Coding Test Y-intercept Xiaoyue Chen

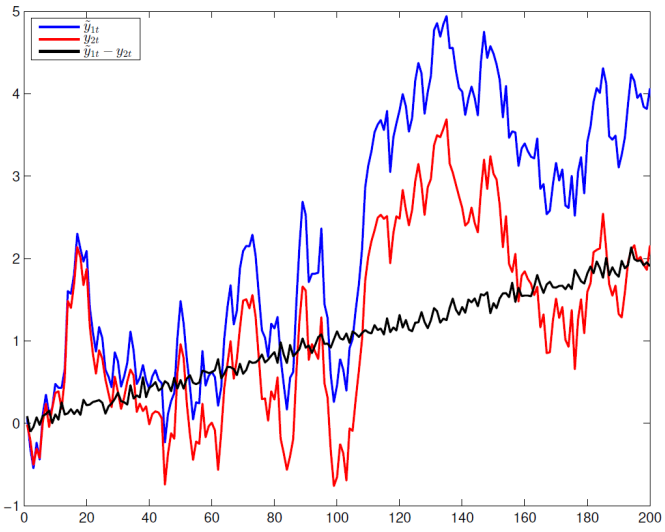
This coding test is about forming a strategy to trade and do back testing to prove it. Firstly, I analyzed the database. Then I formed a pair trading strategy based on the data provided. Afterwards, I did back testing on the strategy and put forward further improvement suggestions based on the result.

Database Analysis

The databased consists of stock ticker, date, historical daily price, and volume data from the past few years. There are 248 stocks in total. If we summarize all stocks by ranging from 2013-2021, many NA values would occur. These stocks are Japanese stocks, and shorting is allowed in Japanese market. Thus, I choose to do pair trading strategy using this database.

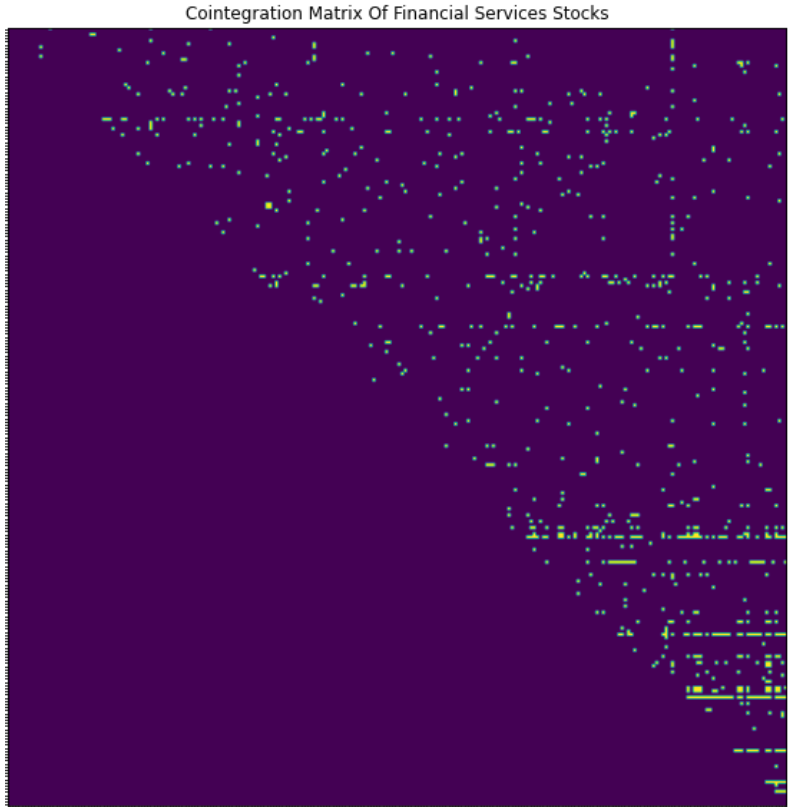
Pair trading strategy

The pair trading strategy typically involves selecting two financial instruments that are highly correlated, and then taking a long position in one and a short position in the other. The idea is to profit from the difference in the prices of the two instruments as they converge back to their usual relationship. Here I apply the Cointegration to decide pairs. The reason why we do not use correlation is that there are some cases as the high correlation would not result in Mean Reversion. For example:



Mean-reversion Verification

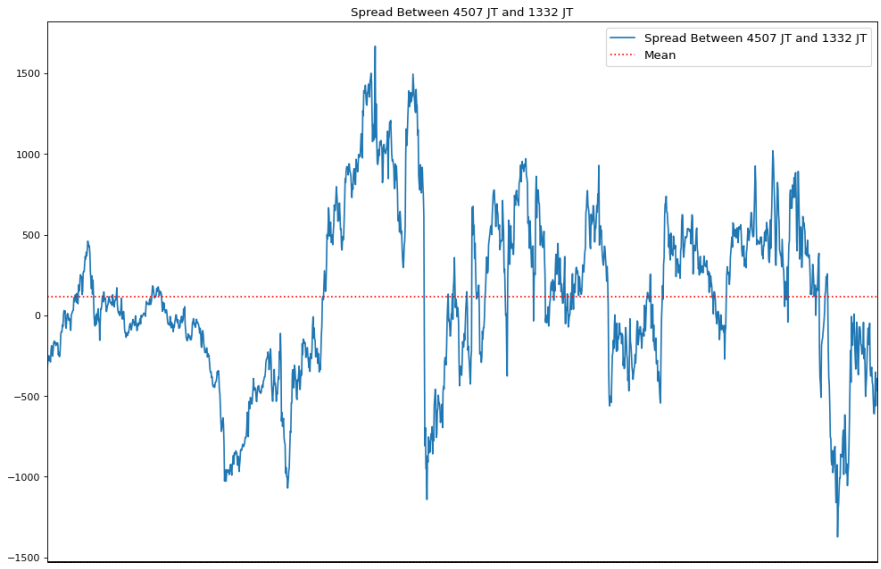
Firstly, I group data by stocks, and then split it into training (70%) and testing (30%) datasets. I mutually match all the stocks to do cointegration test. Here I apply the function *statsmodels.tsa.stattools.coint()* in Python to test for no-cointegration of a univariate equation. P-value less then 0.02 would result in high cointegration. The result shows some recommended pairs. To simplify, we just choose one reasonable pair here to test feasibility. More pairs could be constructed in a portfolio simultaneously if necessary.



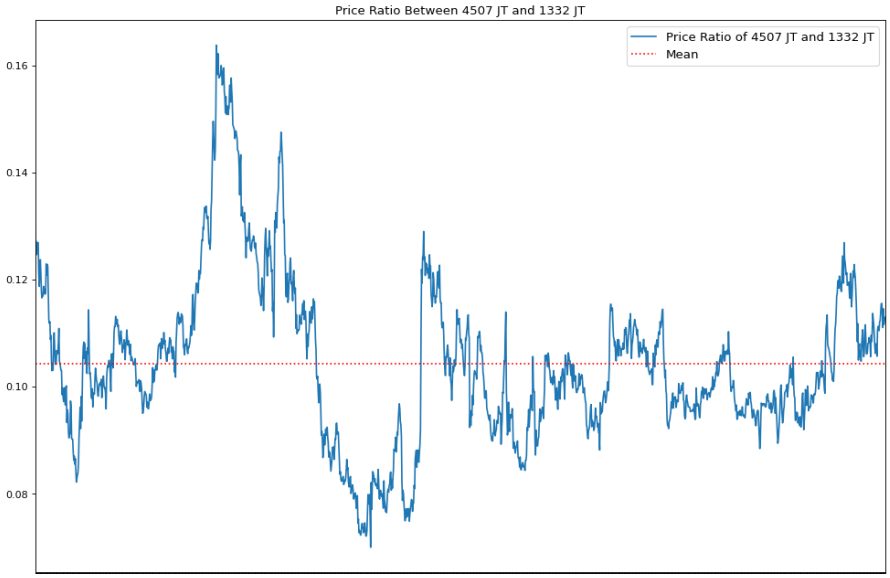
```
[('1332 JT', '2002 JT'),
 ('1332 JT', '3893 JT'),
 ('1332 JT', '4507 JT'),
 ('1332 JT', '8802 JT'),
 ('1334 JT', '2914 JT'),
 ('1334 JT', '3086 JT'),
 ('1605 JT', '5202 JT'),
 ('1721 JT', '3893 JT'),
 ('1721 JT', '7261 JT'),
 ('1721 JT', '8802 JT'),
 ('1801 JT', '4208 JT'),
 ('1801 JT', '4631 JT'),
...
 ('9602 JT', '9735 JT'),
 ('9681 JT', '9735 JT'),
 ('9681 JT', '9766 JT'),
 ('9681 JT', '9983 JT'),
 ('9681 JT', '9984 JT')])
```

The two stocks in one pair should have similar duration and similar average trading volume. For example, '2002 JT' has average trading volume as 881926 while '1332 JT' has average trading volume as 2.853706e+06. Thus, this kind of pair should be deleted as it is hard to encounter arbitrage portfolio strategy later. After checking, I decide to move forward with pair ('1332 JT' and '4507 JT').

Then continuously using the Training Dataset to further verify the spread's mean-reverting performance.



Then I calculated the price ratio to see if it is still mean reverting.



Seems that both the spread and the price ratio are both mean-reverting from the graphs. To further check whether they are stationary or not, I apply the Augmented Dickey Fuller Test here. It tests the null hypothesis that a unit root is present in a time series sample. In this case, the alternative hypothesis is that no unit root exists.

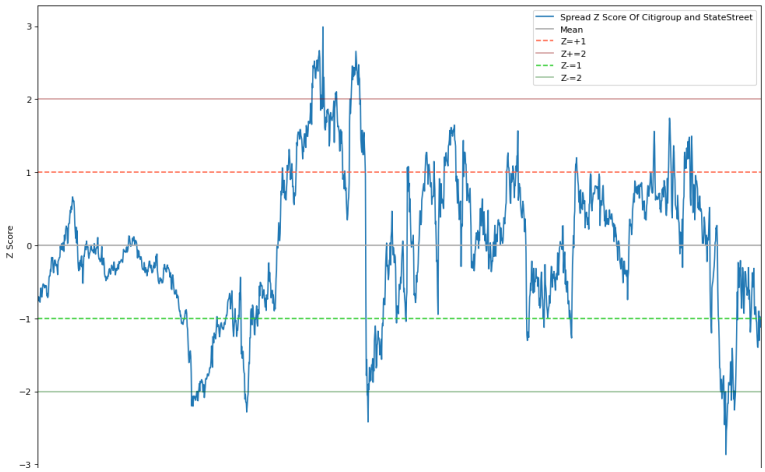
```
# Augmented Dickey Fuller Test
price_ratio_pvalue = round(adfuller(price_ratio)[1],5)
spread_pvalue = round(adfuller(spread)[1],5)

(price_ratio_pvalue, spread_pvalue)
```

✓ 0.1s

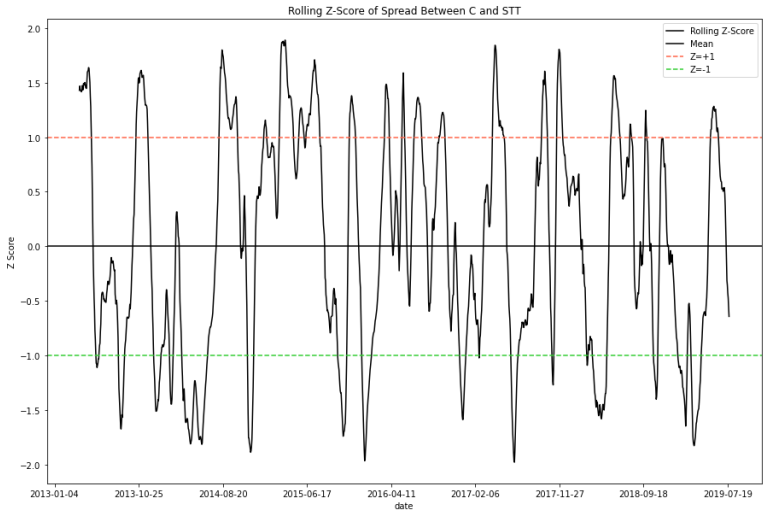
```
(0.01209, 0.00174)
```

The result shows that spread has a lower p-value. Thus, I will use spread as the stationary mean to form the following mean-reversion trading strategy. Then calculate the Z-score of spread alongside over the time.



Given that this trading strategy is primarily based on mean reversion, we can use

moving averages to construct trading signals. To do so, we can plot the 10-day and 60-day moving averages alongside the actual price ratio. I have selected 10-day and 60-day windows, which are common for investment decision, for the short and long periods respectively. Then the rolling Z score is calculated correspondingly.



Trading Strategy Simulation

After verifying mean-reverting performance, I could apply pair trading to do back testing. The following steps are implemented in the *trading_simulation()* function:

1. Calculate the price ratio and rolling average z-score of two assets.
2. Use if statements to execute trades when the price ratio exceeds +-1.25 SD.
3. Keep track of total position sizes and share prices to calculate profit later.
4. Close positions when the price ratio z-score is back within normal range (+-0.5 SD)
5. Keep track of variables to analyze performance, including number of trades, trade dates, trade gains/losses, and overall profit for high/low trades individually.

Back Testing and Analysis

Test the results in-sample

In other words, do the in-sample back-testing. As the cointegration of training dataset holds, which is verifies in the previous sessions, it should be guaranteed that the result should be comparably good.

The performance of pair '1332 JT' and '4507 JT':

```
The total profit between 2013-01-04 and 2019-07-24 was $52374.73
13 trades where the price ratio was high were executed; they were profitable 92.31% of the time, with a largest single gain of $8008.77, and a largest single loss of $-14114.88
13 trades where the price ratio was low were executed they were profitable 84.62% of the time, with a largest single gain of $7358.90, and a largest single loss of $-9945.62
```

Now, let's look at some random pairs put into the same simulation. Also, should be with similar length and trading volume.

The performance of pair '1332 JT' and '1605 JT':

```
The total profit between 2013-01-04 and 2019-07-24 was $-15764.45
13 trades where the price ratio was high were executed; they were profitable 30.77% of the time, with a largest single gain of $6161.47, and a largest single loss of $-14995.83
9 trades where the price ratio was low were executed they were profitable 44.44% of the time, with a largest single gain of $20643.33, and a largest single loss of $-13578.14
```

Test the result out of sample

The performance of pair '1332 JT' and '4507 JT':

```
The total profit between 2019-07-25 and 2021-03-19 was $-2327.63
3 trades where the price ratio was high were executed; they were profitable 100.00% of the time, with a largest single gain of $976.01, and a largest single loss of $955.16
2 trades where the price ratio was low were executed they were
```

```
profitable 0.00% of the time, with a largest single gain of $-1276.46,
and a largest single loss of $-2982.34
```

The performance of pair ‘1332 JT’ and ‘1605 JT’:

```
The total profit between 2013-01-04 and 2019-07-24 was $-15764.45
13 trades where the price ratio was high were executed; they were
profitable 30.77% of the time, with a largest single gain of $6161.47,
and a largest single loss of $-14995.83
9 trades where the price ratio was low were executed they were
profitable 44.44% of the time, with a largest single gain of $20643.33,
and a largest single loss of $-13578.14
```

It seems that the strategy performs poorly at the out of sample test. However, After checking on the entire dataset, I find that the performance of pair ‘1332 JT’ and ‘4507 JT’:

```
The total profit between 2013-01-04 and 2021-03-19 was $73825.90
16 trades where the price ratio was high were executed; they were
profitable 93.33% of the time, with a largest single gain of $10537.51,
and a largest single loss of $-14114.88
18 trades where the price ratio was low were executed they were
profitable 83.33% of the time, with a largest single gain of $7358.90,
and a largest single loss of $-10772.06
```

However, the profit overall is much more than the sum of training and testing data. Thus, I suppose that the split of dataset causes the interruption of mean-reverting overall, which make the strategy does not perform well in the testing dataset. This may be verified further.

Further Improvements

Due to time limit, I come up with further improvements that could be conducted.

1. I could add stop-profit strategy or stop-loss strategy to further reduce maximum drawdown.
2. I may take trading cost into account. However, as the trading frequency is not high, this could be ignored.
3. Using the average holding period to calculate fix-income return in the corresponding market. This would be a better benchmark for evaluating this strategy.
4. I need to further check whether the split of data really matters the result.