether splitting the Financial and Industrial sectors would have an effect on the performance of a Pairs trading strategy on the JSE, but would run the risk of having too many sectors with too few investible pair iterations. Too few possible pair iterations would be likely to result in pairs being formed of shares without a sufficiently close historical price relationship.

Secondly, the portfolios constructed under the sector-restricted section of this study required only that the pairs in the portfolio be sector paired. This was done instead of creating two portfolios, one consisting of only the Top20 RESI and another consisting of only the Top20 FINDI pairs. The rationale behind this is that should two 20 pair portfolios be created, a very large portion of the Top80 shares used in this research study would have to be used in the pairing. This would serve to force pairing between shares with a substantially increased average sum of the squared distances between their normalized historic prices, which could potentially result in the pair relationship failing to hold. An obvious limitation of the method used is that in a number of sub periods the sector-restricted portfolios are exactly the same as (or very similar to) the Unrestricted sample, due to pairs frequently naturally pairing themselves within sectors. For example, banks are, for the most part, exposed to the same external factors (interest rates etc.). These external factors cause the shares to be affected by the same shocks to the market, and therefore more likely to move together. Similarly, gold mining shares have large factor exposures to the gold price and the Rand/Dollar exchange rate. Essentially, even in the case of Unrestricted pairing, shares within sectors have a tendency to pair themselves.

Trading Period	Resi (U)	FINDI (U)	Mixed (U)	Resi (SR)	FINDI (SR)
1	0	17	3	1	19
2	0	20	0	0	20
3	7	11	2	8	12
4	2	15	3	2	18
5	7	6	7	8	12
6	8	5	7	10	10
7	5	8	7	6	14
8	1	19	0	1	19
9	14	2	4	18	2
10	1	17	2	1	19
11	1	12	7	4	16
12	0	20	0	0	20
13	0	20	0	0	20
14	15	4	1	16	4
15	0	20	0	0	20
16	3	12	5	4	16
17	6	12	2	7	13
18	2	18	0	2	18
19	0	20	0	0	20
20	7	10	3	8	12
21	2	11	7	2	18
22	2	18	0	2	18
23	16	3	1	17	3
24	1	18	1	1	19
25	1	17	2	2	18
26	0	20	0	0	20
27	0	18	2	0	20
28	1	18	1	1	19
29	5	10	5	6	14
Average	3,689655	13,82759	2,482759	4,37931	15,62069

Table 6 – Breakdown of Pairs under Unrestricted Pairing

Table 6 displays a breakdown of the pairs making up the Top20 portfolio for the Unrestricted (U) and Sector Restricted (SR) portfolios. As can be seen, the U sample had as many as 9 sub periods that had no mixed pairs in the Top20 portfolio, and therefore the Unrestricted and Sector Restricted results for those sub periods were exactly the same. The largest number of mixed pairs in a sub period was 7 out of the 20 pairs, and this occurred in only 5 of the sub periods, with 5 mixed pairs occurring twice. The remaining 13 sub periods had between 1 and 4 mixed pairs. It is also noted that the majority of the pairs in both the Unrestricted as well as Sector Restricted samples are from the FINDI sector, with 69,14% and 78,1% of pairs respectively. However, this may have been as a result of there being a larger number of shares in the FINDI sector then the RESI sector.

While there is scope for further research into whether stricter sector restrictions benefit Pairs trading, *Figure 6* illustrates that for the Unrestricted sample, returns appear to have moved in relation to, and in the same direction as, the number of mixed pairs in the Top20 portfolio. It must however be noted that the relationship of the co-movement appears to be weak. Perhaps the mixed pairs in the Top20 portfolio of the Unrestricted sample paired up due to unforeseen relationships, which led to positive returns.

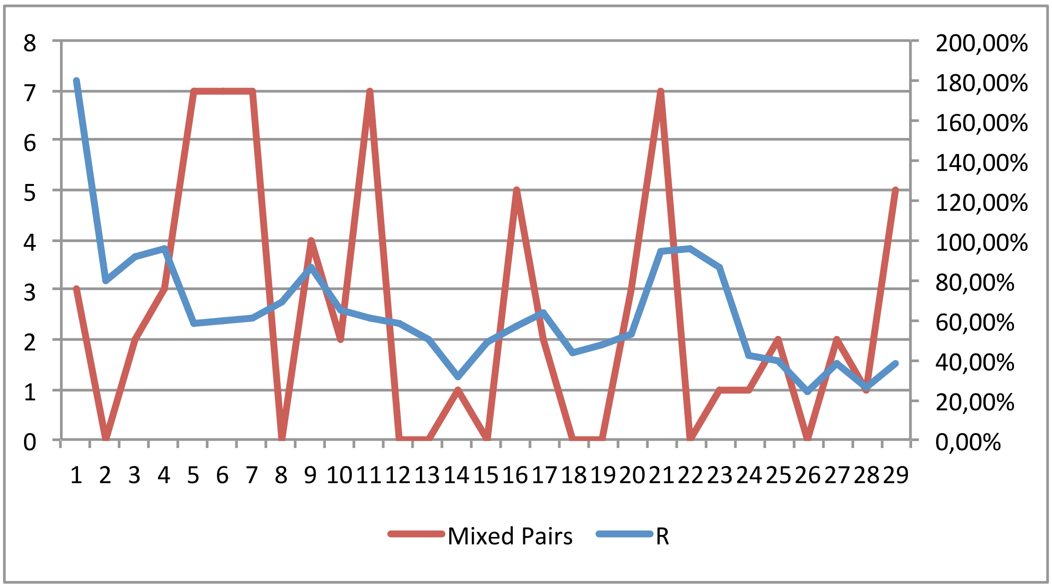


Figure 6 – Number of Mixed Pairs vs Return

Furthermore, a relatively common trading strategy is to pair fundamentally similar shares and trade them when they diverge from their historical relationship. Thus, a Sector Restricted strategy is likely to create identical pairs to that of a completely different quantitative trading strategy and thus have more players in the market, causing potential profits to be more quickly arbitraged away.

For the Sector Restricted portfolios, testing the discrepancies in returns and standard deviations between the Top20, Top5 and Bottom5 portfolios was not carried out. The reasoning underlying this is that any new pair that was included in the Sector Restricted portfolios will have been in the Bottom5 portfolio, and in no cases would have made it into the Top5 portfolio. This is due to no more then 7 pairs in any of the sub-periods having been mixed. By definition, any mixed pairs that were replaced by a Sector Restricted pair will have had a larger SSD then any of the pairs in the Unrestricted 20 pair portfolio, and thus would be included in the Bottom5 portfolio. Thus the changes brought on by sector restriction will make the analysis of the sub portfolios worthless.

5.1.2.1 Sector Restricted (2;0)

The first Sector Restricted strategy that was tested was the basic (2;0) set of trading rules. This was to allow comparison to both this study's basic strategy, as well as to foreign literature, most notably Do and Faff (2009) and Gatev *et al.* (2006).

The Top20 portfolio before-fee performance is summarized in *Table 7.1*. When compared to the Unrestricted (2;0) trading strategy, it can be seen that the average before-fee annualized return of 61,28% was marginally lower when compared to 63,69%. In terms of before-fee returns, the Sector Restricted portfolio outperformed (underperformed) in 6 (3) of the first 13 sub periods, and 0 (11) of the last 16 sub periods (the remainder of the periods had equal returns due to the same 20 pairs being in the portfolio). It appears that there has been a shift over time that has resulted in the Sector Restricted portfolio to start relatively underperforming the Unrestricted portfolio on the JSE. This is in stark contrast to the findings of Do and Faff (2009) and Gatev *et al.* (2006), who concluded that when Unrestricted pairing has ceased to yield statistically positive returns on the S&P500, applying sector restrictions to the pairing served to increase returns. All 29 sub-period returns were significant at the 2% level, and 27 were significant at the 1% level.

Trading Period	Date	R	SD	SR	ASSD	ANOP	NoT	ATL	RPT	T-Stat
1	98/06/25 - 98/12/16	166,70%	0,17	9,89	16,84	6,69	126	6,63	0,50%	**5,35**
2	98/12/17 - 99/06/09	79,70%	0,11	7,47	14,12	9,75	134	9,10	0,25%	**4,55**
3	99/06/10 - 99/12/01	95,35%	0,11	8,88	12,22	9,07	162	7,00	0,25%	**5,28**
4	99/12/02 - 00/05/04	103,14%	0,13	7,76	23,15	10,14	144	8,80	0,30%	**4,56**
5	00/05/05 - 00/10/26	58,95%	0,08	7,75	21,25	7,98	136	7,34	0,19%	**4,89**
6	00/10/27 - 01/04/19	54,83%	0,10	5,64	24,45	10,14	122	10,39	0,20%	**3,58**
7	01/04/20 - 01/10/11	69,83%	0,07	9,56	18,71	10,38	138	9,41	0,22%	**5,92**
8	01/10/12 - 02/04/04	68,70%	0,08	8,22	21,23	8,95	142	7,88	0,21%	**5,10**
9	02/04/05 - 02/09/26	93,60%	0,13	6,96	8,72	10,40	140	9,29	0,28%	**4,15**
10	02/09/27 - 03/03/20	56,51%	0,08	7,11	15,29	8,66	154	7,03	0,16%	**4,50**
11	03/03/21 - 03/09/11	62,07%	0,07	8,75	15,88	7,82	156	6,26	0,18%	**5,49**
12	03/09/12 - 04/03/04	58,51%	0,06	10,11	8,82	8,02	166	6,04	0,16%	**6,38**
13	04/03/05 - 04/08/26	50,54%	0,06	7,83	8,25	10,52	198	6,64	0,11%	**5,01**
14	04/08/27 - 05/02/17	28,99%	0,08	3,49	17,77	9,05	102	11,09	0,13%	**2,33**
15	05/02/18 - 05/08/11	49,13%	0,05	10,21	6,38	8,46	168	6,30	0,13%	**6,55**
16	05/08/12 - 06/02/02	51,36%	0,06	8,92	10,50	7,74	154	6,29	0,15%	**5,70**
17	06/02/03 - 06/07/27	49,74%	0,07	6,94	8,41	8,68	120	9,04	0,19%	**4,45**
18	06/07/28 - 07/01/18	42,90%	0,05	9,40	10,99	5,25	118	5,56	0,17%	**6,10**
19	07/01/19 - 07/07/12	47,43%	0,06	8,19	6,33	9,23	196	5,89	0,11%	**5,27**
20	07/07/13 - 08/01/03	51,52%	0,07	7,64	12,55	7,83	108	9,06	0,21%	**4,88**
21	08/01/04 - 08/06/26	68,42%	0,08	8,67	17,22	8,53	126	8,46	0,24%	**5,38**
22	08/06/27 - 08/12/18	95,31%	0,11	8,47	10,97	8,17	186	5,49	0,21%	**5,04**
23	08/12/19 - 09/06/11	84,25%	0,13	6,32	7,27	9,60	144	8,33	0,25%	**3,82**
24	09/06/12 - 09/12/03	35,13%	0,04	8,20	21,45	5,50	92	7,48	0,18%	**5,41**
25	09/12/04 - 10/05/27	38,39%	0,04	8,53	9,38	8,27	150	6,89	0,12%	**5,59**
26	10/05/28 - 10/11/18	24,10%	0,04	6,03	11,67	7,68	114	8,42	0,10%	**4,07**
27	10/11/19 - 11/05/12	35,86%	0,06	5,86	8,04	9,51	164	7,25	0,10%	**3,86**
28	11/05/13 - 11/11/03	25,46%	0,07	3,82	19,52	10,60	116	11,42	0,10%	**2,57**
29	11/11/04 - 12/04/26	33,59%	0,04	8,60	15,47	7,38	114	8,09	0,14%	**5,69**
Average		61,38%	0,08	7,77	13,89	8,62	141	7,82	0,19%	

Table 7.1 – Return Analysis – Sector Restricted (2;0)

It was expected that imposing a sector restriction on the formation of pairs would serve to decrease the level of risk associated with Pairs trading, as shares in the same sector are more likely to be fundamentally similar (due to them being affected by similar external factors), and therefore non-convergence risk should theoretically decrease. However, the reductions in standard deviations were marginal, from an average of 0,082 for the Unrestricted portfolio, to 0,079 for the Sector Restricted portfolio. The standard deviation of the Unrestricted portfolio was higher (lower) than that of the Sector Restricted portfolio in 11 (3) of the sub periods, and thus it appears that applying a sector restriction did in fact offer a risk reduction more frequently than not, however, the benefits were marginal. Due to the low risk inherent in the Unrestricted Pairs trading strategy, the risk reduction of sector-restriction was negligible, as evidenced by the comparative Sharpe Ratios of the two strategies. The marginally lower before-fee returns and negligibly small difference in standard deviations led to similar before-fee Sharpe Ratio's for the two strategies. On average, 7.84 for the Unrestricted portfolio and 7.77 for the Sector Restricted portfolio. Evidently, sector restriction resulted in a relatively larger reduction in before-fee returns than standard deviations.

Trading Period	R(125 Day)	NoT	Institutional Fee (Per Trade)	Profit After Fees	Annual PAF	Sharpe Ratio
1	63,31%	126	0,1%	50,71%	127,13%	7,54
2	34,05%	134	0,1%	20,65%	45,57%	4,27
3	39,77%	162	0,1%	23,57%	52,69%	4,91
4	42,53%	144	0,1%	28,13%	64,16%	4,83
5	26,07%	136	0,1%	12,47%	26,51%	3,49
6	24,43%	122	0,1%	12,23%	25,96%	2,67
7	30,32%	138	0,1%	16,52%	35,76%	4,90
8	29,88%	142	0,1%	15,68%	33,82%	4,05
9	39,14%	140	0,1%	25,14%	56,60%	4,21
10	25,10%	154	0,1%	9,70%	20,35%	2,56
11	27,31%	156	0,1%	11,71%	24,78%	3,49
12	25,90%	166	0,1%	9,30%	19,47%	3,36
13	22,70%	198	0,1%	2,90%	5,88%	0,91
14	13,57%	102	0,1%	3,37%	6,86%	0,83
15	22,12%	168	0,1%	5,32%	10,92%	2,27
16	23,03%	154	0,1%	7,63%	15,84%	2,75
17	22,37%	120	0,1%	10,37%	21,81%	3,05
18	19,54%	118	0,1%	7,74%	16,08%	3,52
19	21,42%	196	0,1%	1,82%	3,68%	0,63
20	23,09%	108	0,1%	12,29%	26,10%	3,87
21	29,78%	126	0,1%	17,18%	37,30%	4,73
22	39,75%	186	0,1%	21,15%	46,78%	4,16
23	35,74%	144	0,1%	21,34%	47,23%	3,54
24	16,25%	92	0,1%	7,05%	14,59%	3,41
25	17,64%	150	0,1%	2,64%	5,34%	1,19
26	11,40%	114	0,1%	0,00%	0,00%	0,00
27	16,56%	164	0,1%	0,16%	0,32%	0,05
28	12,01%	116	0,1%	0,41%	0,82%	0,12
29	15,58%	114	0,1%	4,18%	8,54%	2,19
Average	26,56%	141		12,46%	27,62%	3,02

Table 7.2 – After-fee Analysis – Sector Restricted (2;0)

Due to the nature of the study, the average sum of the squared distances increased when a sector restriction was imposed (from 13.30 to 13.89), and would have increased to a larger degree should stricter restrictions (such as a FINDI portfolio and a RESI portfolio, or further splitting FINDI into FINI and INI) have been imposed. Both the average number of open pairs (8,62 compared to 8.74), as well as the average trade length (7,82 days compared to 7,88) decreased, but negligibly so. This finding is contrary to expectations as the larger average sum of the squared distances of the Sector Restricted pairs led to the expectation that more historically dissimilar pairs would potentially diverge from their historic relationship more regularly, and be less likely to converge to a weaker historical relationship as quickly. However, a potential driver behind the shorter average trade length, and therefore the average number of open pairs, is that the common external factors affecting both shares in a Sector Restricted pair are likely to drive faster convergence. The average number of trades executed was almost unchanged, at 141, compared to 142. This resulted in an almost identical number of sources of return as well as net trading costs (however, scrip borrowing costs could potentially vary between the strategies should one strategy favour more liquid shares). Both the Unrestricted as well as the Sector Restricted portfolios had a larger number of executed trades than the other in 9 of the sub-periods. In addition, the two portfolios required the same number of trades in the remaining 11 sub-periods (however, of these 11 sub-periods, 9 contained the same 20 pairs as mentioned above).

The marginally lower return, coupled with a marginally lower number of trades, decreased the average return per trade from 0.098% to 0.095%.

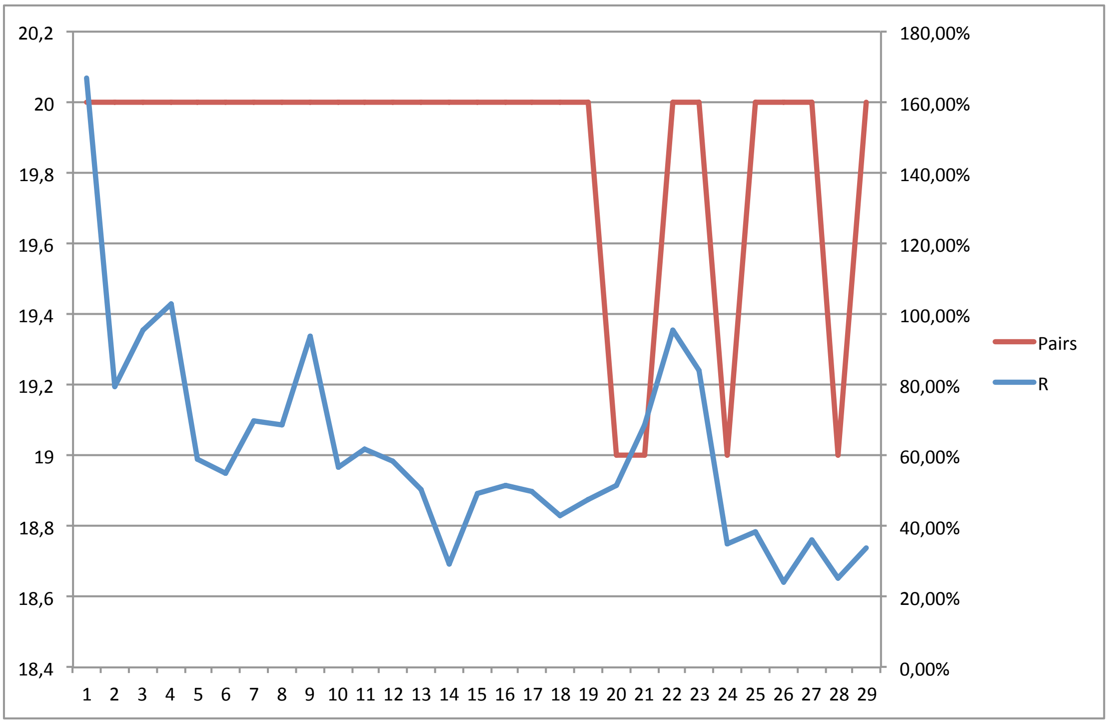


Figure 7 – Before- and After-fee Analysis – Sector Restricted (2;0)

Table 7.2 summarizes the after-fee performance of the Sector Restricted (2;0) strategy. The average trading period (125-day) before-fee return was 26.56%, which resulted in an average after-fee trading period return of 12,46% (27,62% annualized). Comparatively, the Unrestricted portfolio yielded a 125-day before-fee return of 27,46%, and an after-fee return of 13,26% (29,47% annualized). The after-fee Sharpe

Ratios for the Sector Restricted and Unrestricted portfolios were 6.77 and 6.86 respectively. Evidently the Unrestricted portfolio yielded superior before- and after-fee net returns, as well as risk-adjusted returns, despite the minor risk reduction of sector restriction.

Figure 7 displays the before- and after-fee returns of the Sector Restricted portfolio. A familiar pattern to the Unrestricted portfolio was observed, being a downward trend in both before- and after-fee returns, with the exception of the period of increased market volatility.

Trading Period	Date	R(CC)	R(FI)	Pairs Opened	R Min	R Max	% Days<0	% Pairs <0
1	98/06/25 - 98/12/16	166,70%	166,70%	20	-1,09%	8,51%	21,6	0
2	98/12/17 - 99/06/09	79,70%	79,70%	20	-1,57%	2,15%	33,6	0
3	99/06/10 - 99/12/01	95,35%	95,35%	20	-1,76%	3,57%	28,8	10
4	99/12/02 - 00/05/04	103,14%	103,14%	20	-2,00%	2,85%	30,4	5
5	00/05/05 - 00/10/26	58,95%	58,95%	20	-1,01%	2,20%	33,6	5
6	00/10/27 - 01/04/19	54,83%	54,83%	20	-1,32%	2,67%	28,8	10
7	01/04/20 - 01/10/11	69,83%	69,83%	20	-1,52%	1,35%	30,4	0
8	01/10/12 - 02/04/04	68,70%	68,70%	20	-0,95%	2,11%	27,2	5
9	02/04/05 - 02/09/26	93,60%	93,60%	20	-1,35%	3,35%	36	0
10	02/09/27 - 03/03/20	56,51%	56,51%	20	-0,75%	1,84%	37,6	15
11	03/03/21 - 03/09/11	62,07%	62,07%	20	-1,14%	1,73%	32,8	0
12	03/09/12 - 04/03/04	58,51%	58,51%	20	-0,68%	1,88%	24,8	0
13	04/03/05 - 04/08/26	50,54%	50,54%	20	-1,23%	1,40%	32	0
14	04/08/27 - 05/02/17	28,99%	28,99%	20	-1,05%	2,38%	40	15
15	05/02/18 - 05/08/11	49,13%	49,13%	20	-0,58%	1,17%	25,6	0
16	05/08/12 - 06/02/02	51,36%	51,36%	20	-0,76%	1,41%	33,6	0
17	06/02/03 - 06/07/27	49,74%	49,74%	20	-1,14%	1,86%	29,6	0
18	06/07/28 - 07/01/18	42,90%	42,90%	20	-0,64%	1,22%	26,4	0
19	07/01/19 - 07/07/12	47,43%	47,43%	20	-0,94%	1,39%	25,6	10
20	07/07/13 - 08/01/03	51,52%	54,53%	19	-1,07%	2,22%	31,2	0
21	08/01/04 - 08/06/26	68,42%	72,51%	19	-0,88%	1,89%	32	0
22	08/06/27 - 08/12/18	95,31%	95,31%	20	-1,97%	2,86%	31,2	5
23	08/12/19 - 09/06/11	84,25%	84,25%	20	-1,70%	2,91%	33,6	0
24	09/06/12 - 09/12/03	35,13%	37,13%	19	-0,45%	1,05%	30,4	0
25	09/12/04 - 10/05/27	38,39%	38,39%	20	-0,43%	0,98%	28,8	0
26	10/05/28 - 10/11/18	24,10%	24,10%	20	-0,57%	0,83%	33,6	0
27	10/11/19 - 11/05/12	35,86%	35,86%	20	-0,94%	1,30%	35,2	5
28	11/05/13 - 11/11/03	25,46%	26,88%	19	-1,22%	1,11%	32,8	15
29	11/11/04 - 12/04/26	33,59%	33,59%	20	-0,55%	1,30%	23,2	0
Average		61,38%	123,48%	19,86	-1,08%	2,12%	30,70	3,45

Table 7.3 – Profitability Analysis – Sector Restricted (2;0)

A profitability analysis of the strategy is outlined in *Table 7.3*. The lenient trading parameters of opening a position at 2 standard deviations and closing it at the next zero standard deviation convergence of prices resulted in a large number of pairs opening in each of the 29 sub periods, with all 20 pairs in 25 of the 29 period, and 19 opening in the remaining 4 periods, averaging 19,86 pairs (the same figures as under the Unrestricted sample). The large number of pairs that opened made the difference between the Return on Committed Capital and the Fully Invested Return negligible.

As observed under the Unrestricted sample, very few of the pairs yielded negative before-fee returns. An average of only 3.45% of pairs in a sub-period yielded negative returns; with a maximum of 15% (3 pairs) of pairs yielding a negative return. Coincidently, these results were exactly the same as under the Unrestricted sample, however the distribution of the negative pairs was somewhat different. The percentage of days that yielded negative returns ranged between 21.60% and 40.00%, and averaged 30.70% – the range was slightly narrower then that of the Unrestricted sample (20,8% to 40.80%) but at a negligibly higher average (30.23% for the Unrestricted sample). The slightly narrower range of negative returns was expected, due to the marginally lower standard deviations of the returns yielded.

The absolute value of the maximum daily return was higher then the absolute value of the minimum daily return in 27 out of the 29 sub periods (26 out of 29 for the Unrestricted sample). The maximum and minimum daily returns averaged 2.12% and -1.08% respectively. These results were similar to the Unrestricted sample, which averaged 2.13% and -1.18% respectively. The wider spread between the maximum and minimum daily returns again reflecting the higher standard deviation, and associated risk, of the Unrestricted sample. As noted for all the previously tested strategies, before-fee returns were more often than not positive (both in terms of days as well as pairs). Furthermore, positive returns, on average, were larger then negative returns.

It appears that applying sector-restrictions to a Pairs trading strategy on the JSE served to decrease returns (both before and after fees), while not sufficiently decreasing the associated risk (standard deviation) to sufficiently compensate an investor for the reduction in returns. The lower resultant Sharpe Ratios under the Sector Restricted (in comparison to the Unrestricted portfolio) portfolio highlighted the uneven levels of risk and return reductions that arose as a result of applying sector restrictions to the strategy. The underperformance of the Sector Restricted portfolio appears to have been a growing trend, with a number of sub periods of relative outperformance occurring earlier in the period of study and no periods of relative outperformance in the latter periods. It remains to be seen whether or not these findings remain observable after varying the trading rules.

5.1.2.2 Sector Restricted (2;-2)

The Unrestricted (2;-2) strategy yielded the highest after-fee returns, although, not the highest after-fee Sharpe Ratios due to relatively larger standard deviations. However, as noted earlier, Pairs trading is, by its construction, a particularly low risk strategy, and therefore an investor would be more likely to opt for increased returns than marginal risk reduction. The (2;0) Sector Restricted portfolio lagged its comparative Unrestricted portfolio, and therefore underperformance is expected relative to the comparable Unrestricted (2;-2) trading strategy. Furthermore, due to the substantial outperformance of the Unrestricted (2;-2) trading strategy when compared to the Unrestricted (2;0) trading strategy, outperformance is expected over the Sector Restricted (2;0) trading strategy.

Trading Period	Date	R	SD	SR	ASSD	ANOP	NoT	ATL	RPT	T-Stat
1	98/06/25 - 98/12/16	207,45%	0,21	9,96	16,84	17,49	96	22,77	0,78%	**5,16**
2	98/12/17 - 99/06/09	111,97%	0,13	8,43	14,12	19,27	106	22,73	0,43%	**4,89**
3	99/06/10 - 99/12/01	94,46%	0,13	7,11	12,22	18,97	114	20,80	0,35%	**4,23**
4	99/12/02 - 00/05/04	129,99%	0,16	7,91	23,15	18,94	102	23,22	0,51%	**4,48**
5	00/05/05 - 00/10/26	71,53%	0,10	6,97	21,25	18,96	110	21,55	0,28%	**4,30**
6	00/10/27 - 01/04/19	70,75%	0,13	5,45	24,45	18,47	100	23,09	0,31%	**3,37**
7	01/04/20 - 01/10/11	87,10%	0,08	10,88	18,71	19,62	110	22,30	0,33%	**6,55**
8	01/10/12 - 02/04/04	86,08%	0,11	8,01	21,23	18,43	112	20,57	0,33%	**4,83**
9	02/04/05 - 02/09/26	103,08%	0,16	6,31	8,72	19,10	98	24,36	0,43%	**3,71**
10	02/09/27 - 03/03/20	63,49%	0,09	6,73	15,29	19,61	104	23,57	0,27%	**4,21**
11	03/03/21 - 03/09/11	76,18%	0,10	7,67	15,88	18,00	118	19,07	0,28%	**4,70**
12	03/09/12 - 04/03/04	75,33%	0,08	8,97	8,82	17,22	128	16,82	0,25%	**5,50**
13	04/03/05 - 04/08/26	44,13%	0,08	5,32	8,25	19,89	128	19,42	0,16%	**3,45**
14	04/08/27 - 05/02/17	47,88%	0,10	4,79	17,77	15,55	82	23,71	0,26%	**3,08**
15	05/02/18 - 05/08/11	64,26%	0,07	9,39	6,38	18,94	128	18,50	0,22%	**5,86**
16	05/08/12 - 06/02/02	58,61%	0,07	8,20	10,50	17,68	118	18,73	0,22%	**5,17**
17	06/02/03 - 06/07/27	61,67%	0,08	7,85	8,41	19,54	90	27,13	0,30%	**4,92**
18	06/07/28 - 07/01/18	49,36%	0,07	7,12	10,99	15,06	92	20,47	0,24%	**4,57**
19	07/01/19 - 07/07/12	46,11%	0,08	5,93	6,33	19,28	128	18,83	0,16%	**3,83**
20	07/07/13 - 08/01/03	54,76%	0,10	5,31	12,55	18,74	86	27,24	0,28%	**3,37**
21	08/01/04 - 08/06/26	78,57%	0,12	6,77	17,22	18,51	104	22,25	0,32%	**4,13**
22	08/06/27 - 08/12/18	74,67%	0,16	4,76	10,97	17,27	114	18,94	0,28%	**2,92**
23	08/12/19 - 09/06/11	113,62%	0,18	6,39	7,27	19,60	108	22,69	0,43%	**3,70**
24	09/06/12 - 09/12/03	43,86%	0,07	6,31	21,45	12,24	80	19,13	0,25%	**4,09**
25	09/12/04 - 10/05/27	44,53%	0,06	7,78	9,38	18,32	112	20,45	0,18%	**5,04**
26	10/05/28 - 10/11/18	28,43%	0,06	4,41	11,67	15,20	92	20,65	0,14%	**2,95**
27	10/11/19 - 11/05/12	41,61%	0,08	5,46	8,04	19,73	122	20,21	0,16%	**3,55**
28	11/05/13 - 11/11/03	37,73%	0,08	4,77	19,52	18,10	90	25,14	0,19%	**3,13**
29	11/11/04 - 12/04/26	40,06%	0,06	6,93	15,47	19,16	90	26,61	0,20%	**4,53**
Average		72,66%	0,10	6,96	13,89	18,17	106	21,76	0,30%	

Table 8.1 – Returns Analysis – Sector Restricted (2;-2)

Table 8.1 summarizes the before-fee performance of the Sector Restricted portfolio of pairs when traded according to a (2;-2) set of trade execution parameters. As hypothesized, the annualized before-fee return of 72,66% (all 29 trading sub-periods' returns were significant at the 1% level) was higher than that of the Sector Restricted (2;0) set of trading rules' return of 61,38%. Furthermore, as expected, the 72,66% annualized return lagged the Unrestricted (2;-2) portfolio's return of 76,83%. The standard deviation of returns was substantially higher than that of the (2;0) Sector Restricted portfolio, at 0,104 when compared to 0,079. The Unrestricted portfolio tested with the (2;-2) set of trading parameters returned a standard deviation of 0,106 which was higher than both the (2;0) and (2;-2) Sector Restricted strategies. Thus, as noted under the Unrestricted sample, increasing the absolute value of the closing parameter (while keeping the opening parameter constant) serves to increase the associated risk (as observed through a larger standard deviation) of a Pairs trading strategy. However, applying a sector restriction to the formation of pairs appears to marginally decrease the risk of the trading strategy, when compared to an Unrestricted portfolio traded under the same set of trading parameters. The before-fee Sharpe Ratio of the strategy was 6.96, and lagged that of the Sector Restricted (2;0) portfolio (7.77) due to the higher standard deviation, and in spite of the higher before-fee return. Furthermore, the Sharpe Ratio also lagged that of the Unrestricted (2;-2) strategy (7.16) due to the lower return, and in spite of the lower standard deviation. As observed under the Unrestricted sample, the (2;-2) trading strategy offered improved before-fee returns when compared to a (2;0) trading strategy, however, the increased standard deviation resulted in a decreased before-fee Sharpe Ratio (worse risk adjusted performance). Furthermore, as noted under the Sector Restricted (2;0) trading strategy, applying a sector restriction to a Pairs trading strategy on the JSE appears to have marginally decreased the level of risk associated with Pairs trading. However, before-fee returns were also lower, and to a comparatively larger degree thaen the standard deviations, resulting in worse risk adjusted returns (Sharpe Ratios) than the Unrestricted sample.

Both the average number of open pairs (18,17), as well as the average trade length (21,76 days), were substantially larger than under the Sector Restricted (2;0) strategy – 8,62 and 7,82 respectively. This is consistent with the observation under the Unrestricted sample tested with the (2;-2) set of trading parameters (an increased

ANOP and ATL when compared to the (2;0) Unrestricted trading parameters). However, both the ATL, as well as the ANOP, were marginally lower for the Sector Restricted (2;-2) portfolio than for the Unrestricted (2;-2) strategy. Intuitively, it was expected that the Sector Restricted sample would have had a longer ATL, and therefore a higher ANOP, than the comparative Unrestricted sample due to the relatively poor historical price relationship of the pairs (as evidenced by the higher average sum of the squared differences). However, the counterintuitive results are likely as a result of similar external factors affecting shares within the same sectors resulting in quicker convergence.

Trading Period	Date	R(CC)	R(FI)	Pairs Opened	R Min	R Max	% Days<0	% Pairs <0
1	98/06/25 - 98/12/16	207,45%	207,45%	20	-2,41%	8,74%	24,8	0
2	98/12/17 - 99/06/09	111,97%	111,97%	20	-1,80%	3,07%	30,4	0
3	99/06/10 - 99/12/01	94,46%	94,46%	20	-1,92%	3,57%	36	10
4	99/12/02 - 00/05/04	129,99%	129,99%	20	-2,46%	3,59%	31,2	0
5	00/05/05 - 00/10/26	71,53%	71,53%	20	-1,18%	2,23%	36	5
6	00/10/27 - 01/04/19	70,75%	70,75%	20	-1,67%	2,31%	32,8	5
7	01/04/20 - 01/10/11	87,10%	87,10%	20	-0,76%	2,10%	24	0
8	01/10/12 - 02/04/04	86,08%	86,08%	20	-1,31%	2,21%	24,8	10
9	02/04/05 - 02/09/26	103,08%	103,08%	20	-2,28%	3,40%	36	0
10	02/09/27 - 03/03/20	63,49%	63,49%	20	-1,65%	1,91%	33,6	15
11	03/03/21 - 03/09/11	76,18%	76,18%	20	-1,20%	1,96%	34,4	5
12	03/09/12 - 04/03/04	75,33%	75,33%	20	-1,09%	1,99%	33,6	0
13	04/03/05 - 04/08/26	44,13%	44,13%	20	-1,55%	1,64%	34,4	0
14	04/08/27 - 05/02/17	47,88%	47,88%	20	-1,38%	1,95%	42,4	10
15	05/02/18 - 05/08/11	64,26%	64,26%	20	-1,04%	1,13%	25,6	0
16	05/08/12 - 06/02/02	58,61%	58,61%	20	-1,03%	1,41%	32	5
17	06/02/03 - 06/07/27	61,67%	61,67%	20	-1,26%	1,87%	26,4	0
18	06/07/28 - 07/01/18	49,36%	49,36%	20	-0,97%	1,58%	31,2	0
19	07/01/19 - 07/07/12	46,11%	46,11%	20	-0,89%	1,41%	33,6	5
20	07/07/13 - 08/01/03	54,76%	57,98%	19	-1,64%	1,86%	35,2	10
21	08/01/04 - 08/06/26	78,57%	83,33%	19	-1,39%	2,44%	31,2	0
22	08/06/27 - 08/12/18	74,67%	74,67%	20	-3,15%	4,16%	37,6	10
23	08/12/19 - 09/06/11	113,62%	113,62%	20	-1,86%	5,33%	35,2	0
24	09/06/12 - 09/12/03	43,86%	46,38%	19	-0,90%	1,33%	36,8	0
25	09/12/04 - 10/05/27	44,53%	44,53%	20	-1,08%	1,75%	28,8	0
26	10/05/28 - 10/11/18	28,43%	28,43%	20	-1,49%	1,17%	38,4	5
27	10/11/19 - 11/05/12	41,61%	41,61%	20	-1,16%	2,11%	34,4	5
28	11/05/13 - 11/11/03	37,73%	39,89%	19	-1,29%	1,34%	29,6	10
29	11/11/04 - 12/04/26	40,06%	40,06%	20	-0,84%	1,40%	28,8	0
Average		72,66%	146,20%	19,86	-1,47%	2,45%	32,39	3,79

Table 8.3 – Profitability Analysis – Sector Restricted (2;-2)

Furthermore, as observed under the Unrestricted (2;-2) strategy, the average number of executed trades under the Sector Restricted (2;-2) strategy was substantially lower than the Sector Restricted (2;0) strategy, at 106 compared to 141 (a decrease of 25%). The average number of executed trades was identical to the 106 trades under the Unrestricted (2;-2) strategy. Again, this was as a result of a number of positions having not closed (reached -2 standard deviations) when the spread returned to 2 standard deviations. A position that would otherwise have been reopened under the (2;0) strategy was still open, and therefore wouldn't require additional trades being executed. The increased returns, as well as decreased number of trades, resulted in a substantially higher before-fee return per trade of 0,30%, compared to 0,19% under the (2;0) Sector Restricted strategy. Furthermore, as hypothesized, the return per trade was lower than the 0,31% yielded under the Unrestricted (2;-2) portfolio.

A returns analysis is displayed in *Table 8.3*. As with all strategies opening at 2 standard deviations, the average number of pairs that traded in a period was 19,86, meaning that every pair opened in almost every sub period and thus the difference between the Return on Committed Capital and the Fully Invested Return was negligibly different. The increased volatility of the strategy when compared to the Sector Restricted (2;0) strategy, as highlighted by the increased standard deviations, was evident in the maximum before-fee daily return of 2.45% being substantially larger than the maximum daily return of 2.12% yielded under the (2;0) strategy. Similarly, the absolute value of the minimum daily return (-1.47%) was substantially larger than the absolute value of the minimum daily return (-1.08%) yielded by the Sector Restricted (2;0) strategy. These daily return metrics were marginally less volatile (as already highlighted by the smaller standard deviation) than under the Unrestricted (2;-2) portfolio, which ranged between -1,59% and 2,60%. The average percentage of days that yielded a negative return was 32,39%, which (as expected) was marginally more than the Sector Restricted (2;0) strategy (30.70%), and marginally less than the respective Unrestricted strategy (32.44%). However, the average percentage of pairs that yielded a negative return was 3,79%, and was larger than both comparative strategies (both the Sector Restricted (2;0) and the Unrestricted (2;-2) strategies – 3.45% and 3.62% respectively), albeit marginally so. Thus, it is evident that the Sector Restricted (2;-2) trading strategy increased the associated risk and return when compared to the (2;0) set of trading rules imposed on a Sector Restricted portfolio. Furthermore, the associated return and risk was reduced in comparison to the comparative (2;-2) Unrestricted portfolio.

Trading Period	R(125 Day)	NoT	Institutional Fee (Per Trade)	Profit After Fees	Annual PAF	Sharpe Ratio
1	75,34%	96	0,1%	65,74%	174,71%	8,39
2	45,59%	106	0,1%	34,99%	82,23%	6,19
3	39,45%	114	0,1%	28,05%	63,96%	4,81
4	51,66%	102	0,1%	41,46%	100,10%	6,09
5	30,97%	110	0,1%	19,97%	43,92%	4,28
6	30,67%	100	0,1%	20,67%	45,62%	3,52
7	36,79%	110	0,1%	25,79%	58,22%	7,27
8	36,41%	112	0,1%	25,21%	56,78%	5,28
9	42,50%	98	0,1%	32,70%	76,11%	4,66
10	27,86%	104	0,1%	17,46%	37,98%	4,02
11	32,73%	118	0,1%	20,93%	46,25%	4,65
12	32,41%	128	0,1%	19,61%	43,07%	5,13
13	20,06%	128	0,1%	7,26%	15,04%	1,81
14	21,60%	82	0,1%	13,40%	28,61%	2,86
15	28,16%	128	0,1%	15,36%	33,09%	4,83
16	25,94%	118	0,1%	14,14%	30,28%	4,23
17	27,15%	90	0,1%	18,15%	39,60%	5,04
18	22,21%	92	0,1%	13,01%	27,72%	4,00
19	20,88%	128	0,1%	8,08%	16,81%	2,16
20	24,40%	86	0,1%	15,80%	34,11%	3,31
21	33,63%	104	0,1%	23,23%	51,85%	4,47
22	32,16%	114	0,1%	20,76%	45,84%	2,92
23	46,16%	108	0,1%	35,36%	83,21%	4,68
24	19,94%	80	0,1%	11,94%	25,31%	3,64
25	20,22%	112	0,1%	9,02%	18,86%	3,29
26	13,33%	92	0,1%	4,13%	8,43%	1,31
27	19,00%	122	0,1%	6,80%	14,06%	1,84
28	17,36%	90	0,1%	8,36%	17,42%	2,20
29	18,35%	90	0,1%	9,35%	19,57%	3,39
Average	30,79%	106		20,23%	46,16%	4,15

Table 8.2 – After-fee Analysis – Sector Restricted (2;-2)

Table 8.2 lays out the after-fee returns yielded by the trading strategy. After-fee analysis was only done with regard to an institutional investors level of brokerage fees (10 bips per trade), and excluding any scrip borrowing costs. The average before-fee trading period (125-day) return was 30.79%, with (an average of) 106 trades having been executed. Thus, the after-fee return an institutional investor would have yielded was on average 20,23% (46,16% annualized). The lowest 125-day after-fee return was 4,13% and a maximum of 65,74% although the maximum was in Trading Period 1 (TP1), and is an outlier (41,46% was the second highest 125-day return). As hypothesized, annualized after-fee returns were more significant under the (2;-2) Sector Restricted strategy than for the comparative (2;0) Sector Restricted strategy (12,46% per period and 27,62% annualized), while lagging that of the (2;-2) Unrestricted strategy (21,72% per period and 49,87% annualized). Respective after-fee Sharpe Ratios were 4.15, 3.02 and 4.39 for the Sector Restricted (2;-2), (2;0) and Unrestricted (2;-2) strategies respectively. As hypothesized, the Sector Restricted (2;-2) strategy underperformed the Unrestricted (2;-2) strategy on both a returns, as well as a risk-adjusted returns, basis. Furthermore, despite the Sector Restricted (2;-2) strategy underperforming the Sector Restricted (2;0) strategy on a before-fee Sharpe Ratio basis, the substantially lower number of associated trades resulted in lower trading costs, and therefore a higher after-fee Sharpe Ratio, and thus the (2;-2) strategy outperformed the (2;0) strategy on an after-fee risk adjusted basis.

Furthermore, applying sector restriction to pairs' formation resulted in a lower standard deviation than under a comparative Unrestricted portfolio, while reducing returns to a comparatively larger degree, resulting in lower before- and after-fee Sharpe Ratios.

Figure 8 displays the before- and after-fee returns of the Sector Restricted (2;-2) strategy over time. The downward trend in before- and after-fee returns (again, with the exception of the period of increased market volatility) is once again evident.

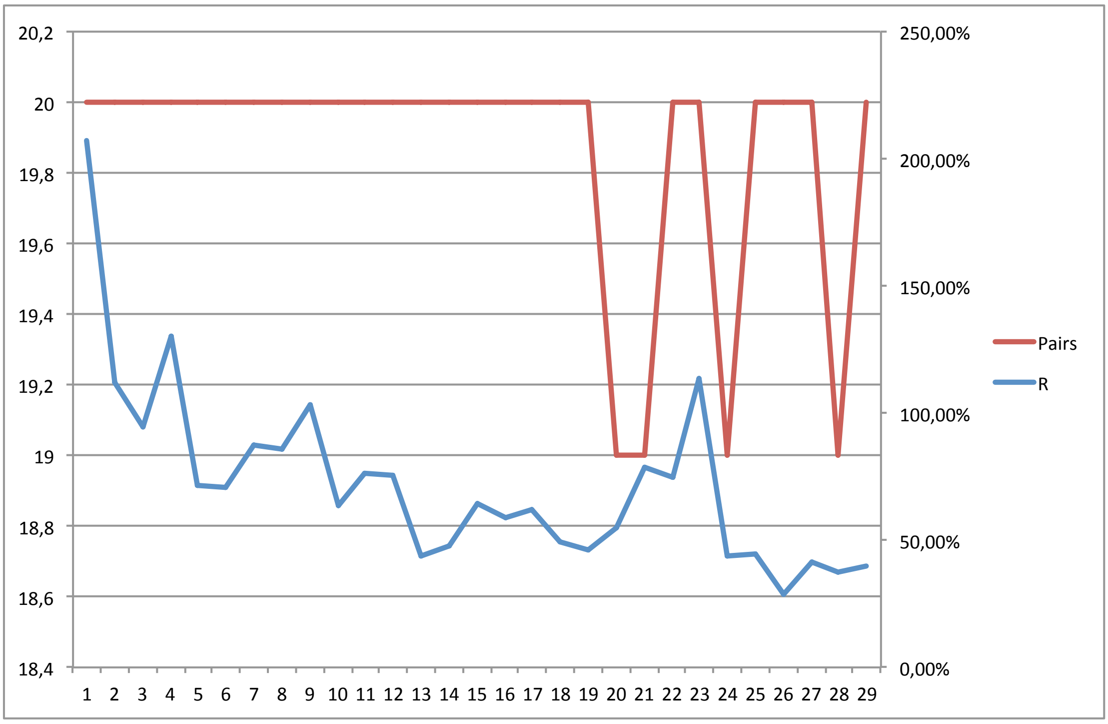


Figure 8 – Before- and After-fee Analysis – Sector Restricted (2;-2)

As concluded under the (2;0) Sector Restricted strategy, it appears that Sector Restricted strategies offer a minor reduction in associated risk (as highlighted by marginally lower standard deviations) when compared to their respective Unrestricted strategies. It is concluded that this is as a result of the shares in every pair being affected by similar external factors, and thus substantial divergence is less likely to be driven by substantial market shocks. However, the reduced levels of risk were accompanied by comparatively more substantial decreases in their yielded returns, which resulted in reduced Sharpe Ratios, and thus lower risk adjusted returns.

Significantly, the observation of relative outperformance of the -2 closing parameter when compared to a 0 standard deviation closing parameter (and using a consistent opening parameter of 2 standard deviations) under the Unrestricted sample remained evident under the Sector Restricted portfolio.

5.1.2.3 Sector Restricted (2;-0,5)

Trading Period	Date	R	SD	SR	ASSD	ANOP	NoT	ATL	RPT	T-Stat
1	98/06/25 - 98/12/16	184,55%	0,18	10,24	16,84	8,68	124	8,75	0,55%	**5,44**
2	98/12/17 - 99/06/09	92,73%	0,12	7,96	14,12	11,78	126	11,68	0,31%	**4,75**
3	99/06/10 - 99/12/01	103,38%	0,11	9,22	12,22	10,58	154	8,59	0,28%	**5,42**
4	99/12/02 - 00/05/04	126,16%	0,16	8,04	23,15	12,53	132	11,86	0,38%	**4,58**
5	00/05/05 - 00/10/26	67,45%	0,08	7,99	21,25	10,21	124	10,29	0,24%	**4,96**
6	00/10/27 - 01/04/19	58,76%	0,10	5,74	24,45	12,11	110	13,76	0,24%	**3,62**
7	01/04/20 - 01/10/11	73,15%	0,08	9,70	18,71	12,92	126	12,82	0,25%	**5,97**
8	01/10/12 - 02/04/04	79,43%	0,09	8,86	21,23	11,12	136	10,22	0,25%	**5,40**
9	02/04/05 - 02/09/26	97,00%	0,14	6,91	8,72	11,91	128	11,63	0,32%	**4,10**
10	02/09/27 - 03/03/20	61,90%	0,09	7,08	15,29	10,46	144	9,08	0,19%	**4,44**
11	03/03/21 - 03/09/11	74,17%	0,08	9,38	15,88	9,98	150	8,32	0,21%	**5,76**
12	03/09/12 - 04/03/04	63,51%	0,06	10,18	8,82	9,83	152	8,09	0,18%	**6,37**
13	04/03/05 - 04/08/26	55,58%	0,07	8,22	8,25	12,98	182	8,91	0,14%	**5,22**
14	04/08/27 - 05/02/17	30,36%	0,09	3,44	17,77	10,22	96	13,30	0,15%	**2,29**
15	05/02/18 - 05/08/11	55,39%	0,05	10,58	6,38	10,30	158	8,15	0,16%	**6,71**
16	05/08/12 - 06/02/02	51,38%	0,06	8,33	10,50	9,80	140	8,75	0,16%	**5,32**
17	06/02/03 - 06/07/27	57,57%	0,07	7,98	8,41	11,19	108	12,95	0,24%	**5,05**
18	06/07/28 - 07/01/18	49,37%	0,05	9,16	10,99	6,89	112	7,69	0,20%	**5,88**
19	07/01/19 - 07/07/12	51,94%	0,06	8,51	6,33	10,78	186	7,25	0,13%	**5,43**
20	07/07/13 - 08/01/03	52,86%	0,07	7,24	12,55	10,39	100	12,99	0,24%	**4,62**
21	08/01/04 - 08/06/26	69,49%	0,08	8,33	17,22	10,46	118	11,08	0,26%	**5,16**
22	08/06/27 - 08/12/18	87,14%	0,12	7,09	10,97	9,35	160	7,31	0,23%	**4,27**
23	08/12/19 - 09/06/11	98,68%	0,15	6,79	7,27	12,25	132	11,60	0,31%	**4,02**
24	09/06/12 - 09/12/03	36,33%	0,05	7,28	21,45	6,73	86	9,78	0,19%	**4,79**
25	09/12/04 - 10/05/27	39,29%	0,05	7,94	9,38	10,26	138	9,30	0,13%	**5,19**
26	10/05/28 - 10/11/18	23,62%	0,05	5,01	11,67	10,18	98	12,98	0,11%	**3,38**
27	10/11/19 - 11/05/12	38,46%	0,06	6,03	8,04	11,24	152	9,24	0,12%	**3,95**
28	11/05/13 - 11/11/03	29,01%	0,07	4,11	19,52	12,03	108	13,93	0,13%	**2,74**
29	11/11/04 - 12/04/26	39,75%	0,04	9,47	15,47	9,26	114	10,15	0,16%	**6,19**
Average		67,19%	0,09	7,82	13,89	10,57	131	10,36	0,22%	

Table 9.1 – Returns Analysis – Sector Restricted (2;-0,5)

The two Sector Restricted strategies that have been tested thus far have been the (2;0) and the (2;-2) sets of trading parameters. The rationale behind this is that the (2;0) trading strategy is the basic trading strategy of this study, and the (2;-2) strategy resulted in the highest after-fee returns under the Unrestricted sample. A final strategy to be tested is the (2;-0,5) trading strategy, as it yielded the highest after-fee Sharpe Ratio when tested on the Unrestricted sample. It is expected that the (2;-0,5) strategy will outperform the Sector Restricted (2;0) strategy, while underperforming the Unrestricted (2;-0,5) strategy with regards to both returns as well as Sharpe Ratios. Furthermore, it is expected to underperform both the Sector Restricted and Unrestricted (2;-2) strategies with regards to returns, while outperformance is expected with regards to Sharpe Ratios.

Trading Period	R(125 Day)	NoT	Institutional Fee (Per Trade)	Profit After Fees	Annual PAF	Sharpe Ratio
1	68,68%	124	0,1%	56,28%	144,25%	8,01
2	38,83%	126	0,1%	26,23%	59,34%	5,10
3	42,61%	154	0,1%	27,21%	61,82%	5,52
4	50,39%	132	0,1%	37,19%	88,20%	5,62
5	29,40%	124	0,1%	17,00%	36,90%	4,37
6	26,00%	110	0,1%	15,00%	32,25%	3,15
7	31,59%	126	0,1%	18,99%	41,58%	5,51
8	33,95%	136	0,1%	20,35%	44,85%	5,00
9	40,35%	128	0,1%	27,55%	62,70%	4,47
10	27,24%	144	0,1%	12,84%	27,33%	3,13
11	31,97%	150	0,1%	16,97%	36,82%	4,66
12	27,87%	152	0,1%	12,67%	26,95%	4,32
13	24,73%	182	0,1%	6,53%	13,49%	2,00
14	14,18%	96	0,1%	4,58%	9,36%	1,06
15	24,66%	158	0,1%	8,86%	18,50%	3,53
16	23,04%	140	0,1%	9,04%	18,89%	3,06
17	25,53%	108	0,1%	14,73%	31,62%	4,38
18	22,22%	112	0,1%	11,02%	23,24%	4,31
19	23,26%	186	0,1%	4,66%	9,54%	1,56
20	23,64%	100	0,1%	13,64%	29,13%	3,99
21	30,19%	118	0,1%	18,39%	40,16%	4,81
22	36,80%	160	0,1%	20,80%	45,92%	3,74
23	40,96%	132	0,1%	27,76%	63,21%	4,35
24	16,76%	86	0,1%	8,16%	16,99%	3,41
25	18,02%	138	0,1%	4,22%	8,62%	1,74
26	11,18%	98	0,1%	1,38%	2,79%	0,59
27	17,67%	152	0,1%	2,47%	5,00%	0,78
28	13,58%	108	0,1%	2,78%	5,65%	0,80
29	18,22%	114	0,1%	6,82%	14,10%	3,36
Average	28,74%	131		15,66%	35,14%	3,67

Table 9.2 – After-fee Analysis – Sector Restricted (2;-0,5)

Table 9.1 lays out the before-fee performance of the strategy. As hypothesized, the average before-fee return of 67,19% was greater than the 61,38% yielded by the Sector Restricted (2;0) strategy, and smaller than the 70,54% yielded by the Unrestricted (2;-0,5) strategy. It also lagged the 72,66% yielded by the Sector Restricted (2;-2) strategy. As noted earlier, sector restriction resulted in a marginally decreased standard deviation of 0.086, compared to 0.088 for the Unrestricted (2;-0,5) strategy. Similarly, the incremental shift of the closing parameter resulted in an increased standard deviation from 0.79 under the Sector Restricted (2;0) strategy. The resultant Sharpe Ratios were 7.82, 7.77, 6.96 and 7.99 for the Sector Restricted (2;-0,5), (2;0), (2;-2) and Unrestricted (2;-0,5) strategies respectively. As hypothesized, the before-fee return and risk-adjusted return of the Sector Restricted (2;-0,5) strategy outperformed that of the Sector Restricted (2;0) strategy, while underperforming the Unrestricted (2;-0,5) strategy. Similarly, underperformance relative to the Sector Restricted (2;-2) strategy with regards to before-fee returns, and outperformance with regards to Sharpe Ratios was observed.

Trading Period	Date	R(CC)	R(FI)	Pairs Opened	R Min	R Max	% Days<0	% Pairs <0
1	98/06/25 - 98/12/16	184,55%	184,55%	20	-1,68%	8,67%	26,4	0
2	98/12/17 - 99/06/09	92,73%	92,73%	20	-1,71%	2,90%	32	0
3	99/06/10 - 99/12/01	103,38%	103,38%	20	-1,76%	3,57%	28,8	10
4	99/12/02 - 00/05/04	126,16%	126,16%	20	-2,39%	4,06%	31,2	0
5	00/05/05 - 00/10/26	67,45%	67,45%	20	-1,01%	2,23%	36	5
6	00/10/27 - 01/04/19	58,76%	58,76%	20	-1,30%	2,18%	30,4	5
7	01/04/20 - 01/10/11	73,15%	73,15%	20	-1,18%	1,49%	31,2	0
8	01/10/12 - 02/04/04	79,43%	79,43%	20	-1,13%	2,06%	25,6	5
9	02/04/05 - 02/09/26	97,00%	97,00%	20	-1,52%	3,35%	35,2	0
10	02/09/27 - 03/03/20	61,90%	61,90%	20	-1,58%	1,69%	34,4	10
11	03/03/21 - 03/09/11	74,17%	74,17%	20	-1,02%	1,71%	30,4	0
12	03/09/12 - 04/03/04	63,51%	63,51%	20	-0,66%	1,70%	22,4	0
13	04/03/05 - 04/08/26	55,58%	55,58%	20	-1,23%	1,48%	28	0
14	04/08/27 - 05/02/17	30,36%	30,36%	20	-1,35%	2,38%	39,2	20
15	05/02/18 - 05/08/11	55,39%	55,39%	20	-0,58%	1,13%	24,8	0
16	05/08/12 - 06/02/02	51,38%	51,38%	20	-0,76%	1,41%	35,2	0
17	06/02/03 - 06/07/27	57,57%	57,57%	20	-1,10%	1,52%	28	0
18	06/07/28 - 07/01/18	49,37%	49,37%	20	-0,68%	1,38%	26,4	0
19	07/01/19 - 07/07/12	51,94%	51,94%	20	-0,84%	1,41%	28,8	10
20	07/07/13 - 08/01/03	52,86%	55,95%	19	-1,07%	2,18%	29,6	5
21	08/01/04 - 08/06/26	69,49%	73,65%	19	-1,16%	1,72%	32,8	0
22	08/06/27 - 08/12/18	87,14%	87,14%	20	-1,78%	2,86%	34,4	5
23	08/12/19 - 09/06/11	98,68%	98,68%	20	-2,26%	2,54%	34,4	0
24	09/06/12 - 09/12/03	36,33%	38,40%	19	-0,46%	1,15%	35,2	0
25	09/12/04 - 10/05/27	39,29%	39,29%	20	-0,52%	1,04%	32	0
26	10/05/28 - 10/11/18	23,62%	23,62%	20	-0,62%	0,88%	37,6	0
27	10/11/19 - 11/05/12	38,46%	38,46%	20	-1,00%	1,50%	31,2	5
28	11/05/13 - 11/11/03	29,01%	30,64%	19	-1,27%	1,27%	34,4	10
29	11/11/04 - 12/04/26	39,75%	39,75%	20	-0,65%	1,40%	24	0
Average		67,19%	135,13%	19,86	-1,18%	2,17%	31,03	3,10

Table 9.3 – Profitability Analysis – Sector Restricted (2;-0,5)

The strategy required a lower number of trades, 131, when compared to 141 and 132 for the Sector Restricted (2;0) and Unrestricted (2;-0,5) strategies respectively. In comparison to the Sector Restricted (2;0) strategy, the longer holding period (2,5 standard deviations compared to 2 standard deviations) could potentially be the driving force behind the reduced number of trades. The resultant average trade lengths (average number of open pairs) were 10,36 days (10,57 pairs), 7,82 days (8,62 pairs) and 10,31 days (10,63 pairs) for the Sector Restricted (2;-0,5), (2;0) and Unrestricted (2;-0,5) strategies respectively.

As hypothesized, the before-fee return per trade of 0,22% was between 0,19% and 0,23% as yielded under the Sector Restricted (2;0) and Unrestricted (2;-0,5) strategies respectively.

An after-fee analysis of the strategy is presented in *Table 9.2*. The average 125-day return for the Sector Restricted (2;-0,5), (2;0) and Unrestricted (2;-0,5) strategies were 28,74%, 26,56% and 30,01% respectively. The resulting after-fee returns were 15,66%, 12,46% and 16,80% respectively. Furthermore, the after-fee Sharpe Ratios were 3.67, 3.02 and 3.88 for the three respective strategies. As hypothesized, the Sector Restricted (2;-0,5) strategy outperformed the Sector Restricted (2;0) strategy and underperformed the Unrestricted (2;-0,5) strategy in terms of before-and after-fee returns, as well as risk adjusted returns.

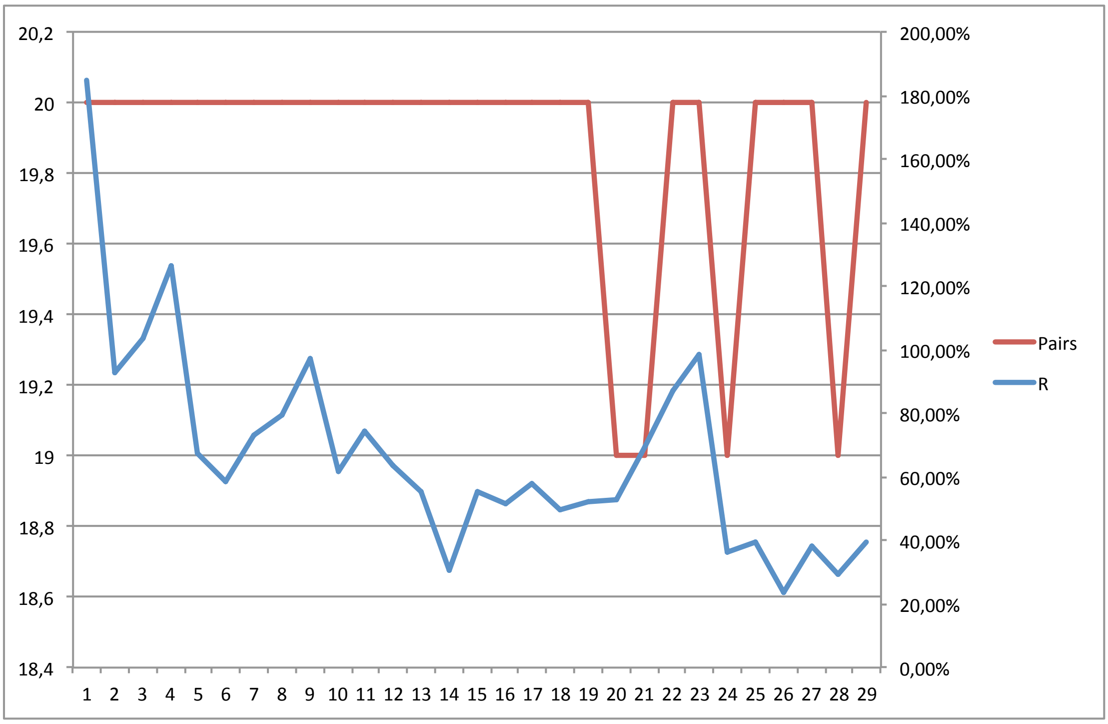


Figure 9 – Before- and After-fee Analysis – Sector Restricted (2;-0,5)

Figure 9 plots the before-and after-fee returns yielded by the trading strategy. As noted under every earlier tested strategy, a clear downward trend in both before- and after-fee returns is evident (with the exception of the period of increased market volatility). Significantly, the downward trend in returns appears to be particularly significant.

A profitability analysis of the trading strategy is laid out in *Table 9.3*. Similarly to all of the other strategies tested using an opening parameter of 2 standard deviations, almost every pair opened in every trading period (an average of 19,86 pairs per period). This resulted in a negligible difference between the Return on Committed Capital and the Fully Invested Return. The minimum and maximum daily returns yielded by the strategy were -1,18% and 2,17% respectively. The comparatives were -1,08% and 2,12%, and -1,20% and 2,20% for the Sector Restricted (2;0) and Unrestricted (2;-0,5) strategies respectively. This highlights the decreased volatility (risk) in comparison to Unrestricted strategies and increased volatility associated with increasing the absolute value of the closing parameter. The percentage of days (pairs) yielding a negative return were negligibly different between the three strategies at 31,03% (3,10%), 30,70% (3,45%) and 30,51% (3,10%) for the Sector Restricted (2;-0,5), (2;0) and Unrestricted (2;-0,5) strategies respectively.

It appears that sector restricting the formation of pairs on the JSE, in its weak form, leads to a reduction in both the net returns, as well as the volatility of returns (a risk measure) yielded by the strategy. Significantly, however, the reduction in returns was comparatively larger than the risk reduction, which led to inferior risk-adjusted returns. This observation held true for a number of different strategies tested, namely, the basic (2;0) strategy, and another two strategies, the (2;-0,5) and (2;-2) strategies which yielded the highest risk adjusted returns and highest returns respectively under the Unrestricted sample. Furthermore, the same trading parameters that led to relative outperformance under the Unrestricted sample achieved relative outperformance when applied to a portfolio of Sector Restricted pairs.

5.2 Comparison Over Time

To compare the performance over time by Pairs trading on the JSE, the period of analysis has been split into quarters. As there are an uneven number of sub periods, and TP1 appears to be an outlier (perhaps based on older, more dubious data), it has been excluded. Thus, the periods of comparison each consist of 7 sub periods of 125 days each and are just short of a 3.5 year period. The first period runs from 17/12/1998 until 04/04/2002 and the second period runs from 05/04/2002 until 11/08/2005, the third from 12/08/2005 until 18/12/2008 and the fourth from 19/12/2008 until 26/04/2012, which is the end date of the study. The initial strategy analyzed will be the portfolio with the best performance (based on after-fee returns), namely the Unrestricted sample under the trading parameters of (2;-2).

Trading Period	R	SD	SR	NoT	RPT	Profit After Fees	ATL	ANOP
2 to 8	39,16%	0,125	7,59	107	0,37%	28,48%	22,36	19,05
9 to 15	30,66%	0,097	7,52	113	0,28%	19,41%	20,68	18,36
16 to 22	28,82%	0,099	6,87	105	0,28%	18,27%	21,80	18,08
23 to 29	23,70%	0,086	6,20	101	0,24%	13,65%	22,15	17,69

Table 10.1 – Comparison Over Time – Unrestricted (2;-2)

Table 10.1 highlights the main differences between the sub periods. Significantly, the average before-fee (after-fee) 125 day trading period returns decreased substantially over the four sub-periods, from an average of 39,16% (28,48%) in the first to 23,70% (13,65%) in the last. It should be noted that after a sustained period of relative underperformance in the fourth period, before-fee returns in the last period increased to a 5 trading period relative high of 20,49% - spanning from the middle of 2010 (Trading Period 25) (20,66%). Another period of sustained relative underperformance was seen in trading periods 19 to 24 (07/01/19 to 09/12/03). However, periods of relative underperformance tended to occur later in the period of study and the overall trend in returns (as highlighted by the returns analysis of the quartered sample) was downward. This highlights the decline in returns yielded by Pairs trading on the JSE over time, a trend regularly documented in studies based on foreign exchanges, most notably Gatev *et al.* (2006), Do and Faff (2009) on the S&P500. While returns appear to have not declined to the same extent on the JSE, it could merely be a function of the maturity of the market and returns could potentially be expected to decline further.

The declining returns were matched with declining standard deviations from 0,125 to 0,097, followed by a minor increase to 0,099, and finally to 0,086, highlighting a decreasing level of associated risk over time. As theorized in Gatev *et al.* (2006), the decline in the standard deviation of the strategy over time could explain a decreased exposure to a latent risk factor, which in turn could explain the decreasing returns yielded by Pairs trading over time. Higher returns in the earlier periods could be compensation for taking on additional risk due to the aforementioned latent risk factor. The latent risk factor was not identified in Gatev *et al.* (2006), and this study offers no further explanation as to what the source of the latent risk factor is. Despite the decrease of the standard deviations over time, the substantially decreased returns led to the Sharpe Ratios also declining from 7.59 to 6.20, highlighting that risk adjusted returns yielded by Pairs trading on the JSE appear to be on a downward trend. The comparatively drastic decline in both the standard deviation, as well as return, from the first to the second sub period highlight the probability of the exposure to a latent risk factor that substantially decreased between those two periods.

The numbers of executed trades appear to have been relatively constant over time, with 107 in the first period, 113 and 105 in the middle two periods, before declining to 101 in the final period. Clearly the first period outperformed substantially in terms of both return per trade (0.37%, 0.09% higher than the second highest quarter and 0.13% higher than the lowest quarter) as well as after-fee returns (28,48%, 9,07% higher than the second highest quarter) due to a substantially larger before-fee return. The most recent period yielded the poorest performance of the four quarters, based on before (23,70%) and after-fee returns (13,65%), return per trade (0.24%) and before-fee Sharpe Ratio (6.20) yet still yielded substantial after-fee returns at a low level of risk (standard deviation).

The second set of rules that was tested over time is the Unrestricted sample of pairs tested according to the basic strategy of (2;0), in order to allow comparisons over time to foreign studies. It is summarized in *Table 10.2.*

The downward trend of before-fee returns was still evident, with returns having decreased from 31,71% in the first quarter to only 18,91% in the fourth quarter. However, the third quarter bucked the trend, which didn't happen under the (2;-2) strategy, and yielded a higher before-fee average return than the second quarter (28,13% compared to 25,39%). As noted under the (2;-2) strategy, relative periods of underperformance occurred, and in this case, during the trading periods 12 to 16 (03/09/12 to 06/02/02), 18 to 20 (06/07/28 to 08/01/03) and 25 to 29 (09/12/04 to 12/04/26). Again, periods of relative underperformance tended to occur later in the period of study.

Trading Period	R	SD	SR	NoT	RPT	Profit After Fees	ATL	ANOP
2 to 8	31,71%	0,099	7,48	137	0,23%	18,03%	8,96	9,70
9 to 15	25,39%	0,076	8,05	153	0,17%	10,13%	7,65	9,07
16 to 22	28,13%	0,075	8,67	151	0,19%	13,07%	6,65	7,81
23 to 29	18,91%	0,063	6,84	129	0,15%	5,96%	8,49	8,68

Table 10.2 – Comparison Over Time – Unrestricted (2;0)

Consistent with the (2;-2) strategy, standard deviations declined over time, from 0.099 to 0.063 and, as expected, in all four sub-periods the (2;0) strategy resulted in lower standard deviations than the (2;-2) strategy. The greatest decline in standard deviations was present between the first and second quarters, dropping from 0.099 to 0.076. The largest decline in standard deviation for the (2;-2) strategy occurred between the same two quarters, which further serves to suggest a drastic decline in an exposure to a latent risk factor that resulted in substantially decreased returns.

The number of executed trades spiked substantially in the middle two quarters, from 137 to 153 and 151, before declining substantially to 129 trades. The number of trades resulted in a substantially higher return per trade in the first quarter (0.23%) than the other three quarters (dropping as low as 0,15% in the fourth period). Significantly, before-fee returns (18,91%) declined so substantially in the fourth quarter that the substantial decrease in the number of trades still failed to increase the return per trade (0.15%) above that of the other three quarters (a previous low of 0.17%).

Similarly to the before-fee return, the after-fee return of the strategy declined over time (with the exception of the third quarter that yielded a slight gain) from 18,03% to only 5,96%. Due to the decline in the standard deviation, the before-fee

Sharpe Ratios spiked in the middle two quarters from 7.48 (in the first quartile) to 8.05 and 8.67, before finally decreasing substantially to 6.84 in the fourth quartile.

Both the (2;0) and (2;-2) strategies appear to have declined over time, in terms of both before- and after-fee returns. In addition, the standard deviations of returns yielded by Pairs trading declined over time, but to a lesser degree than returns, which resulted in declining Sharpe Ratios (with the exception of the middle periods in the (2;0) strategy). Significantly, the (2;-2) strategy appears to have had a resurgence of before- and after-fee returns in the last trading period to a 5 period high.

The findings in this study are therefore similar to those of comparable studies on foreign exchanges, namely, a reduction over time in both before- and after-fee returns, as well as standard deviations. However, the return reductions have not been to the same degree as on foreign exchanges, and positive returns still appear to be achievable through Pairs trading on the JSE. A potential reason for this could be that the JSE is a less mature market then the S&P500, and therefore market inefficiencies that are identified through quantitative strategies are more easily exploitable. A more mature market is more likely to have market inefficiencies arbitraged out (and therefore no longer exploitable to earn positive returns) more quickly, and the spreads are less likely to widen as substantially due to a greater number of active traders.

6 Potential Topics for Future Research

As noted throughout this study, there are a number of potential topics for further research into the profitability of Pairs trading on the JSE. They arise from a number of reasons, ranging from how sector restrictions were imposed, to the potential use of leverage.

The first area for potential future research is comparable methods of stock pairing. A number of other methods that have been tested in earlier papers include co-integration, Pearson's correlation, Spearman's rank correlation and Beta's. A further study could be conducted to determine whether another of the pairing methods could potentially outperform the method tested in this study.

The average Pairs trading strategy in this study was under invested, and a number of strategies resulted in, on average, fewer than 50% of pairs in the Top20 portfolio being open at any one time. Furthermore, the strategies that tended to outperform had higher average numbers of open pairs. Therefore, there is potential to improve the performance of a number of Pairs trading strategies through the use of gearing, by increasing the maximum permitted percentage holding in each pair. Another potential area for improvement could be in increasing the investible universe of each strategy (still limiting an allocation of 5% of the portfolio to a pair, but including a larger number of pairs in the strategy). This could potentially allow for better utilization of allocated capital, and therefore improved performance. However, both increasing the investible universe and allowing for gearing is likely to increase the risk associated with the trading strategies. Allowing for gearing results in more concentrated bets, and allowing for more pairs in a strategy could potentially begin to include sub optimally paired shares.

Secondly, as alluded to, the sector restrictions imposed on pair formations in this study were particularly lenient. There is potential scope for further risk reductions that could arise from applying stricter sector restrictions, by splitting up the FINDI sector into FINI and INI or creating two 20 pairs portfolios of only FINDI and RESI shares respectively. Stricter still, 3 20 pair portfolios could be formed, namely; INI, FINI and RESI. A potential further reduction in the standard deviations of the strategies, coupled with potentially smaller decreases in returns could result in improved risk adjusted performance.

Another potential room for further research is into potentially forcing pairing to occur only between mixed pairs – a completely different strategy to sector restriction. Contrary to findings in prior literature, this study found a weak positive relationship between the number of mixed pairs in a portfolio and the resultant returns yielded by the strategy. Potential research could therefore be conducted in order to determine whether this observed relationship is potentially exploitable.

Lastly, it was observed that the returns generated by Pairs trading appear to increase during periods of elevated market stress, in particular late 1998, and again during the crash period of 2008 are two in sample examples of this. Increased stress on the market results in increased market volatility, and it is hypothesized that Pairs trading benefits from this increased volatility that surrounds a market crash. The increased market volatility could potentially result in a higher number of pairs temporarily diverging from their historical relationships, and thus increase the sources of return generation temporarily.

Therefore, potential further research can be done into the Volatility Index (VIX) as a leading indicator for potential significant outperformance of Pairs trading. However, it must be noted that in periods of increased market stress, the costs associated with scrip borrowing (in order to short shares on the market) increase drastically.

7 Conclusion

A number of Pairs trading strategies were tested on the JSE over a substantial time horizon spanning almost 14 years, ranging from 1998/06/25 to 2012/04/26. The period of study included both bull and bear (the crash of 2008) periods on both the JSE and international stock markets. Regarding the formation of pairs, trading strategies were tested on both an Unrestricted sample, as well as a sample subject to sector restrictions. Furthermore, different opening and closing parameters on both the Unrestricted and Sector Restricted samples were tested. The methodology utilized for the formation, as well as trading, of pairs is similar to the methodologies utilized by Gatev *et al.* (1999), Gatev *et al.* (2006), Do and Faff (2009), Perlin (2007) and Bolgun *et al.* (2009) in order to aid comparisons between the different literatures. Shares were paired through a process of minimizing the sum of the squared distances between their normalized price series'. Pairs were then traded in a contrarian manner when they diverged from their historic price relationships. A short position was taken in the stock that had recently increased in its relative price (to its paired stock), and a long position was simultaneously taken in the relative loser. Both the long and the short positions were of equal magnitude, and the trading simulation was undertaken out of sample from the formation of the pairs on a rolling 125 day basis.

The results of this study are subject to a number of caveats, primarily with respect to the associated costs. Firstly, the brokerage fees included were 10 bips per trade, which are substantially lower than an individual investor would pay and in line with the expected costs of an institutional investor. Thus, with respect to brokerage costs, an individual investor would yield substantially lower after-fee returns.

More substantially, scrip borrowing costs have not been included in this study due to the unpredictable level of costs, and availability, of scrip on the JSE. The price and availability of scrip borrow on the JSE differs greatly between stock tickers. In addition to the lack of scrip borrowing costs, the potential costs of a short recall are also particularly difficult to forecast and therefore have been excluded from this study. The inclusion of costs that are associated with scrip borrowing would result in reduced after-fee returns.

The calculation of risk-adjusted returns, particularly in the case of Sharpe Ratios, used a risk-free rate of zero. This is due to the strategy being both relatively market neutral and self-funding, as a result of the equal magnitude of the long and short positions.

It was concluded that all 8 of the Pairs trading strategies tested yielded economically and statistically significant before- and after-fee returns. Average annualized before-fee returns ranged from 42,19% to 76,83% for the worst and best performing strategies respectively (with regards to net returns, and not risk adjusted returns). Similarly, after-fee returns ranged from 27,87% to 49,87%. In addition, for the period 2002/06/11 to 2012/04/26, the cumulative before-fee returns of all 8 Pairs trading strategies ranged from 333,53% to 564,50% and outperformed the ALSI (170,30%). Furthermore, despite the substantial drag on before-fee returns that arose as a result of the high frequency of trades required to engage in Pairs trading, the cumulative after-fee returns ranged from 158,22% to 341,50%. Thus, despite the high frequency of trading substantially decreasing the after-fee returns, only 1 out of the 8 Pairs trading strategy underperformed the ALSI on an after brokerage costs basis. It remains to be seen whether the outperformance would be eroded by scrip borrowing costs or not.

The statistically significant outperformance of Pairs trading is a violation of the Efficient Market Hypothesis (EMH), even in its Weak Form. The Weak Form EMH states that an investor cannot generate significant outperformance through information contained in past prices, while Pairs trading appears to have significantly outperformed the ALSI by arbitraging diversions from a historic price relationship.

A consequence of a Pairs trading strategy having equal long and short positions and, furthermore, pairs tended to naturally pair from the same sector, is that a Pairs trading strategy is generally fairly close to being market neutral. The market neutrality becomes even greater when sector restrictions were imposed, due to the paired shares being more fundamentally similar when from the same sector (as they are influenced by the same external variables). This is evident in the low resultant standard deviations of all of the Pairs trading strategies. The average Unrestricted Pairs trading strategy's standard deviations ranged from 0,06 to 0,11. The effect of imposing sector restrictions on portfolios resulted in marginal reductions in the resultant standard deviations when compared to their respective Unrestricted portfolios. To illustrate this, the Sector Restricted (2;-2) strategy yielded a standard deviation of 0,10 and the Unrestricted (2;-2) strategy yielded a standard deviation of 0,11.

Significantly, and in contradiction to the findings of Gatev *et al.* (2006) and Do and Faff (2009), the Unrestricted sample of pairs outperformed its comparative Sector Restricted portfolios with respect to both before- and after-fee returns. Applying a sector restriction to the construction of portfolios did however result in marginally decreased standard deviations as a result of pairing shares that are more fundamentally similar, and therefore exposed to similar macroeconomic factors. However, significantly, under all three Sector Restricted strategies that were tested, the reductions in returns (when compared to the Unrestricted sample) were relatively larger than the reductions in standard deviations. Therefore the before- and after-fee Sharpe Ratios of the Sector Restricted portfolios lagged those of their comparable Unrestricted portfolios. Before- and after-fee Sharpe Ratios (calculated over cash due to the low risk nature of Pairs trading and the self-funding nature of Pairs trading – the formula justification is supplied in the methodology) of the Sector Restricted strategies ranged from 6.96 to 7.82 and 3.02 to 4.15 respectively. The comparative (excluding un (3;-0,5) and un (2;-1) as they aren't comparative portfolios) Unrestricted Sharpe Ratios were 7.16 to 7.99 and 3.16 to 4.39 respectively. Therefore, applying sector restrictions to the formation of pairs for a Pairs trading strategy on the JSE appears to have resulted in underperformance relative to a strategy trading a portfolio of pairs constructed in the absence of sector restrictions, despite the marginally reduced risk. Of further significance, under the Unrestricted sample, a weak positive relationship between the number of mixed pairs (from different sectors) in a portfolio and the return yielded was observed, further indicating that an Unrestricted sample of pairs is likely to yield improved relative performance on the JSE.

Significantly, reiterating the conclusions of prior literature, returns (before- and after-fee) were found to have declined substantially over time. The average before-fee (after-fee) returns declined substantially under the best performing strategy (based on returns, and not risk-adjusted returns), from 39,16% (28,48%) in the first quarter of the study to 23,70% (13,65%) in the last quarter of the study. The declining returns occurred for all strategy iterations tested in this study. This is a phenomenon that has been documented on the S&P500 by Gatev *et al.* (2006) and Do and Faff (2009), the Turkish stock exchange by Bolgun *et al.* (2009) and the Brazilian stock exchange by Perlin (2007). However, while Do and Faff (2009) concluded that, on average, the after-fee returns yielded by Pairs trading on the S&P500 had become statistically insignificant over time, it appears that economically and statistically significant after-fee returns remain achievable on the JSE through a Pairs trading strategy. It remains to be seen whether this outperformance is completely eroded, to the point of statistical insignificance, over time, as it appears to have on the S&P500. In addition to the declining returns over time, the standard deviation of returns yielded by Pairs trading appears to have also declined over time, from 0,125 to 0,086 for the best performing strategy. It was surmised by Gatev *et al.* (2006) that the decline in both returns and standard deviations yielded by Pairs trading over time could be due to a declining exposure to an unknown latent risk factor.

Significantly, despite returns declining over time, returns yielded by Pairs trading appear to have increased substantially during periods of increased market stress, due to the elevated levels of market volatility. Most notably from the middle of 2007 until the middle of 2009 all of the Pairs trading strategies appear to have yielded increased relative returns. Furthermore, substantially higher returns were yielded in the first period of the study (late 1998). While this period was a period of increased market stress, the outcome could be an outlier due to it being an isolated and drastic spike in returns.

A number of different opening and closing parameters were tested. The base set of rules, as chosen with reference to prior literature, was the (2;0) strategy. Under the (2;0) strategy, a pair would be opened when the normalized prices of the paired shares were at a 2 standard deviation spread from their historical mean, and closed at the subsequent convergence (to the historical mean) of the normalized prices (a 0 standard deviation spread). The average annualized after-fee return of the Unrestricted (2;0) strategy was 29,47% and the Sharpe Ratio (over cash) was 3.16.

The opening signal of 2 standard deviations appears to have remained the best performing opening parameter when compared to the other opening parameter that was tested, namely 3 standard deviations. This was a result of a more substantial number of pairs opening in each trading period (on average 19,86 of the 20 pairs opened in every trading period and comparatively only 17,28 pairs opened under the 3 standard deviation opening signal). A higher number of pairs opening in a trading period results in a more substantial number of sources of return generation for the strategy. However, the closing parameter of 0 standard deviations was found to be sub-optimal, and altering the closing parameter resulted in improved performance of the Pairs trading strategy.

It appears to be beneficial to the returns yielded by a Pairs trading strategy to have a longer (wider spread) holding period for each pair that opens. A longer holding period serves to increase the return generated by each pair that opens and closes. A closing parameter of -0,5 standard deviations (the pairs are only closed when the relative prices of the shares move by a half standard deviation spread in the opposite direction to when it opened) resulted in the highest Sharpe Ratio (risk adjusted return measure); an average annualized before-fee (after-fee) return of 70,54% (37,88%) and Sharpe Ratio of 7.99 (3.88). Furthermore, a closing parameter of -2 standard deviations resulted in the highest before- and after-fee returns; an average annualized before-fee (after-fee) return of 76,83% (49,87%) and Sharpe Ratio of 7.16 (4.39).

Further analysis was done on the Top20 portfolio, to determine which pairs within it yielded superior risk and return characteristics, namely, the pairs with the closer or weaker historical price relationships. This was done through creating an additional 2 portfolios within the Top20 portfolio, one of the 5 closest pairs and another of the 5 weakest pairs. The results arising from this were mixed, and therefore it is inconclusive whether closer pairing is beneficial or detrimental to Pairs trading returns.

It therefore appears that Pairs trading has been, and continues to be, a low risk strategy capable of yielding significantly positive before- and after-fee returns on the JSE. However, it remains to be tested whether the returns yielded by Pairs trading are resilient to the additional costs associated with scrip borrowing that is required to short the shares in the market. Furthermore, it remains to be seen whether the observed declining profitability of the strategy will continue into the future and follow the suit of the S&P500 and begin to yield insignificant returns.

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9 Appendix

Detail for Tables:

R= Return
SD = Standard Deviation
SR = Sharpe Ratio
ASSD = Average Sum of Squared Distances
ANOP = Average Number of Open Pairs
MR = Monthly Return
NoT = Number of Trades
ATL = Average Trade Length
RPT = Return Per Trade

Calculated as follows:

ASSD: The average of the sum of the Sum of Squared Distances of the 20 pairs that make up the portfolio.

ANOP: The number of open pairs is tracked daily, and averaged for the entire trading period.

MR: The 125 day (roughly 6 months) return is converted to an annual return, and then to a monthly return using the equations:

Annual: $R_{annual} = (1 + r)^2 - 1$

Monthly: $R_{monthly} = \sqrt[12]{(1 + r)} - 1$

NoT: A binary calculation is input to excel to return a 1 when a position is opened, else a 0. Another binary calculation is input to return a 1 when a position is closed, else a 0. At the end of each period, these are summed to give the number of trades put on. This figure is then multiplied by two, as each trade that is opened or closed requires a long position to be taken in one stock and a short position in another.

ATL: The total number of days each pair is open is calculated, and then all 20 are summed. This number is divided by the number of pair trades opened (half of the NoT), to ascertain the average length a pair is open.

RPT: The trading period return is divided by the NoT.

Table 11.1 - Stock Ticker, Name and Sector

Ticker	Name	Sector
ASA	Barclays Africa Group Ltd (Now BGA)	Findi
AIP	Adcock Ingram Holdings Ltd	Findi
AFE	Aeci Ltd	Findi
ARI	African Rainbow Minerals Ltd	Resi
ABL	African Bank Investments Ltd	Findi
AGL	Anglo American PLC	Resi
AMS	Anglo American Platinum Ltd	Resi
ANG	AngloGold Ashanti Ltd	Resi
ACL	ArcelorMittal South Africa Ltd	Resi
APN	Aspen Pharmacare Holdings Ltd	Findi
AEG	Aveng Ltd	Findi
AVI	AVI Ltd	Findi
BAW	Barloworld Ltd	Findi
BIL	BHP Billiton PLC	Resi
BVT	Bidvest Group Ltd	Findi
BAT	Brait SE	Findi
CPL	Capital Property Fund	Findi
CSO	Intu Properties PLC (now ITU)	Findi
CFR	Cie Financiere Richemont SA	Findi
CLS	Clicks Group Ltd	Findi
CML	Coronation Fund Managers Ltd	Findi
DTC	DataTec Ltd	Findi
DSY	Discovery Ltd	Findi
EXX	Exxaro Resources Ltd	Resi
FSR	FirstRand Ltd	Findi
FPT	Fountainhead Property Trust	Findi
GFI	Gold Fields Ltd	Resi
GRT	Growthpoint Properties Ltd	Findi
HAR	Harmony Gold Mining Co Ltd	Resi
HCI	Hosken Consolidated Investments Ltd	Findi
HYP	Hyprop Investments Ltd	Findi
ILV	Illovo Sugar Ltd	Resi
IMP	Impala Platinum Holdings Ltd	Resi
IPL	Imperial Holdings Ltd	Findi
INL	Investec Ltd	Findi
INP	Investec PLC	Findi
JDG	JD Group Ltd South Africa	Findi
KIO	Kumba Iron Ore Ltd	Resi
LBH	Liberty Holdings Ltd	Findi
LON	Lonmin PLC	Resi
MSM	Massmart Holdings Ltd	Findi
MDC	Mediclinic International Ltd	Findi
MMI	MMI Holdings Ltd South Africa	Findi
MNP	Mondi PLC	Resi
MPC	Mr Price Group Ltd	Findi
MTN	MTN Group Ltd	Findi

MUR	Murray & Roberts Holdings Ltd	Findi
NPK	Nampak Ltd	Findi
NPN	Naspers Ltd	Findi
NED	Nedbank Group Ltd	Findi
NTC	Netcare Ltd	Findi
NHM	Northam Platinum Ltd	Resi
OML	Old Mutual PLC	Findi
PIK	Pick n Pay Stores Ltd	Findi
PFG	Pioneer Foods Ltd	Findi
PPC	PPC Ltd	Findi
RDF	Redefine Properties Ltd	Findi
REI	Reinet Investments SCA	Findi
REM	Remgro Ltd	Findi
RES	Resilient Property Income Fund Ltd	Findi
RLO	Reunert Ltd	Findi
RMH	RMB Holdings Ltd	Findi
SAB	SABMiller PLC	Findi
SLM	Sanlam Ltd	Findi
SNT	Santam Ltd	Findi
SAP	Sappi Ltd	Resi
SOL	Sasol Ltd	Resi
SHP	Shoprite Holdings Ltd	Findi
SPP	The Spar Group Ltd	Findi
SBK	Standard Bank Group Ltd	Findi
SHF	Steinhoff International Holdings Ltd	Findi
TKG	Telkom SA SOC Ltd	Findi
TFG	The Foschini Group Ltd	Findi
TBS	Tiger Brands Ltd	Findi
TON	Tongaat Hulett Ltd	Resi
TRE	Trencor Ltd	Findi
TRU	Truworths International Ltd	Findi
TSH	Tsogo Sun Holdings Ltd	Findi
VOD	Vodacom Group Ltd	Findi
WHL	Woolworths Holdings Ltd South Africa	Findi

TKG	TFG	TBS	TON	TRE	TRU	TSH	VOD	WHL	
226,53213	64,1926253	17,7779161	68,7225196	74,7736417	57,3453888	305,088477	223,314612	49,2615912	ASA
177,01195	42,2853854	19,8359283	58,7352993	42,3204494	42,3895221	357,696753	191,994864	24,1033883	AIP
132,647324	40,7688153	88,8894015	143,224238	48,4000763	53,9664851	441,805175	111,127692	42,2094196	AFE
188,571508	63,0340665	32,6592815	54,8514585	61,0829427	53,2017902	340,082031	221,684141	55,6721935	ARI
152,189572	34,6640386	35,3506508	85,9563338	53,0904439	39,2661655	347,486044	205,177571	42,4949792	ABL
152,658147	227,581716	235,015821	164,774787	276,997305	271,859504	244,777431	263,534871	280,860708	Agl
79,1599726	183,032523	219,719923	170,720556	228,94704	236,894998	313,476246	199,375287	233,0984	AMS
151,226278	252,566986	342,980357	314,988074	283,845958	290,910568	349,197579	171,291071	294,793707	ANG
355,698135	440,352729	372,498648	313,337239	414,116728	429,993074	54,497661	385,312256	423,911393	ACL
111,854481	16,9662644	67,4364394	113,494266	54,2636935	34,6089149	422,190877	137,00211	43,6130328	APN
222,83641	259,295905	279,914419	213,630837	289,015595	274,187745	202,523062	301,660227	295,121485	AEG
185,628348	31,0713109	26,4111073	84,3967284	34,8546284	18,6289482	369,177311	167,054582	14,6452885	AVI
108,943733	87,9626259	90,6000432	76,6551789	120,850501	119,034718	354,023663	185,003662	112,882988	BAW
261,266298	228,848246	166,613175	128,165515	242,976777	228,696294	168,032795	330,728564	239,50729	BIL
253,237536	96,9307519	44,127451	84,4198225	94,8888729	74,247407	277,849506	250,189705	71,8426556	BVT
220,758827	188,772995	197,70183	175,895419	190,493819	202,119246	363,656527	174,061641	178,224851	BAT
130,649823	108,818784	94,4922398	98,1266089	161,156096	139,82185	308,387375	188,117455	140,003207	CPL
238,597476	329,937544	278,231283	209,557383	347,357564	356,769806	101,5055	382,882126	358,891487	CSO
219,573822	55,4554746	21,3788766	60,6042	68,8033297	49,3858287	336,688849	209,065957	46,1088152	CFR
132,231357	14,8954307	54,8876373	102,540205	30,754638	15,459204	438,371984	118,875486	14,8500981	CLS
118,051297	53,8952157	108,975341	140,186897	62,4962208	77,3312732	443,888777	132,015673	63,0624412	CML
169,599003	36,2284801	56,4812054	125,446984	32,0762584	33,7039938	405,274924	147,808097	16,4752302	DTC
138,308629	21,4963262	58,5367226	105,889463	18,8375085	21,8946856	438,731244	148,914473	17,9936722	DSY
180,974086	53,8066902	21,504242	51,2536127	57,5542312	52,5764173	347,0699	206,555438	45,3225801	EXX
162,482039	27,6580039	37,5859073	75,2619253	51,9957539	34,7439004	413,089575	148,973912	35,4191149	FSR
168,263355	40,1572243	32,0017195	73,8787864	41,8742823	41,7762439	350,499088	225,136428	37,6842427	FPT
146,022036	263,462327	356,256049	329,65479	294,800983	299,621381	336,020891	179,489223	313,592856	GFI
131,817386	19,5068017	54,709957	109,704896	21,0797695	19,7469956	427,967411	148,967441	22,1391339	GRT
254,193584	358,266162	402,799016	358,518083	386,682621	376,346674	240,265802	242,769414	392,616614	HAR
149,959989	25,6281872	48,9359936	100,557316	19,0266714	20,8658944	406,767646	145,124762	17,1272094	HCI
145,384955	27,3071675	39,6539782	93,1081797	20,2752094	23,9345672	407,604259	158,072085	13,5962793	HYP
391,475319	379,611726	296,646587	243,931553	343,02153	352,939818	148,787434	320,424003	337,746552	ILV
200,731244	175,204105	132,647879	83,2830234	213,379159	206,414776	266,177395	257,414518	200,172738	IMP
176,091563	27,3931757	46,7541141	101,25611	37,8571105	16,732569	370,697393	179,287682	23,8576034	IPL
160,785313	40,5351515	36,5431167	70,7219122	58,5730419	45,689928	350,256206	202,337595	46,8064501	INL
178,384576	51,1417677	36,9679132	61,7926651	65,1894738	51,5794029	340,503238	211,230988	54,1279675	INP
244,469123	331,283272	299,613262	210,247933	366,918216	344,917142	146,164023	308,078599	363,876653	JDG
224,345918	86,1585732	37,3608189	70,3809632	67,4474054	65,3023465	311,696331	234,998573	57,7274309	KIO
137,082755	23,8702717	40,2729962	93,3617333	28,6224099	28,4042565	394,281134	173,0582	28,0768509	LBH
270,134949	317,595436	249,713283	169,765152	342,831497	336,062026	113,350168	356,851828	336,770749	LON
147,272998	16,8181989	60,273427	121,81577	34,3126326	20,2333991	441,780064	112,698399	18,2710893	MSM
118,704497	27,6209693	65,3891219	111,088841	49,3568811	41,5804177	410,146989	136,978546	37,8086592	MDC
114,659712	22,0340543	58,1486383	105,431211	31,1067105	34,0647829	426,399787	133,939215	22,1938947	MMI
191,793839	37,6657124	29,3970462	73,9539262	39,9140111	30,5188111	375,024707	198,456222	30,1409829	MNP
172,375966	23,3804934	42,1678775	104,339411	18,9351303	9,63727584	419,049722	139,971291	5,27131357	MPC
247,160281	245,175119	220,581992	232,304362	265,782727	229,983566	183,54587	261,978246	260,521667	MTN
161,518215	294,627252	312,200607	252,420793	354,334719	348,779394	165,393429	283,347513	349,932064	MUR
167,560726	25,5906364	37,8989087	95,572288	20,4301815	14,2754229	391,868218	179,551021	11,1286877	NPK
160,05912	75,8286605	114,377351	141,813419	130,129063	90,0730381	364,629671	160,876217	118,246747	NPN
154,076177	19,789346	51,0796882	104,01976	54,6851816	31,3988404	421,819851	113,113323	31,9180886	NED
89,5411135	105,726867	120,905493	88,3843521	148,990495	136,263828	328,71526	180,451264	137,748705	NTC
199,25933	211,290854	137,212265	81,7646526	204,797608	229,561214	230,802565	278,856802	197,970584	NHM
186,967029	139,914503	141,23251	133,566787	161,876785	142,613251	292,858887	238,000573	168,13826	OML
170,058793	51,6113917	57,4837304	96,9918565	96,9085085	64,6217736	329,838676	201,9472	75,9563449	PIK
236,004414	201,94999	175,182623	135,225727	193,10212	203,523367	292,435353	213,552435	182,647014	PFG
264,723664	311,303002	285,715909	219,292898	367,223237	349,959748	155,914666	303,885059	355,197689	PPC
185,128533	57,5191342	32,6262856	71,1441162	56,326334	55,6473132	319,3921	238,587273	49,6085086	RDF
288,559982	309,806322	234,099851	198,570241	313,400031	311,720531	96,7639106	378,764322	317,137784	REI
165,286074	27,5075678	24,8147363	74,9116754	41,6254021	26,6377044	386,634932	161,605598	24,7406813	REM
109,928141	31,0199525	64,7092521	105,206178	40,5318353	48,066943	417,144602	145,980084	33,4720774	RES
176,038791	192,475299	188,869852	122,885985	244,682233	230,532751	265,823677	262,272116	243,382007	RLO
149,204703	35,4813527	56,5736841	105,434416	46,0324353	38,3240011	440,302841	109,321378	29,8272626	RMH
73,6948092	132,541658	197,739001	175,144146	178,904382	180,394245	368,817417	162,81669	183,211796	SAB
233,189999	66,7893618	50,4392482	110,44604	54,8068851	36,2642037	334,501185	206,560113	48,995041	SLM
237,800512	186,268354	155,841308	112,961283	182,277144	169,107554	281,811587	251,013023	177,598825	SNT
245,417002	355,969315	335,424216	251,227975	400,810226	384,830356	127,687554	317,398477	401,302769	SAP
158,177938	210,180369	202,170768	148,450743	251,854877	248,069366	237,808061	273,328046	253,501154	SOL
191,21067	38,5793963	38,6578078	108,344042	23,7877593	21,6482842	377,17352	175,374052	11,1756629	SHP
160,863252	24,4611687	31,3337111	82,2732011	31,531274	19,3145593	400,524986	146,388524	12,9203293	SPP
217,67903	47,1772667	14,1091602	69,5353245	51,282626	34,3913257	344,577281	199,33386	31,0291333	SBK
204,189977	215,299107	176,954665	110,040125	249,880403	231,542587	221,284367	280,644185	244,524125	SHF
0	128,746339	194,406398	191,137955	157,095101	169,416009	355,95995	133,727794	167,318519	TKG
	0	42,2268244	103,139853	30,7761873	14,5900243	415,196278	144,354263	15,2503594	TFG
		0	56,916924	56,5270616	42,8162007	341,026977	204,10572	32,5281858	TBS
			0	115,543257	113,717194	300,721584	249,289605	99,6037571	TON
				0	21,6064501	413,543973	170,52246	17,6807429	TRE
					0	414,45635	140,034848	7,37912652	TRU
						0	407,970961	404,940884	TSH
							0	154,723501	VOD
								0	WHL

Table 11.2 – A Portion of the SSD Matrix (Chosen Pairs Highlighted)

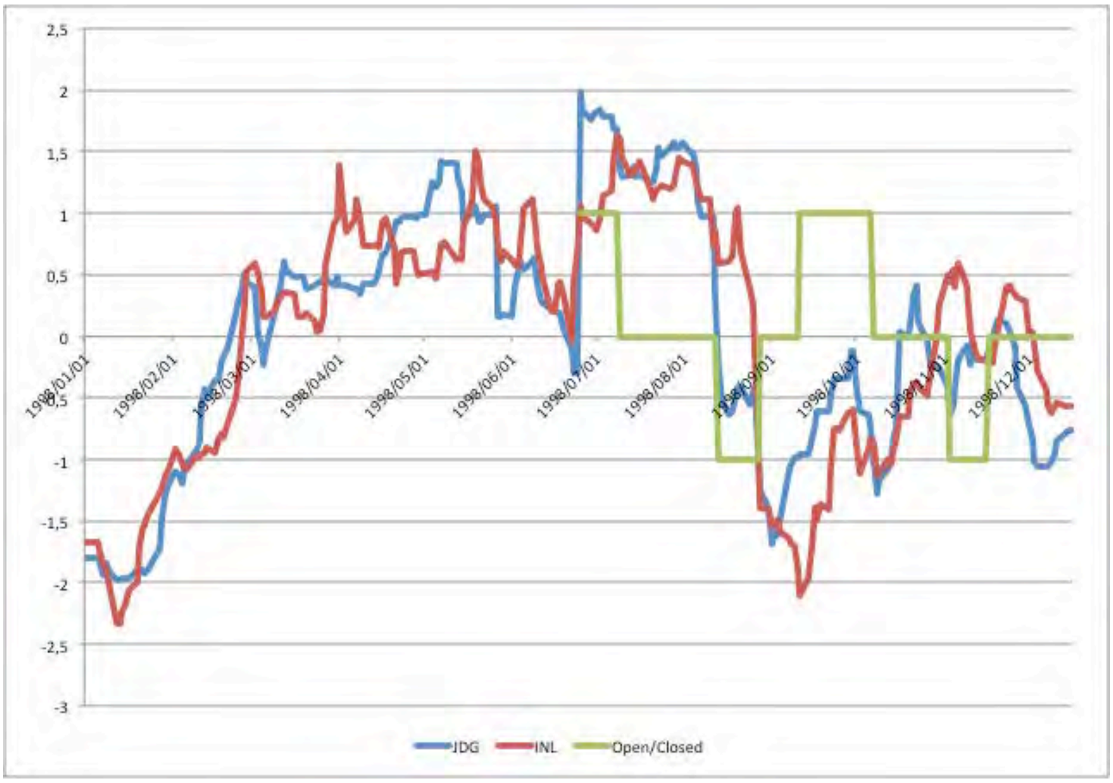

Figure 10 – Normalized Prices of Paired Shares + Open/Close of the Pair