Pair Trading Strategy Using Kalman Filter

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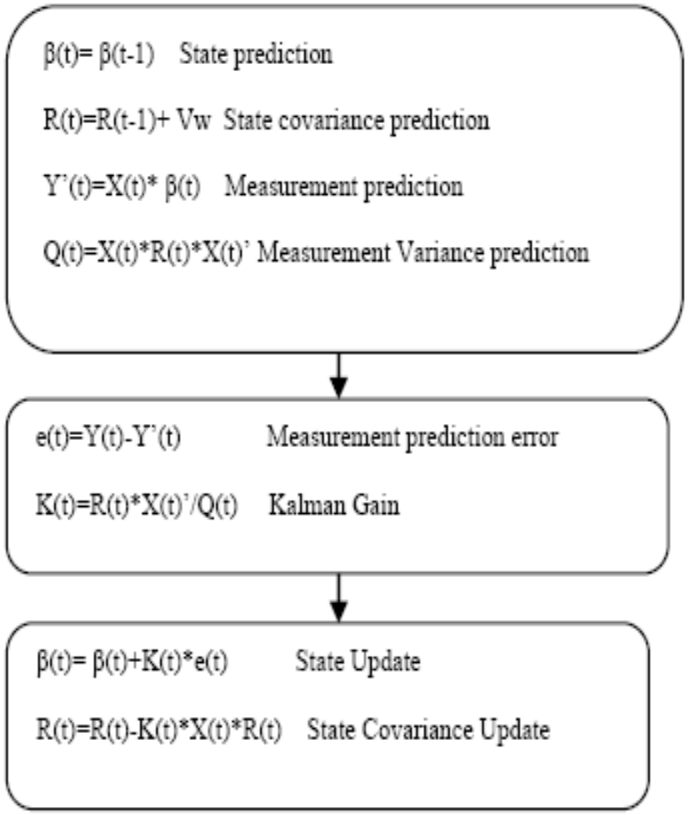
Motivation and Kalman Filter Algorithm

- In pairs trading strategy we usually analyze historical prices to find out hedge ratios to generate the spread
- This has a disadvantage that if the look-back period is short or if it has spurious movements at the beginning or at the end of time series of prices it can have an artificial impact on the hedge ratios
- To tackle this problem we use Kalman filter which is an optimal linear algorithm that smoothens out random noise from the spread
- Kalman Filtering is a 3 step process and the steps involved are
  - Prediction
  - Observation
  - Correction
- The corrected state is calculated as per below formula

  Corrected State= Predicted State + K*(Actual observation – Predicted observation)

  Where K -> Kalman Gain
- The above process is repeated for the state at every time interval making Kalman filtering an iterative prediction-correction method.



kalman Filter Flow Chart

Pair Trading Strategy Using Kalman Filter

Backtesting Data

- For backtesting this strategy we take stocks from 5 sectors in the Indian Equity markets namely Information Technology, Private Sector banking, FMCG, Energy and Pharmaceutical
- Historical data is taken from period 1-Jan-2011 till 18-Feb-2015 and has been divided into 3 parts
- Subset 1 (1-Jan-2011 to 1-Jan-2013): Required for calculation of correlation matrix to shortlist stock pairs, testing for co-integration, calculation of initial Beta and Signal to Noise ratio
- Subset 2 (2-Jan-2013 to 10-Mar-2013): Required for calibration of parameters in the pair trading algorithm
- Subset 3 (11-Mar-2013 to 15-Dec-2015): Required for backtesting and performance analysis of the Pair Trading Strategy
- We backtest the algorithm by generating Trading Signals using $|1\sigma|$ and $|1.5\sigma|$ bands

Pairs Selection Criteria

- For selection of pairs we calculate the correlation matrix for the stocks in each sector and select a maximum of 4 pairs having correlation of at least 75%
- Once we have a set of selected pairs we test them for cointegration using Cointegrated ADF test(at 90%ile)
- After short listing the cointegrated pairs Signal-to-Noise (Q/R) Ratio is calculated for each pair from period 1-Jan-2011 to 1-Jan-2013 Where Q is Variance of Beta process and R is Variance of price process i.e. (Y-Y*)
- The Idea is to check if the relation between two stocks is more stable (less volatile) than the stock process itself
- If Q/R is lower(Q/R<10^-4) then variance of Beta process is lower relative to Price process and we can determine beta accurately over time and hence obtain accurate estimates of true price Y(t) based on X(t)
- After calculating Q/R for all pairs we observed that all pairs had relatively lower Q/R

Summary of Shortlisted Pairs

Sector	Dependent	Independent	ADF	Initial Beta	Q/R(10^6)
IT	TCS	HCL	-3.1	5.09	9
IT	TechM	HCL	-3.5	2.94	7
Banking	Yes	IndusInd	-4.13	1.11	12
Banking	Kotak	IndusInd	-3.53	0.87	13
Banking	IndusInd	HDFC	-3.84	0.61	5
FMCG	Godrej	ITC	-4.21	2.517	60
FMCG	Marico	ITC	-5.75	0.76	27
FMCG	Marico	Godrej	-4.81	0.3	15
Energy	Gail	IOC	-4.33	1.32	9
Pharma	Sun Pharma	Lupin	-4.47	0.6	6

Stop-Loss Implementation

- As a measure of Risk Management and to prevent large losses we implement stop-loss for each pair
- Stop-loss thresholds are calculated using historical Returns deviation of the pairs
- We run the pair trading algorithm for the period 1-Jan-2011 to 1-Jan-2013 (1st Subset) and calculate daily standard deviation of returns
- For each pairs this deviation is calculated and the stop-loss is set as 2.5*(Daily Standard Deviation) i.e. whenever this threshold is breached for any pair the positions are squared off
- This method provides a significant improvement in our backtested results

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Aggregate Performance Analysis of Average Weighted Strategy

- We analyze the performance at an aggregate level by allocating equal capital to each pair and aggregating the gains/Losses generated by them over time
- We analyze the performance of the strategy on basis of 4 parameters
  - Annual Percentage returns(APR)
  - Sharpe Ratio (APR/Annualized Volatility)
  - Maximum Drawdown(Max DD)
  - Calmar's Ratio (APR/Maximum Drawdown)
- The table below shows how the strategy has performed on an aggregate level for both |1σ| and |1.5σ| bands

Band	APR	Annual Vol	APR/Vol	Max DD	Calmar
|σ|	17.59%	4.76%	3.69	-2.49%	7.06
|1.5σ|	15.12%	4.20%	3.60	-1.88%	8.06

Aggregate Performance Analysis of Dynamically Weighted Strategy

- Another Method to construct a consolidated strategy is to dynamically weight individual pairs based on its more recent performance
- The dynamically weighted Index ranks all the pairs based on its recent performance and allocates the weights accordingly
- The pairs are ranked based on rolling 3 month Sharpe ratios, with better Sharpe ratios allocated higher weights. The table below shows the weights allocations based on the rank

Rank	1	2	3	4	5	6	7	8	9	10
Weight	20%	17%	15%	12%	10%	8%	6%	5%	4%	3%

- This dynamic strategy provides superior returns but at a cost of higher annual standard deviation of returns. The table below shows the performance of the dynamic strategy for |1σ| and |1.5σ| bands

Band	APR	Annual Vol	APR/Vol	Max DD	Calmar
|σ|	20.71%	10.17%	2.04	-7.42%	2.79
|1.5σ|	15.12%	7.76%	1.95	-4.47%	3.64

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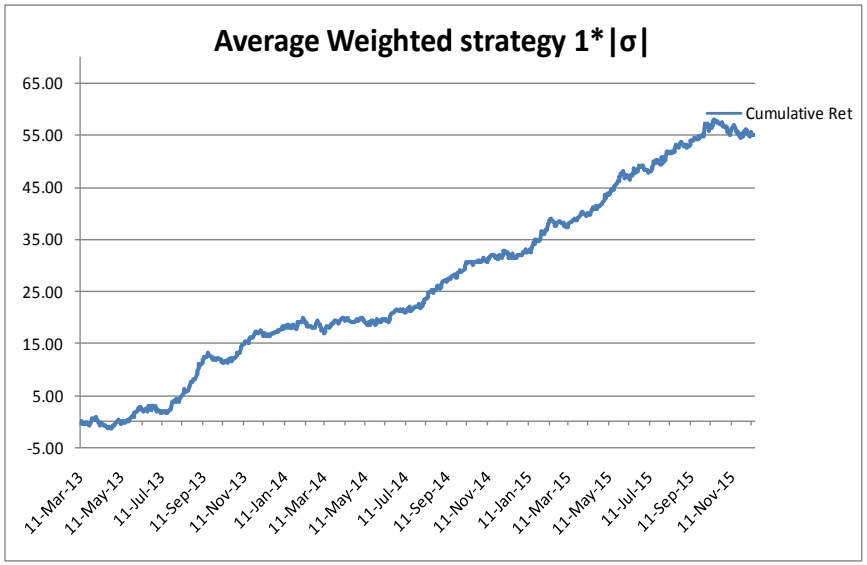
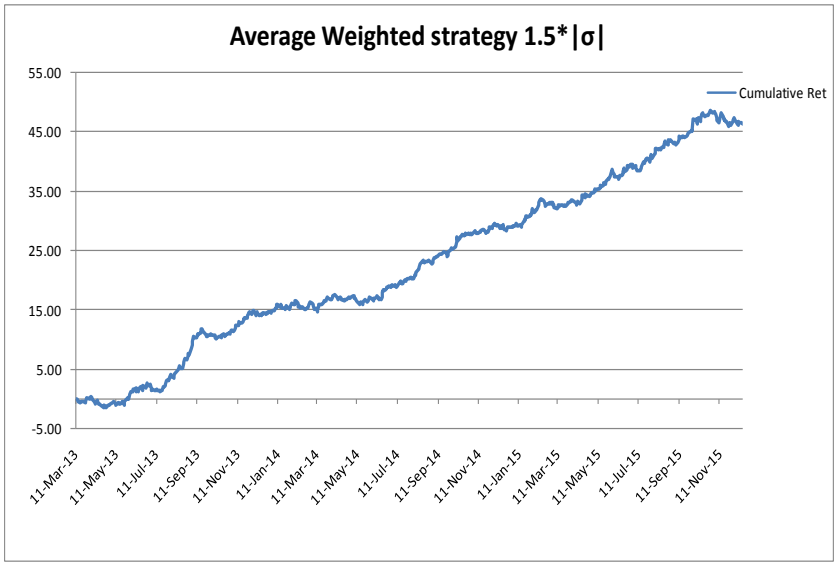
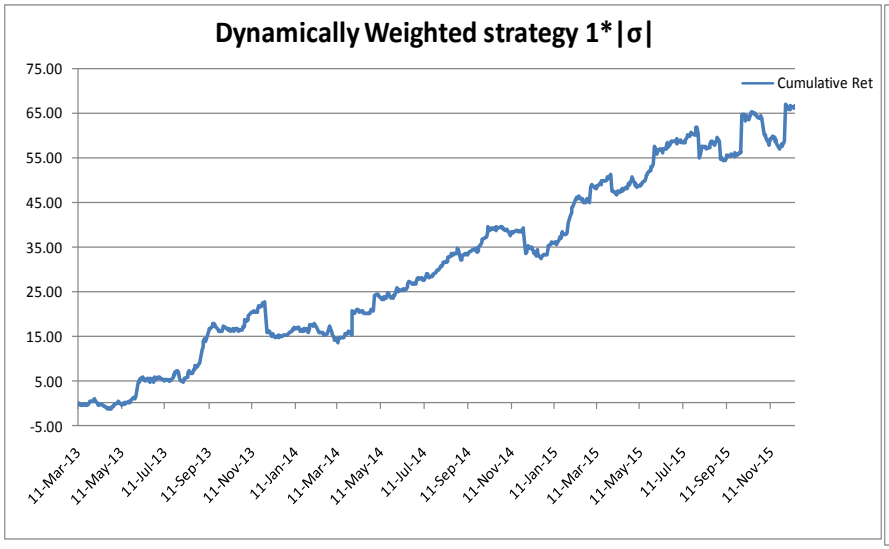
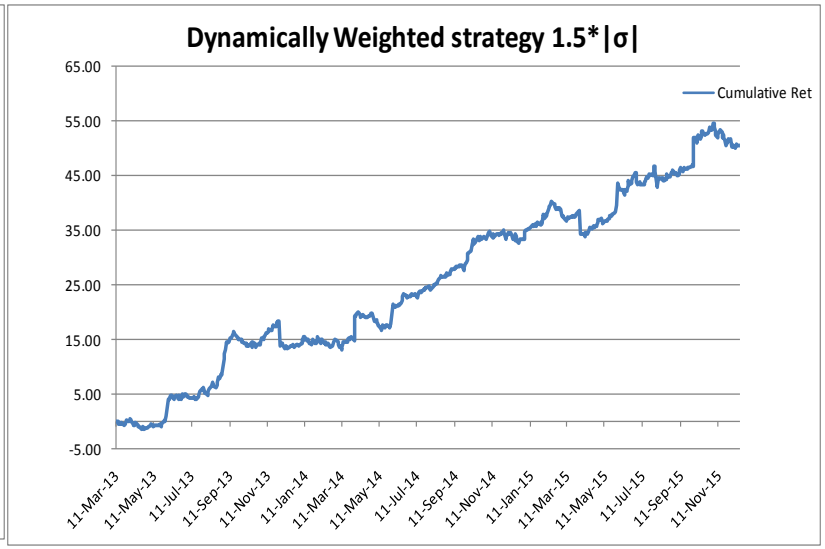
Return Profile of Average Weighted Index





Return Profile of Dynamically Weighted Index





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Performance Analysis of Individual Pairs

- The table shows the performance of individual pairs using both 1*|σ| and 1.5*|σ| bands
- TCS-HCL was the best performing pair for both bands and at sector level pharmaceutical was the performer
- In pharmaceutical sector companies tend to be relatively uncorrelated with each other
- As each stock in pharmaceutical is affected by parameters like FDA rulings, R&D, and new drug development that are company specific.

Sector	Dependent	Independent	1*|σ|		1.5*|σ|	
			APR	APR/Vol	APR	APR/Vol
IT	TCS	HCL	36.79%	2.64	33.94%	2.48
IT	TechM	HCL	10.86%	0.82	3.93%	0.36
Banking	Yes	IndusInd	8.28%	0.63	11.38%	0.95
Banking	Kotak	IndusInd	12.47%	1.06	14.26%	1.46
Banking	IndusInd	HDFC	14.12%	1.6	10.47%	1.47
FMCG	Godrej	ITC	10.38%	0.53	9.73%	0.5
FMCG	Marico	ITC	12.22%	0.91	16.14%	1.38
FMCG	Marico	Godrej	31.23%	3.00	13.84%	2.34
Energy	Gail	IOC	28.21%	1.74	25.44%	1.66
Pharma	Sun Pharma	Lupin	3.07%	0.27	6.66%	0.74

Future Scope and Conclusion

- At aggregate level the average weighted strategy provides a very good drawdown which in effect leads an impressive Calmar's ratio for both |1σ| and |1.5σ| bands
- Use of stop-loss significantly improves the performance the strategy providing superior returns and Sharpe ratios
- The algorithm can be further optimized by Modifying the trading strategy by using **Signal-to-Noise** ratio filter which will ignore Trading Signals when the ratio exceeds some specified level to avoid spurious estimates of the price process
- For optimal performance of the strategy monthly/Bi-Monthly recalibration of the algorithm to check or recalculate Cointegration of pairs, returns deviation, Returns/Loss profiles, Max DD and such is suggested