

Statistical Arbitrage Project

Pairs-Trading Based on Co-integration in US Equity Market

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Executive Summary

We implement and optimize the pairs-trading strategy based on co-integration relationship in the US equity market. Co-integration indicates that although each stock price series may not be stationary, their linear combination exists long-term stationarity with short-term deviation and mean-reversion trend following, which is favorable to pairs-trading strategies. We use all NYSE stocks daily data from Jan 2001 to August 2016 to conduct the in-sample (Jan 2001 to Dec 2010) and out-of-sample (Jan 2011 to August 2016) tests.

There are two core problems related to this strategy: stock pairs selection and trading rules determination. We cut the data into consecutive formation periods and trading periods with different lengths, and use the formation period data to select stock pairs and use the trading period data to generate trading signals based on pre-determined trading rules.

We perform a three-stage selection procedure based on the logarithm of stock closing prices: first, through "Correlation matrix", "Clustering", or "Graphical Lasso" pre-select stock groups with similar price movement patterns; second, through "Co-integration test" choose stock pairs or baskets that pass the statistical test with 99% significant level; third, through in-sample simulated trading choose the top 20 pairs with highest Sharpe Ratio as the profitability measure. We compare the performances of each selection method with and without the Sharpe Ratio test.

In the trading period, we utilize the estimated coefficients from the formation period to linearly combine the logarithm of selected stock prices. We call the linear combination "spread" in the following context. We observe the standardized spread each trading day using the closing bid and ask prices, and compare it with six pre-set thresholds (short bail-out, short open, short close, long close, long open and long bail-out from top to bottom) to determine when to enter into the market and when to exit the market. To calculate the mean and standard deviation to normalize the spread, we utilize two methods: moving look-back windows and formation periods.

Combining the selection and trading rules, we totally have 8 strategies: correlation matrix with and without Sharpe Ratio test, Graphical Lasso with and without Sharpe Ratio test, and for each of the

above four selection methods, we consider using moving windows or formation periods to calculate the statistics to standardize the spread.

There are two important sets of parameters we need to tune: one is the lengths of formation and trading periods, the other is the level of the six thresholds. We consider 9 combinations for the first set of parameters, 5 combinations for the second set and in total 45 possible sets for each trading strategy.

To approximate the real trading environments, we use the bid and ask prices instead of the closing prices to buy and sell the stocks and take into consideration transaction costs including slippage, commission fees and rental costs for short stocks. In addition, to avoid look-ahead bias, we treat unavailable price data differently for formation periods and trading periods, and only use the historical data to design strategies and generate the trading signals.

Comparing in-sample and out-of-sample results for different trading strategies with optimal parameters, we conclude that, Sharpe Ratio test can help to significantly improve the Sharpe Ratio in the trading period under all cases. Although Graphical Lasso can pre-select stocks with higher profit potential, the performance is less stable and the drawdown is larger. Comparatively, performances of correlation matrix are more stable and more consistent in sample and out of sample. Using moving average windows to standardize spreads can realize a higher winning percentages than using formation periods. The higher cumulative profits by using formation periods are largely due to a few extremely large daily profits. Therefore, we prefer the strategy with correlation matrix as pre-selection measure and moving look-back windows as standardizing methods.

We further conduct statistical arbitrage tests based on t and $t + AR(1)$ residuals and find that our strategy results do not reject the null hypothesis, which means that it is not satisfies statistical arbitrage strategy even though it could have positive profits.

There are still some issues worth further investigation: first, we should try different data

frequencies to find the optimal choice for co-integration pairs-trading strategy to improve the Sharpe Ratio; second, we need to find the reasons of extreme values in the profit series to come up with possible solutions to reduce the volatility; third, we should further consider trading strategies with hedging options to determine whether hedging would improve the strategy performance; fourth, we can use other information to determine the trade size instead of the price series, like volume data and minimum profit level we would like to realize.

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1. Motivation

Pairs trading is a classical statistical arbitrage strategy that is still popular along the street, where we take a long position and a short position simultaneously. There are many measures to select the assets to buy and sell. In our strategy, we focus mainly on the co-integration method and its utilization in US equity market. We try to find the long-term stationary relationship between stocks so that once the linear combination deviates too much from the threshold, we will long or short the spread accordingly and wait for it to return to the stable level. For this strategy, there are two main parts: pairs or baskets selection and trading rules determination.

We use a three-stage stock selection procedure. Considering such a large pool of candidate stock pairs, we try to pre-select stock groups with similar price movement pattern before conducting the co-integration tests. We consider three preselection methods: correlation, clustering and Graphical Lasso. Then we perform co-integration tests to choose the stock pairs or baskets which pass the co-integration test, indicating there exists a long-term stable relationship among the pairs. Based on that, we can make investment decision. Finally, through in-sample simulated trading we choose the top 20 pairs with highest Sharpe Ratio. We introduce the third selection criterion since the final purpose of our strategy is to realize a high profitability measure (Sharpe Ratio is one of the most important measures), but highly co-integrated pairs do not necessarily achieve high Sharpe Ratios, and adding this filter enables us to focus on the ones that tend be more profitable in the real trading.

As for the trading rules, we preset the open, close, and bail-out thresholds and look at the path of the standardized spread to determine when to enter into the market and when to exit. To standardize the spreads, we need to have mean and standard deviation. Here, we employ two different methods: calculating the statistics using moving look-back window and using formation period data.

There are some parameters we need to tune: the length of formation period and that of trading period and the six levels of thresholds. Then we use the cumulative profit-and-loss, volatility of returns, Sharpe Ratio, maximum drawdown and winning percentage to compare different strategies with different sets of parameters in-sample and out-of-sample.

2. Pairs Selection Methods

We choose co-integration test to select stock pairs or baskets. There are two problems we need to solve before that. First, what is the target time series. Second, which pairs or baskets of stocks should we test on.

For the first problem, since the distribution of stock price has heavier tails than normal distribution and cannot be negative, we take the logarithm of the stock price as our target time series, which is approximately normal distributed.

For the second problem, one possible answer is to test on all possible pairs or baskets. However, the number of tests would explode as the number of candidate stocks increases. Therefore, we utilize some methods to reduce the pool size first and then perform co-integration tests. We tried three methods: correlation, clustering and Graphical Lasso.

2.1. Correlation and Co-Integration Test

Before performing co-integrating test, we pre-select prospective pairs based on their correlation. The correlation threshold is pre-set to be 0.97. However, this parameter could be adjusted or tuned. Then, we conduct co-integration test and if the ADF test value is below -2.57 under $\alpha = 0.01$, we denote this pair passes this test and the residual display somewhat co-integration property. The coefficients in the regression are used for long short amount calculation.

2.2. Clustering and Co-Integration Test

Before performing co-integrating test, we pre-select prospective pairs based on their clustering group. In order to better approximate the real equity market, we choose the clustering group number to be 11, which is the total sector number in S&P 500. Again, in each clustering group, we conduct co-integration test on each pair and if the ADF test value is below -2.57 under $\alpha = 0.01$, we denote this pair passes this test and the residual display somewhat co-integration property. The coefficients in the regression are used for long short amount calculation.

2.3. Graphical Lasso and Co-Integration Test

Graphical Lasso is another method we use to preselect stock pairs. It treats the whole collection of candidate stocks as a network and finds a small collection of stocks that appear to be co-integrated. We set $\rho = 0.88$ in the Graphical Lasso function and only choose the baskets with 2-5 stocks to further conduct co-integration test. Then we use Johansen test to choose the stocks we are going to trade in the following trading period. We set the significant level as 1% and select the baskets satisfying two criteria: 1) at least one coefficient is negative and 2) there is only one relation.

2.4. In-sample Sharpe Ratio

In order to better select the top performance stock pair, we add another in sample Sharpe ratio criteria and generate trade list based on top 20 pairs.

We introduce the extra selection criterion since the final purpose of our strategy is to realize a high profitability measure (Sharpe Ratio is one of the most important measures), but highly co-integrated pairs do not necessarily achieve high SRs. Adding this filter enables us to focus on the ones that tend to be more profitable in real trading. We are going to compare the results with and without this criterion to see whether it is helpful.

3. Trading Rules

3.1. Basic Trading Idea

Co-integration means linear combination of two or more series is a stationary process, which has a desirable property of mean-reversion for pairs trading strategy. Therefore, we can look at the dynamics of the linear combination of logarithm price processes (we call it “spread” in the following context). If the spread is too low, we expect it would move up toward the mean level and take a long position of the spread (long in stocks with positive coefficients and short in stocks with negative coefficients); when the spread returns to the mean or near the mean, we close the position and realize the profit. Similarly, if the spread is too high, we expect it would move down toward the mean level and take a short position of the spread (short in stocks with positive coefficients and long in stocks with negative coefficients); when the spread returns to the mean or near the mean, we close the position and realize the profit.

To apply the same thresholds as consistent measures of whether the spread is too high or too low, we first standardize the spread with its mean and standard deviation since the spreads are in different scales for different stock pairs or baskets.

3.2. Possible Risks

One primary risk related to this kind of strategy is that it is possible that the spread goes further and further away from its mean level and never goes back. To reduce the possible loss size, one way is to set some stop-loss or bail-out levels. When the spread crosses and goes beyond the levels, we close our position by force.

3.3. Transaction Costs

There are three types of transaction costs: bid-ask spread, commission fee, and market impact.

To take into consideration the bid-ask spread in the market, we use ask prices when we buy stocks, and bid prices when we sell stocks.

As for the other two kinds of transaction cost, we charged 0.05% to open or close any

trade. This is comprised of $2 \times 0.01\%$ brokerage fee, slippage $2 \times 0.005\%$ and 0.02% rental cost for short positions.

Another issue we should bear in mind is that in real trading, we cannot trade with the close prices that triggers the trading signals. However, we do not have access to open bid and ask prices, the length of waiting periods is too long if we wait to the end of next day. Therefore, we assume that the open bid and ask prices are very close to closing bid and ask prices, and when we receive the trading signals, we use current day's closing prices to enter into the market with 0.02% slippage.

3.4. Trading Rules Formulation

Therefore, the trading rules can be formulated as follows. Let S_1 and S_2 be the two stocks we select.¹ Define $LR = \log(ask_1) - \beta \log(bid_2)$ and $SR = \log(bid_1) - \beta \log(ask_2)$ as the log price spreads of long pair and short pair. $sLR = \frac{LR - Lm}{Ls}$ and $sSR_s = \frac{SR - Sm}{Ss}$ are the standardized log price spreads, where Lm , Ls , Sm and Ss are the mean, standard deviation of long pair and mean and standard deviation of short pair. There are six thresholds in the trading rules and from top to bottom are short bail-out level (Sb), short enter level (So), short exist level (Sc), long exist level (Lc), long enter level (Lo) and long bail-out level (Lb). The trading rules are:

- If we do not hold any position currently, when $sLR_t < Lo$ and $sLR_t > Lb$, we take a long position of the spread;
- If we hold a long spread position currently, when $sSR_t \geq Lc$ or $sSR_t \leq Lb$, we close the position;
- If we do not hold any position currently, when $sSR_t > So$ and $sSR_t < Sb$, we take a short position of the spread;
- If we hold a short spread position currently, when $sLR_t \leq Sc$ or $sLR_t \geq Sb$, we close the position.

Here, we have two remaining questions to be answered, 1) how to determine the mean

¹ This can be easily extended to the case of more than two stocks.

and standard deviation, and 2) how many shares to trade.

3.4.1. How to determine the mean

For the first question, we come up with two solutions: one is to use moving look-back windows and the other is to use data in the formation periods.

- Moving Look-back Window

On each day t , we use the past k days' spread (we set $k = 20$ in our case) to calculate the mean and standard deviation. Then we use them to normalize today's spread, and compare it with the predetermined thresholds of trading signals. Once we enter into the market, we freeze the mean and standard deviation as the ones when we open the position. After we close the position, we unfreeze the mean and standard deviation and recalculate it on a rolling basis.

- Formation Period

We cut our data into formation period and trading period. We use the formation period to select stock pairs and determine the co-integration coefficients. One natural way to use formation data to calculate the mean and standard deviation and then use these numbers to standardize the spread in the trading period.

3.4.2. How many shares to trade

After we conduct the co-integration test, we can get the coefficients to combine the logarithm of stock price processes. Although these coefficients are related to logarithm of stock prices, which are not tradable, we can actually use them to determine the number of shares we are going to buy and sell. The reason is as follows.

Let S_1 and S_2 be the two stocks we select and their co-integration relationship is $\log(P_1(t_0)) - \beta \log(P_2(t_0))$. Assuming at t_0 the spread is too small, we decide to open a long position and expect it would move up toward the mean level. Later on, at time t_1 , the spread returns and we close the position. If we could trade the log spread, we

would get

$$\log (P_1(t_1)) - \beta \log (P_2(t_1)) - (\log (P_1(t_0)) - \beta \log (P_2(t_0))) > 0.$$

Using $\log(1+x) \sim x$, we have

$$\begin{aligned} & \log (P_1(t_1)) - \log (P_1(t_0)) - \beta (\log (P_2(t_1)) - \log (P_2(t_0))) \\ &= (P_1(t_1) - P_1(t_0))/P_1(t_0) - \beta (P_2(t_1) - P_2(t_0))/P_2(t_0) > 0, \end{aligned}$$

which means that if we buy $1/P_1(t_0)$ shares of stock 1 and sell $\beta/P_2(t_0)$, we could earn a profit. Therefore, assuming we can trade in fractional shares, the number of shares we are going to buy or sell is equal to the coefficients from co-integration test over the initial price when we decide to enter into the market.

3.5. Close types

There are 8 types to close a position, 4 for long position and 4 for short positions. We summarize as follows.

Position	Symbol	Meaning
Long pairs	du	Down and up, return to mean.
	dd	Down and down, bail out.
	dexc	Down and exceed the maximum holding length.
	dna	Down and encounter unavailable data.
Short pairs	ud	Up and down, return to mean.
	uu	Up and up, bail out.
	uexc	Up and exceed the maximum holding length.
	una	Up and encounter unavailable data.

“Du” and “ud” are the close types we are looking for since it means after deviation, the spread returns back to the normal range and we close the position with a positive profit. “Dd” and “uu” are due to the fact that we set the stop-loss levels and when the spread deviates from its mean level too much, we close the position we hold with a controllable loss.

We cut the data into non-overlapping rolling trading periods, and for each trading period we use the formation period just before it to select stock pairs to trade in this period. Since we can open a position at any point in the trading period, it is possible that we enter into the market at the end of this trading period. Considering this possibility, we extend the holding period to the end of the trading period plus 50 days by default. That means we are permitted to hold an open position after the current trading period with maximum 50 days following the end of the trading period, while we are not permitted to open a position after the current trading periods with the selected pairs from the previous formation period. There are 2 kinds of close types with this setting: “dexc” and “uexc”, which represent that we get to the last day of the extended holding period and close the position at the last day.

“Una” and “dna” mean that after we open the position, we encounter NA prices, and under this condition we close the position with last day’s price data.

4. Data Description

We downloaded data from CRSP. We used quarterly updates, NYSE listed stocks from 2001/01/02 to 2016/08/31. We identify stocks by their unique Ticker information. We collected time series information of each stock including Price, Ask or High, Bid or Low, Closing Bid, Closing Ask and Cumulative Factor. We use Price/Cumulative Factor as the adjusted closing price. There are in total 2104 stocks and 2944 trading days.

In order to utilize data into our model, we reshape each time series information into a separate matrix format. Each row represents that information on a specific date. Each matrix has 2944 rows according to length of trading dates and 2104 columns according to total stocks.

We split whole data set into training and testing parts. Training data is from 2001/01/02 to 2010/12/31, approximately 60% of our whole dataset. The rest is used for testing.

4.1. Data cleaning

For closing prices, there are some negative values, and according to the documentation of CRSP it is due to missing data and comes from negating the average of closing bid and ask price. Therefore, we take the absolute value of the closing price. There is no negative ask and bid prices.

4.2. Unavailable data

When dealing with real data, we would find there are some unavailable data and our solutions are different based on whether we are in formation period and trading period. In the formation period, since we have all the historical data, and we only focus on the stocks with full records during this period and select stock pairs or baskets from them. In the trading period, to avoid look-ahead bias, we do not delete any price series and deal with the unavailable data as follows.

- If we do not hold any position and today's price data is unavailable, we move to the next day.
- If we have already opened a position and today's price data is unavailable, in theory there are three possible conditions: 1) the stock is delisted that day, and we should clear our position; 2) the stock does not have trading activity that day, and we could hold the position until there are available trading data; 3) missing records. However, we could not distinguish these conditions and therefore, once we encounter NA data after we open a position, we close the position using last day's price information.

5. Empirical Results

5.1. Training period and testing period

We cut our data into two parts: training data and testing data. The training period is from the beginning of Jan 2001 to the end of Dec 2010, and the testing period is from the beginning of Jan 2011 to the end of June 2016. For each period, we further cut the data into formation period and trading period. We use the data in formation periods to select

stock pairs and use the data in trading periods to conduct simulation trading. Trading periods are not overlapped while formation periods are likely to overlap with each other. For example, if we take 6 months of data to form stock pairs and 3 months of data to simulate trading, then the first trading period is from 2002.1.1 to 2002.3.31 and the second trading period is from 2002.4.1 to 2002.6.30, where the first formation period is from 2001.7.1 to 2001.12.31 and the second formation period is from 2001.10.1 to 2002.3.31.

5.2. Parameters to tune

The first set of tuning parameters is the length of formation and that of trading periods. Denote J as the length of formation period in unit of days and K as the length of trading period in unit of days. J and K both can take value of 60, 90 and 120, leading to a and there are totally of 9 possible combinations.

Another set of important parameters to tune is the six trading rule thresholds: short bail-out level (S_b), short enter level (S_o), short exist level (S_c), long exist level (L_c), long enter level (L_o) and long bail-out level (L_b). We consider the following possible 5 combinations. Combined with J and K , there are in total 45 cases for each selection and trading strategy.

Lb	Lo	Lc	Sc	So	Sb
-6	-2	0	0	2	6
-10	-2	0	0	2	10
-3.5	-2	0	0	2	3.5
-10	-2	-0.5	0.5	2	10
-6	-1	0	0	1	6

5.3. Stock selection and trading rules combination

We consider 4 stock selection methods: correlation + co-integration test with and without in-sample Sharpe Ratio test, and graphical lasso + co-integration test with and without

in-sample Sharpe Ratio test; 2 trading rules: spread standardized using moving windows and spread standardized using formation statistics. In total, we have 8 possible combinations of stock selection and trading strategies.

5.4. Performance measurement

We use the following statistics to measure the performance of our trading strategies.

Name	Calculation Method
Average PnL	Mean of monthly PnL series
Standard Deviation of PnL	Standard deviation of monthly PnL series
Cumulative PnL	Total PnL during the whole trading periods
Winning Percentage	Number of days with positive profit over total number of days with non-negative profit
Maximum Drawdown	The maximum of the difference series between historical maximum cumulative PnL and today's cumulative PnL
Total Long Numbers	Total number of trades opened for taking a long position of the pairs
Total Short Numbers	Total number of trades opened for taking a short position of the pairs
Average Long Days	Average number of holding period for taking a long position of the pairs
Average Short Days	Average number of holding period for taking a short position of the pairs
Close Types	ud, uu, uexc, una for short position in pairs du, dd, dexc, dna for long position in pairs

5.5. In-sample results

Using data from 2001.1.2 to 2010.12.31, the best set of parameters using Sharpe Ratio as the criteria for each combination of stock selection and trading strategy is as follows. We also list the average Profit-and-Loss (PnL), standard deviation of PnL, cumulative PnL (with and without Sharpe transaction cost), winning percentage, maximum drawdown,

total number of long pairs and short pairs, average holding period pf long pairs and short pairs, and average pairs of stocks selected for trading period.

Pairs Selection Methods	Correlation + Co-integration Test				Graphical Lasso + Co-integration Test			
	with SR test		without SR test		with SR test		without SR test	
Trading Rule	mv	rolling	mv	rolling	mv	rolling	mv	rolling
J	120	120	120	90	120	90	120	90
K	120	90	60	90	120	60	120	120
Sb	10	6	10	6	6	6	6	6
So	2	2	2	2	1	2	1	2
Sc	0	0	0	0	0	0	0	0
Lc	0	0	0	0	0	0	0	0
Lo	-2	-2	-2	-2	-1	-2	-1	-2
Lb	-10	-6	-10	-6	-6	-6	-6	-6
Sharpe Ratio	0.09046	0.0521	-0.0637	-0.1017	-0.0054	0.2535	-0.006	0.1844
Average PnL	0.08	0.03	-0.81	-12.67	-0.08	1.23	-0.09	2.29
PnL Volatility	0.87	0.52	12.84	124.55	14.77	4.84	14.77	12.40
Cumulative PnL	9.79	3.44	-102.31	-1583.12	-10.00	153.61	-11.12	286.09
Sharpe Ratio With TC	0.0903	0.0520	-0.064	-0.1017	-0.0056	0.2535	-0.006	0.1844
Average PnL With TC	0.078	0.0274	-0.821	-12.671	-0.082	1.228	-0.091	2.286
PnL Volatility With TC	0.866	0.527	12.842	124.612	14.76	4.845	14.77	12.39
Cumulative PnL With TC	9.770	3.428	-102.675	-1583.92	-10.21	153.53	-11.33	285.79

Winning Percentage	0.65	0.30	0.63	0.26	0.51	0.41	0.51	0.39
Maximum Drawdown	7.67	3.22	183.63	1584.27	183.71	6.25	185.13	45.76
Total Long Number	576	36	22976	791	881	164	923	670
Total Short Number	643	56	22392	1301	927	147	973	773
Average Long Days	23.08	28.03	27.28	25.68	16.65	9.30	16.39	11.65
Average Short Days	29.00	48.63	27.90	31.07	16.99	8.32	17.00	8.98
Average Pairs Number	16.70	16.44	548.775	659.184	14.25	13.39	14.9	14.09

From the above table, we can see that:

- With the additional Sharpe Ratio test, all kinds of strategies' performance have improved.
- While longer formation period has better selection results compared to shorter formation period, the best trading period can take any value of 60, 90 and 120.
- We prefer higher bail-out levels, which implies that although sometimes the spread can become very large, there still exists a high possibility that it will return back to the normal level.
- Comparing across different strategies, the Sharpe Ratio is highest for Graphical Lasso + co-integration test with SR test using rolling windows to standardize price spreads and trigger trading signals.
- The largest average and cumulative PnL is achieved when using Graphical Lasso + co-integration test without SR test using rolling windows. However, its PnL's standard deviation is very high and therefore its Sharpe Ratio is less than the corresponding one with SR test.

- The winning percentages of strategy using moving windows are all higher than those of strategies using rolling statistics. The former ones' winning percentages are higher than 50% and the latter ones' are lower than 50%.
- Using correlation methods to pre-select stock pairs, the resulting volatility of PnL is much smaller than those using Graphical Lasso preselection method, and the holding periods are longer than the latter ones.
- On average, each period we select 15 to 20 stock pairs to trade except for correlation + co-integration test, since we set the minimum correlation as the selection criteria instead of limits of maximum pair numbers.
- The performance is worst if we use correlation to preselect stock pairs and without additional SR test.

In summary, we prefer Graphical Lasso as the pre-selection method to Correlation method, which implies that higher correlation does not imply higher performance for pairs-trading strategies. Moving average method can guarantee higher winning percentages but due to large negative returns it may lead to, the average PnL is not as good as rolling method.

5.6. Out-of-sample results

For each trading strategy, we select the best 3 sets of parameters to conduct out-of-sample tests and compare the results with the in-sample results.

The following chart shows the in-sample and out-of-sample performance comparison of the best in-sample set of parameters for each trading strategy.

Pairs Selection Methods	Correlation + Co-integration Test				Graphical Lasso + Co-integration Test			
	with SR test		without SR test		with SR test		without SR test	
Trading Rule	mv	rollin g	mv	rolling	mv	rollin g	mv	rolling

Sharpe Ratio With TC	In-sample	0.09	0.05	-0.06	-0.10	-0.01	0.25	-0.01	0.18
	Out-of-sample	0.12	0.12	0.25	-0.12	-0.03	-0.08	-0.03	-0.21
Average PnL With TC	In-sample	0.08	0.03	-0.82	-12.67	-0.08	1.23	-0.09	2.29
	Out-of-sample	0.20	0.26	1.22	-0.09	-0.32	-0.31	-0.32	-2.25
PnL Volatility With TC	In-sample	0.87	0.53	12.84	124.61	14.76	4.85	14.77	12.39
	Out-of-sample	1.72	2.07	4.80	0.81	9.24	3.91	9.24	10.84
Cumulative PnL With TC	In-sample	9.77	3.43	-102.68	-1583.92	-10.21	153.53	-11.33	285.79
	Out-of-sample	14.10	18.27	86.42	-6.61	-22.79	-22.18	-22.79	-159.72

From the above table, we can see that:

- Graphical Lasso has highest in-sample Sharpe Ratio with TC and average PnL with TC but the out-of-sample Sharpe Ratio and average PnL with TC are negative, indicating this is not a trustable strategy.
- Correlation Co-integration with SR Test has relative stable positive Sharpe Ratio and Average PnL with TC in both in-sample and out-of-sample, implying this is a reliable strategy. In addition, it has quite low standard deviation and fairly large out-of-sample PnL.
- Maximum out-of-sample Sharpe Ratio lies in the Correlation Co-integration Test, however, the in-sample results are quite disappointing. Hence, we couldn't select this strategy from the in-sample statistics.
- Generally speaking, compared with mv method, rolling method has quite discrepant results in-sample and out-of-sample. It's very volatile in terms of Sharpe Ratio, average PnL and Cumulative PnL with TC.

The following chart shows the best parameter among the best three in-sample parameters

and their results.

Pairs Selection Methods	Correlation + Co-integration Test				Graphical Lasso + Co-integration Test			
	with SR test		without SR test		with SR test		without SR test	
Trading Rule	mv	rolling	mv	rolling	mv	rolling	mv	rolling
J	120	120	90	90	90	90	90	90
K	120	90	120	90	120	60	120	120
Sb	10	6	10	6	10	6	10	6
So	2	2	2	2	2	2	2	1
Sc	0	0	0	0	0	0	0	0.5
Lc	0	0	0	0	0	0	0	-0.5
Lo	-2	-2	-2	-2	-2	-2	-2	-1
Lb	-10	-6	-10	-6	-10	-6	-10	-6
Sharpe Ratio	0.12	0.12	0.25	-0.12	0.10	-0.08	0.10	-0.21
Average PnL	0.20	0.26	0.46	-0.09	0.21	-0.31	0.21	-2.25
PnL Volatility	1.73	2.07	1.79	0.81	2.15	3.91	2.15	10.83
Cumulative PnL	14.11	18.29	32.41	-6.60	14.59	-22.14	14.59	-159.56
Sharpe Ratio With TC	0.12	0.12	0.25	-0.12	0.10	-0.08	0.10	-0.21
Average PnL With TC	0.20	0.26	0.46	-0.09	0.20	-0.31	0.20	-2.25
PnL Volatility With TC	1.72	2.07	1.79	0.81	2.15	3.91	2.15	10.84
Cumulative PnL With TC	14.10	18.27	32.38	-6.61	14.55	-22.18	14.55	-159.72
Winning Percentage	0.78	0.47	0.81	0.31	0.71	0.43	0.71	0.37
Maximum	4.01	7.87	5.53	12.67	9.22	40.49	9.22	178.45

Drawdown								
Total Long Number	213	64	1498	56	177	61	177	274
Total Short Number	221	53	1341	90	181	38	181	348
Average Long Days	28.35	35.44	24.28	30.23	28.57	11.05	28.57	9.95
Average Short Days	32.40	38.21	23.12	31.44	31.61	11.16	31.61	10.57
Average Pairs Num	11.91	11.87	62.00	40.20	8.50	7.70	8.58	8.58

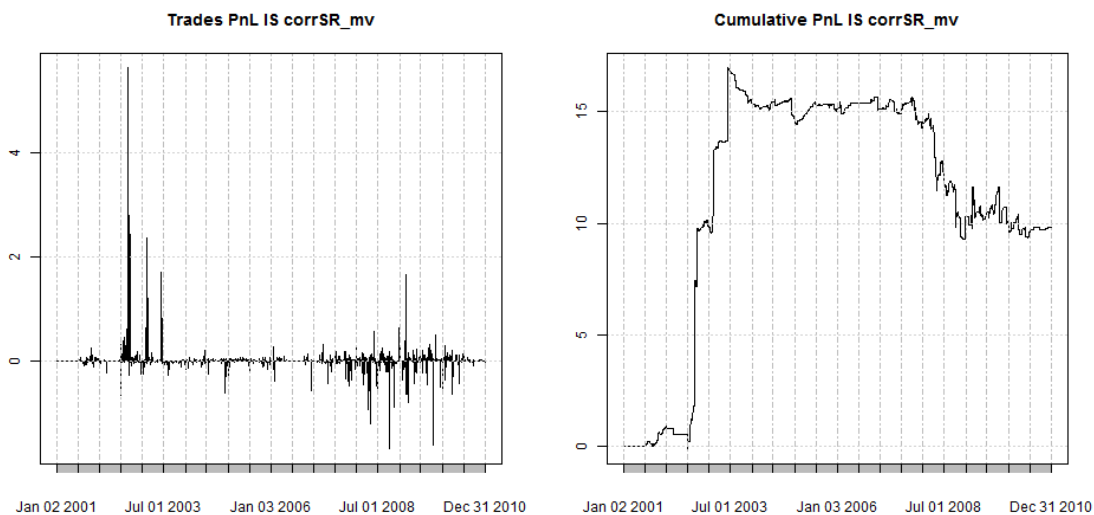
It's not difficult to reach the following findings:

- Compared to in-sample best parameters, out-of-sample parameters don't change for Correlation Co-integration with SR Test (both mv and rolling trading rules), Correlation Co-integration without SR test Rolling rule and Graphical Lasso with SR test Rolling rule.
- Compared to in-sample best parameters, Correlation Co-integration methods' Sharpe Ratio, average PnL and Winning Percentage improved in the out-of-sample result. Other methods' out-of-sample results are somewhat not in line with the in-sample test results.
- Compared with mv trading rule, the rolling rule has smaller winning percentage, smaller Sharpe Ratio as well as average PnL in general. Thus mv trading rule is better empirically.
- Conclusion: Correlation Co-integration method with SR test based on mv trading rule should be the optimal choice considering in-sample out-of-sample consistency, overall profitability and reliability.

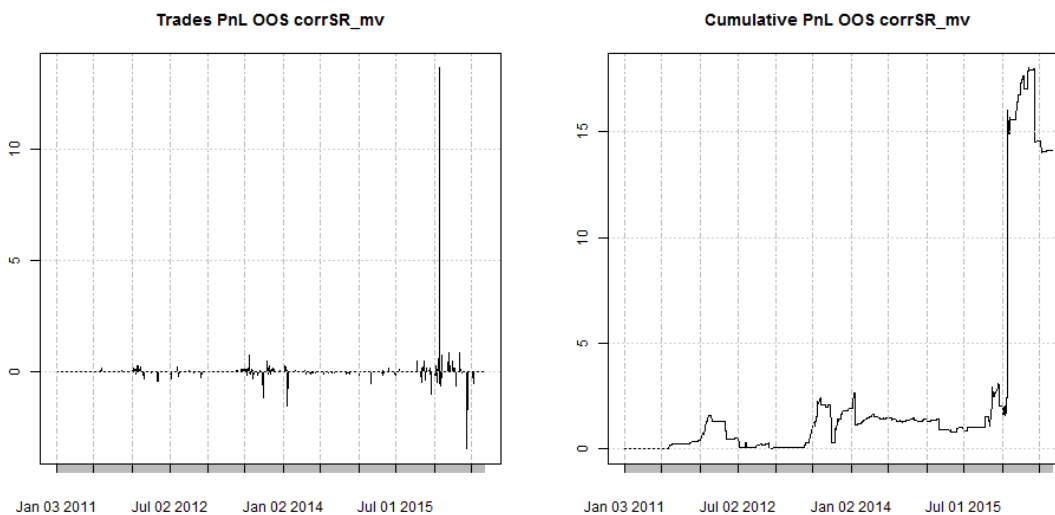
5.7. Result visualization

For comparison, here we pasted the best and worst pairs of profit and cumulative profit from in-sample test and out-of-sample test.

Best in-sample instance



Corresponding out-of-sample instance



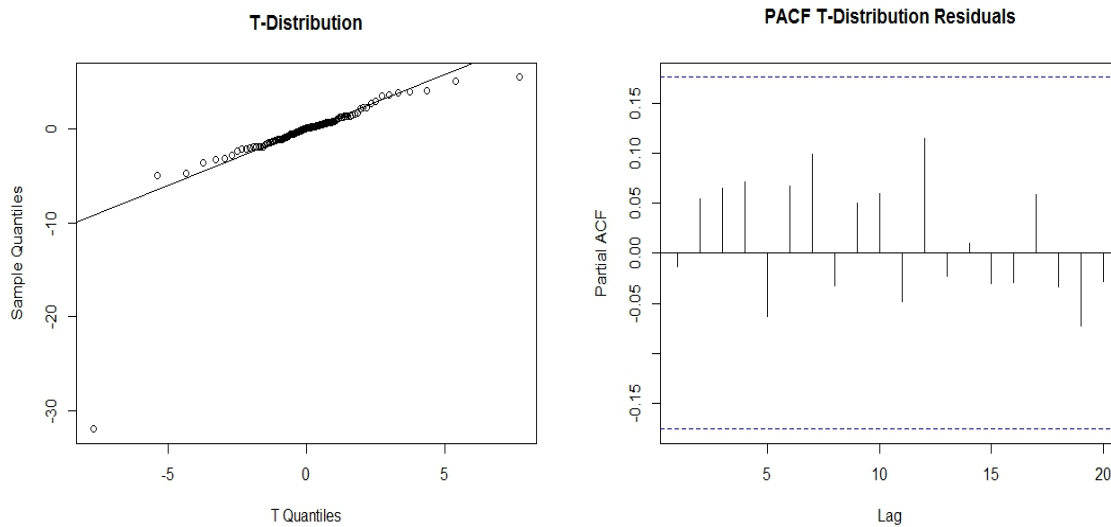
We can see that significant portion of cumulative profit is contributed by jumps of the profit sequence, for the out-of-sample corresponding plots, we see the profit is quite random.

6. Statistical Arbitrage Test

The In-Sample CorrSR_mv T-Statistical give the following p-value

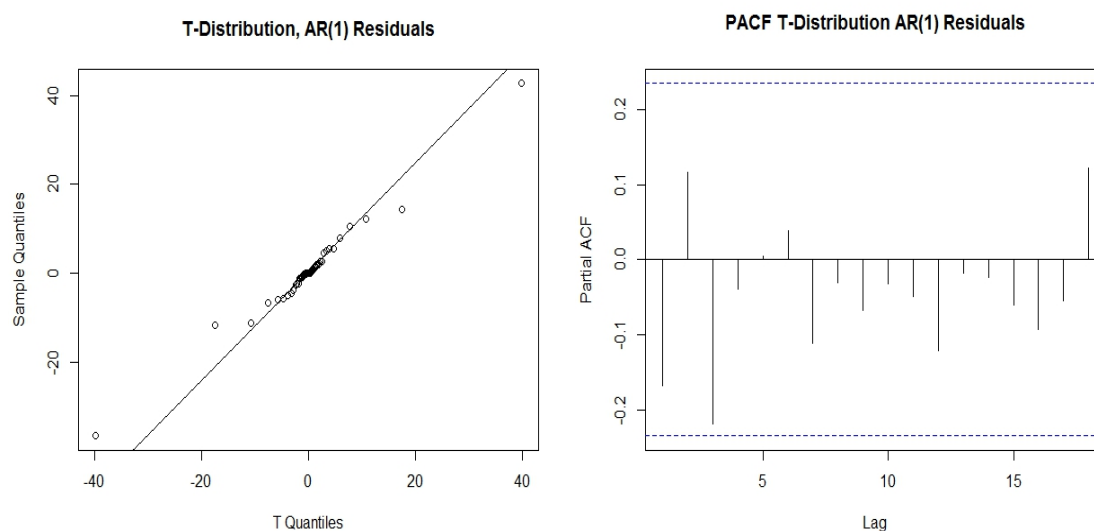
	mu	lambda	df
CorrSR_mv	0.9746943	0.8619055	0.4813791

The residual QQplot and PACF plot are



Out-Of-Sample CorrSR_mv T-Statistical AR(1) give the following P-value

	mu	lambda	df
Corr_MV	0.5653275	0.9616601	0.999771



The in-sample and out-of-sample tests cannot make us confident about the fact that this is a profitable arbitrage strategy. The sudden spikes still make us believe high frequency would be a better choice. And we will dig more into why this happens if time allowed.

7. Conclusion and Future Research

We executed our model as proposed and simulated our trading strategy based on the best tuning parameters. That is, using correlation as our first stage stocks screening, using Sharpe Ratio as additional criterion and using moving window to estimate mean and standard deviation for both in-sample and out-of-sample.

The in-sample Sharpe Ratio is 0.09, maximum drawdown is 7.67 and winning percentage is 65%. The out-of-sample Sharpe Ratio is 0.25, maximum drawdown is 5.53 and winning percentage is 81%.

To further update our model, we intended to increase the trading frequency. Besides, we also intend to adjust our trading strategy to require a minimum profit of K . The theoretic minimum profit strategy is following:

Suppose S_1 and S_2 is the selected pair following the co-integration process

$$\log S_1(t) + \beta \log S_2(t) = \epsilon(t)$$

Let a and b be our open and close position threshold, and K is the minimum profit we want to obtain in the end. Suppose we long the pair, that means we short stock S_1 and long S_2 .

Suppose at one trading day, $\epsilon(t_0) > a$, we long n_2 shares of S_2 . At this point, we have

to short $n_1 = \frac{n_2 P_2(t_0)}{|\beta| P_1(t_0)}$ shares of S_1 . Then at the closing date, the profit is

$$\begin{aligned} & n_2(P_2(t_c) - P_2(t_0)) + n_1(P_1(t_0) - P_1(t_c)) \\ &= \frac{n_2 P_2(t_0)}{\beta} * \left(\beta * \left(\frac{P_2(t_c)}{P_2(t_0)} - 1 \right) + \left(\frac{P_1(t_c)}{P_1(t_0)} - 1 \right) \right) \\ &= \frac{n_2 P_2(t_0)}{\beta} * (\beta * \log P_2(t_c) + \log P_1(t_0) - (\beta * \log P_2(t_0) + \log P_1(t_0))) \\ &= \frac{n_2 P_2(t_0)}{\beta} * (b - a) > K \end{aligned}$$

To satisfy the above condition, at the start period, we need to long

$K * \frac{\beta}{(b-a)P_2(t_0)}$ shares of S_2 and short $\frac{K}{b-a} * P_1(t_0)$ shares of S_1 .

8. Reference

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Appendix:

Table 1 Tuning Parameters Combination

No.	Lb	Lo	Lc	Sc	So	Sb	formation	holding
1	-6	-2	0	0	2	6	90	60
2	-10	-2	0	0	2	10	90	60
3	-3.5	-2	0	0	2	3.5	90	60
4	-6	-1	0	0	1	6	90	60
5	-10	-2	-0.5	0.5	2	10	90	60
6	-6	-2	0	0	2	6	90	90
7	-10	-2	0	0	2	10	90	90
8	-3.5	-2	0	0	2	3.5	90	90
9	-6	-1	0	0	1	6	90	90
10	-10	-2	-0.5	0.5	2	10	90	90
11	-6	-1	-0.5	0.5	1	6	90	120
12	-6	-2	0	0	2	6	90	120
13	-10	-2	0	0	2	10	90	120
14	-3.5	-2	0	0	2	3.5	90	120
15	-6	-1	0	0	1	6	90	120
16	-10	-2	-0.5	0.5	2	10	60	60
17	-6	-1	-0.5	0.5	1	6	60	60
18	-6	-2	0	0	2	6	60	60
19	-10	-2	0	0	2	10	60	60
20	-3.5	-2	0	0	2	3.5	60	60
21	-6	-1	0	0	1	6	60	90
22	-10	-2	-0.5	0.5	2	10	60	90
23	-6	-1	-0.5	0.5	1	6	60	90
24	-6	-2	0	0	2	6	60	90
25	-10	-2	0	0	2	10	60	90
26	-3.5	-2	0	0	2	3.5	60	120
27	-6	-1	0	0	1	6	60	120
28	-10	-2	-0.5	0.5	2	10	60	120
29	-6	-1	-0.5	0.5	1	6	60	120
30	-6	-2	0	0	2	6	60	120
31	-10	-2	0	0	2	10	120	60
32	-3.5	-2	0	0	2	3.5	120	60
33	-6	-1	0	0	1	6	120	60
34	-10	-2	-0.5	0.5	2	10	120	60
35	-6	-1	-0.5	0.5	1	6	120	60
36	-6	-2	0	0	2	6	120	90
37	-10	-2	0	0	2	10	120	90
38	-3.5	-2	0	0	2	3.5	120	90
39	-6	-1	0	0	1	6	120	90
40	-10	-2	-0.5	0.5	2	10	120	90
41	-6	-1	-0.5	0.5	1	6	120	120
42	-6	-2	0	0	2	6	120	120
43	-10	-2	0	0	2	10	120	120
44	-3.5	-2	0	0	2	3.5	120	120
45	-6	-1	0	0	1	6	120	120

Table 2 Correlation + Co-integration + Moving Look-back Window (mv)

[illegible]

Table 3 Correlation + Co-integration + Formation Period (rolling)

No.	Average PnL PnL tility	Volia SharpeF atio	Cumulati vePnL Cost	Average PnL PnL Plus tility Plus atio Plus vePnL P Cost	Winning Percenta ge	Maximu mDD	TotalLo ngNum	TotalSh ortNum	Average Long Da Short Da PairsNu m	uexc	ud	uu	una	dexc	du	dd	dna						
1	-3.25	26.36	-0.12	-405.86	-3.25	26.37	-0.12	-406.07	0.22	405.93	674	881	27.54	33.50	564.00	201	153	404	123	108	84	253	33
2	-3.25	26.36	-0.12	-405.86	-3.25	26.37	-0.12	-406.07	0.22	405.93	674	881	27.54	33.50	564.00	201	153	404	123	108	84	253	33
3	-3.25	26.36	-0.12	-405.86	-3.25	26.37	-0.12	-406.07	0.22	405.93	674	881	27.54	33.50	564.00	201	153	404	123	108	84	253	33
4	-3.25	26.36	-0.12	-405.86	-3.25	26.37	-0.12	-406.07	0.22	405.93	674	881	27.54	33.50	564.00	201	153	404	123	108	84	253	33
5	-3.25	26.36	-0.12	-405.86	-3.25	26.37	-0.12	-406.07	0.22	405.93	674	881	27.54	33.50	564.00	201	153	404	123	108	84	253	33
6	-12.66	124.55	-0.10	-1583.12	-12.67	124.61	-0.10	-1583.92	0.26	1584.27	791	1301	25.68	31.07	659.15	193	228	565	315	74	147	329	70
7	-12.66	124.55	-0.10	-1583.12	-12.67	124.61	-0.10	-1583.92	0.26	1584.27	791	1301	25.68	31.07	659.15	193	228	565	315	74	147	329	70
8	-12.66	124.55	-0.10	-1583.12	-12.67	124.61	-0.10	-1583.92	0.26	1584.27	791	1301	25.68	31.07	659.15	193	228	565	315	74	147	329	70
9	-12.66	124.55	-0.10	-1583.12	-12.67	124.61	-0.10	-1583.92	0.26	1584.27	791	1301	25.68	31.07	659.15	193	228	565	315	74	147	329	70
10	-12.66	124.55	-0.10	-1583.12	-12.67	124.61	-0.10	-1583.92	0.26	1584.27	791	1301	25.68	31.07	659.15	193	228	565	315	74	147	329	70
11	-3.36	26.65	-0.13	-420.30	-3.36	26.66	-0.13	-420.52	0.21	420.39	653	882	31.69	39.61	463.67	99	133	358	92	63	83	249	61
12	-3.36	26.65	-0.13	-420.30	-3.36	26.66	-0.13	-420.52	0.21	420.39	653	882	31.69	39.61	463.67	99	133	358	92	63	83	249	61
13	-3.36	26.65	-0.13	-420.30	-3.36	26.66	-0.13	-420.52	0.21	420.39	653	882	31.69	39.61	463.67	99	133	358	92	63	83	249	61
14	-3.36	26.65	-0.13	-420.30	-3.36	26.66	-0.13	-420.52	0.21	420.39	653	882	31.69	39.61	463.67	99	133	358	92	63	83	249	61
15	-3.36	26.65	-0.13	-420.30	-3.36	26.66	-0.13	-420.52	0.21	420.39	653	882	31.69	39.61	463.67	99	133	358	92	63	83	249	61
16	-1.54	6.32	-0.24	-192.70	-1.54	6.33	-0.24	-192.81	0.23	193.24	923	1112	16.56	22.64	703.66	138	206	546	222	69	159	366	32
17	-1.54	6.32	-0.24	-192.70	-1.54	6.33	-0.24	-192.81	0.23	193.24	923	1112	16.56	22.64	703.66	138	206	546	222	69	159	366	32
18	-1.54	6.32	-0.24	-192.70	-1.54	6.33	-0.24	-192.81	0.23	193.24	923	1112	16.56	22.64	703.66	138	206	546	222	69	159	366	32
19	-1.54	6.32	-0.24	-192.70	-1.54	6.33	-0.24	-192.81	0.23	193.24	923	1112	16.56	22.64	703.66	138	206	546	222	69	159	366	32
20	-1.54	6.32	-0.24	-192.70	-1.54	6.33	-0.24	-192.81	0.23	193.24	923	1112	16.56	22.64	703.66	138	206	546	222	69	159	366	32
21	-0.28	1.64	-0.17	-34.48	-0.28	1.64	-0.17	-34.52	0.22	36.31	397	475	10.29	16.46	563.54	29	92	322	32	4	69	196	12
22	-0.28	1.64	-0.17	-34.48	-0.28	1.64	-0.17	-34.52	0.22	36.31	397	475	10.29	16.46	563.54	29	92	322	32	4	69	196	12
23	-0.28	1.64	-0.17	-34.48	-0.28	1.64	-0.17	-34.52	0.22	36.31	397	475	10.29	16.46	563.54	29	92	322	32	4	69	196	12
24	-0.28	1.64	-0.17	-34.48	-0.28	1.64	-0.17	-34.52	0.22	36.31	397	475	10.29	16.46	563.54	29	92	322	32	4	69	196	12
25	-0.28	1.64	-0.17	-34.48	-0.28	1.64	-0.17	-34.52	0.22	36.31	397	475	10.29	16.46	563.54	29	92	322	32	4	69	196	12
26	-8.24	78.10	-0.11	-1030.36	-8.25	78.13	-0.11	-1030.89	0.25	1030.36	1067	1155	18.54	27.79	788.66	95	265	541	254	58	185	435	40
27	-8.24	78.10	-0.11	-1030.36	-8.25	78.13	-0.11	-1030.89	0.25	1030.36	1067	1155	18.54	27.79	788.66	95	265	541	254	58	185	435	40
28	-8.24	78.10	-0.11	-1030.36	-8.25	78.13	-0.11	-1030.89	0.25	1030.36	1067	1155	18.54	27.79	788.66	95	265	541	254	58	185	435	40
29	-8.24	78.10	-0.11	-1030.36	-8.25	78.13	-0.11	-1030.89	0.25	1030.36	1067	1155	18.54	27.79	788.66	95	265	541	254	58	185	435	40
30	-8.24	78.10	-0.11	-1030.36	-8.25	78.13	-0.11	-1030.89	0.25	1030.36	1067	1155	18.54	27.79	788.66	95	265	541	254	58	185	435	40
31	-1.17	5.80	-0.20	-145.68	-1.17	5.80	-0.20	-145.78	0.26	152.83	807	1209	27.74	34.03	548.78	250	212	441	306	111	115	341	79
32	-1.17	5.80	-0.20	-145.68	-1.17	5.80	-0.20	-145.78	0.26	152.83	807	1209	27.74	34.03	548.78	250	212	441	306	111	115	341	79
33	-1.17	5.80	-0.20	-145.68	-1.17	5.80	-0.20	-145.78	0.26	152.83	807	1209	27.74	34.03	548.78	250	212	441	306	111	115	341	79
34	-1.17	5.80	-0.20	-145.68	-1.17	5.80	-0.20	-145.78	0.26	152.83	807	1209	27.74	34.03	548.78	250	212	441	306	111	115	341	79
35	-1.17	5.80	-0.20	-145.68	-1.17	5.80	-0.20	-145.78	0.26	152.83	807	1209	27.74	34.03	548.78	250	212	441	306	111	115	341	79
36	-7.90	76.10	-0.10	-987.66	-7.91	76.14	-0.10	-988.17	0.23	990.36	807	986	37.63	44.94	549.52	211	212	456	107	114	140	314	71
37	-7.90	76.10	-0.10	-987.66	-7.91	76.14	-0.10	-988.17	0.23	990.36	807	986	37.63	44.94	549.52	211	212	456	107	114	140	314	71
38	-7.90	76.10	-0.10	-987.66	-7.91	76.14	-0.10	-988.17	0.23	990.36	807	986	37.63	44.94	549.52	211	212	456	107	114	140	314	71
39	-7.90	76.10	-0.10	-987.66	-7.91	76.14	-0.10	-988.17	0.23	990.36	807	986	37.63	44.94	549.52	211	212	456	107	114	140	314	71
40	-7.90	76.10	-0.10	-987.66	-7.91	76.14	-0.10	-988.17	0.23	990.36	807	986	37.63	44.94	549.52	211	212	456	107	114	140	314	71
41	-0.27	1.05	-0.25	-33.35	-0.27	1.05	-0.25	-33.37	0.21	37.65	268	475	28.24	29.74	393.30	45	71	304	55	16	42	100	33
42	-0.27	1.05	-0.25	-33.35	-0.27	1.05	-0.25	-33.37	0.21	37.65	268	475	28.24	29.74	393.30	45	71	304	55	16	42	100	33
43	-0.27	1.05	-0.25	-33.35	-0.27	1.05	-0.25	-33.37	0.21	37.65	268	475	28.24	29.74	393.30	45	71	304	55	16	42	100	33
44	-0.27	1.05	-0.25	-33.35	-0.27	1.05	-0.25	-33.37	0.21	37.65	268	475	28.24	29.74	393.30	45	71	304	55	16	42	100	33
45	-0.27	1.05	-0.25	-33.35	-0.27	1.05	-0.25	-33.37	0.21	37.65	268	475	28.24	29.74	393.30	45	71	304	55	16	42	100	33

Table 4 Correlation + Co-integration + In-sample SR + Moving Look-back Window (mv)

No.	Average PnL PnL	Volatility tilty	Average Sharpe ratio	Cumulative vePnL	Average PnL Cost	Volatility Cost	Average Sharpe Plus ratio	Cumulative Cost	Winning ge	Maximum mDD	Total Lo ngNum	Total Sh ortNum	Average Long Da ys	Average Short Da ys	Average Paris Nu m	uexc	ud	uu	una	dexc	du	dd	dna
1	-0.11	0.99	-0.11	-13.74	-0.11	0.99	-0.11	-13.74	0.56	21.57	975	957	16.55	17.52	16.95	50	540	320	47	44	551	310	70
2	-0.10	0.93	-0.11	-12.85	-0.10	0.93	-0.11	-12.88	0.67	18.34	842	796	23.15	24.07	16.95	84	517	137	58	91	540	129	82
3	-0.24	0.80	-0.30	-29.81	-0.24	0.80	-0.30	-29.84	0.37	31.90	1274	1279	8.73	9.35	16.95	29	450	764	36	23	481	722	48
4	-0.24	1.09	-0.22	-30.52	-0.24	1.09	-0.22	-30.56	0.55	33.52	1453	1424	15.59	15.59	16.95	62	955	328	79	66	972	322	93
5	-0.14	0.91	-0.16	-17.84	-0.14	0.91	-0.16	-17.86	0.69	20.67	909	878	19.30	19.60	16.95	67	624	136	51	82	631	126	70
6	-0.24	1.49	-0.16	-30.61	-0.25	1.49	-0.16	-30.65	0.52	32.74	847	851	17.59	19.57	17.19	31	447	316	57	27	487	271	62
7	-0.24	1.54	-0.16	-29.87	-0.24	1.54	-0.16	-29.91	0.63	32.70	709	712	24.88	27.02	17.19	70	429	142	71	56	459	123	71
8	-0.37	1.43	-0.26	-46.06	-0.37	1.43	-0.26	-46.10	0.37	46.06	1174	1248	8.93	9.91	17.19	24	424	759	41	7	458	659	50
9	-0.41	1.85	-0.22	-51.20	-0.41	1.85	-0.22	-51.25	0.52	51.95	1234	1239	16.48	17.60	17.19	47	798	307	87	47	841	260	86
10	-0.28	1.52	-0.18	-34.97	-0.28	1.52	-0.18	-35.00	0.64	37.00	773	785	21.06	22.61	17.19	64	516	139	66	47	538	122	66
11	-0.22	0.51	-0.43	-27.14	-0.22	0.51	-0.43	-27.17	0.50	27.49	1507	1438	12.28	10.93	16.81	32	1102	237	67	31	1141	260	75
12	-0.08	0.48	-0.18	-10.53	-0.08	0.48	-0.18	-10.56	0.55	13.05	818	754	18.56	18.51	16.81	31	440	229	54	33	448	268	69
13	-0.06	0.53	-0.11	-7.15	-0.06	0.53	-0.11	-7.17	0.66	7.72	654	590	28.95	24.83	16.81	41	399	94	56	67	418	94	75
14	-0.21	0.47	-0.43	-25.70	-0.21	0.47	-0.43	-25.72	0.35	26.22	1149	1091	9.29	9.22	16.81	14	421	616	40	14	419	668	48
15	-0.17	0.50	-0.35	-21.86	-0.18	0.50	-0.35	-21.89	0.53	23.08	1175	1115	17.54	15.53	16.81	41	774	222	78	45	794	257	79
16	-0.15	0.77	-0.20	-19.04	-0.15	0.77	-0.20	-19.07	0.66	23.52	1007	921	18.01	19.78	17.95	72	635	144	70	75	714	144	74
17	-0.39	1.24	-0.31	-48.34	-0.39	1.24	-0.31	-48.38	0.53	49.60	1987	1951	10.43	10.69	17.95	49	1454	352	96	48	1478	359	102
18	-0.16	0.90	-0.18	-20.57	-0.16	0.90	-0.18	-20.60	0.54	26.52	1060	1010	16.27	17.20	17.95	52	549	340	69	44	599	344	73
19	-0.09	0.72	-0.12	-10.80	-0.09	0.72	-0.12	-10.83	0.65	15.75	919	853	22.18	23.83	17.95	86	544	145	78	91	605	145	78
20	-0.27	1.06	-0.25	-33.64	-0.27	1.06	-0.25	-33.67	0.39	35.85	1401	1366	8.68	9.05	17.95	17	507	799	43	18	553	776	54
21	-0.05	1.06	-0.05	-6.80	-0.05	1.06	-0.05	-6.83	0.63	19.17	1341	1364	16.74	17.10	18.21	59	889	317	99	67	893	284	97
22	-0.03	1.12	0.03	3.55	0.03	1.12	0.03	3.52	0.66	12.11	864	835	19.95	22.30	18.21	56	579	134	66	57	624	112	71
23	-0.11	1.06	-0.10	-13.71	-0.11	1.06	-0.10	-13.74	0.54	24.46	1751	1757	11.26	12.06	18.21	46	1290	326	95	46	1338	275	92
24	0.00	1.10	0.00	0.06	0.00	1.10	0.00	0.04	0.53	12.86	922	917	18.00	19.50	18.21	46	489	314	68	45	535	275	67
25	0.03	1.14	0.03	3.74	0.03	1.14	0.03	3.71	0.66	12.70	775	748	24.42	27.54	18.21	75	461	135	77	71	520	113	71
26	-0.28	0.91	-0.31	-35.27	-0.28	0.91	-0.31	-35.30	0.38	35.92	1332	1258	9.31	9.70	18.76	11	485	726	36	15	508	762	47
27	-0.21	1.20	-0.17	-26.13	-0.21	1.20	-0.17	-26.17	0.54	26.34	1336	1313	16.78	16.21	18.76	39	899	283	92	44	873	319	100
28	-0.08	0.81	-0.10	-10.32	-0.08	0.81	-0.10	-10.35	0.67	14.78	841	780	21.03	21.77	18.76	44	568	108	60	49	594	121	77
29	-0.33	1.25	-0.27	-41.77	-0.33	1.25	-0.27	-41.81	0.52	42.40	1692	1652	11.96	11.89	18.76	32	1245	290	85	32	1232	331	97
30	-0.13	0.93	-0.14	-16.56	-0.13	0.93	-0.14	-16.59	0.57	18.03	920	880	18.67	18.79	18.76	30	510	283	57	35	522	302	61
31	-0.02	1.01	-0.02	-3.12	-0.03	1.01	-0.02	-3.15	0.67	16.74	799	842	22.30	24.51	16.98	89	529	140	84	66	550	119	64
32	-0.21	1.13	-0.19	-26.04	-0.21	1.13	-0.19	-26.07	0.40	28.10	1214	1320	8.69	9.90	16.98	16	494	756	54	11	524	642	37
33	-0.18	1.19	-0.15	-22.28	-0.18	1.19	-0.15	-22.32	0.56	31.62	1361	1415	15.38	16.79	16.98	66	943	315	91	59	965	263	74
34	-0.04	0.99	-0.04	-4.86	-0.04	0.99	-0.04	-4.89	0.69	18.32	859	916	17.93	19.92	16.98	67	637	137	75	44	633	121	61
35	-0.23	1.03	-0.22	-28.71	-0.23	1.03	-0.22	-28.74	0.56	32.98	1704	1764	10.75	12.11	16.98	45	1315	320	84	35	1327	273	69
36	-0.11	0.57	-0.20	-14.27	-0.11	0.57	-0.20	-14.29	0.53	16.09	795	811	20.09	18.11	16.44	26	447	280	58	33	451	258	53
37	-0.05	0.70	-0.07	-6.32	-0.05	0.70	-0.07	-6.35	0.65	9.17	666	669	27.82	24.35	16.44	56	427	117	69	70	445	96	55
38	-0.16	0.61	-0.27	-20.38	-0.16	0.61	-0.27	-20.40	0.39	21.89	1089	1133	10.36	9.80	16.44	5	422	656	50	11	437	604	37
39	-0.21	0.73	-0.29	-26.29	-0.21	0.73	-0.29	-26.32	0.54	27.63	1169	1148	18.34	16.25	16.44	36	763	270	79	50	782	262	75
40	-0.08	0.74	-0.11	-10.17	-0.08	0.74	-0.11	-10.20	0.67	12.53	730	755	22.99	20.16	16.44	49	527	119	60	64	518	98	50
41	-0.08	0.70	-0.11	-9.50	-0.08	0.70	-0.11	-9.53	0.54	15.07	1405	1513	10.40	12.59	16.70	29	1170	243	71	22	1147	176	60
42	0.01	0.63	0.01	1.11	0.01	0.63	0.01	1.09	0.56	7.99	704	776	17.06	21.52	16.70	28	443	247	58	14	467	181	42
43	0.08	0.87	0.09	9.79	0.08	0.87	0.09	9.77	0.56	7.68	576	643	23.08	28.99	16.70	51	413	109	70	26	442	64	44
44	-0.07	0.54	-0.12	-8.14	-0.07	0.54	-0.12	-8.16	0.42	11.66	986	1145	8.78	10.70	16.70	11	438	650	46	3	457	504	22
45	-0.04	0.82	-0.05	-5.38	-0.04	0.82	-0.05	-5.41	0.54	16.83	1072	1171	15.40	17.60	16.70	37	820	233	81	29	813	163	67

Table 5 Correlation + Co-integration + In-sample SR + Formation Period (rolling)

No.	Average PnL Volatility Sharpe Ratio Cumulative PnL				Average PnL Volatility Sharpe Ratio Cumulative PnL Plus Volatility				Average PnL Volatility Sharpe Ratio Cumulative PnL Plus Volatility Plus Sharpe Ratio				Average PnL Volatility Sharpe Ratio Cumulative PnL Plus Volatility Plus Sharpe Ratio Plus Volatility				Average PnL Volatility Sharpe Ratio Cumulative PnL Plus Volatility Plus Sharpe Ratio Plus Volatility Plus Sharpe Ratio				Average PnL Volatility Sharpe Ratio Cumulative PnL Plus Volatility Plus Sharpe Ratio Plus Volatility Plus Sharpe Ratio Plus Volatility				Average PnL Volatility Sharpe Ratio Cumulative PnL Plus Volatility Plus Sharpe Ratio Plus Volatility Plus Sharpe Ratio Plus Volatility Plus Sharpe Ratio				Average PnL Volatility Sharpe Ratio Cumulative PnL Plus Volatility Plus Sharpe Ratio Plus Volatility Plus Sharpe Ratio Plus Volatility Plus Sharpe Ratio Plus Volatility				Average PnL Volatility Sharpe Ratio Cumulative PnL Plus Volatility Plus Sharpe Ratio Plus Volatility Plus Sharpe Ratio Plus Volatility Plus Sharpe Ratio Plus Volatility Plus Sharpe Ratio				Average PnL Volatility Sharpe Ratio Cumulative PnL Plus Volatility Plus Sharpe Ratio Plus Volatility Plus Sharpe Ratio Plus Volatility Plus Sharpe Ratio Plus Volatility Plus Sharpe Ratio Plus Volatility				Average PnL Volatility Sharpe Ratio Cumulative PnL Plus Volatility Plus Sharpe Ratio Plus Volatility Plus Sharpe Ratio Plus Volatility Plus Sharpe Ratio Plus Volatility Plus Sharpe Ratio Plus Volatility Plus Sharpe Ratio				Average PnL Volatility Sharpe Ratio Cumulative PnL Plus Volatility Plus Sharpe Ratio Plus Volatility Plus Sharpe Ratio Plus Volatility Plus Sharpe Ratio Plus Volatility Plus Sharpe Ratio Plus Volatility Plus Sharpe Ratio Plus Volatility Plus Sharpe Ratio				Average PnL Volatility Sharpe Ratio Cumulative PnL Plus Volatility Plus Sharpe Ratio Plus Volatility Plus Sharpe Ratio Plus Volatility Plus Sharpe Ratio Plus Volatility Plus Sharpe Ratio Plus Volatility Plus Sharpe Ratio Plus Volatility Plus Sharpe Ratio Plus Volatility Plus Sharpe Ratio				Average PnL Volatility Sharpe Ratio Cumulative PnL Plus Volatility Plus Sharpe Ratio Plus Volatility Plus Sharpe Ratio Plus Volatility Plus Sharpe Ratio Plus Volatility Plus Sharpe Ratio Plus Volatility Plus Sharpe Ratio Plus Volatility Plus Sharpe Ratio Plus Volatility Plus Sharpe Ratio Plus Volatility Plus Sharpe Ratio				Average PnL Volatility Sharpe Ratio Cumulative PnL Plus Volatility Plus Sharpe Ratio Plus Vol			
-----	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	---	--	--	--

Table 6 Graphical Lasso + Co-integration + Moving Look-back Window (mv)

No.	Average PnL PnL	Volatility tility	Sharpe Ratio atio	Average Cumulative PnL ve PnL	Plus Sharpe Ratio Cost	Volatility Cost	Sharpe Ratio Cost	Winning ge	Maximum m.DD	Total Loss ng Num	Total Short ort Num	Average Long Long	Average Short Short	Average Paris Paris	Number of uexc	Number of ud	Number of uu	Number of una	Number of dex	Number of du	Number of dd	Number of dna	
1	-1.55	7.52	-0.21	-193.43	-1.55	7.52	-0.21	-193.64	0.47	194.77	855	854	16.31	15.34	14.27	25	448	291	90	36	420	288	111
2	-1.64	8.65	-0.19	-205.16	-1.64	8.65	-0.19	-205.38	0.57	207.68	726	719	22.47	20.37	14.27	46	445	129	99	54	408	118	146
3	-2.33	6.26	-0.37	-290.73	-2.33	6.26	-0.37	-290.94	0.32	292.01	1119	1072	9.31	8.40	14.27	11	398	598	65	15	373	656	75
4	-2.91	10.48	-0.28	-363.92	-2.91	10.48	-0.28	-364.22	0.45	369.41	1241	1247	14.81	13.87	14.27	34	776	292	145	43	725	308	165
5	-1.56	9.38	-0.17	-195.52	-1.57	9.39	-0.17	-195.76	0.56	197.53	781	770	18.59	17.53	14.27	39	513	127	91	37	490	122	132
6	-0.82	3.94	-0.21	-102.41	-0.82	3.94	-0.21	-102.54	0.48	129.10	699	718	17.82	17.24	13.70	24	345	253	96	24	322	255	98
7	-0.86	3.69	-0.23	-107.51	-0.86	3.69	-0.23	-107.64	0.59	114.49	669	580	25.34	23.39	13.70	33	331	108	108	37	315	103	114
8	-1.28	4.74	-0.27	-159.99	-1.28	4.74	-0.27	-160.15	0.33	177.87	969	971	9.67	9.32	13.70	9	337	555	70	11	292	597	69
9	-1.25	5.03	-0.25	-156.81	-1.26	5.03	-0.25	-156.99	0.49	194.58	970	983	16.34	16.25	13.70	28	570	255	130	30	557	254	129
10	-0.80	3.94	-0.20	-99.64	-0.80	3.94	-0.20	-99.78	0.60	117.59	618	632	21.03	20.05	13.70	30	399	109	94	33	376	107	102
11	-1.69	10.96	-0.15	-210.83	-1.69	10.96	-0.15	-211.11	0.46	213.45	1212	1232	11.49	11.19	14.10	13	885	231	103	11	846	242	113
12	-0.45	8.44	-0.05	-55.75	-0.45	8.43	-0.05	-55.93	0.51	104.24	685	695	17.43	17.07	14.10	14	384	219	78	14	366	228	77
13	-0.42	9.08	-0.05	-52.10	-0.42	9.08	-0.05	-52.29	0.61	83.92	567	566	24.35	22.83	14.10	36	365	79	86	24	349	95	99
14	-1.12	6.89	-0.16	-140.58	-1.13	6.89	-0.16	-140.76	0.37	142.90	955	922	9.29	9.63	14.10	6	365	489	62	4	347	549	55
15	-1.59	11.19	-0.14	-199.08	-1.59	11.19	-0.14	-199.35	0.50	201.77	955	975	16.15	15.56	14.10	25	613	223	114	13	593	232	117
16	-1.40	8.37	-0.17	-175.20	-1.40	8.38	-0.17	-175.46	0.57	222.15	692	626	18.95	20.09	11.98	45	383	107	91	42	417	134	99
17	-2.37	9.08	-0.26	-296.80	-2.38	9.08	-0.26	-297.10	0.45	312.55	1287	1233	11.05	10.88	11.98	26	833	262	112	29	831	308	119
18	-1.53	8.08	-0.19	-191.04	-1.53	8.08	-0.19	-191.29	0.47	253.14	764	700	15.96	16.71	11.98	37	331	242	90	27	347	292	98
19	-1.21	8.57	-0.14	-150.83	-1.21	8.58	-0.14	-151.10	0.56	207.94	643	587	22.27	23.24	11.98	58	320	110	99	49	350	141	103
20	-2.39	9.30	-0.26	-298.83	-2.39	9.30	-0.26	-299.09	0.33	325.96	986	917	9.35	8.96	11.98	10	310	540	57	14	316	592	64
21	-3.01	14.71	-0.20	-375.80	-3.01	14.72	-0.20	-376.13	0.49	396.81	930	867	16.81	15.58	11.93	23	500	238	106	29	511	264	126
22	-1.92	12.72	-0.15	-239.54	-1.92	12.72	-0.15	-239.86	0.57	269.99	617	519	20.39	21.98	11.93	27	311	100	81	28	364	123	102
23	-3.08	14.43	-0.21	-385.57	-3.09	14.44	-0.21	-385.89	0.48	406.77	1141	1055	12.31	11.73	11.93	18	696	239	102	24	739	262	116
24	-2.15	12.54	-0.17	-269.24	-2.16	12.55	-0.17	-269.51	0.48	305.60	677	605	18.18	18.12	11.93	18	281	232	74	16	305	256	100
25	-2.00	12.92	-0.15	-249.86	-2.00	12.92	-0.15	-250.14	0.57	280.98	565	482	23.62	25.66	11.93	35	264	101	82	29	304	124	108
26	-2.84	12.41	-0.23	-354.38	-2.84	12.41	-0.23	-354.68	0.34	391.13	936	788	9.63	9.72	12.52	6	277	452	53	5	288	568	75
27	-3.39	11.90	-0.28	-424.09	-3.40	11.91	-0.29	-424.43	0.49	426.05	882	785	16.92	16.32	12.52	14	470	197	104	22	476	251	133
28	-2.47	11.96	-0.21	-309.26	-2.48	11.96	-0.21	-309.56	0.59	350.83	607	489	20.08	21.57	12.52	17	309	80	83	24	371	110	102
29	-3.78	11.41	-0.33	-472.87	-3.79	11.41	-0.33	-473.19	0.48	473.25	1099	971	12.25	11.97	12.52	11	665	202	93	9	699	262	129
30	-2.47	13.00	-0.19	-308.93	-2.47	13.01	-0.19	-309.22	0.46	348.25	663	560	17.74	16.62	12.52	14	280	191	75	17	293	251	102
31	-3.05	15.34	-0.20	-381.27	-3.05	15.35	-0.20	-381.59	0.59	386.79	687	719	22.64	22.27	14.55	60	408	153	98	51	416	111	109
32	-3.21	7.74	-0.41	-400.80	-3.21	7.75	-0.41	-401.04	0.33	402.07	1051	1122	8.96	8.86	14.65	14	382	663	63	7	401	583	60
33	-2.72	20.20	-0.13	-340.58	-2.73	20.20	-0.14	-341.03	0.47	452.63	1216	1265	14.48	14.70	14.65	47	755	323	140	38	791	265	122
34	-3.16	15.35	-0.21	-394.94	-3.16	15.35	-0.21	-395.26	0.58	400.90	740	780	18.76	18.21	14.65	42	493	154	91	44	482	113	101
35	-3.24	20.37	-0.16	-404.67	-3.24	20.37	-0.16	-405.14	0.44	506.53	1475	1520	10.42	10.88	14.65	30	1039	322	129	21	1065	277	112
36	-2.44	7.94	-0.31	-305.31	-2.44	7.95	-0.31	-305.50	0.46	309.33	728	758	17.49	16.94	14.81	24	375	274	85	25	359	248	96
37	-2.09	7.10	-0.29	-261.23	-2.09	7.11	-0.29	-261.42	0.58	266.39	582	625	24.92	24.08	14.81	44	366	121	94	36	337	107	102
38	-2.58	8.99	-0.29	-322.96	-2.59	8.99	-0.29	-323.16	0.33	324.18	985	1064	8.97	9.40	14.81	14	364	623	63	10	342	571	62
39	-3.88	11.86	-0.33	-485.18	-3.88	11.86	-0.33	-485.47	0.48	491.25	1061	1090	15.82	15.88	14.81	38	658	273	121	39	635	260	127
40	-2.19	7.03	-0.31	-273.85	-2.19	7.03	-0.31	-274.03	0.60	277.91	648	704	21.01	18.56	14.81	36	456	121	91	32	414	108	94
41	-0.40	14.93	-0.03	-50.60	-0.41	14.92	-0.03	-50.82	0.47	221.88	1196	1231	11.33	12.06	14.90	33	845	244	109	19	875	205	97
42	-0.68	3.14	-0.22	-85.27	-0.68	3.14	-0.22	-85.39	0.49	113.62	666	708	17.36	17.75	14.90	25	353	248	82	20	359	191	86
43	-0.77	3.35	-0.23	-95.83	-0.77	3.35	-0.23	-95.95	0.62	130.23	531	569	24.60	25.44	14.90	41	332	109	87	41	324	74	92
44	-1.31	5.13	-0.26	-163.77	-1.31	5.14	-0.26	-163.91	0.35	169.91	927	996	9.53	9.24	14.90	9	336	589	62	11	357	500	59
45	-0.09	14.77	-0.01	-11.12	-0.09	14.77	-0.01	-11.33	0.51	185.13	923	973	16.39	17.00	14.90	39	577	236	121	28	590	198	107

Table 7 Graphical Lasso + Co-integration + Formation Period (rolling)

No.	Average PnL	PnL Sharpe Ratio	F Cumulative	Average PnL	PnL Sharpe Ratio	F Cumulative	Winning Percentage	Maximum	Total	Lo	Total	Sh	Average	Average	uexc	ud	uu	una	dexc	du	dd	dna	
	titlty	atio	vePnL	Cost	Cost	usCost	ge	m.DD	ngNum	onNum	ys	m											
1	2.83	20.39	0.14	353.28	2.82	20.39	0.14	352.78	0.41	96.40	837	948	11.18	9.34	14.27	7	486	393	62	12	237	241	75
2	2.83	20.39	0.14	353.28	2.82	20.39	0.14	352.78	0.41	96.40	837	948	11.18	9.34	14.27	7	486	393	62	12	237	241	75
3	2.83	20.39	0.14	353.28	2.82	20.39	0.14	352.78	0.41	96.40	837	948	11.18	9.34	14.27	7	486	393	62	12	237	241	75
4	2.83	20.39	0.14	353.28	2.82	20.39	0.14	352.78	0.41	96.40	837	948	11.18	9.34	14.27	7	486	393	62	12	237	241	75
5	2.83	20.39	0.14	353.28	2.82	20.39	0.14	352.78	0.41	96.40	837	948	11.18	9.34	14.27	7	486	393	62	12	237	241	75
6	0.79	16.85	0.05	98.64	0.79	16.84	0.05	98.29	0.37	177.44	712	757	11.09	10.07	13.70	6	388	317	46	14	184	269	47
7	0.79	16.85	0.05	98.64	0.79	16.84	0.05	98.29	0.37	177.44	712	757	11.09	10.07	13.70	6	388	317	46	14	184	269	47
8	0.79	16.85	0.05	98.64	0.79	16.84	0.05	98.29	0.37	177.44	712	757	11.09	10.07	13.70	6	388	317	46	14	184	269	47
9	0.79	16.85	0.05	98.64	0.79	16.84	0.05	98.29	0.37	177.44	712	757	11.09	10.07	13.70	6	388	317	46	14	184	269	47
10	0.79	16.85	0.05	98.64	0.79	16.84	0.05	98.29	0.37	177.44	712	757	11.09	10.07	13.70	6	388	317	46	14	184	269	47
11	2.29	12.40	0.18	286.09	2.29	12.40	0.18	285.79	0.39	45.76	670	773	11.65	8.97	14.10	5	405	328	35	13	173	222	36
12	2.29	12.40	0.18	286.09	2.29	12.40	0.18	285.79	0.39	45.76	670	773	11.65	8.97	14.10	5	405	328	35	13	173	222	36
13	2.29	12.40	0.18	286.09	2.29	12.40	0.18	285.79	0.39	45.76	670	773	11.65	8.97	14.10	5	405	328	35	13	173	222	36
14	2.29	12.40	0.18	286.09	2.29	12.40	0.18	285.79	0.39	45.76	670	773	11.65	8.97	14.10	5	405	328	35	13	173	222	36
15	2.29	12.40	0.18	286.09	2.29	12.40	0.18	285.79	0.39	45.76	670	773	11.65	8.97	14.10	5	405	328	35	13	173	222	36
16	2.23	66.25	0.03	279.20	2.23	66.23	0.03	278.34	0.37	433.91	776	821	10.08	8.57	11.98	5	368	393	55	5	255	285	59
17	2.23	66.25	0.03	279.20	2.23	66.23	0.03	278.34	0.37	433.91	776	821	10.08	8.57	11.98	5	368	393	55	5	255	285	59
18	2.23	66.25	0.03	279.20	2.23	66.23	0.03	278.34	0.37	433.91	776	821	10.08	8.57	11.98	5	368	393	55	5	255	285	59
19	2.23	66.25	0.03	279.20	2.23	66.23	0.03	278.34	0.37	433.91	776	821	10.08	8.57	11.98	5	368	393	55	5	255	285	59
20	2.23	66.25	0.03	279.20	2.23	66.23	0.03	278.34	0.37	433.91	776	821	10.08	8.57	11.98	5	368	393	55	5	255	285	59
21	0.36	49.55	0.01	45.05	0.35	49.53	0.01	44.32	0.35	440.56	674	765	9.41	8.54	11.93	1	348	367	49	3	181	269	48
22	0.36	49.55	0.01	45.05	0.35	49.53	0.01	44.32	0.35	440.56	674	765	9.41	8.54	11.93	1	348	367	49	3	181	269	48
23	0.36	49.55	0.01	45.05	0.35	49.53	0.01	44.32	0.35	440.56	674	765	9.41	8.54	11.93	1	348	367	49	3	181	269	48
24	0.36	49.55	0.01	45.05	0.35	49.53	0.01	44.32	0.35	440.56	674	765	9.41	8.54	11.93	1	348	367	49	3	181	269	48
25	0.36	49.55	0.01	45.05	0.35	49.53	0.01	44.32	0.35	440.56	674	765	9.41	8.54	11.93	1	348	367	49	3	181	269	48
26	-1.47	25.89	-0.06	-183.85	-1.48	25.90	-0.06	-184.39	0.35	361.52	662	723	9.14	8.60	12.52	3	339	338	43	3	167	286	35
27	-1.47	25.89	-0.06	-183.85	-1.48	25.90	-0.06	-184.39	0.35	361.52	662	723	9.14	8.60	12.52	3	339	338	43	3	167	286	35
28	-1.47	25.89	-0.06	-183.85	-1.48	25.90	-0.06	-184.39	0.35	361.52	662	723	9.14	8.60	12.52	3	339	338	43	3	167	286	35
29	-1.47	25.89	-0.06	-183.85	-1.48	25.90	-0.06	-184.39	0.35	361.52	662	723	9.14	8.60	12.52	3	339	338	43	3	167	286	35
30	-1.47	25.89	-0.06	-183.85	-1.48	25.90	-0.06	-184.39	0.35	361.52	662	723	9.14	8.60	12.52	3	339	338	43	3	167	286	35
31	-0.54	21.83	-0.02	-67.15	-0.54	21.83	-0.02	-67.63	0.43	217.04	735	830	13.12	10.46	14.65	7	412	343	68	12	250	214	68
32	-0.54	21.83	-0.02	-67.15	-0.54	21.83	-0.02	-67.63	0.43	217.04	735	830	13.12	10.46	14.65	7	412	343	68	12	250	214	68
33	-0.54	21.83	-0.02	-67.15	-0.54	21.83	-0.02	-67.63	0.43	217.04	735	830	13.12	10.46	14.65	7	412	343	68	12	250	214	68
34	-0.54	21.83	-0.02	-67.15	-0.54	21.83	-0.02	-67.63	0.43	217.04	735	830	13.12	10.46	14.65	7	412	343	68	12	250	214	68
35	-0.54	21.83	-0.02	-67.15	-0.54	21.83	-0.02	-67.63	0.43	217.04	735	830	13.12	10.46	14.65	7	412	343	68	12	250	214	68
36	-1.08	15.22	-0.07	-134.39	-1.08	15.23	-0.07	-134.70	0.44	164.04	592	801	14.28	10.16	14.81	11	379	358	53	13	189	206	44
37	-1.08	15.22	-0.07	-134.39	-1.08	15.23	-0.07	-134.70	0.44	164.04	592	801	14.28	10.16	14.81	11	379	358	53	13	189	206	44
38	-1.08	15.22	-0.07	-134.39	-1.08	15.23	-0.07	-134.70	0.44	164.04	592	801	14.28	10.16	14.81	11	379	358	53	13	189	206	44
39	-1.08	15.22	-0.07	-134.39	-1.08	15.23	-0.07	-134.70	0.44	164.04	592	801	14.28	10.16	14.81	11	379	358	53	13	189	206	44
40	-1.08	15.22	-0.07	-134.39	-1.08	15.23	-0.07	-134.70	0.44	164.04	592	801	14.28	10.16	14.81	11	379	358	53	13	189	206	44
41	1.11	9.87	0.11	138.75	1.11	9.87	0.11	138.53	0.38	72.29	627	737	10.37	9.26	14.90	3	377	324	33	5	186	202	35
42	1.11	9.87	0.11	138.75	1.11	9.87	0.11	138.53	0.38	72.29	627	737	10.37	9.26	14.90	3	377	324	33	5	186	202	35
43	1.11	9.87	0.11	138.75	1.11	9.87	0.11	138.53	0.38	72.29	627	737	10.37	9.26	14.90	3	377	324	33	5	186	202	35
44	1.11	9.87	0.11	138.75	1.11	9.87	0.11	138.53	0.38	72.29	627	737	10.37	9.26	14.90	3	377	324	33	5	186	202	35
45	1.11	9.87	0.11	138.75	1.11	9.87	0.11	138.53	0.38	72.29	627	737	10.37	9.26	14.90	3	377	324	33	5	186	202	35

Table 8 Graphical Lasso + Co-integration + In-sample SR +Moving Look-back Window (mv)

No.	Average PnL	Volatility ratio	Sharpe's ratio	Cumulative vePnL	Average Cost	PnL Plus tilly, Plus ratio, Plus vePnL, P1	Winning ge	Maximu m,DD	Total Lo ng,Num	Total Sh ort,Num	Average Long Da ys	Average Short Da ys	Average Pair's, Nu m	uexc	ud	uu	una	dexc	du	dd	dna
1	-1.33	7.37	-0.18	-166.16	-1.33	7.37	0.49	167.50	796	803	16.60	15.40	13.39	24	419	274	86	34	391	273	98
2	-1.36	8.46	-0.16	-169.73	-1.36	8.46	0.58	172.24	675	674	22.88	20.31	13.99	43	417	122	92	51	380	113	131
3	-2.06	5.97	-0.35	-257.32	-2.06	5.97	0.33	258.61	1059	1004	9.44	8.36	13.39	10	371	560	63	15	349	630	65
4	-2.50	10.21	-0.24	-312.58	-2.50	10.22	0.47	318.07	1147	1153	15.18	14.16	13.99	33	711	127	137	42	670	290	145
5	-1.28	9.20	-0.14	-159.68	-1.28	9.20	0.57	161.69	727	721	18.91	17.60	13.99	37	479	120	85	35	458	117	117
6	-0.52	3.44	-0.15	-64.83	-0.52	3.44	0.49	91.52	648	673	18.04	17.67	12.93	24	327	238	84	22	303	239	84
7	-0.55	3.02	-0.18	-69.03	-0.55	3.02	0.61	76.00	526	541	25.95	23.88	12.93	32	313	102	94	36	296	96	98
8	-0.89	3.89	-0.23	-111.68	-0.89	3.89	0.33	129.56	904	917	9.88	9.27	12.93	7	321	526	63	11	274	563	56
9	-0.81	4.05	-0.20	-101.45	-0.81	4.05	0.51	139.22	901	911	16.50	16.82	12.93	28	529	238	116	29	529	236	107
10	-0.48	3.24	-0.15	-60.49	-0.48	3.24	0.62	78.44	573	593	21.37	20.37	12.93	29	378	103	83	32	355	99	87
11	-1.52	10.96	-0.14	-190.58	-1.53	10.96	0.47	193.19	1137	1140	11.43	11.58	13.24	13	822	212	93	11	801	226	99
12	-0.36	8.33	-0.04	-44.51	-0.36	8.33	0.51	93.42	643	653	17.23	17.47	13.24	14	368	202	69	14	348	213	68
13	-0.34	9.03	-0.04	-42.50	-0.34	9.03	0.61	74.62	537	533	24.00	23.09	13.24	35	350	73	75	23	335	90	89
14	-0.98	6.84	-0.14	-122.95	-0.98	6.84	0.37	125.68	906	867	9.36	9.54	13.24	6	349	459	53	4	333	524	45
15	-1.49	11.16	-0.13	-186.48	-1.49	11.16	0.51	189.17	889	900	16.28	16.08	13.24	25	569	202	104	13	558	216	102
16	-1.16	8.09	-0.14	-144.90	-1.16	8.09	0.57	191.84	682	616	18.94	20.07	11.78	45	378	105	88	42	411	132	97
17	-2.09	9.21	-0.23	-261.24	-2.09	9.21	0.45	276.99	1269	1212	11.02	10.88	11.78	26	821	255	110	29	820	303	117
18	-1.26	7.77	-0.16	-157.03	-1.26	7.77	0.47	219.12	751	690	15.94	16.76	11.78	37	328	236	89	27	340	289	95
19	-0.96	8.28	-0.12	-120.36	-0.96	8.28	0.56	177.47	633	578	22.30	23.24	11.78	58	316	108	96	49	345	138	101
20	-2.14	9.19	-0.23	-267.68	-2.14	9.19	0.33	294.61	969	899	9.33	9.02	11.78	10	305	528	56	14	308	585	62
21	-3.01	14.71	-0.20	-375.80	-3.01	14.72	0.49	396.81	930	867	16.81	16.12	11.93	23	500	238	106	29	511	264	126
22	-1.92	12.72	-0.15	-239.54	-1.92	12.72	0.57	269.98	617	519	20.39	21.98	11.93	27	311	100	81	28	364	123	102
23	-3.08	14.43	-0.21	-385.57	-3.09	14.44	0.48	406.77	1141	1055	12.31	11.73	11.93	18	696	239	102	24	739	262	116
24	-2.15	12.54	-0.17	-269.24	-2.16	12.55	0.48	305.60	677	605	18.18	18.12	11.93	18	281	232	74	16	305	256	100
25	-2.00	12.92	-0.15	-249.86	-2.00	12.92	0.57	280.98	555	482	23.62	25.66	11.93	35	264	101	82	29	304	124	108
26	-2.84	12.41	-0.23	-354.38	-2.84	12.41	0.34	391.13	936	788	9.63	9.72	12.52	6	277	452	53	5	288	568	75
27	-3.39	11.90	-0.28	-424.09	-3.40	11.91	0.49	426.05	882	785	16.92	16.32	12.52	14	470	197	104	22	476	251	133
28	-2.47	11.96	-0.21	-309.26	-2.48	11.96	0.49	350.83	607	489	20.08	21.57	12.52	17	309	80	83	24	371	110	102
29	-3.78	11.41	-0.33	-472.87	-3.79	11.41	0.48	473.25	1099	971	12.25	11.97	12.52	11	665	202	93	9	699	262	129
30	-2.47	13.00	-0.19	-308.93	-2.47	13.01	0.46	348.25	663	560	17.74	18.62	12.52	14	280	191	75	17	293	251	102
31	-2.25	14.40	-0.16	-281.55	-2.25	14.40	0.59	286.89	627	657	23.25	22.69	13.58	55	372	143	87	50	375	102	100
32	-2.44	5.63	-0.43	-304.98	-2.44	5.63	0.34	306.38	970	1036	9.10	8.96	13.58	13	348	616	59	7	366	543	54
33	-1.23	17.68	-0.07	-153.76	-1.23	17.68	0.48	265.51	1118	1137	14.85	15.08	13.58	43	667	303	124	38	722	247	111
34	-2.31	14.35	-0.16	-289.26	-2.32	14.35	0.59	295.03	677	711	19.26	18.73	13.58	39	448	144	80	43	437	104	93
35	-1.48	17.60	-0.08	-184.99	-1.48	17.60	0.45	286.56	1356	1371	10.69	11.13	13.58	28	925	301	117	21	974	258	103
36	-1.29	3.34	-0.39	-161.57	-1.29	3.34	0.47	165.55	650	692	18.03	17.27	13.59	23	347	256	66	24	319	224	83
37	-1.05	4.18	-0.25	-131.52	-1.05	4.18	0.58	136.59	516	568	25.70	24.92	13.59	42	338	112	76	33	298	96	89
38	-1.34	3.33	-0.40	-167.01	-1.34	3.33	0.34	168.37	878	974	9.22	9.57	13.59	13	337	572	52	10	313	506	49
39	-1.96	5.13	-0.38	-245.56	-1.97	5.13	0.49	251.59	952	947	16.01	16.46	13.59	37	589	256	95	34	574	235	109
40	-1.12	3.90	-0.29	-140.21	-1.12	3.90	0.61	144.17	579	674	21.53	18.91	13.59	34	477	112	71	29	370	97	83
41	-0.39	14.93	-0.03	-49.29	-0.40	14.92	0.47	220.07	1143	1167	11.63	12.09	14.25	33	798	232	104	19	827	203	94
42	-0.68	3.13	-0.22	-84.97	-0.68	3.13	0.49	113.02	641	680	17.59	17.64	14.25	25	341	238	76	20	339	199	83
43	-0.77	3.33	-0.23	-95.80	-0.77	3.33	0.62	129.84	508	544	25.15	25.66	14.25	40	319	104	81	41	305	73	89
44	-1.31	5.13	-0.25	-163.23	-1.31	5.13	0.35	169.42	899	950	9.58	9.27	14.25	9	321	562	58	11	339	493	56
45	-0.08	14.77	-0.01	-10.00	-0.08	14.76	0.51	183.71	881	927	16.65	17.00	14.25	39	549	227	112	26	555	196	104

Table 9 Graphical Lasso + Co-integration+ In-sample SR + Formation Period (rolling)

No.	Average PnL PnL	Volia Sharpe ratio	Cumulative vePnL	Average PnL Cost	Volia Sharpe Cost	Cumulative usCost	Winning ge	Maximum m.DD	Total Lo ngNum	Total Sh ortNum	Average Long	Average Short	Average Pairs	uexc	ud	uu	una	dexc	du	dd	dna		
1	1.23	4.85	0.25	153.61	1.23	4.84	0.25	153.52	0.41	6.25	164	147	9.30	8.32	13.39	2	84	50	11	5	32	44	6
2	1.23	4.85	0.25	153.61	1.23	4.84	0.25	153.52	0.41	6.25	164	147	9.30	8.32	13.39	2	84	50	11	5	32	44	6
3	1.23	4.85	0.25	153.61	1.23	4.84	0.25	153.52	0.41	6.25	164	147	9.30	8.32	13.39	2	84	50	11	5	32	44	6
4	1.23	4.85	0.25	153.61	1.23	4.84	0.25	153.52	0.41	6.25	164	147	9.30	8.32	13.39	2	84	50	11	5	32	44	6
5	1.23	4.85	0.25	153.61	1.23	4.84	0.25	153.52	0.41	6.25	164	147	9.30	8.32	13.39	2	84	50	11	5	32	44	6
6	-0.11	0.75	-0.15	-13.83	-0.11	0.75	-0.15	-13.85	0.29	15.72	94	104	14.86	9.32	12.93	3	27	69	5	6	20	41	11
7	-0.11	0.75	-0.15	-13.83	-0.11	0.75	-0.15	-13.85	0.29	15.72	94	104	14.86	9.32	12.93	3	27	69	5	6	20	41	11
8	-0.11	0.75	-0.15	-13.83	-0.11	0.75	-0.15	-13.85	0.29	15.72	94	104	14.86	9.32	12.93	3	27	69	5	6	20	41	11
9	-0.11	0.75	-0.15	-13.83	-0.11	0.75	-0.15	-13.85	0.29	15.72	94	104	14.86	9.32	12.93	3	27	69	5	6	20	41	11
10	-0.11	0.75	-0.15	-13.83	-0.11	0.75	-0.15	-13.85	0.29	15.72	94	104	14.86	9.32	12.93	3	27	69	5	6	20	41	11
11	1.17	5.15	0.23	146.22	1.17	5.15	0.23	146.13	0.29	8.88	178	176	8.85	6.10	13.24	0	115	53	8	5	29	32	5
12	1.17	5.15	0.23	146.22	1.17	5.15	0.23	146.13	0.29	8.88	178	176	8.85	6.10	13.24	0	115	53	8	5	29	32	5
13	1.17	5.15	0.23	146.22	1.17	5.15	0.23	146.13	0.29	8.88	178	176	8.85	6.10	13.24	0	115	53	8	5	29	32	5
14	1.17	5.15	0.23	146.22	1.17	5.15	0.23	146.13	0.29	8.88	178	176	8.85	6.10	13.24	0	115	53	8	5	29	32	5
15	1.17	5.15	0.23	146.22	1.17	5.15	0.23	146.13	0.29	8.88	178	176	8.85	6.10	13.24	0	115	53	8	5	29	32	5
16	-0.32	1.24	-0.26	-39.94	-0.32	1.24	-0.26	-39.96	0.35	40.57	87	122	11.05	8.66	11.78	2	41	73	6	2	32	29	6
17	-0.32	1.24	-0.26	-39.94	-0.32	1.24	-0.26	-39.96	0.35	40.57	87	122	11.05	8.66	11.78	2	41	73	6	2	32	29	6
18	-0.32	1.24	-0.26	-39.94	-0.32	1.24	-0.26	-39.96	0.35	40.57	87	122	11.05	8.66	11.78	2	41	73	6	2	32	29	6
19	-0.32	1.24	-0.26	-39.94	-0.32	1.24	-0.26	-39.96	0.35	40.57	87	122	11.05	8.66	11.78	2	41	73	6	2	32	29	6
20	-0.32	1.24	-0.26	-39.94	-0.32	1.24	-0.26	-39.96	0.35	40.57	87	122	11.05	8.66	11.78	2	41	73	6	2	32	29	6
21	-0.07	0.62	-0.12	-8.94	-0.07	0.62	-0.12	-8.96	0.38	9.52	143	122	9.08	9.71	11.93	0	74	44	4	2	36	53	11
22	-0.07	0.62	-0.12	-8.94	-0.07	0.62	-0.12	-8.96	0.38	9.52	143	122	9.08	9.71	11.93	0	74	44	4	2	36	53	11
23	-0.07	0.62	-0.12	-8.94	-0.07	0.62	-0.12	-8.96	0.38	9.52	143	122	9.08	9.71	11.93	0	74	44	4	2	36	53	11
24	-0.07	0.62	-0.12	-8.94	-0.07	0.62	-0.12	-8.96	0.38	9.52	143	122	9.08	9.71	11.93	0	74	44	4	2	36	53	11
25	-0.07	0.62	-0.12	-8.94	-0.07	0.62	-0.12	-8.96	0.38	9.52	143	122	9.08	9.71	11.93	0	74	44	4	2	36	53	11
26	-0.18	1.49	-0.12	-22.99	-0.18	1.49	-0.12	-23.03	0.31	27.20	118	122	6.96	9.49	12.52	3	37	76	6	0	30	48	2
27	-0.18	1.49	-0.12	-22.99	-0.18	1.49	-0.12	-23.03	0.31	27.20	118	122	6.96	9.49	12.52	3	37	76	6	0	30	48	2
28	-0.18	1.49	-0.12	-22.99	-0.18	1.49	-0.12	-23.03	0.31	27.20	118	122	6.96	9.49	12.52	3	37	76	6	0	30	48	2
29	-0.18	1.49	-0.12	-22.99	-0.18	1.49	-0.12	-23.03	0.31	27.20	118	122	6.96	9.49	12.52	3	37	76	6	0	30	48	2
30	-0.18	1.49	-0.12	-22.99	-0.18	1.49	-0.12	-23.03	0.31	27.20	118	122	6.96	9.49	12.52	3	37	76	6	0	30	48	2
31	-0.04	1.75	-0.02	-4.45	-0.04	1.75	-0.02	-4.49	0.37	31.72	70	122	11.16	15.27	13.58	5	33	70	14	4	25	23	0
32	-0.04	1.75	-0.02	-4.45	-0.04	1.75	-0.02	-4.49	0.37	31.72	70	122	11.16	15.27	13.58	5	33	70	14	4	25	23	0
33	-0.04	1.75	-0.02	-4.45	-0.04	1.75	-0.02	-4.49	0.37	31.72	70	122	11.16	15.27	13.58	5	33	70	14	4	25	23	0
34	-0.04	1.75	-0.02	-4.45	-0.04	1.75	-0.02	-4.49	0.37	31.72	70	122	11.16	15.27	13.58	5	33	70	14	4	25	23	0
35	-0.04	1.75	-0.02	-4.45	-0.04	1.75	-0.02	-4.49	0.37	31.72	70	122	11.16	15.27	13.58	5	33	70	14	4	25	23	0
36	-0.87	10.89	-0.08	-108.29	-0.87	10.90	-0.08	-108.39	0.44	139.82	64	83	10.33	14.96	13.59	3	33	38	9	2	21	15	7
37	-0.87	10.89	-0.08	-108.29	-0.87	10.90	-0.08	-108.39	0.44	139.82	64	83	10.33	14.96	13.59	3	33	38	9	2	21	15	7
38	-0.87	10.89	-0.08	-108.29	-0.87	10.90	-0.08	-108.39	0.44	139.82	64	83	10.33	14.96	13.59	3	33	38	9	2	21	15	7
39	-0.87	10.89	-0.08	-108.29	-0.87	10.90	-0.08	-108.39	0.44	139.82	64	83	10.33	14.96	13.59	3	33	38	9	2	21	15	7
40	-0.87	10.89	-0.08	-108.29	-0.87	10.90	-0.08	-108.39	0.44	139.82	64	83	10.33	14.96	13.59	3	33	38	9	2	21	15	7
41	0.00	1.36	0.00	0.30	0.00	1.36	0.00	0.27	0.34	16.51	77	108	8.92	14.28	14.25	3	28	64	13	2	22	22	2
42	0.00	1.36	0.00	0.30	0.00	1.36	0.00	0.27	0.34	16.51	77	108	8.92	14.28	14.25	3	28	64	13	2	22	22	2
43	0.00	1.36	0.00	0.30	0.00	1.36	0.00	0.27	0.34	16.51	77	108	8.92	14.28	14.25	3	28	64	13	2	22	22	2
44	0.00	1.36	0.00	0.30	0.00	1.36	0.00	0.27	0.34	16.51	77	108	8.92	14.28	14.25	3	28	64	13	2	22	22	2
45	0.00	1.36	0.00	0.30	0.00	1.36	0.00	0.27	0.34	16.51	77	108	8.92	14.28	14.25	3	28	64	13	2	22	22	2

Table 10 Out-of-Sample Testing Results

Lb	Lo	Lc	Sc	So	Sb	formatio n	holding	Average. PnL	PnL.Vola tility	Sharpe.R atio	Cumulati ve.PnL	Average. PnL.Plus. Cost	PnL.Vola tility.Plus .Cost	Sharpe.R atio.Plus. Cost	Cumulati ve.PnL.PI us.Cost	Winning. Percenta ge	Maximu m.DD
-10	-2	0	0	2	10	120	60	1.22	4.80	0.25	86.49	1.22	4.80	0.25	86.42	0.80	8.50
-10	-2	0	0	2	10	120	90	1.69	7.55	0.22	119.78	1.69	7.55	0.22	119.69	0.80	8.07
-10	-2	0	0	2	10	90	120	0.46	1.79	0.25	32.41	0.46	1.79	0.25	32.38	0.81	5.53
-6	-2	0	0	2	6	90	90	-0.09	0.81	-0.12	-6.60	-0.09	0.81	-0.12	-6.61	0.31	12.67
-10	-2	0	0	2	10	90	90	-0.09	0.81	-0.12	-6.60	-0.09	0.81	-0.12	-6.61	0.31	12.67
-3.5	-2	0	0	2	3.5	90	90	-0.09	0.81	-0.12	-6.60	-0.09	0.81	-0.12	-6.61	0.31	12.67
-10	-2	0	0	2	10	120	120	0.20	1.73	0.12	14.11	0.20	1.72	0.12	14.10	0.78	4.01
-10	-2	0	0	2	10	60	90	0.03	0.81	0.03	1.80	0.03	0.81	0.03	1.78	0.76	5.71
-10	-2	-0.5	0.5	2	10	60	90	-0.01	0.64	-0.02	-0.86	-0.01	0.64	-0.02	-0.87	0.79	5.41
-6	-2	0	0	2	6	120	90	0.26	2.07	0.12	18.29	0.26	2.07	0.12	18.27	0.47	7.87
-10	-2	0	0	2	10	120	90	0.26	2.07	0.12	18.29	0.26	2.07	0.12	18.27	0.47	7.87
-3.5	-2	0	0	2	3.5	120	90	0.26	2.07	0.12	18.29	0.26	2.07	0.12	18.27	0.47	7.87
-6	-1	0	0	1	6	120	120	-0.32	9.24	-0.03	-22.66	-0.32	9.24	-0.03	-22.79	0.61	61.90
-6	-1	-0.5	0.5	1	6	120	120	-0.74	5.29	-0.14	-52.89	-0.75	5.29	-0.14	-52.97	0.58	78.31
-10	-2	0	0	2	10	90	120	0.21	2.15	0.10	14.59	0.20	2.15	0.10	14.55	0.71	9.22
-6	-1	-0.5	0.5	1	6	90	120	-2.25	10.83	-0.21	-159.56	-2.25	10.84	-0.21	-159.72	0.37	178.45
-6	-2	0	0	2	6	90	120	-2.25	10.83	-0.21	-159.56	-2.25	10.84	-0.21	-159.72	0.37	178.45
-10	-2	0	0	2	10	90	120	-2.25	10.83	-0.21	-159.56	-2.25	10.84	-0.21	-159.72	0.37	178.45
-6	-1	0	0	1	6	120	120	-0.32	9.24	-0.03	-22.66	-0.32	9.24	-0.03	-22.79	0.61	61.90
-6	-1	-0.5	0.5	1	6	120	120	-0.74	5.29	-0.14	-52.89	-0.75	5.29	-0.14	-52.97	0.58	78.31
-10	-2	0	0	2	10	90	120	0.21	2.15	0.10	14.59	0.20	2.15	0.10	14.55	0.71	9.22
-6	-2	0	0	2	6	90	60	-0.31	3.91	-0.08	-22.14	-0.31	3.91	-0.08	-22.18	0.43	40.49
-10	-2	0	0	2	10	90	60	-0.31	3.91	-0.08	-22.14	-0.31	3.91	-0.08	-22.18	0.43	40.49
-3.5	-2	0	0	2	3.5	90	60	-0.31	3.91	-0.08	-22.14	-0.31	3.91	-0.08	-22.18	0.43	40.49

total_nu mb_long	total_sh ort_num s	average_ long_da ys	average_ short_da ys	pairs_nu m	uexc	ud	uu	una	dexc	du	dd	dna	Trade_type
2329.00	2140.00	23.37	22.29	86.05	233.00	1776.00	104.00	27.00	257.00	1896.00	131.00	45.00	corr_mv
2604.00	2379.00	26.71	24.63	106.07	236.00	1951.00	109.00	83.00	267.00	2086.00	153.00	98.00	corr_mv
1498.00	1341.00	24.28	23.12	62.00	90.00	1129.00	78.00	44.00	103.00	1231.00	96.00	68.00	corr_mv
56.00	90.00	30.23	31.44	40.20	17.00	18.00	50.00	5.00	8.00	8.00	24.00	4.00	corr_rolling
56.00	90.00	30.23	31.44	40.20	17.00	18.00	50.00	5.00	8.00	8.00	24.00	4.00	corr_rolling
56.00	90.00	30.23	31.44	40.20	17.00	18.00	50.00	5.00	8.00	8.00	24.00	4.00	corr_rolling
213.00	221.00	28.35	32.40	11.91	22.00	163.00	26.00	10.00	30.00	151.00	20.00	12.00	corrSR_mv
231.00	203.00	28.75	31.43	9.75	25.00	144.00	31.00	3.00	31.00	155.00	35.00	10.00	corrSR_mv
262.00	229.00	22.58	24.59	9.75	20.00	174.00	33.00	2.00	25.00	191.00	37.00	9.00	corrSR_mv
64.00	53.00	35.44	38.21	11.87	15.00	12.00	19.00	7.00	9.00	14.00	17.00	10.00	corrSR_rolling
64.00	53.00	35.44	38.21	11.87	15.00	12.00	19.00	7.00	9.00	14.00	17.00	10.00	corrSR_rolling
64.00	53.00	35.44	38.21	11.87	15.00	12.00	19.00	7.00	9.00	14.00	17.00	10.00	corrSR_rolling
265.00	267.00	17.76	20.40	7.82	9.00	173.00	75.00	10.00	11.00	178.00	68.00	8.00	graph_mv
364.00	359.00	11.84	13.72	7.82	8.00	262.00	80.00	9.00	9.00	274.00	73.00	8.00	graph_mv
177.00	181.00	28.57	31.61	8.58	15.00	118.00	39.00	9.00	12.00	118.00	31.00	16.00	graph_mv
274.00	348.00	9.95	10.57	8.58	3.00	125.00	216.00	4.00	3.00	76.00	112.00	9.00	graph_rolling
274.00	348.00	9.95	10.57	8.58	3.00	125.00	216.00	4.00	3.00	76.00	112.00	9.00	graph_rolling
274.00	348.00	9.95	10.57	8.58	3.00	125.00	216.00	4.00	3.00	76.00	112.00	9.00	graph_rolling
265.00	267.00	17.76	20.40	7.82	9.00	173.00	75.00	10.00	11.00	178.00	68.00	8.00	graphSR_mv
364.00	359.00	11.84	13.72	7.82	8.00	262.00	80.00	9.00	9.00	274.00	73.00	8.00	graphSR_mv
177.00	181.00	28.57	31.61	8.50	15.00	118.00	39.00	9.00	12.00	118.00	31.00	16.00	graphSR_mv
61.00	38.00	11.05	11.16	7.70	1.00	19.00	17.00	1.00	1.00	14.00	28.00	2.00	graphSR_roll
61.00	38.00	11.05	11.16	7.70	1.00	19.00	17.00	1.00	1.00	14.00	28.00	2.00	graphSR_roll
61.00	38.00	11.05	11.16	7.70	1.00	19.00	17.00	1.00	1.00	14.00	28.00	2.00	graphSR_roll