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PAIR TRADING STRATEGY IN INDIAN CAPITAL MARKET: A COINTEGRATION APPROACH

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ABSTRACT

Pairs trading methodology was designed by a team of scientists from different areas to use statistical methods to develop computer based trading platforms, where the human subjectivity had no influence whatsoever in the process of making the decision of buy or sell a particular stock. Such systems were quite successful for a period of time, but the performance wasn't consistent after a while.

The objective of this study was to analyze the univariate and multivariate versions of the classical pairs trading strategy. Such framework is carefully exposed and tested for the Indian financial market by applying the trading algorithm over the researched data. The performance of the method regarding return and risk was assessed with the execution of the trading rules to daily observations of 26 assets of the Indian financial market using a database from the period of 2008 to 2010.

The research shows that the return from the pair trading strategy is much higher than the return from naïve investment.

Key Words: Pairs Trading, Multivariate, Bivariate, Hedgers

INTRODUCTION

The market efficiency theory has been tested by different types of research. Such concept assumes, on its weak form, that the past trading information of a

stock is reflected on its value, meaning that historical trading data has no potential for predicting future behavior of asset's prices. The main theoretical consequence of this concept is that no logical rules of trading based on historical data should have a significant positive excessive return over some benchmark portfolio.

In opposition to the market efficiency theory, several papers have showed that past information is able, in some extent, to explain future stock market returns. Such predictability can appear in different ways, including time anomalies (day of the weak effect) and correlation between the asset's returns and others variables. A respectable amount of papers have tried to use quantitative tools in order to model the market and build trading rules. The basic idea of this type of research is to look for some kind of pattern in the historical stock price behavior and, using only historical information, take such pattern into account for the creation of long and short trading positions.

The *equalized* strategy, in addition to holding stocks long and short in equal dollar balance, adds a permanent stock index futures overlay in an amount equal to the invested capital. The *hedge* strategy also holds stocks long and short in equal dollar balance but also has a variable equity market exposure based on a market outlook. The variable market exposure is achieved using stock index futures. Do, Faff and Hamza [1](2006) structure the different approaches to long/short equity investing slightly differently to Jacobs and Levy (1993) and, in doing so, attempt to clarify the position of a pairs trading strategy amongst other seemingly related hedge fund strategies. Do et al (2006) note that due to the strategies' fundamentals, which involve the simultaneous purchase of under-valued stocks and the shorting of over-valued stocks, pairs trading is essentially a form of long/short equity investing. After consulting academic sources and informal, internet-based sources, they declare that long/short equity strategies can be classified as either *market neutral* strategies or *pairs trading* strategies. This interpretation can be reconciled to that proposed by Jacobs and Levy [2] (1993) since all three of their long/short strategies include elements of market

neutrality, even if the resulting portfolio may exhibit some market risk. Ultimately, the difference between the strategies originates from their definition of "mispricing". The long/short strategies described by Jacobs and Levy (1993) refer to an *absolute* mispricing.

Both classes of strategies, as defined by Do et al (2006) require the simultaneous opening of long and short positions in different stocks and thus, fall under the "umbrella of long/short equity investments" (Do et al, 2006 p.1). Debate continues amongst academics and practitioners alike regarding the role, if any, of market neutrality for a successful pairs trading strategy.

Pair trading strategy is a very ancient concept and used by the investors extensively worldwide. The strategy by its nature has the potential of bagging the arbitrage opportunity on a varied timeframe as well can be used for hedging the existing exposure of an asset by finding suitable pair for it. In India there is a very few evidence of organized pair trading strategy. The study aims to find out the potential and applicability of the pair trading strategy in Indian capital market. It's a known fact that pair trading requires understanding of the industry pairs and their behavioral nature. The study brings out the nature of variability of the pairs and their applicability.

REVIEWS OF LITERATURE

"Pair trading is one of Wall Street's quantitative methods of speculation which dates back to the mid-1980s (Vidyamurthy). There are many methods of pairs trading, out of which 2 most important are distance trading and cointegration model.

The distance method is used in Gatev [3] et al (1999) and Nath [4] (2003) for empirical testing where as the Cointegration method is detailed by Vidyamurthy (2004).The application of this particular strategy has

3 already been conducted for financial time series. This includes the work of Nath (2003), Gatev et al (1999) and, more recently, Perlin (2006b)[5].

In opposition to the market efficiency theory, several papers have showed that past information is able, in some extent, to explain future stock market returns. Such predictability can appear in different ways, including time anomalies (day of the weak effect, French (1980)) and correlation between the asset's returns and others variables, Fama and French [6] (1992). A substantial review on the market efficiency subject can be found at the papers of Fama [7] (1991) and Dimson e Mussavian [8] (1998).

Jacobs and Levy (1993) categorize long/short equity strategies as market neutral, equitized, and hedge strategies. The market neutral strategy holds both long and short positions with equal market risk exposures at all times. Takashi Kanamura, Svetlozar T. Rachev and Frank J. Fabozzi [9] (1997) examined the usefulness of a hedge fund trading strategy ("pairs trading") as applied to energy futures markets, focusing on the characteristics of energy futures. The comparative statics of the expected return using the model indicated that both strong mean reversion and high volatility of price spreads give rise to high expected returns from pairs trading.

Alexander, C., Dimitriu, A [10] (2000) in the paper 'The Cointegration Alpha: Enhanced Index Tracking and Long-Short Market Strategies' has shown that, when applied to constructing trading strategies, the co-integration technique produces encouraging results.

Vidyamurthy [1]2004), in his paper on pair trading strategies, enlighten about the details of the algorithms. The paper emphasized on the normalized prices of the assets rather than absolute prices.

Chris Brooks, Apostolos Katsaris and Gita Persand [12] (2005) employed the omega ratio, an approach that considers the entire distribution of returns and not just the mean and variance, the timing strategy based on speculative bubbles is the second best and all approaches outperform a buy-and-hold equities rule.

Steven Skiena [13] (2005) in his research has shown empirically, how to generate excess return through the effective use of the pair trading algorithm in NYSE.

Juan Ledesma Padilla [14] (2005) in his research paper "Market Neutral" Strategy between Telecom Arg and Nortel Inversora shows long run relationships within valuation models, is expected that mean reverting forces are put in place and price converges to its fair value.

Binh Do, Robert Faff and Kais Hamza [15] (2006) proposed a general approach to model relative mispricing for pairs trading purposes, in a continuous time setting. The novelty in this approach lies in its quantification of mean reversion behavior, taking into account theoretical asset pricing relationships.

Marcelo Scherer Perlin [16] (2006) has suggested a univariate approach of pair trading considering the market transaction cost and extended his own work by suggesting a multivariate approach of pair trading. The basic idea of this proposed approach is to build a pair for each stock based on information of others stocks, instead of just finding one, as was done in the univariate method.

Joseph Engelberg, Pengjie Gao and Ravi Jagannathan [17] (2007) investigated the source of profits from pairs trading. They documented that the profitability from pairs trading is strongly related to the way information diffuses across the stocks in the pair and the frictions which stifle this information flow.

Michael Bock and Roland Mestel [18] (2008) in their paper of A regime-switching relative value arbitrage rules how the relative value arbitrage rule ("pairs trading") is a well-established speculative investment strategy on financial markets, dating back to the 1980s.

Christian Oliver-Ewald, Ian Gregory and Pieter Knox [19] (2010) showed in their paper OU, CIR and GARCH Dilution as a Sequential Stopping Problem for Pairs Trading that, how arbitrarily sized long/short baskets whose port- folio

value is modelled with spread or ratio of any asset weighting can be treated as a sequential stopping problem.

STATEMENT OF PROBLEM

Hedging techniques are used by corporate and financial intermediaries to avoid the unforeseen loss and to reduce the risk in existing exposure. On the other hand the arbitrage is the tool for opportunity scouting in the capital and derivative market. Pair trading is such a kind of investment strategy which offers both hedging and arbitrage opportunity. In Indian capital market pair trading is a very little known concept and it requires extensive research to bring out the crux and the advantages of pair trading strategies. Applicability of the pair trading strategy as an effective hedging and arbitrage tool is not yet fully known. But the investment strategy has a lot of potential. To address this existing gap this study has been undertaken.

OBJECTIVES OF RESEARCH

The present study has been undertaken with the following objectives:

- To find out the effectiveness of the Pair trading strategy.
- To find out the natural pairs (Univariate) for each stocks.
- To build artificial pairs (bivariate and trivariate) for each stock.
- To compare the pair trading strategy return with Naïve return (Simulated return).

HYPOTHESIS

For each class of pairs the trading strategy return is compared with simulated return. For each comparison blanket hypothesis is:

Null Hypothesis H_0: Means of strategy return and simulated return are equal

$$\mu strategy = \mu Naive$$

Alternate Hypothesis H_1: Means of strategy return and simulated return are not equal

$$\mu strategy \neq \mu Naive$$

SAMPLING PROCEDURE

For secondary data analysis the stocks were chosen from the NSE listed firms. 4 most important industries are chosen as the scope of the study. These industries are Banking Industry, IT and ITes Industry, Infrastructure Industry and Pharmaceutical Industry

In these industries the cut off liquidity is set and the stocks above that level is taken as sample stocks. Cut off liquidity is set in terms of average trade volume in study period and it is 800000. All stocks above this level are considered as eligible to be sample stock in this study.

DATA ANALYSIS

In the selected 4 industries out of 26 sample stocks, industry wise all possible pairs are formed. Pairs are made industry wise because the volatility in the pair returns is less within the same industry, whereas between the industry pair's standard deviation is high. Hence cross industry pairs are not a feasible option for investment and hence excluded. These pairs include:

- All Natural pairs
- All Artificial pairs with 2 stocks and
- All Artificial pairs with 3 stocks

Artificial pairs with more than 3 stocks are not considered as the sample of the study, because the transaction cost involved is very high and profit potential reduces accordingly. Moreover it's been studied that the correlation between the stock and its pair with more than 3 stocks is considerably low and does not give any significant return. So, artificial pairs with more than 3 stocks are excluded from the scope of this study.

Thus a total of possible 445 pairs are formed for analysis of their return in the chosen study period. The analysis has been done separately for

- Natural pairs
- Artificial pair with 2 stocks formed using equal weigh method
- Artificial pair with 3 stocks formed using equal weight method
- Artificial pair with 2 stocks formed using correlation weight method
- Artificial pair with 3 stocks formed using correlation weight method

Nature of Pair	No of Pairs
Natural pairs	73
Artificial pair with 2 stocks formed using equal weigh method	101
Artificial pair with 3 stocks formed using equal weight method	85
Artificial pair with 2 stocks formed using correlation weight method	101
Artificial pair with 3 stocks formed using correlation weight method	85
Total No of Pairs	445

Table 1: No. of pairs

Return for each pair is calculated for 9 selected trading signal. This wide array of trading signal gives us the insight about the effect of transaction cost on total no. of trade and its impact on the average return, risk-return behavior of the pair trading strategies etc. The signal for trade opening, square off and spread for all 9 signals are tabulated below:

Trade opening	Square off	Spread
0.7 or -0.7	0.5 or -0.5	0.2
0.7 or -0.7	0.4 or -0.4	0.3
0.6 or -0.6	0.4 or -0.4	0.2
0.6 or -0.6	0.3 0r -0.3	0.3
0.5 or -0.5	0.3 0r -0.3	0.2
0.5 or -0.5	0.2 or -0.2	0.3
0.4 or -0.4	0.2 or -0.2	0.2
0.4 or -0.4	0.1 or -0.1	0.3
0.3 0r -0.3	0.1 or -0.1	0.3
ei is the unit of measurement		

Table 2: Spread and Trade signals

Natural Pair

For 73 natural pairs, trade signal wise generated no of trades are plotted to get the trend.

Trade signal	Avg. No. of Trades
0.7/0.5	5.6
0.7/0.4	4.7
0.6/0.4	7.0
0.6/0.3	5.6
0.5/0.3	8.2
0.5/0.2	6.7
0.4/0.2	10.3
0.4/0.1	7.9
0.3/0.1	11.3

Table 3: Natural pair Avg No. of trades

All the 73 pairs are not found feasible for trading. Pairs with low correlation with the trading asset are having higher volatility and hence give uncertain return. So, a cut off correlation is derived for this segment, which is

shown graphically below. The cut off correlation value is 0.78. For further analysis the pairs with correlation above 0.78 are only considered as they follow conventional risk-return relationship. 49 such pairs are found in this segment.

For these 49 pairs individual sample 2-tail t-test is done for each trading signal to check the statistical significance of the obtained returns. The test result includes mean return for each signal, standard deviation of each signal set, and t statistics. The test result is shown below:

One-Sample Statistics				
Trade Signal	N	Mean	Std. Deviation	Std. Error Mean
0.7/0.5	49	7.657	15.660	2.237
0.7/0.4	49	8.798	25.224	3.603
0.6/0.4	49	4.247	6.465	0.924
0.6/0.3	49	3.423	2.907	0.415
0.5/0.3	49	2.378	1.878	0.268
0.5/0.2	49	2.460	1.783	0.255
0.4/0.2	49	1.961	2.071	0.296
0.4/0.1	49	2.369	3.464	0.495
0.3/0.1	49	1.410	1.163	0.166

Table .4: mean stat for natural pairs

One-Sample Test						
	Test Value = 0					
Trade Signal	T	Df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
0.7/0.5	3.423	48	0.001	7.657	3.159	12.155
0.7/0.4	2.442	48	0.018	8.798	1.553	16.044
0.6/0.4	4.598	48	0.000	4.247	2.390	6.104
0.6/0.3	8.243	48	0.000	3.423	2.588	4.258

0.5/0.3	8.863	48	0.000	2.378	1.839	2.918
0.5/0.2	9.660	48	0.000	2.460	1.948	2.972
0.4/0.2	6.628	48	0.000	1.961	1.366	2.556
0.4/0.1	4.788	48	0.000	2.369	1.374	3.364
0.3/0.1	8.485	48	0.000	1.410	1.076	1.744

Table .5: t stat for natural pairs

For 48 degree of freedom t critical value (2 tailed) at 95% confidence level is 2.008. In the test result all the obtained t values are greater than the critical value, which suggests that the return series of every trade signal are statistically significant at 95% confidence level. In other words, it suggests that the average returns are feasible and reproducible in the future following the same trade signal.

This pair trading strategy return is statistically compared with the naïve approach return. For the purpose the average of all signal return of every eligible pair is compared with the 1000 random simulation return from the NSE Index in the same time frame of the study. One way ANOVA testing has been done for mean comparison.

Mean of Natural pair strategy returns is = $\mu_{strategy}$ = 386%

Mean of 1000 random return from NSE Nifty 50 index = μ_{Naive} = 16.89%

ANOVA					
natural_pair_simulation					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	635.342	1	635.342	481.458	0.000
Within Groups	1397.477	1059	1.320		
Total	2032.819	1060			

Table.6: ANOVA result for natural pairs

Two series of variables are grouped and tested. Test result signifies that F value is very high compared to Critical F value. Hence the Null hypothesis is

rejected at 99% confidence level. So, the means of Pair strategy return and Naïve return are statistically different. Pair strategy return is much higher than the Naïve return, and hence its recommended to invest in natural pair to cash the arbitrage opportunity.

Artificial Pair with 2 stocks formed using Equal Method

For this segment of bivariate pairs, trade signal wise generated no of trades are plotted to get the trend.

Trade signal	Avg. No. of Trades
0.7/0.5	6.6
0.7/0.4	5.1
0.6/0.4	6.9
0.6/0.3	5.5
0.5/0.3	7.5
0.5/0.2	5.8
0.4/0.2	8.0
0.4/0.1	6.1
0.3/0.1	7.9

Table 7: Avg no. of trade for equal weight method

All the 101 bivariate pairs with equal weigh are not found feasible for trading. Empirical result shows, pairs with low correlation with the trading asset are having higher volatility and hence give uncertain return. So, a cut off correlation is derived for this segment, which is shown graphically below. The cut off correlation value is 0.75. For further analysis the pairs with correlation above 0.75 are only considered as they follow conventional risk-return relationship. 54 such pairs are found in this segment.

For these 54 pairs individual sample 2-tail t-test is done for each trading signal to check the statistical significance of the obtained returns. The test result includes mean return for each signal, standard deviation of each signal set, and t statistics. The test result is shown below:

One-Sample Statistics				
	N	Mean	Std. Deviation	Std. Error Mean
0.7/0.5	54	2.558	1.865	0.254
0.7/0.4	54	3.569	4.632	0.630
0.6/0.4	54	2.631	2.753	0.375
0.6/0.3	54	2.613	2.169	0.295
0.5/0.3	54	7.373	33.520	4.561
0.5/0.2	54	2.219	1.312	0.179
0.4/0.2	54	2.121	2.218	0.302
0.4/0.1	54	3.095	7.591	1.033
0.3/0.1	54	2.102	2.923	0.398

Table 8: Mean stat for bivariate pair: equal

One-Sample Test						
	Test Value = 0					
Trade Signal	t	Df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
0.7/0.5	10.078	53	6.41E-14	2.56E+00	2.05E+00	3.07E+00
0.7/0.4	5.662	53	6.20E-07	3.57E+00	2.30E+00	4.83E+00
0.6/0.4	7.024	53	4.12E-09	2.63E+00	1.88E+00	3.38E+00
0.6/0.3	8.855	53	4.95E-12	2.61E+00	2.02E+00	3.20E+00
0.5/0.3	1.616	53	1.12E-01	7.37E+00	-1.78E+00	1.65E+01
0.5/0.2	12.429	53	2.47E-17	2.22E+00	1.86E+00	2.58E+00
0.4/0.2	7.028	53	4.07E-09	2.12E+00	1.52E+00	2.73E+00
0.4/0.1	2.996	53	4.15E-03	3.10E+00	1.02E+00	5.17E+00
0.3/0.1	5.285	53	2.41E-06	2.10E+00	1.30E+00	2.90E+00

Table 9: t stat for bivariate pairs: equal

For 53 degree of freedom t critical value (2 tailed) at 95% confidence level is 1.997. In the test result all the obtained t values are greater than the critical value, which suggests that the return series of every trade signal are statistically significant at 95% confidence level. In other words, it suggests that the average returns are feasible and reproducible in the future following the same trade signal.

This pair trading strategy return is statistically compared with the naïve approach return. For the purpose the average of all signal return of every eligible pair is compared with the 1000 random simulation return from the NSE Index in the same time frame of the study. One way ANOVA testing has been done for mean comparison.

Mean of Bivariate equal weight pair strategy returns is = $\mu_{strategy}$ = 314%

Mean of 1000 random return from NSE Nifty 50 index = μ_{Naive} = 16.00%

ANOVA					
Artificial_pair_equal_bi_simulation					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	455.68	1	455.689	451.91	1.029E-83
Within Groups	1060.7	1052	1.00835		
Total	1516.4	1053			

Table10: ANOVA result for bivariate (equal) pairs

Two series of variables are grouped and tested. Test result signifies that F value is very high compared to Critical F value. Hence the Null hypothesis is rejected at 99% confidence level. So, the means of Pair strategy return and Naïve return are statistically different. Pair strategy return is much higher than the Naïve return, and hence it's recommended to invest in bivariate equal weight pair to cash the arbitrage opportunity.

Artificial Pair with 3 stocks formed using Equal Method

All the 85 trivariate pairs with equal weigh are not found feasible for trading. Cut off correlation is derived for this segment, which is shown graphically below. The cut off correlation value is 0.67. For further analysis the pairs with correlation above 0.67 are only considered as they follow conventional risk-return relationship. 60 such pairs are found in this segment.

For these 60 pairs individual sample 2-tail t-test is done for each trading signal to check the statistical significance of the obtained returns. The test result includes mean return for each signal, standard deviation of each signal set, and t statistics. The test result is shown below:

One-Sample Statistics				
	N	Mean	Std. Deviation	Std. Error Mean
0.7/0.5	60	2.649	2.272	0.293
0.7/0.4	60	3.942	6.120	0.790
0.6/0.4	60	2.963	2.436	0.314
0.6/0.3	60	2.660	1.660	0.214
0.5/0.3	60	3.932	6.090	0.786
0.5/0.2	60	2.333	1.809	0.233
0.4/0.2	60	1.841	1.892	0.244
0.4/0.1	60	2.335	5.730	0.740
0.3/0.1	60	1.433	1.293	0.167

Table 11: Mean test result: trivariate pars: equal

One-Sample Test						
	Test Value = 0					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
0.7/0.5	9.030	59	1.02E-12	2.649	2.062	3.236

0.7/0.4	4.989	59	5.67E-06	3.942	2.361	5.522
0.6/0.4	9.421	59	2.29E-13	2.963	2.334	3.592
0.6/0.3	12.409	59	4.33E-18	2.660	2.231	3.089
0.5/0.3	5.002	59	5.41E-06	3.932	2.359	5.505
0.5/0.2	9.993	59	2.64E-14	2.333	1.866	2.800
0.4/0.2	7.536	59	3.34E-10	1.841	1.352	2.329
0.4/0.1	3.157	59	0.002513	2.335	0.855	3.815
0.3/0.1	8.589	59	5.57E-12	1.433	1.099	1.767

Table 12: t stat for trivariate pairs: equal

For 59 degree of freedom t critical value (2 tailed) at 95% confidence level is 2.000. In the test result all the obtained t values are greater than the critical value, which suggests that the return series of every trade signal are statistically significant at 95% confidence level. In other words, it suggests that the average returns are feasible and reproducible in the future following the same trade signal.

This trivariate equal weigh pair trading strategy return is statistically compared with the naïve approach return. For the purpose the average of all signal return of every eligible pair is compared with the 1000 random simulation return from the NSE Index in the same time frame of the study. One way ANOVA testing has been done for mean comparison.

Mean of Bivariate equal weight pair strategy returns is = $\mu_{strategy}$ = 268%

Mean of 1000 random return from NSE Nifty 50 index = μ_{Naive} = 17.53%

ANOVA					
Artificial_pair_equal_tri_simulation					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	354.08	1	354.08	1186.861	5.03E-175
Within Groups	315.6365	1058	0.298333		
Total	669.7165	1059			

Table.13: ANOVA result for trivariate (equal) pairs

Two series of variables are grouped and tested. Test result signifies that F value is very high compared to Critical F value. Hence the Null hypothesis is rejected at 99% confidence level. So, the means of Pair strategy return and Naïve return are statistically different. Trivariate equal weigh Pair strategy return is much higher than the Naïve return, and hence it's recommended to invest in trivariate equal weight pair to cash the arbitrage opportunity.

Artificial Pair with 2 stocks formed using Correlation Weight Method

For this segment of correlation weighed pairs, trade signal wise generated no of trades are plotted to get the trend.

Trade signal	Avg. No. of Trades
0.7/0.5	6.7
0.7/0.4	5.1
0.6/0.4	7.1
0.6/0.3	5.6
0.5/0.3	7.5
0.5/0.2	5.9
0.4/0.2	8.0
0.4/0.1	6.2
0.3/0.1	8.0

Table 14: Avg no. of trade for correlation weight method

All the 101 bivariate pairs with correlation weigh are not found feasible for trading. Empirical result shows, pairs with low correlation with the trading asset are having higher volatility and hence give uncertain return. So, a cut off correlation is derived for this segment, which is shown graphically below. The cut off correlation value is 0.72. For further analysis the pairs with correlation above 0.72 are only considered as they follow conventional risk-return relationship. 64 such pairs are found in this segment.

For these 64 pairs individual sample 2-tail t-test is done for each trading signal to check the statistical significance of the obtained returns. The

test result includes mean return for each signal, standard deviation of each signal set, and t statistics. The test result is shown below:

One-Sample Statistics				
	N	Mean	Std. Deviation	Std. Error Mean
0.7/0.5	64	3.685	10.481	1.310
0.7/0.4	64	4.136	11.074	1.384
0.6/0.4	64	2.860	2.805	0.351
0.6/0.3	64	2.736	2.225	0.278
0.5/0.3	64	7.251	31.051	3.881
0.5/0.2	64	2.823	4.132	0.517
0.4/0.2	64	2.032	1.991	0.249
0.4/0.1	64	2.802	7.050	0.881
0.3/0.1	64	1.971	2.632	0.329

Table 15: mean stat for bivariate pairs (correlation)

One-Sample Test						
	Test Value = 0					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
0.7/0.5	2.813	63	0.007	3.685	1.067	6.303
0.7/0.4	2.988	63	0.004	4.136	1.370	6.902
0.6/0.4	8.156	63	0.000	2.860	2.159	3.561
0.6/0.3	9.836	63	0.000	2.736	2.180	3.292
0.5/0.3	1.868	63	0.066	7.251	-0.505	15.007
0.5/0.2	5.466	63	0.000	2.823	1.791	3.856
0.4/0.2	8.164	63	0.000	2.032	1.535	2.530
0.4/0.1	3.179	63	0.002	2.802	1.041	4.563
0.3/0.1	5.991	63	0.000	1.971	1.314	2.628

Table 16: t stat for bivariate pair (correlation)

For 63 degree of freedom t critical value (2 tailed) at 95% confidence level is 1.998. In the test result all the obtained t values are greater than the critical value, which suggests that the return series of every trade signal are statistically significant at 95% confidence level. In other words, it suggests that the average returns are feasible and reproducible in the future following the same trade signal.

This bivariate correlation weigh pair trading strategy return is statistically compared with the naïve approach return. For the purpose the average of all signal return of every eligible pair is compared with the 1000 random simulation return from the NSE Index in the same time frame of the study. One way ANOVA testing has been done for mean comparison.

Mean of Bivariate equal weight pair strategy returns is = $\mu_{strategy}$ = 337%

Mean of 1000 random return from NSE Nifty 50 index = μ_{Naive} = 12.57%

ANOVA					
artificial_pair_correl_bi_simulation					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	631.65	1	631.6518	464.45	9.618E-86
Within Groups	1444.32	1062	1.360003		
Total	2075.98	1063			

Table.17: ANOVA result for bivariate (correlation) pairs

Two series of variables are grouped and tested. Test result signifies that F value is very high compared to Critical F value. Hence the Null hypothesis is rejected at 99% confidence level. So, the means of Pair strategy return and Naïve return are statistically different. Pair strategy return is much higher than the Naïve return, and hence it's recommended to invest in bivariate correlation weigh pair.

Artificial Pair with 3 stocks formed using Correlation Weight Method

All the 85 trivariate pairs with correlation weigh are not found feasible for trading. Cut off correlation is derived for this segment, which is shown graphically below. The cut off correlation value is 0.68. For further analysis the pairs with correlation above 0.68 are only considered as they follow conventional risk-return relationship. 60 such pairs are found in this segment.

For these 60 pairs individual sample 2-tail t-test is done for each trading signal to check the statistical significance of the obtained returns. The test result includes mean return for each signal, standard deviation of each signal set, and t statistics. The test result is shown below:

One-Sample Statistics				
	N	Mean	Std. Deviation	Std. Error Mean
0.7/0.5	60	2.623	2.207	0.285
0.7/0.4	60	4.302	6.597	0.852
0.6/0.4	60	3.195	3.522	0.455
0.6/0.3	60	2.718	1.886	0.244
0.5/0.3	60	3.950	5.982	0.772
0.5/0.2	60	2.166	1.440	0.186
0.4/0.2	60	1.895	1.949	0.252
0.4/0.1	60	2.339	5.806	0.750
0.3/0.1	60	1.314	1.221	0.158

Table 18: mean stat for trivariate pairs (correlation)

One-Sample Test						
	Test Value = 0					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
0.7/0.5	9.208	59	5.16E-13	2.62E+00	2.05E+00	3.19E+00

0.7/0.4	5.051	59	4.52E-06	4.30E+00	2.60E+00	6.01E+00
0.6/0.4	7.025	59	2.45E-09	3.19E+00	2.28E+00	4.10E+00
0.6/0.3	11.162	59	3.56E-16	2.72E+00	2.23E+00	3.21E+00
0.5/0.3	5.115	59	3.59E-06	3.95E+00	2.40E+00	5.50E+00
0.5/0.2	11.649	59	6.22E-17	2.17E+00	1.79E+00	2.54E+00
0.4/0.2	7.530	59	3.42E-10	1.90E+00	1.39E+00	2.40E+00
0.4/0.1	3.120	59	2.80E-03	2.34E+00	8.39E-01	3.84E+00
0.3/0.1	8.336	59	1.48E-11	1.31E+00	9.98E-01	1.63E+00

Table 19: t stat for trivariate pair (correlation)

For 59 degree of freedom t critical value (2 tailed) at 95% confidence level is 2.000. In the test result all the obtained t values are greater than the critical value, which suggests that the return series of every trade signal are statistically significant at 95% confidence level. In other words, it suggests that the average returns are feasible and reproducible in the future following the same trade signal.

This trivariate correlation weigh pair trading strategy return is statistically compared with the naïve approach return. For the purpose the average of all signal return of every eligible pair is compared with the 1000 random simulation return from the NSE Index in the same time frame of the study. One way ANOVA testing has been done for mean comparison.

Mean of Bivariate equal weight pair strategy returns is = $\mu_{strategy}$ = 272%

Mean of 1000 random return from NSE Nifty 50 index = μ_{Naive} = 14.03%

ANOVA					
artificial_pair_correl_tri_simulation					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	377.38	1	377.38	947.19	4.6236E-149
Within Groups	421.53	1058	0.40		
Total	798.91	1059			

Table 20: ANOVA result for trivariate (correlation) pairs

Two series of variables are grouped and tested. Test result signifies that F value is very high compared to Critical F value. Hence the Null hypothesis is rejected at 99% confidence level. So, the means of Pair strategy return and Naïve return are statistically different. Trivariate correlation weigh Pair strategy return is much higher than the Naïve return, and hence it's recommended to invest in trivariate correlation weigh pair to cash the arbitrage opportunity.

Consolidating all the results we get:

TYPE OF PAIR	RETURN
Natural pairs	386%
Artificial pair with 2 stocks formed using equal weigh method	314%
Artificial pair with 3 stocks formed using equal weight method	268%
Artificial pair with 2 stocks formed using correlation weight method	337%
Artificial pair with 3 stocks formed using correlation weight method	272%

Table.21: consolidated returns

It is clear from the above table that, natural (univariate) pairs have the highest potential for profitability. At a same risk level natural pairs give higher returns. So, this can be used as the arbitrage opportunity to grab the supernormal profit from the market. On the other hand, among the artificial pairs, the correlation weigh method proved to be superior to the equal weigh method in both the cases bivariate and trivariate pairs. Multivariate pair's risk is also higher than the natural pairs. So, rather than arbitrage options, these can be used as effective hedging tool for the existing exposure in the market by creating suitable pair for the assets.

Findings

The research finds that the pair trading strategy is capable of giving good return when invested in an informed way. The multivariate approach studied reveals that, while natural pairs are good for arbitrage opportunities, multivariate pairs can be used as effective hedging tool to hedge existing exposure. All the findings are consolidated and listed below:

- The return from the pair trading strategy is much higher than the return from naïve investment. All the pairs studied (natural and multivariate) are able to beat the return of an unskilled investor in the capital market by a huge margin.
- Investment in pair trading strategy requires significant understanding of the pair behavior. Investor has to be flexible in terms of trading signal. For different kind of pairs different trading signal is proved to be good. Investors have to be careful in selecting the spread and to explore the maximum opportunity in the market.
- All the Pair trading strategies follow the conventional risk-return characteristics. So, return depends on the investor's risk appetite.
- Natural pairs are easily available in the Indian capital market across the industries. Investment in natural pairs is least risky and generates maximum return. So risk-return pay off is highest in case of natural pairs. Hence natural pair investment can be considered as the arbitrage opportunity in the market.
- On the other hand although the multivariate pairs are able to beat the naïve return in the market by a huge margin, their return is lesser than the natural pair.
- In multivariate pairs, out of two methods used to assign weight to the constituent stocks of the pair, correlation weigh method is proved to be better than the equal weight method.

CONCLUSION

Finding natural pairs and using two versions of a linear framework in the multivariate approach, the main evidence of this study is that the trading rules from the univariate and multivariate pairs trading strategy had a respectable performance when applied to the Indian Equity market. The evidence of positive excessive return was found at different values of the threshold parameter,

showing consistency of the performance. The returns from the eligible pairs are tested for their consistency threshold limit wise and the test results show extreme consistency at a significant confidence interval. The results found at this study motivate the application of such quantitative formulation to other industries in order to check if such positive results can be replicated in a different database.

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BIOGRAPHY

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