INDIAN INSTITUTE OF TECHNOLOGY, KANPUR

MTH517- Time Series Analysis

Project Report

"Pairs Trading Strategy"

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Acknowledgment

We express our gratitude to Prof. Amit Mitra for giving us an opportunity to work on this project. Working on a real-life problem in the form of time series analysis further strengthened the theoretical concepts we developed during the course, and broadened our perspective towards analyzing and possibly solving similar problems encountered in our day-to-day lives.

Analytical approach to Time Series

Order of Integration

The minimum number of successive difference that need to be applied to a time series to make it covariance stationary is called its order of integration. It is denoted by *I(d)*. A covariance stationary time series is said to have order of integration as 0 i.e. it is a I(0) time series.

Co-Integration

Two non-stationary time series of stock prices xt and yt are co-integrated if they tend to move together through time if their linear combination is a stationary process.

$$\alpha X_t + \beta Y_t \rightarrow I(0)$$

Co-integration is used to test for correlation between two non-stationary time series in long run. If two series are co-integrated, it tells us that the difference between their means remains constant and will not depart from the equilibrium in long run.

If the two variables may be completely different from each other but have a common trend they are said to be co-integrated.

Normalization of Data

- Z-scores

$$P_{normalized} = \frac{P - mean(P)}{std(P)}$$

where,

$P_{normalized}$: normalized price

$mean(P)$: mean of the stock price

$std(P)$: standard deviation of the price

Moving Average

The moving average helps to level the value of the time series over a specified period by creating a constantly updated average value. MA are example of 'low pass' filters which means they decrease the variability and smoothens the data. It filters out rapidly fluctuating component of the data.

A simple moving average is calculated by taking the arithmetic mean of the value of the variable over a specified number of observations.

We can classify moving averages in the following ways.

- Equal weighted MA - In this MA, all the observations are given equal weight.

- One-Sided MA - In this MA, only the past values are used to calculate the mean value.

- Window Size - The number of consecutive observations taken to find the mean.

Application to the project

Stock prices are generally not a stationary time series but can be made covariance stationary by applying difference successively i.e. they are of type $I(d)$ where $d \neq 0$.

Our aim is to find pair of co-integrable stocks and use the fact that their linear combination is a stationary series to predict their future movement.

In this project, we are going to use equal weighted one-sided MA of two different window sizes. We will normalize the data for better results.

Engle-Granger two-step cointegration test

The count function of the STATSMODELS library of Python used in this project uses Engle-Granger two-step cointegration test to identify if the series are cointegrated or not.

The Engle-Granger method first constructs residuals (errors) based on the static regression.The residuals are tested for the presence of unit roots using ADF or a similar test. If the time series is co-integrated, then the residuals will be practically stationary.

In this test, the null-hypothesis is that no co-integration exists between the series and the alternative hypothesis is that cointegration exists.

H_0 : No cointegration exists

H_1 : Cointegration exists

If the p-value of the result comes out to be less than threshold value (here 0.05) we assume the stock prices to be co-integrated.

Pairs Trading Strategy

About

Pairs trading is a type of strategic trading which remains unhindered by the direction in which market is moving. It assumes neutrality in the market.

Pair traders in a market neutrality concept expect the price of the securities that are not performing well at the moment to bounce back and the price of the over-performing securities to fall soon. If a trader detects that the correlation between the stock prices is getting disturbed, they can choose to deploy this strategy. The traders can even get rid of the short stock by selling it as its prices are expected to fall, whereas they can keep the long stock as its prices are expected to increase. If the trader is unsure of the movement of both the stocks but knows that A's position would be better than B then even if the prices of both of them goes down, he will make a profit as long as A's position is better than B.

The key factor in this strategy is that the stocks should necessarily have a higher rate of positive correlation or equivalently should be co-integrated.

Co-Integration approach

Source of dataset - We will be downloading the data of NIFTY-50 stocks from Yahoo Finance from 2015 to 2021 to find the best pairs of stocks to invest in.

As mentioned earlier, we will find out pairs of stocks on the basis of p-value. If the p-value is less than the threshold value, we consider the pair of stocks to be co-integrable. [Our take on how to trade?]

We found the best 5 pairs out of which the best the pair having the highest co-integration value is BAJFINANCE.NS [Bajaj Finance] and KOTAKBANK.NS [Kotak Bank], while other good pair of stocks are:

- BAJAJ-AUTO.NS and ULTRACEMCO.NS

- ITC.NS and NTPC.NS

- KOTAKBANK.NS and TITAN.NS

- INDUSINDBK.NS and NTPC.NS

Hence we calculate the spread of the two most correlated stocks in our dataset after normalizing their data.
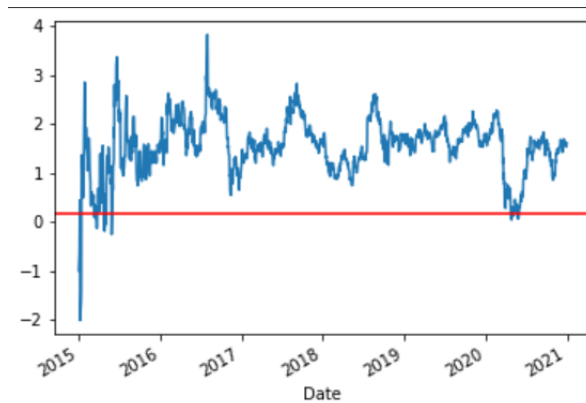

Figure 1: Graph of ratio of BAJFINANCE.NS and KOTAKBANK.NS red is the mean line


Figure 2: Ploting them over the timeline

Our take on how to trade?

We have find out best pairs of stocks which have the highest correlation (they are co-integrated).

We consider the ratio of the value of the two stocks (Y/X) and begin with calculating the moving average on window size of $window_1$ (or short window) and $window_2$ (long window) and the moving standard deviation for window size of $window_2$ for the ratio(Y/X) of stocks. We have taken the size of short window to be of 1 week (7days) and long window of 2 months (60 days).

If the stocks are co-integrated, the normalized value of the ratio X/Y follows a standard normal distribution has a mean of 0 and a standard deviation 1. If the time series moves up beyond the mean, it tends to revert back towards the mean and similarly if it goes down the mean, it will again revert back.
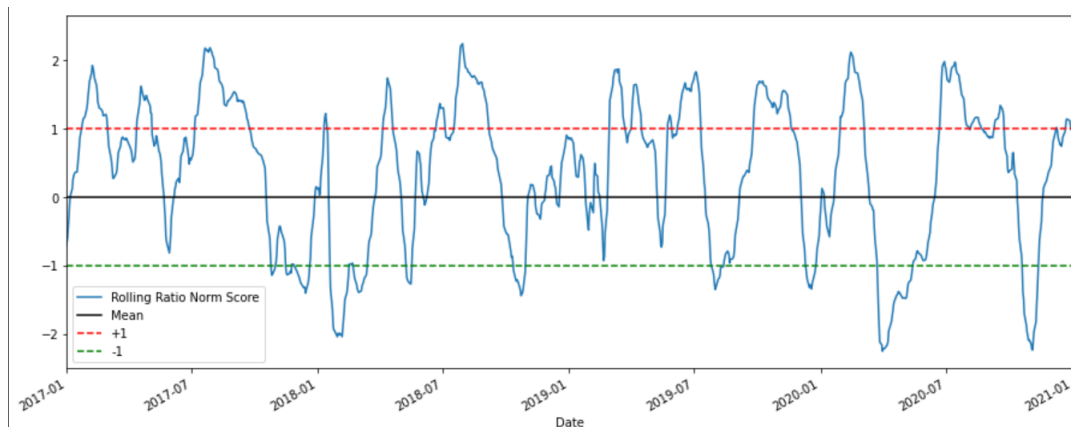
Using these models, we can create the following trading signals:

* Buy(1) whenever the $norm_{score}$ is below c2=0.8, meaning we expect the ratio to increase.

* Sell(-1) whenever the $norm_{score}$ is above c1=0.9, meaning we expect the ratio to decrease.

Now, when **moving_average_window1 > moving_average_window2 + c1 * standard_deviation_window2**, we short the stock Y and go for long on stock X.

We would square off when **moving_average_window1 < moving_average_window2 - c2 * standard_deviation_window2** i.e. we long the stock Y and short the stock X.

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Results

We tried our trading strategy from January 2021 to November 2022 on the Bajaj Finance and Kotak Bank stocks with the following result. Net gain for Bajaj Finance and Kotak Bank: 4706.739666894927

Return: 47.06739666894927 %

We also tried this on other random stock pairs like Cipla and Wipro & Tata Consumer and TCS with the following results.

Net gain for Cipla and Wipro: -3683.369598728352

Return: -36.83369598728351 %.

Net gain for Tata Consumer and TCS: 1601.8932179995145

Return: 16.018932179995147 %.

This indicates that our strategy works well only if the stocks are cointegrable.