Pairs Trading Strategy

by

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1. Introduction

In this report, the pairs trading strategy is implemented and back-tested with NSE NIFTY 50 data for the period 2008 to 2019. 'Pairs Trading' is an investment strategy used by many Hedge Funds. Consider two similar stocks which trade at some spread. If the spread widens short the high stock and buy the low stock. As the spread narrows again to some equilibrium value, a profit results. Pairs trading is a market neutral strategy i.e. it doesn't matter whether the market is trending upwards or downwards, the two open positions for each stock hedge against each other. (Fig.1)

[Mean] - The value of the ratio tends to lie around the mean value.

The key challenges in pairs trading are :

i) Choosing a pair which will give you good statistical arbitrage opportunities over time

ii) Choosing the entry/exit points

2. Literature review

3. Data collection

This study was conducted on the companies listed on the National Stock Exchange, namely stocks that are listed on the Nifty 50 index. NSE was preferred over BSE because of higher daily trading volume which translates to more liquidity. The data used in the study consisted of the stock prices of the companies. Additionally the returns of Nifty 50 index was also taken to benchmark the performance of our strategy against just investing in the index itself.

4. Methodology

❖ Selecting the universe of stocks on which the trading will take place
➢ We choose NSE NIFTY 50 as the universe of stocks
❖ Choosing the duration over which the strategy will be implemented and tested
➢ We choose the period from 2008 to 2019 as the testing duration
❖ Daily price data collection for all the stocks present in the chosen universe
❖ Pairs formation by analysing the mutual behaviour of stock prices of each possible stocks pair in the chosen universe of stocks
❖ Tracking the behaviour of this relationship on a daily basis
❖ Looking for anomalies in the price behaviour and trading to benefit out of those anomalies

Assumptions taken:-
❖ Short selling is freely allowed in Indian markets.
❖ There are no market friction forces like transaction costs.

5. Implementation

5.1 Rolling Window Model

Having defined the stocks universe, and the testing period we move on to pairs formation by analysing the mutual behaviour of stock prices of each possible stocks pair in the chosen universe of stocks. For this task we follow a rolling window model, which basically says if we have to trade using the pairs strategy in the duration say month t to month t+2 then the pairs to be traded in this duration should be formed on the basis of their price behaviour in the period t-12 to t-1. In other words, we have a window of 12 months which rolls over 1 month at a time over the testing period which we have chosen. The window is chosen to be 12 months to account for the changes in stock prices due to seasonal factors. We find such 131 windows in the chosen testing periods.

Example:

Testing period starts from 1st Jan 2008, hence:

First window: 1st Jan 2008 – 31st Dec 2008 ⮕ Trading start date: 1st Jan 2009

Second window: 1st Feb 2008 – 31st Jan 2009 ⮕ Trading start date: 1st Feb 2009

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Last (i.e. 131st) window: 1st Nov 2018 – 31st Oct 2019 ⮕ Trading start date: 1st Nov 2019

5.2 Pairs formation

For the purpose of pairs formation, we take each window as defined in the previous section. For each window we start with all the possible pairs in our stocks universe. Our stocks universe consists of 50 stocks hence to start off with we have 1225 pairs. If some stocks aren't traded on some days or if the price data for some stocks is unavailable for some days, then we remove those stocks from our universe. We had to remove 7 such stocks from our universe, hence the final number of pairs at our hand was 903.

Once we have 903 pairs and the prices data, we find co-integration for the price series for each of these pairs and the p-value of each of these co-integration scores. Once the p-value value scores are obtained for each of the pairs for the selected window we set a threshold and choose keep only those pairs whose p-value is less than the defined threshold. (Table 1)

For Period vs No. of pairs refer Appendix 1

Example:

Window: 1st Jan 2008 – 31st Dec 2008

No. of pairs available: 903

p-value threshold: 0.01

No. of pairs having p-value below the threshold: 90

5.2.1 Co-integration

The most common test for Pairs Trading is the co-integration test. Co-integration is a statistical property of two or more time-series variables which indicates if a linear combination of the variables is stationary.

Spread = log(a) – nlog(b), where 'a' and 'b' are prices of stocks A and B respectively.

For each stock of A bought, we have sold n stocks of B. If A and B are co-integrated, then it implies that this equation above is stationary. A stationary process has very valuable features which are required to model Pairs Trading strategies. For instance, in this case, if the equation above is stationary, that suggests that the mean and variance of this equation remains constant over time. So if we start with 'n', which is called the hedge ratio, so that spread = 0, the property of stationary implies that the expected value of spread will remain as 0. Any deviation from this expected value is a case for statistical abnormality, hence a case for pairs trading. (Fig.2)

For sample heat map refer Appendix 2

5.3 Trading Algorithm

Step 1: Decide the trading period i.e. **start and end date**

Constraints: The trading period should be between 1 month and 3 months

Step 2: Find the **Z score** for each day starting from the 11th day (procedure given below)

Find natural log of the ratio of daily prices of stocks for each day, denote it as **ln(ratio)**

Find **10 days moving average** of **ln(ratio)** starting from the 11th day for each day

Find **10 days standard deviation** of **ln(ratio)** starting from the 11th day for each day

Z score = {ln(ratio) of nth day – 10 days moving average}/{10 days standard deviation}

Step 3: Detecting **entry points** on the basis of **Z score**

i) Z score < -2 : ln(ratio) has gone very low compared to 10 DMA; expect it to come up again

Therefore, if ln(ratio) increases then stock 1 (numerator) increases and (or) stock 2 decreases

Hence, **Signal = BUY the ratio** ⮕ Long stock 1 and short stock 2

ii) 2> Z score > -2 : No signal as no anomaly is present

iii) Z score > 2 : ln(ratio) has gone very high compared to 10 DMA; expect it to come down again

Therefore, if ln(ratio) decreases then stock 1 (numerator) decreases and (or) stock 2 increases

Hence, **Signal = SELL the ratio** ⮕ Short stock 1 and long stock 2

Step 4: Detecting **exit points** on the basis of **Z score**

i) abs (Z score) >3: A BUY or SELL position which was taken when **abs (Z score) >2**. But it seems like the ration isn't reverting to the mean and is continuing to go in the same direction, hence once the **abs (Z score)** crosses 3 then square off the position to limit our losses

ii) Z score[i]/Z score[i-1] < 0: If we are holding any position and if the Z score changes the sign i.e. ln(ratio) crosses the mean and goes to the other side then square off the position and take the profit.

For sample trading sheet refer Appendix 3

6. Results and Conclusion

Some insights into the performance of the strategy:-

Parameters: Stoploss = 4

1. Number of quarters in which NIFTY gave negative returns: 38
Number of quarters in which NIFTY gave negative returns and was beaten: 35

2. Number of quarters in which NIFTY gave positive returns: 87
Number of quarters in which NIFTY gave positive returns and was beaten: 27

3.

| Instrument	Start date	End date	Initial amount	Final amount
Pairs trading	1st Jan 2009	30th Nov 2019	1000 Rs	3391 Rs
NIFTY	1st Jan 2009	30th Nov 2019	1000 Rs	3972 Rs
Bank F.D. (7% pa)	1st Jan 2009	30th Nov 2019	1000 Rs	2058 Rs

7. Graphs

Cumulative returns graph (Portfolio in red and Risk free in blue (investing 1000 Rs. in both))
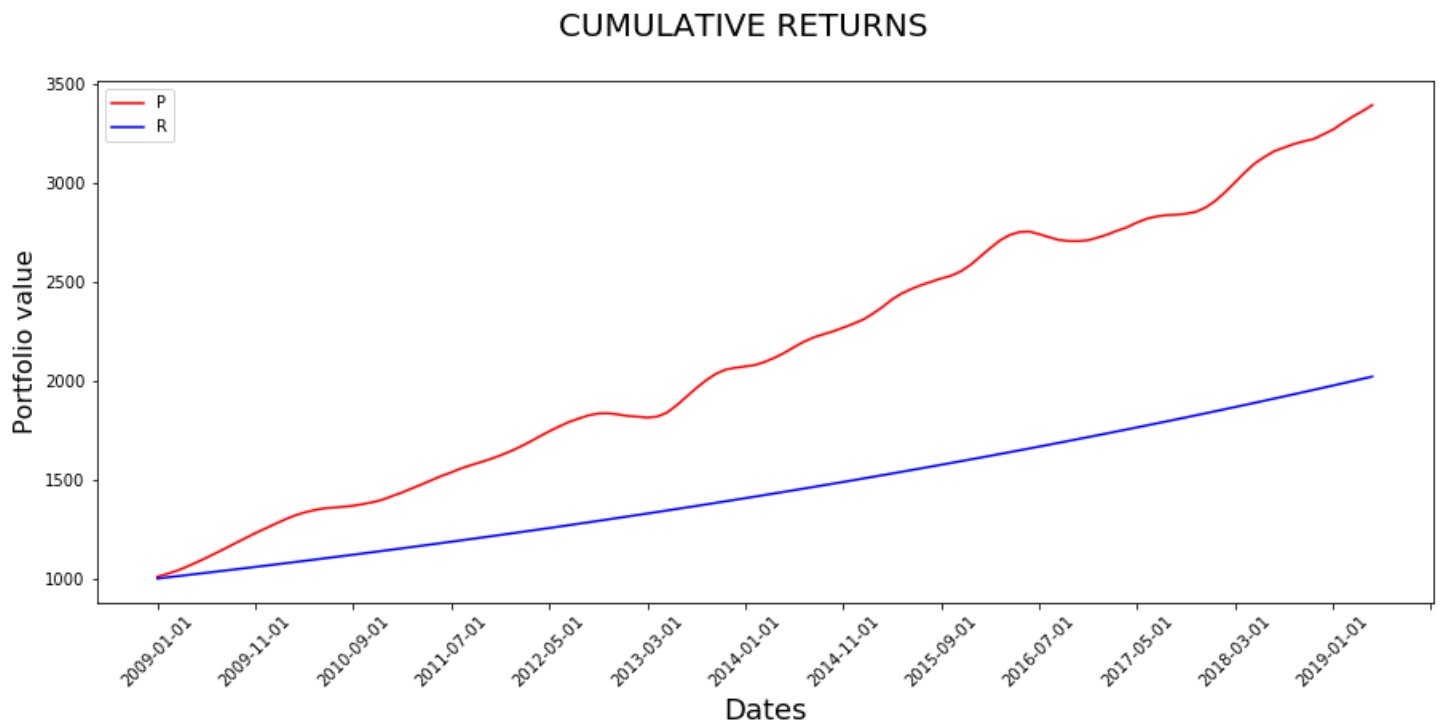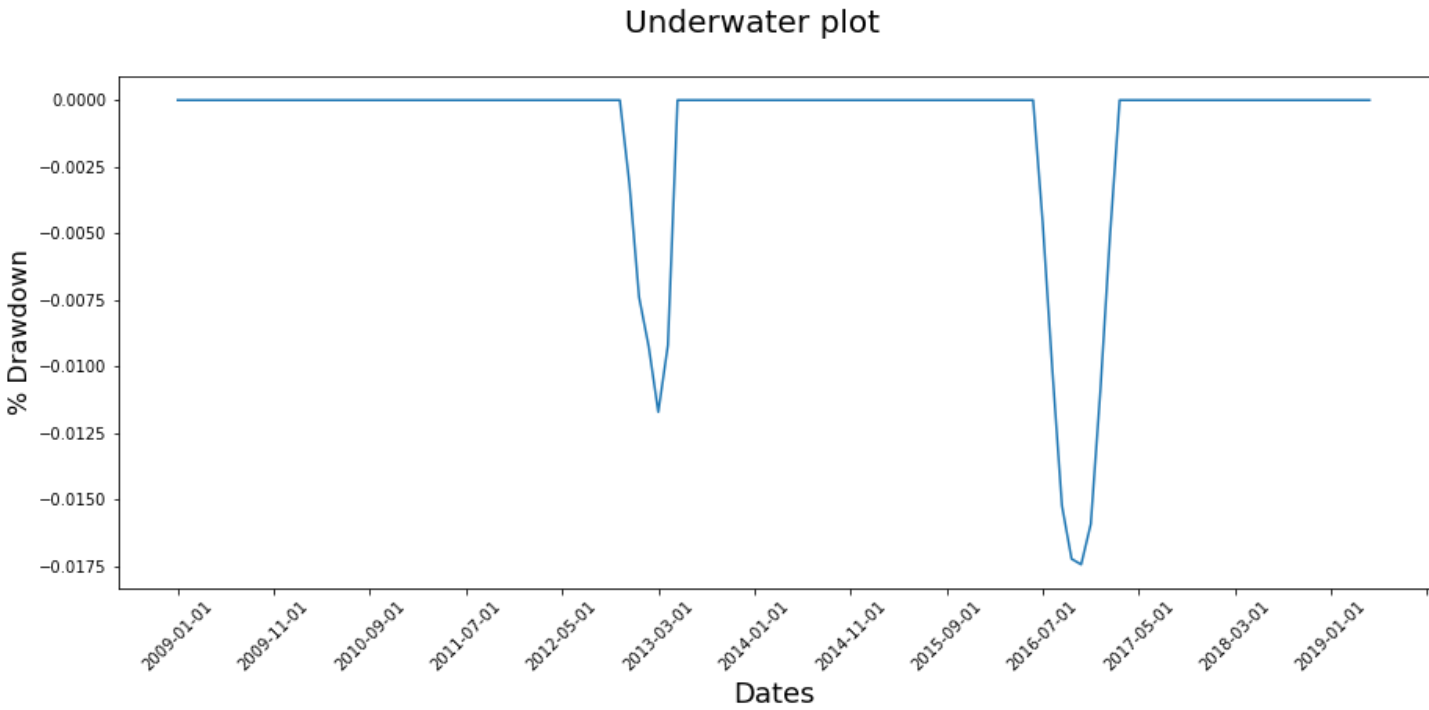

1 Year Rolling Sharpe, the overall sharpe is **0.58**. (Red - Portfolio, Blue - Risk Free)
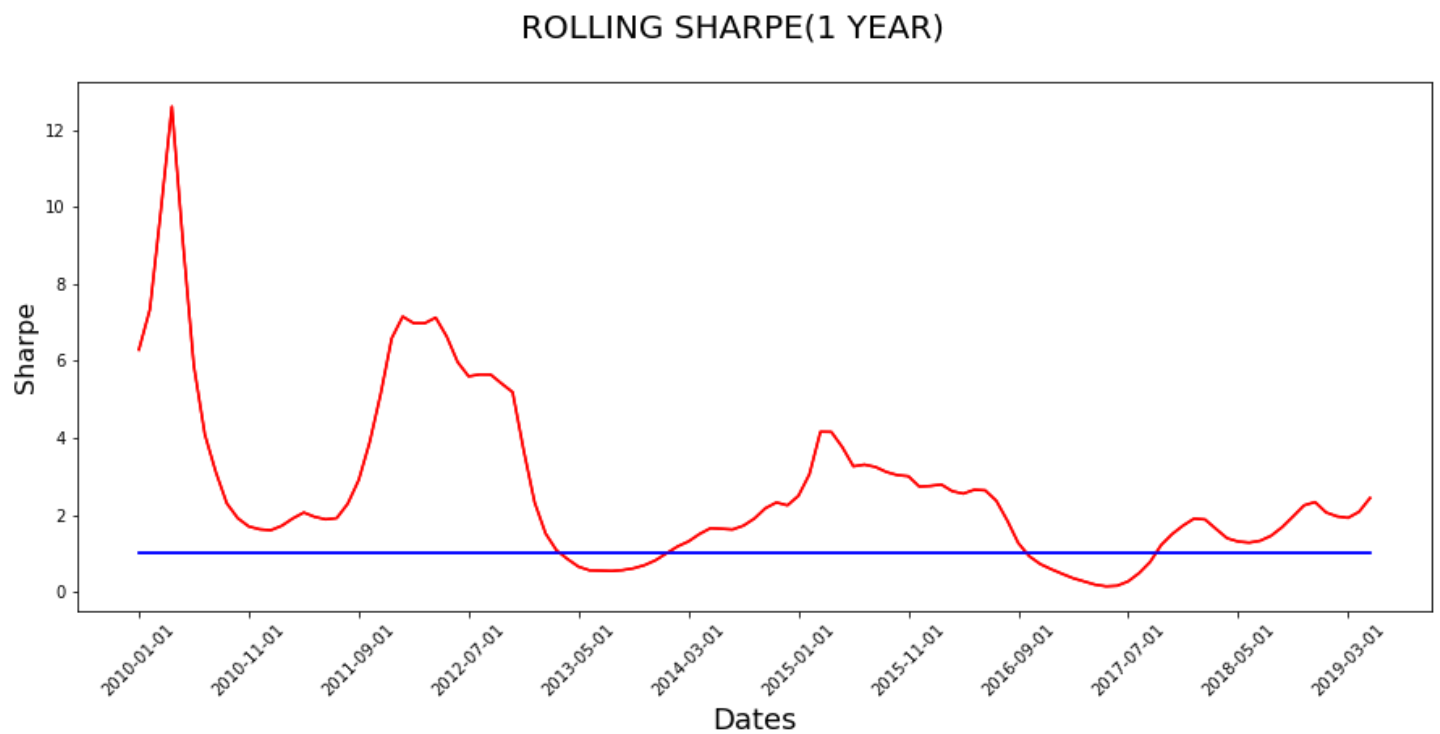
**Drawdown** (Red - Portfolio, Blue - 0% drawdown line)
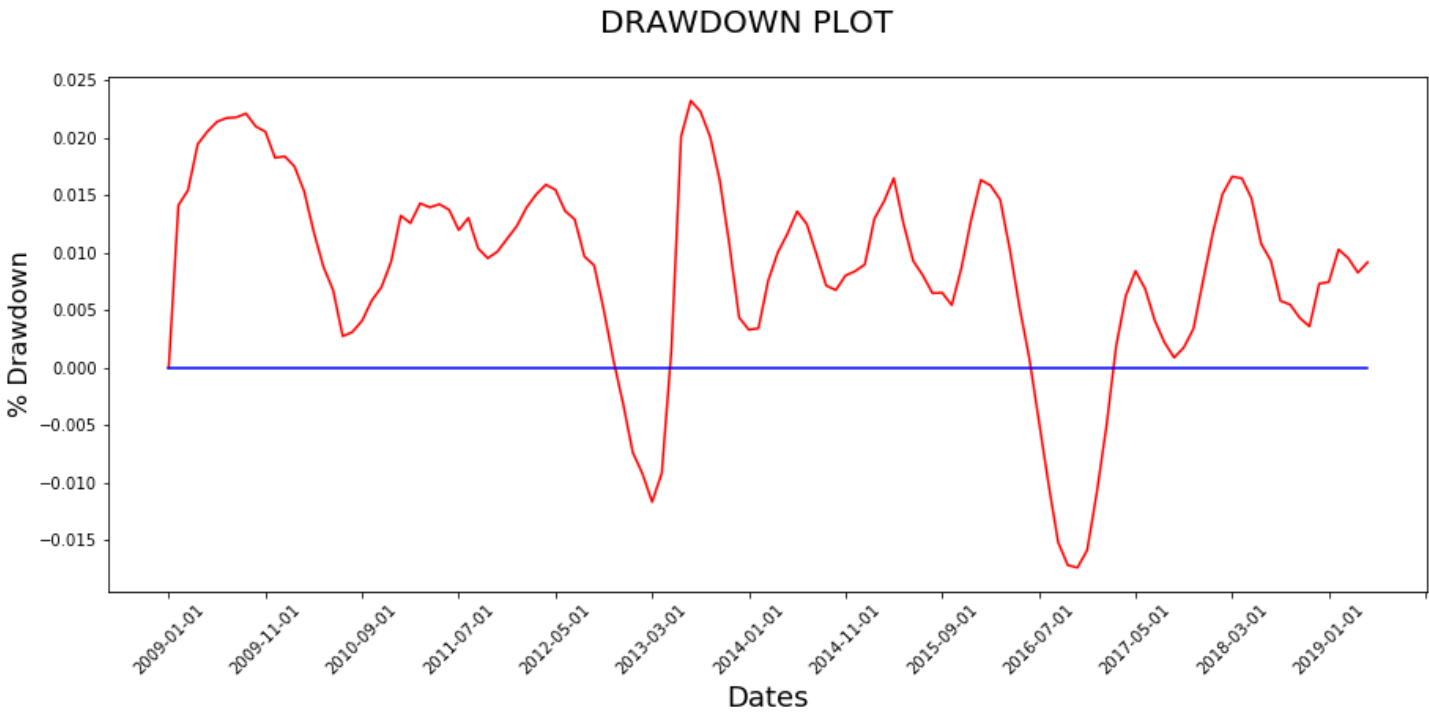
Underwater plot

8. Appendix

1. Table

	Window duration = 12 months						Date format = mm/dd/yyyy						
Window starting date	1/1/2008	2/1/2008	3/1/2008	4/1/2008	5/1/2008	6/1/2008	7/1/2008	8/1/2008	9/1/2008	10/1/2008	11/1/2008	12/1/2008	1/1/2009
No. of pairs	90	70	81	73	79	69	61	37	61	84	63	64	50
Window starting date	2/1/2009	3/1/2009	4/1/2009	5/1/2009	6/1/2009	7/1/2009	8/1/2009	9/1/2009	10/1/2009	11/1/2009	12/1/2009	1/1/2010	2/1/2010
No. of pairs	47	55	59	115	93	45	60	28	31	49	29	38	13
Window starting date	3/1/2010	4/1/2010	5/1/2010	6/1/2010	7/1/2010	8/1/2010	9/1/2010	10/1/2010	11/1/2010	12/1/2010	1/1/2011	2/1/2011	3/1/2011
No. of pairs	9	13	17	17	17	15	27	29	34	43	83	40	24
Window starting date	4/1/2011	5/1/2011	6/1/2011	7/1/2011	8/1/2011	9/1/2011	10/1/2011	11/1/2011	12/1/2011	1/1/2012	2/1/2012	3/1/2012	4/1/2012
No. of pairs	38	91	46	39	74	9	23	55	11	23	13	18	12
Window starting date	5/1/2012	6/1/2012	7/1/2012	8/1/2012	9/1/2012	10/1/2012	11/1/2012	12/1/2012	1/1/2013	2/1/2013	3/1/2013	4/1/2013	5/1/2013
No. of pairs	21	25	17	19	31	35	28	38	40	46	30	43	22
Window starting date	6/1/2013	7/1/2013	8/1/2013	9/1/2013	10/1/2013	11/1/2013	12/1/2013	1/1/2014	2/1/2014	3/1/2014	4/1/2014	5/1/2014	6/1/2014
No. of pairs	28	47	54	40	61	18	17	14	15	32	17	119	70
Window starting date	7/1/2014	8/1/2014	9/1/2014	10/1/2014	11/1/2014	12/1/2014	1/1/2015	2/1/2015	3/1/2015	4/1/2015	5/1/2015	6/1/2015	7/1/2015
No. of pairs	70	67	58	61	85	53	72	26	34	46	37	32	51
Window starting date	8/1/2015	9/1/2015	10/1/2015	11/1/2015	12/1/2015	1/1/2016	2/1/2016	3/1/2016	4/1/2016	5/1/2016	6/1/2016	7/1/2016	8/1/2016
No. of pairs	45	30	23	58	40	29	26	32	32	28	19	22	35
Window starting date	9/1/2016	10/1/2016	11/1/2016	12/1/2016	1/1/2017	2/1/2017	3/1/2017	4/1/2017	5/1/2017	6/1/2017	7/1/2017	8/1/2017	9/1/2017
No. of pairs	42	54	72	43	50	25	18	20	28	21	63	27	13
Window starting date	10/1/2017	11/1/2017	12/1/2017	1/1/2018	2/1/2018	3/1/2018	4/1/2018	5/1/2018	6/1/2018	7/1/2018	8/1/2018	9/1/2018	10/1/2018
No. of pairs	10	29	10	16	24	15	12	20	22	22	26	24	47
Window starting date	11/1/2018												
No. of pairs	22												

2. Cointegration heat map
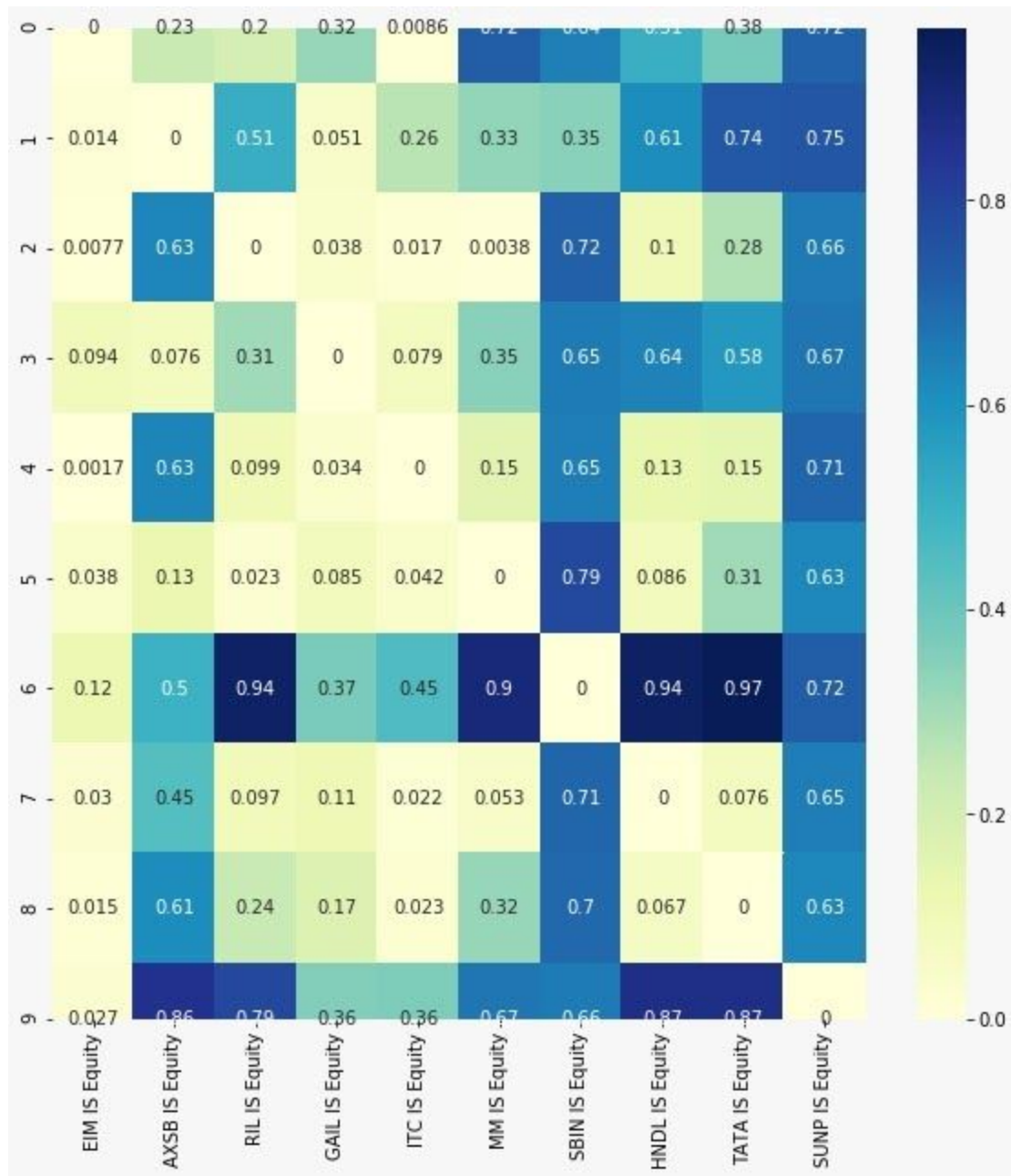
3. Trading Sheet

The pair involves **RIL IS Equity** and **INFO IS Equity** over the trading period **2019-02-01 00:00:00** to **2019-05-01 00:00:00**
The net profit over the trading period is **5.41 %**
The nifty return over the trading period is **0.14 %**
If **1000** INR is invested over the trading period (with compounding), it finally amounts to **1052.47** INR
The respective profit on each individual position is **[4.1, -4.64, 1.66, 4.29]** in %
The trading sheet over the period is:-

date	RIL IS Equity	INFO IS Equity	z_score	signal	status
2019-02-01 00:00:00	1249.95	757.05	0		
2019-02-04 00:00:00	1290.9	755.9	0		
2019-02-05 00:00:00	1291.55	754.85	0		
2019-02-06 00:00:00	1310.25	763.3	0		
2019-02-07 00:00:00	1290.4	764	0		
2019-02-08 00:00:00	1277.7	760.9	0		
2019-02-11 00:00:00	1253.25	762.8	0		
2019-02-12 00:00:00	1256.4	750.45	0		
2019-02-13 00:00:00	1245.95	754.9	0		
2019-02-14 00:00:00	1224.2	740.05	0		
2019-02-15 00:00:00	1244.45	741.95	0.00657487		
2019-02-18 00:00:00	1220.1	741.05	1.37589		
2019-02-19 00:00:00	1216.1	724.3	-0.204514		
2019-02-20 00:00:00	1234.35	740.7	0.201219		
2019-02-21 00:00:00	1246.9	733.45	-2.20193	BUY	BUY
2019-02-22 00:00:00	1232.35	734.95	-0.569213		BUY
2019-02-25 00:00:00	1232.3	754.9	2.02871	SELL	TP
2019-02-26 00:00:00	1220.25	742.5	1.18879		
2019-02-27 00:00:00	1223.5	735.25	-0.0775317		
2019-02-28 00:00:00	1231.05	734.3	-0.653059		
2019-03-01 00:00:00	1226.05	741.9	0.705823		
2019-03-05 00:00:00	1237.65	732.5	-1.33871		
2019-03-06 00:00:00	1264.8	732.5	-2.92099	BUY	BUY
2019-03-07 00:00:00	1270.25	722.95	-3.12671	BUY	BUY
2019-03-08 00:00:00	1267.1	712.35	-2.61912	BUY	BUY
2019-03-11 00:00:00	1304.1	711.25	-3.00647	BUY	BUY
2019-03-12 00:00:00	1331.35	706.95	-2.73557	BUY	BUY
2019-03-13 00:00:00	1347.3	708.45	-2.1653	BUY	BUY