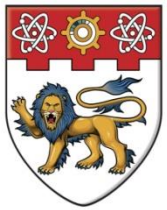

NANYANG TECHNOLOGICAL UNIVERSITY

The Singapore 2010 Youth Olympic Village

Implementation of Pairs Trading Strategies

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Nanyang MFE
FE8827: Quantitative Trading Strategies

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CONTENT

1. INTRODUCTION

Executive Summary

- Search for profitable pairs for the implementation of pair-trading strategies using the method of cointegration
- Establish a search process and search criteria
- Explore various pair-trading strategies
- Analyze results on various trading instruments, i.e. Stocks, ETF, Stock Indices

1. INTRODUCTION

Pair-Trading

- Long one asset against short another (buy the cheap one and sell the expensive one)
- Mean-Reversion Strategy: Spread between two highly correlated assets tends to mean revert
- Stock-Picking Strategy: Eliminates systematic market risk and capitalize on mispricing in stocks
- This report focus on the mean-reversion strategy

1. INTRODUCTION

Stationarity & Cointegration

- Construct a mean-reverting spread through linear combination
- Cointegrating factor (the hedge ratio) is determined by the Johansen method
- Spread is checked to be stationary using the Augmented-Dicky-Fuller test

1. INTRODUCTION

Trading Instruments

- **Equity**: 50 US stocks from different sectors: Technology, Industrials, Energy, Consumer Staples, Finances, Material, Healthcare
- **ETF**: 13 ETFs replicating index in various countries: Dow Jones, Midcap Value, Midcap Growth, Brazil, Germany, UK, Australia.
- **Indices**: 10 Major Indexes: DJIA, Nasdaq, S&P, DAX, CAC, STI, HSI, Nikkei, etc

2. SEARCH PROCESS & CRITERIA

Search Process

- Search process is run between individual asset in each instrument class via a MATLAB script
- Search process is initiated with 40 days of historical data recursively from 31st Dec 2009
- If statistical test for mean reversion is significant (taking 95% confidence level), the spread is extended with 20 days
- The iteration is repeated until there is no significant evidence for mean reversion

2. SEARCH PROCESS & CRITERIA

Pair-Trade Criteria

Factors suggesting suitable trading pairs include:

- Length: Longest period showing significant evidence of mean reversion
- t-statistic: More negative t-statistic signifying a more statistically significant evidence of mean reversion

3. TRADING STRATEGIES

Back-testing Procedure

- Trading pairs are determined from the search procedure using historical data recursively from 31st Dec 2009
- Identified trading pairs are back-tested using historical data from 1st Jan 2010 to 31st Dec 2010 to determine the cumulative profit
- 3 different trading strategies are employed on the 3 different classes of trading instruments

3. TRADING STRATEGIES

Trading Strategy I

- Using calibrated hedge ratio & mean to trade without recalibration or rebalancing
- Strategy
  - Buy when z < mean + 0.5 * sigma
  - Sell when z > mean + 0.5 * sigma
- Intuition: Assumes mean reversion about the historical long-term mean exist

3. TRADING STRATEGIES

Trading Strategy II

- Adopts a dynamic calibration of hedge ratio & mean for a window of every 10 trading days and used to trade for the next 10 trading days with rebalancing
- Strategy
  - Buy when z < mean + 0.5 * sigma
  - Sell when z > mean + 0.5 * sigma
- Intuition: Assumes mean reversion about a mean with stochastic drift exist

3. TRADING STRATEGIES

Trading Strategy III

- Using calibrated hedge ratio to trade without recalibration or rebalancing
- Strategy
  - Buy when $z_t < z_{t-1} + 0.5 * \text{sigma}$
  - Sell when $z_t > z_{t-1} + 0.5 * \text{sigma}$
- Intuition: Assumes that mean reversion follows immediately after a price shock

4. RESULTS – Search for Cointegrated Pairs

- Results on the search of cointegrated pairs for Equity

Top 10 Equity Pairs based on Length

No	Stock I	Stock II	Length	Beta	T-statistics	Mean	Std. Deviation
1	GR	F	159	7.38	-3.987	0.823	5.163
2	AMZN	NYX	79	4.18	-3.941	1.416	26.152
3	CVX	LM	59	2.42	-4.749	0.214	4.422
4	CVX	MS	59	2.42	-4.749	0.214	4.422
5	CVX	AA	59	5.53	-4.665	0.495	6.520
6	CVX	HD	59	2.81	-4.613	0.122	3.272
7	CVX	WFC	59	2.76	-4.584	0.231	4.804
8	CVX	VLO	59	4.35	-4.534	0.546	7.149
9	CVX	JNJ	59	1.24	-4.514	0.056	2.439
10	CVX	MCD	59	1.26	-4.489	0.059	1.925

4. RESULTS – Search for Cointegrated Pairs

- Results on the search of cointegrated pairs for ETF and Indices

Top 5 ETF Pairs based on T-Statistics

No	ETF I	ETF II	Length	Beta	T-statistics	Mean	Std. Deviation
1	MSCI Pacific Ex. Japan	MSCI UK	39	2.545	-3.345	0.002	0.492
2	iShares Australia	MSCI UK	39	1.415	-3.260	-0.001	0.350
3	iShares Dow Jones Transportation	S&P Global Energy	39	2.013	-3.230	0.033	2.886
4	MSCI Brazil	Russell Midcap Growth Index Fund	39	1.703	-3.201	0.055	2.909
5	MSCI Germany	S&P Global Energy	39	0.623	-3.199	0.002	0.325

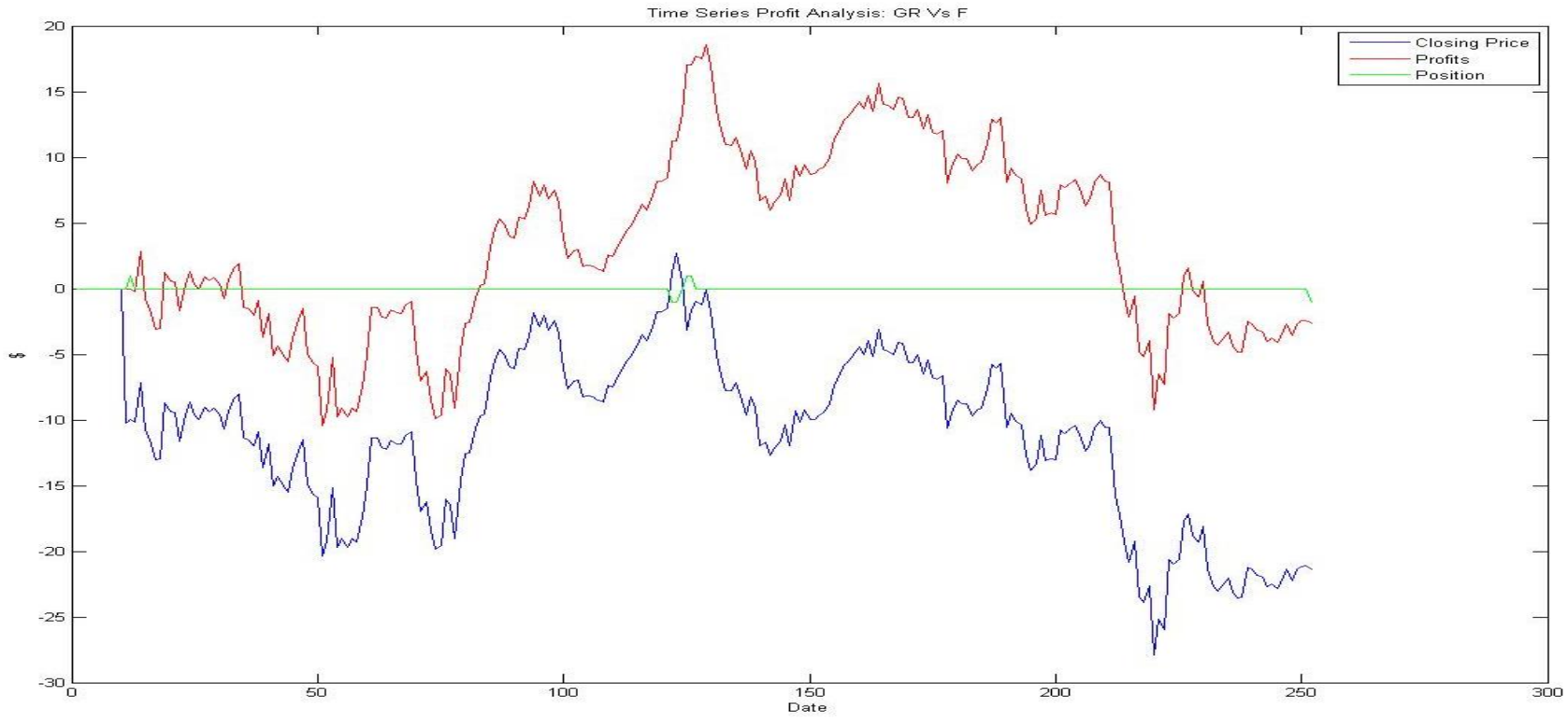
Top 5 Indices Pairs based on T-Statistics

No	Indices I	Indices II	Length	Beta	T-statistics	Mean	Std. Deviation
1	Dow Jones	Nikkei 225	39	1.045	-3.880	15.278	392.753
2	Dow Jones	Hang Seng	39	0.472	-3.749	7.371	303.495
3	CAC	Nikkei 225	39	0.386	-3.668	3.363	102.133
4	S&P 500	FSSTI	39	0.397	-3.564	0.195	12.719
5	CAC	KOSPI	39	2.353	-3.235	1.046	68.074

4. RESULTS & ANALYSIS - EQUITY

Trading Strategy I

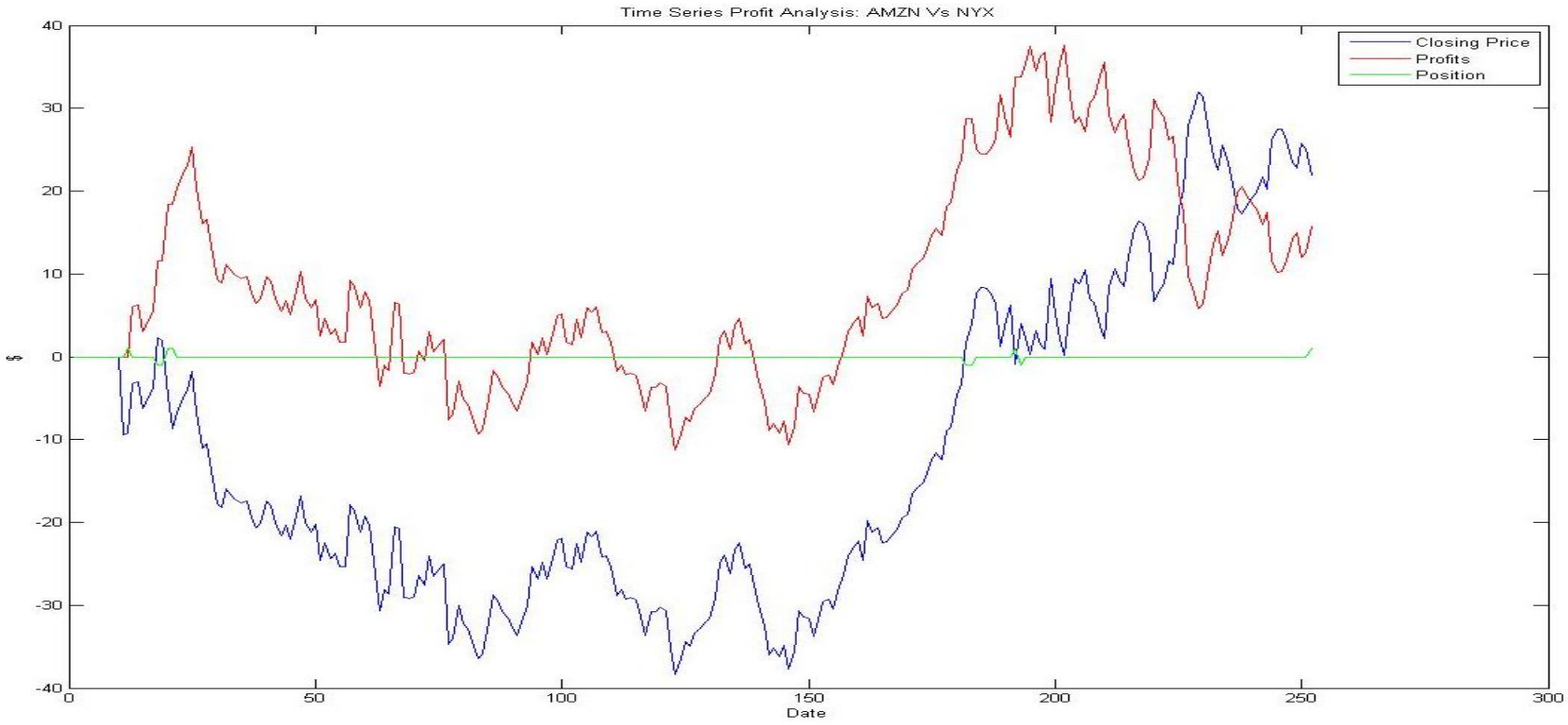
- GR Vs F P&L: -2.44



4. RESULTS & ANALYSIS - EQUITY

Trading Strategy I

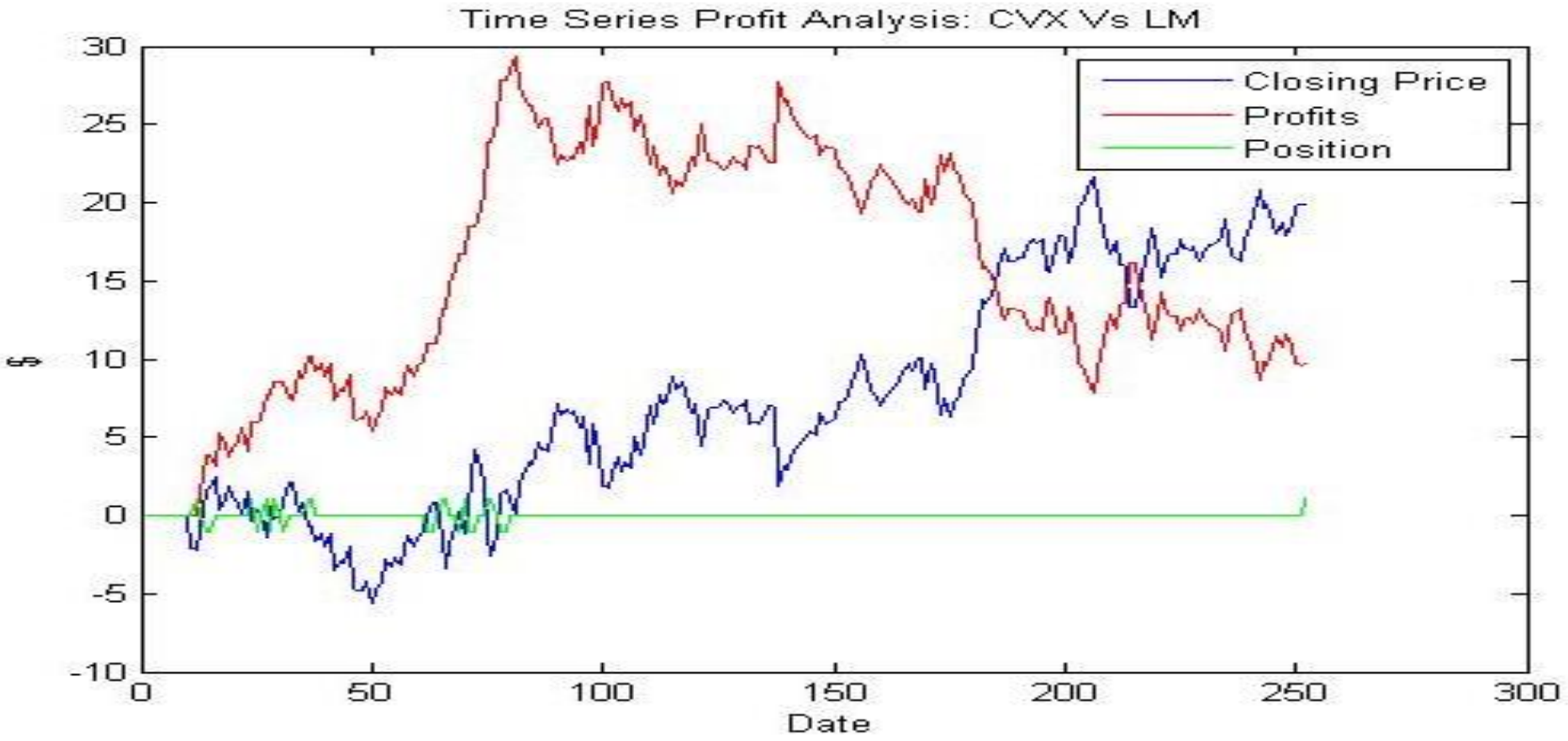
- AMZN Vs NYX P&L: 12.63



4. RESULTS & ANALYSIS - EQUITY

Trading Strategy I

- CVX Vs LM P&L: 9.63



4. RESULTS & ANALYSIS - EQUITY

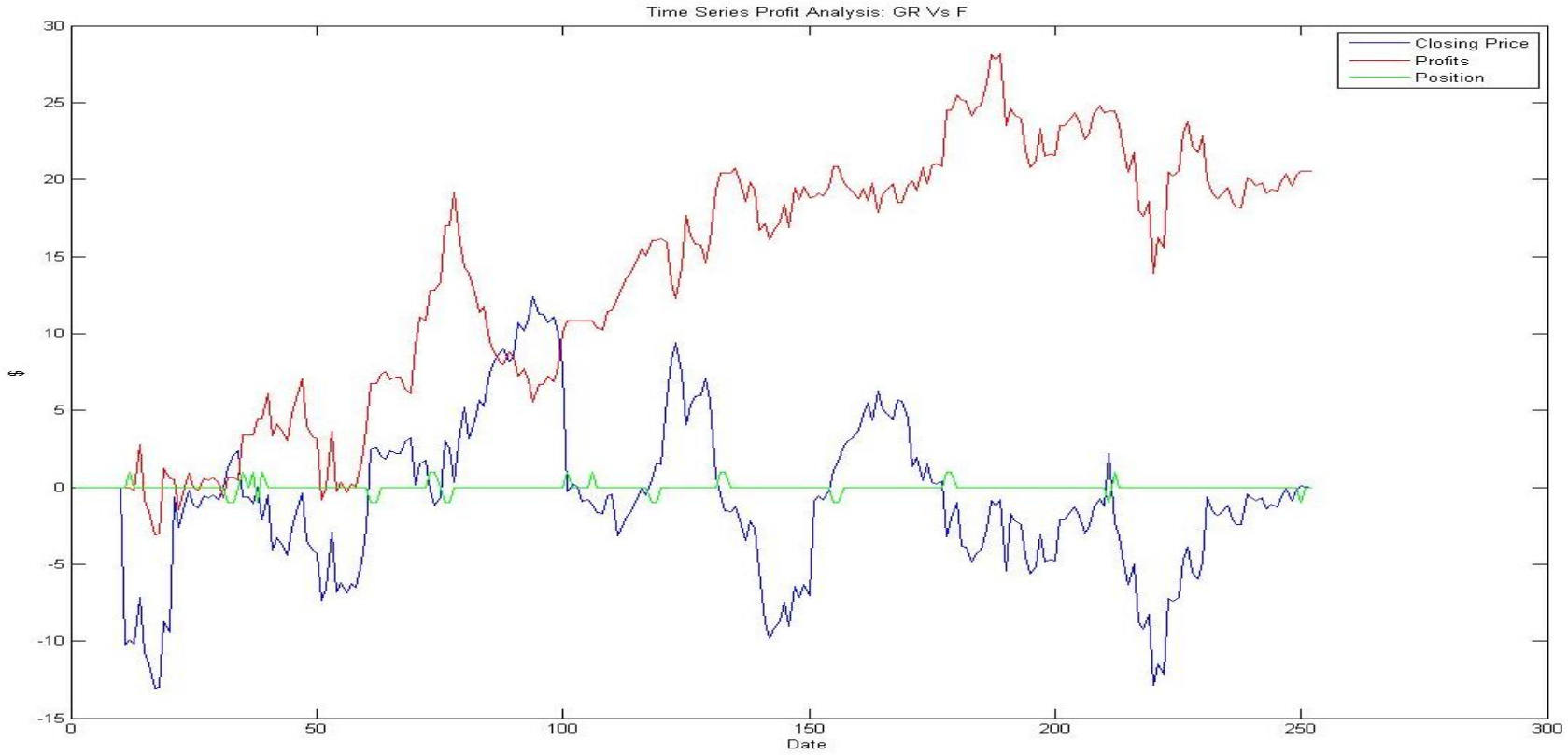
Trading Strategy I: Analysis

- Spread is not mean reverting around the historical long-term mean.
- A trading position is entered into and the position is held for prolonged period as there is no exit signal.
- Not a feasible trading strategy.

4. RESULTS & ANALYSIS - EQUITY

Trading Strategy II

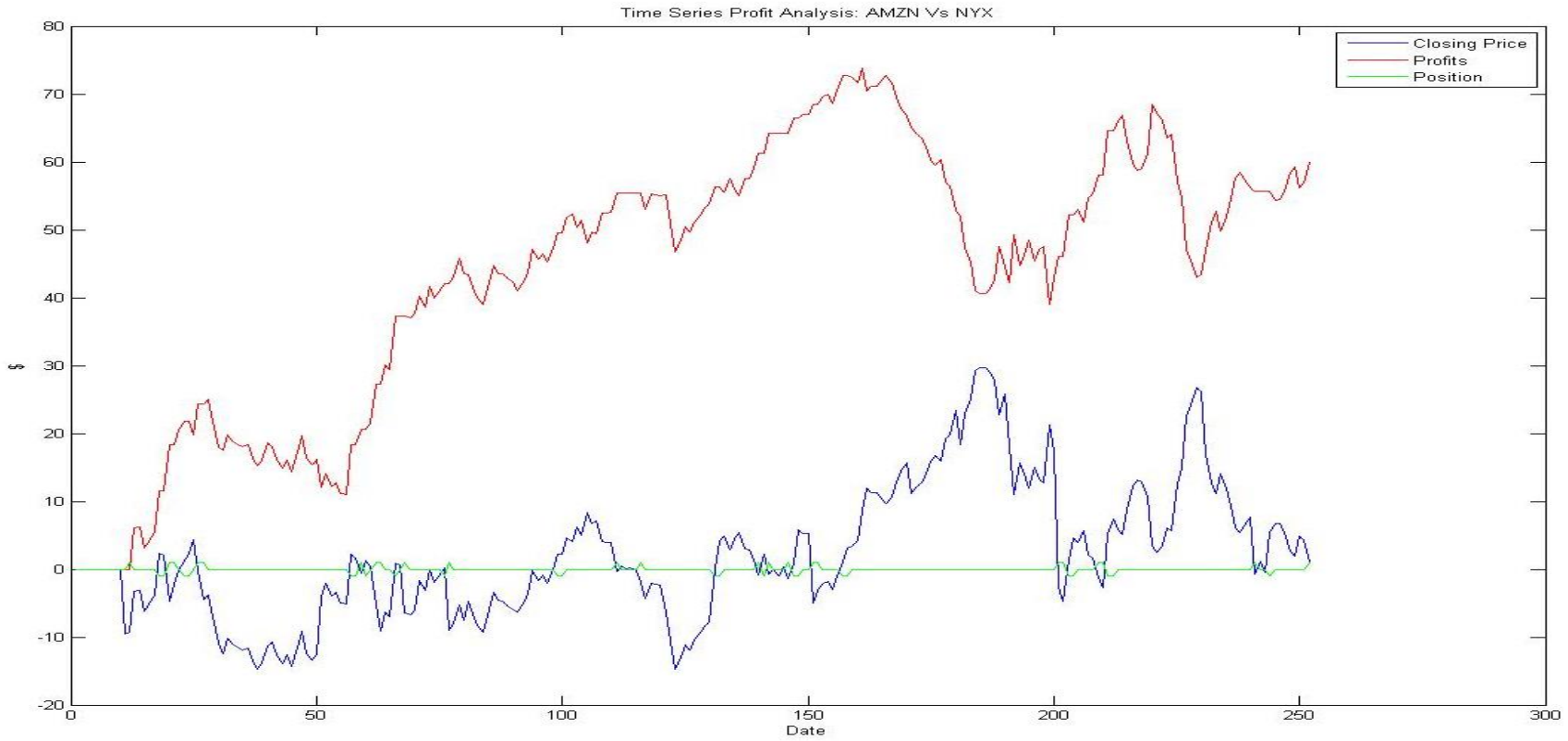
- GR Vs F P&L: 20.57



4. RESULTS & ANALYSIS - EQUITY

Trading Strategy II

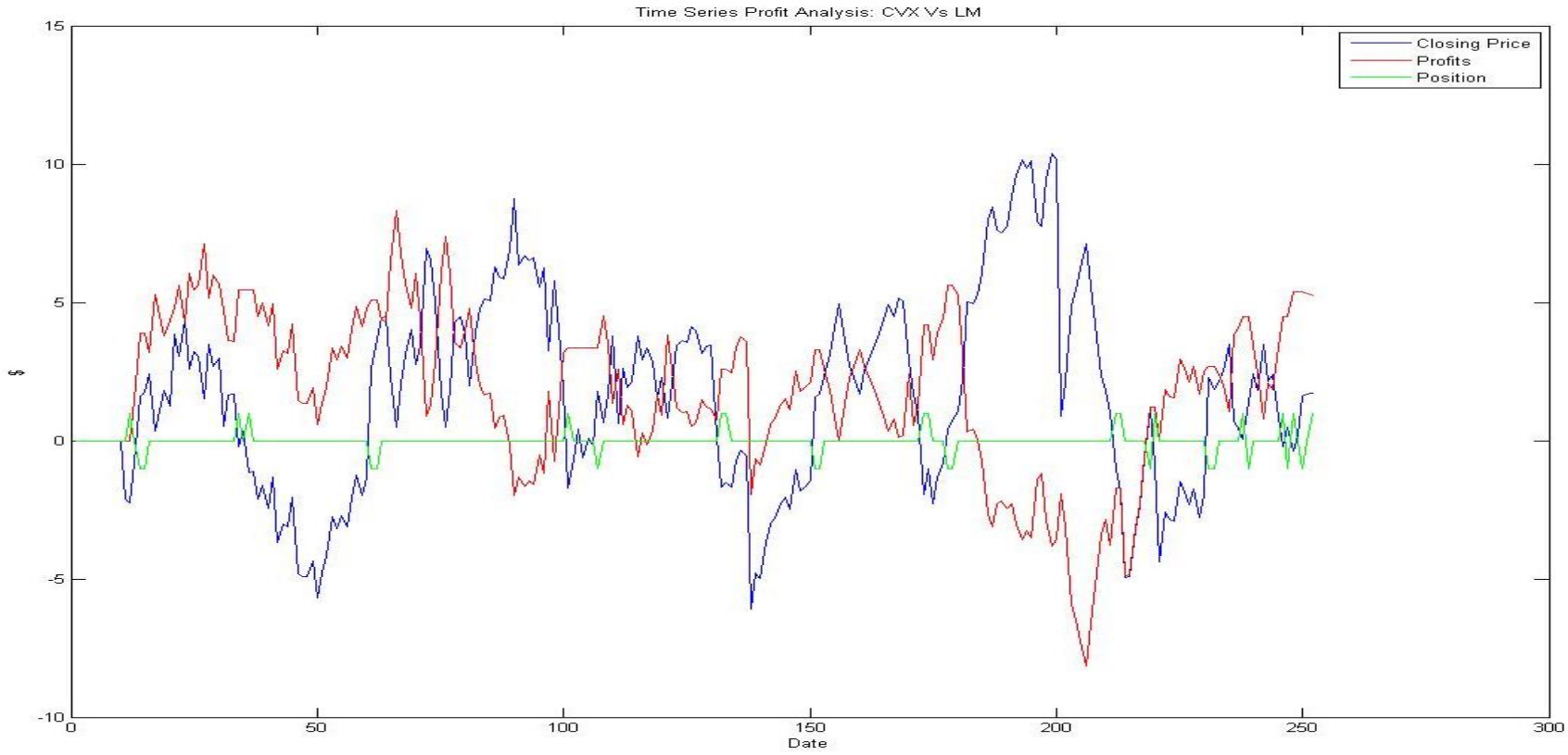
- AMZN Vs NYX P&L: 56.80



4. RESULTS & ANALYSIS - EQUITY

Trading Strategy II

- CVX Vs LM P&L: 5.31



4. RESULTS & ANALYSIS - EQUITY

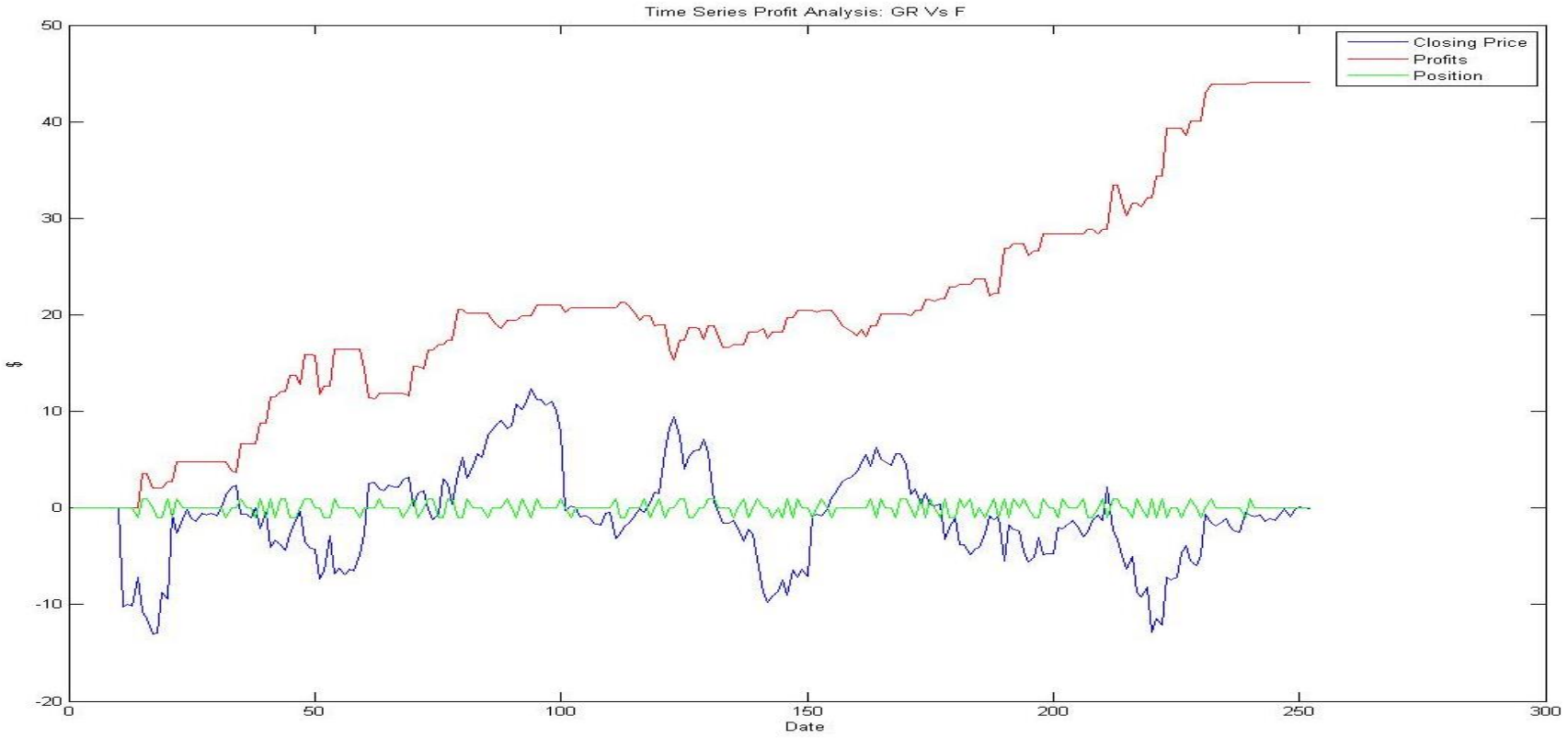
Trading Strategy II: Analysis

- Shows a higher trading activity compared to Strategy I and is consistently profitable for the pairs analyzed.
- Apparently the most appropriate pair-trading strategy for Equity.

4. RESULTS & ANALYSIS - EQUITY

Trading Strategy III

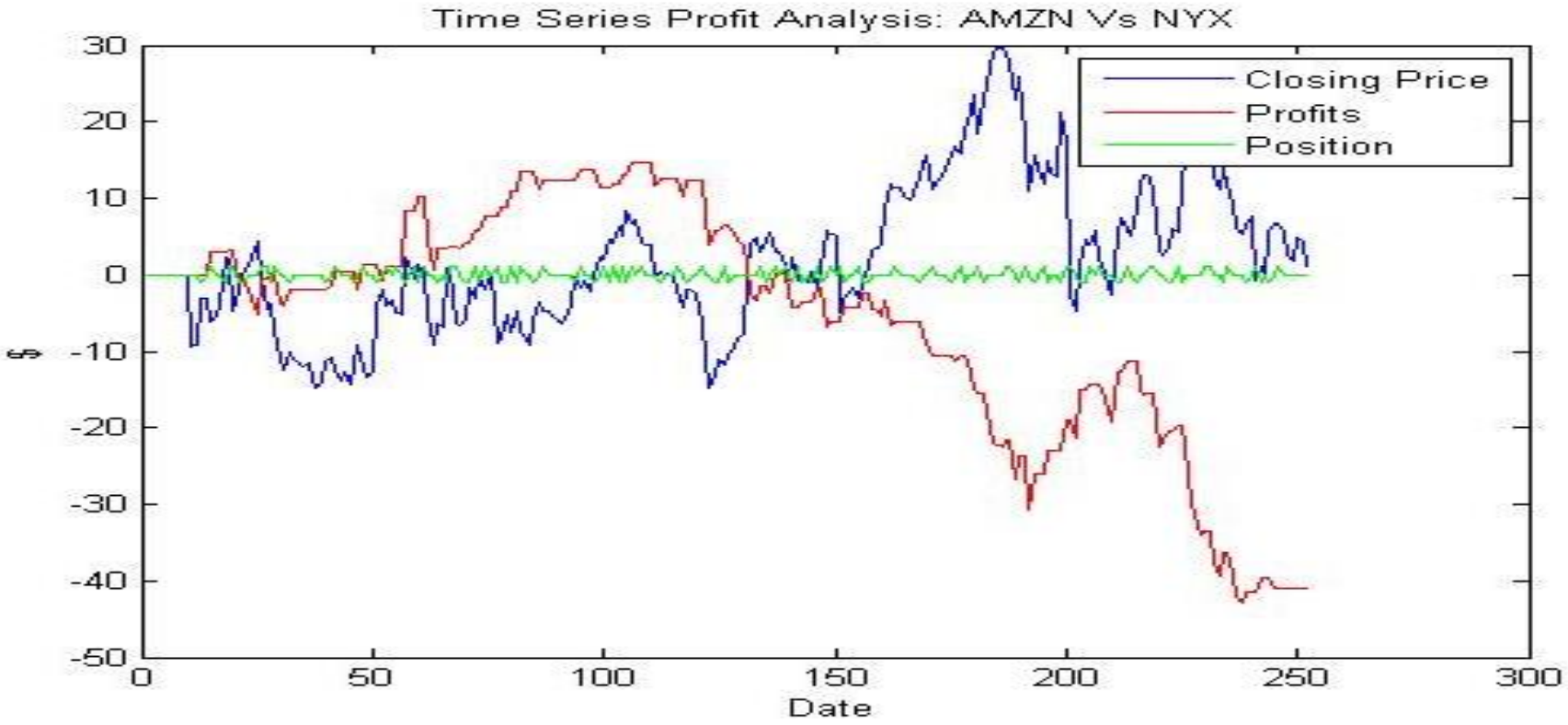
- GR Vs F P&L: 44.10



4. RESULTS & ANALYSIS - EQUITY

Trading Strategy III

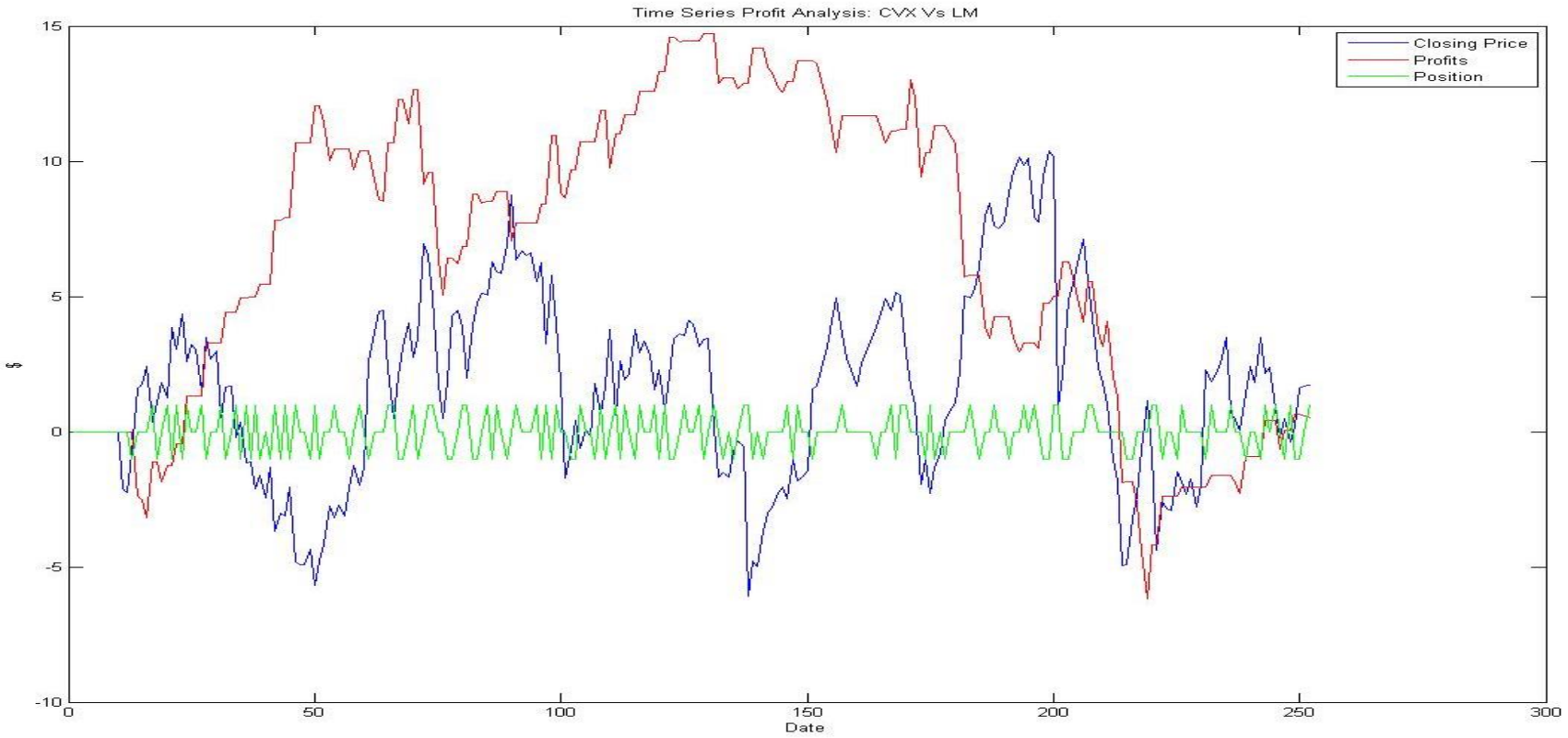
- AMZN Vs NYX P&L: -40.89



4. RESULTS & ANALYSIS - EQUITY

Trading Strategy III

- CVX Vs LM P&L: 0.58



4. RESULTS & ANALYSIS - EQUITY

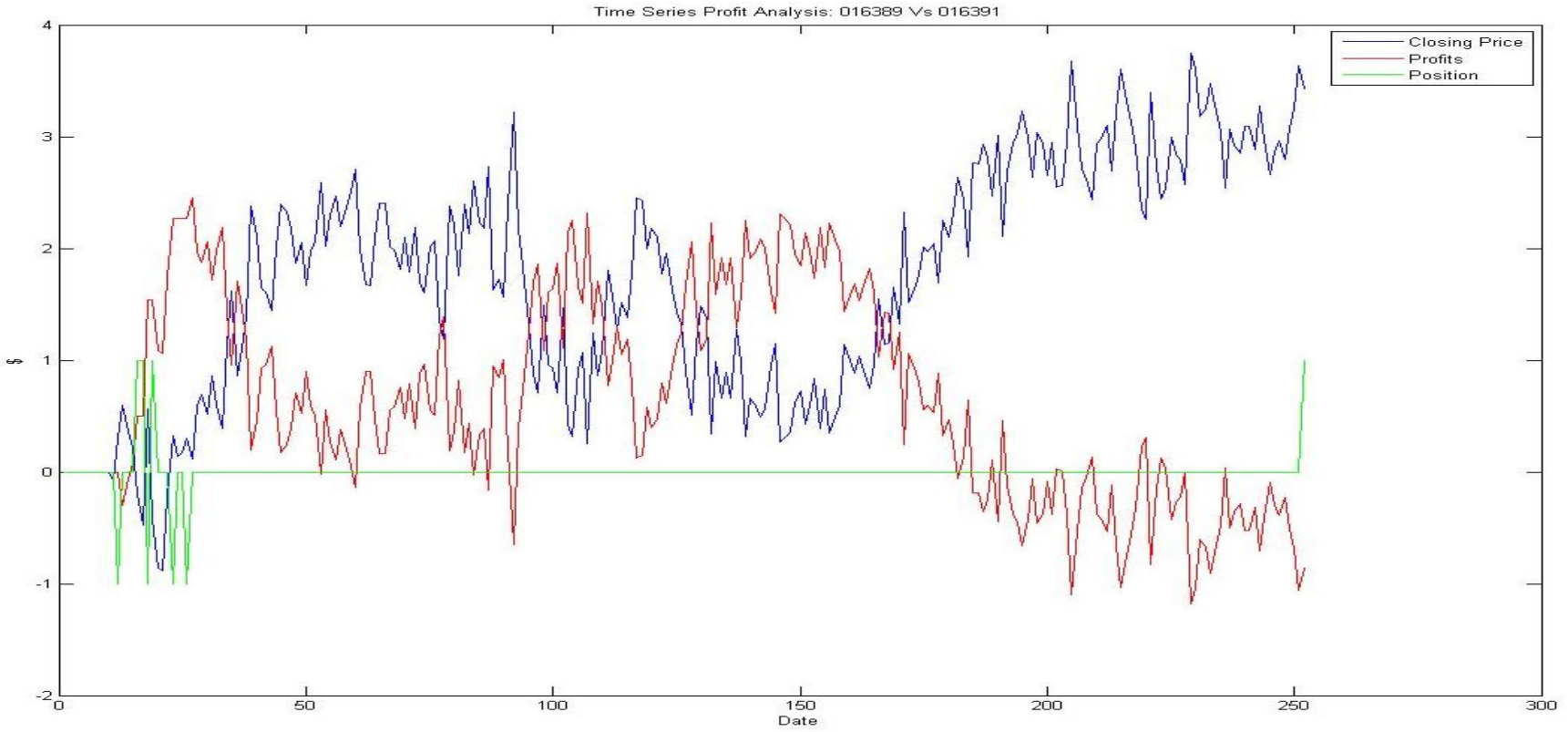
Trading Strategy III: Analysis

- Displays inconsistent performance across the pairs analyzed. There is a possibility of huge profits as well as huge losses.
- This implies that there is no specific reaction to price shocks for equity pair-trading.

4. RESULTS & ANALYSIS - ETF

Trading Strategy I

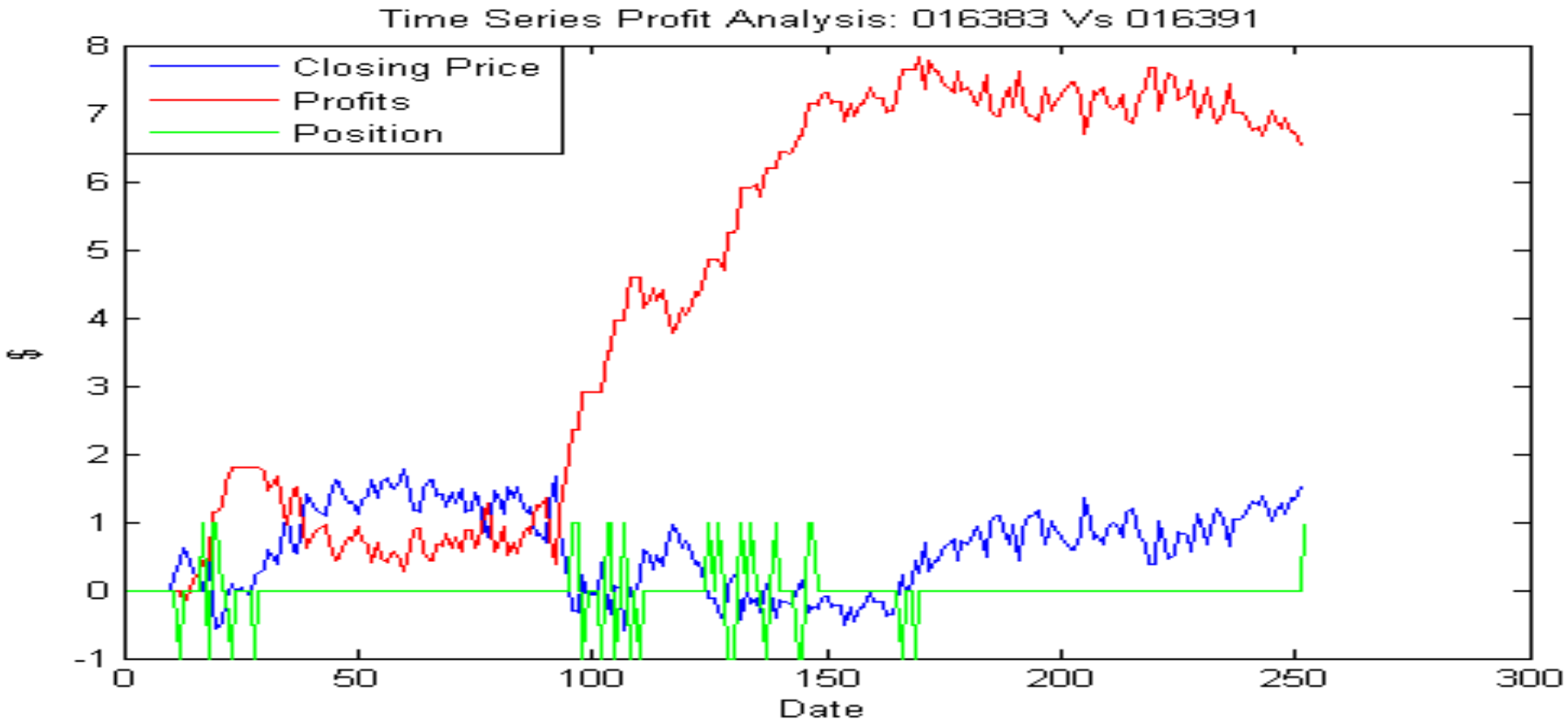
- MSCI Pac Ex-Jap Vs MSCI UK P&L: -1.06



4. RESULTS & ANALYSIS - ETF

Trading Strategy I

- iShares Aust Index Vs MSCI UK P&L: 6.55



4. RESULTS & ANALYSIS - ETF

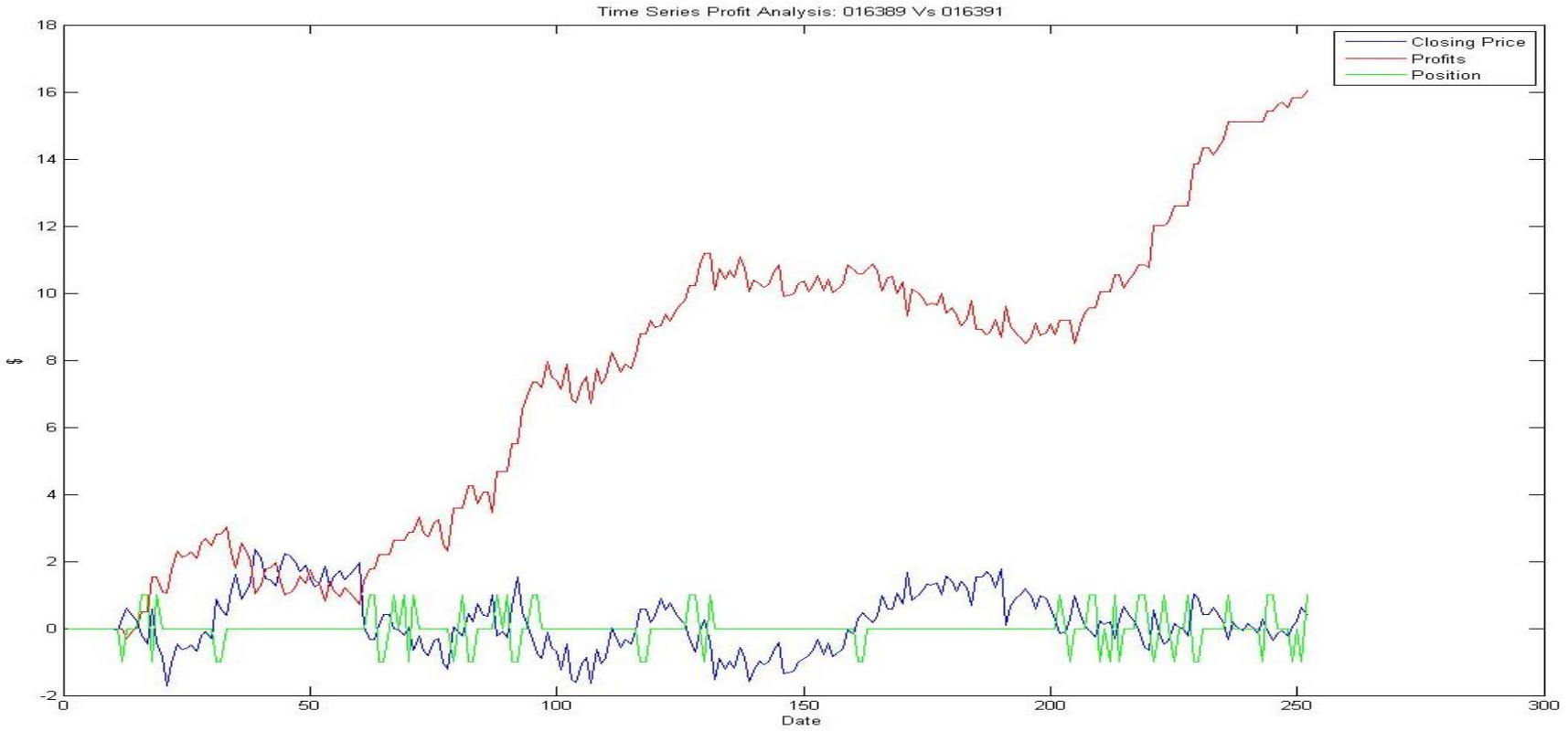
Trading Strategy I: Analysis

- Spread is not mean reverting around the historical long-term mean.
- A trading position is entered into and the position is held for prolonged period with few exit signals.
- Trading activity is more as compared to Equity.
- Not a feasible trading strategy.

4. RESULTS & ANALYSIS - ETF

Trading Strategy II

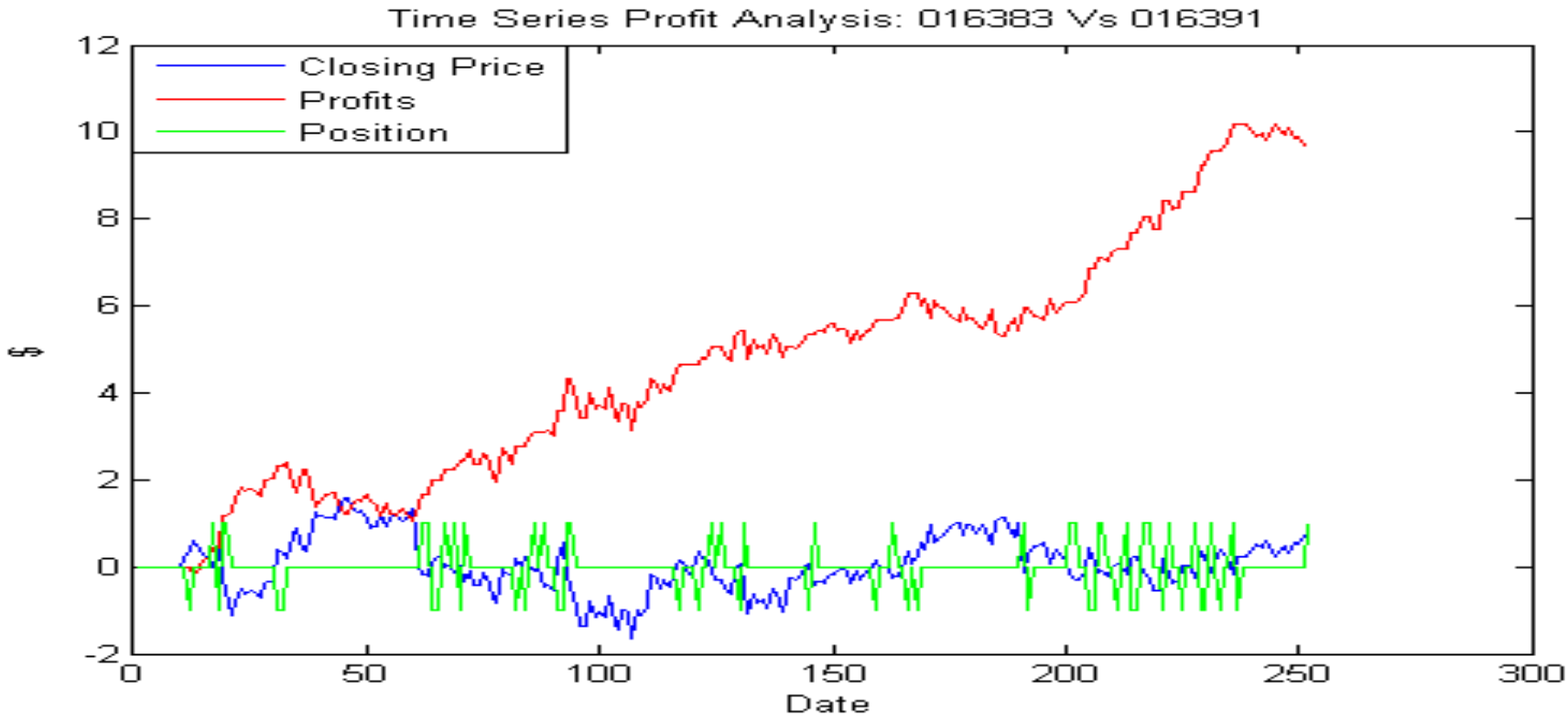
- MSCI Pac Ex-Jap Vs MSCI UK P&L: 15.82



4. RESULTS & ANALYSIS - ETF

Trading Strategy II

- iShares Aust Index Vs MSCI UK P&L: 9.70



4. RESULTS & ANALYSIS - ETF

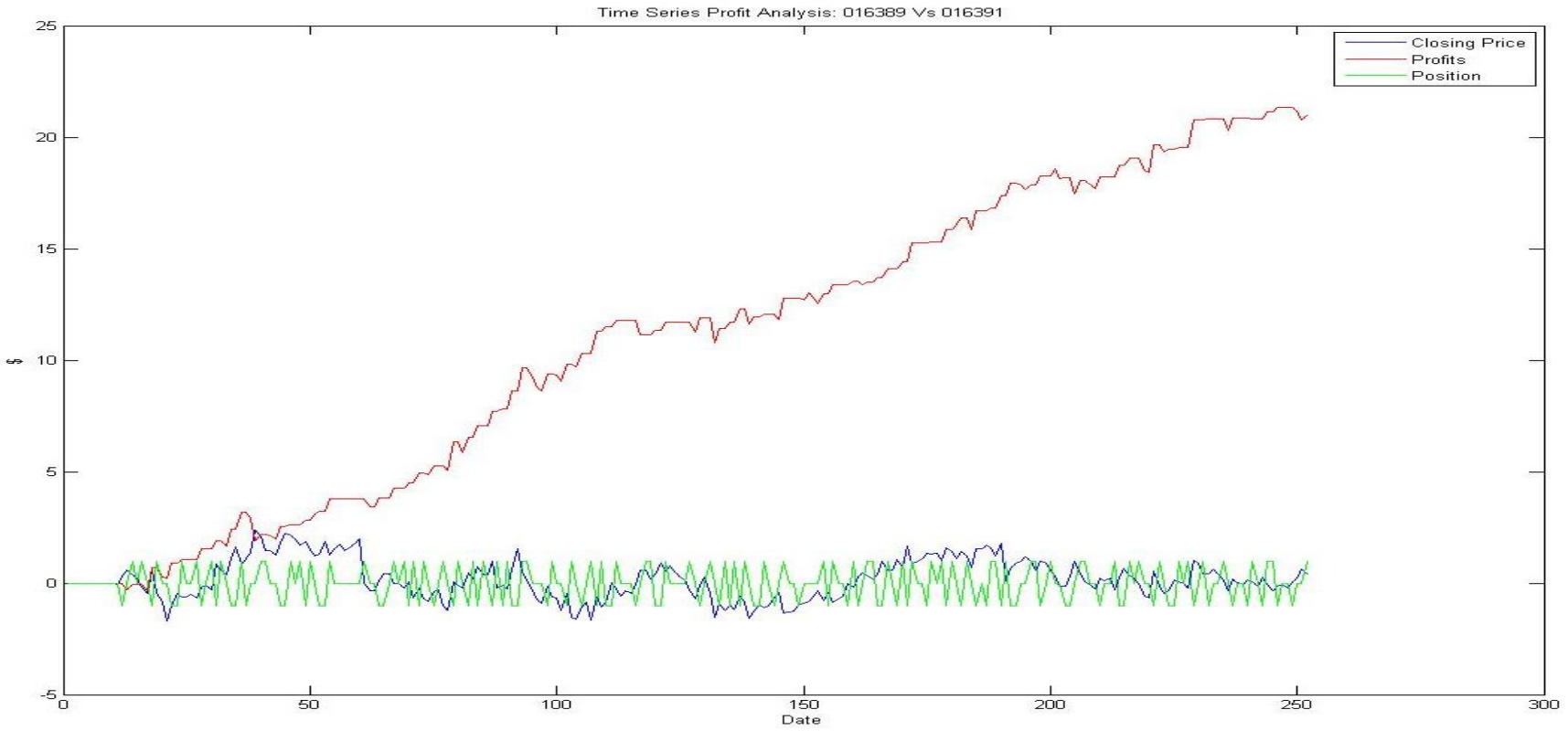
Trading Strategy II: Analysis

- Shows a higher trading activity compared to Strategy I and is consistently profitable for the pairs analyzed.
- It is an appropriate strategy for ETF.

4. RESULTS & ANALYSIS - ETF

Trading Strategy III

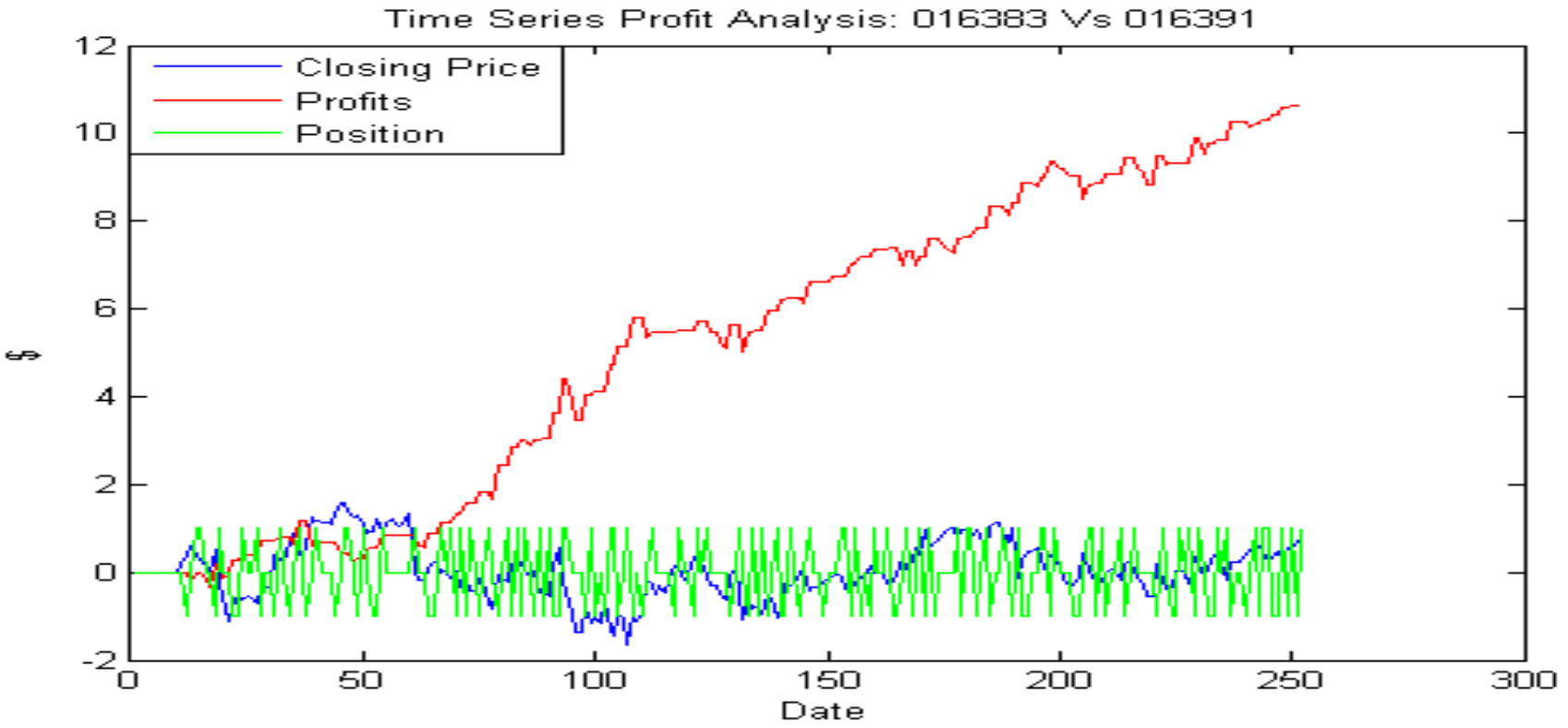
- MSCI Pac Ex-Jap Vs MSCI UK P&L: 20.76



4. RESULTS & ANALYSIS - ETF

Trading Strategy III

- iShares Aust Index Vs MSCI UK P&L: 10.61



4. RESULTS & ANALYSIS - ETF

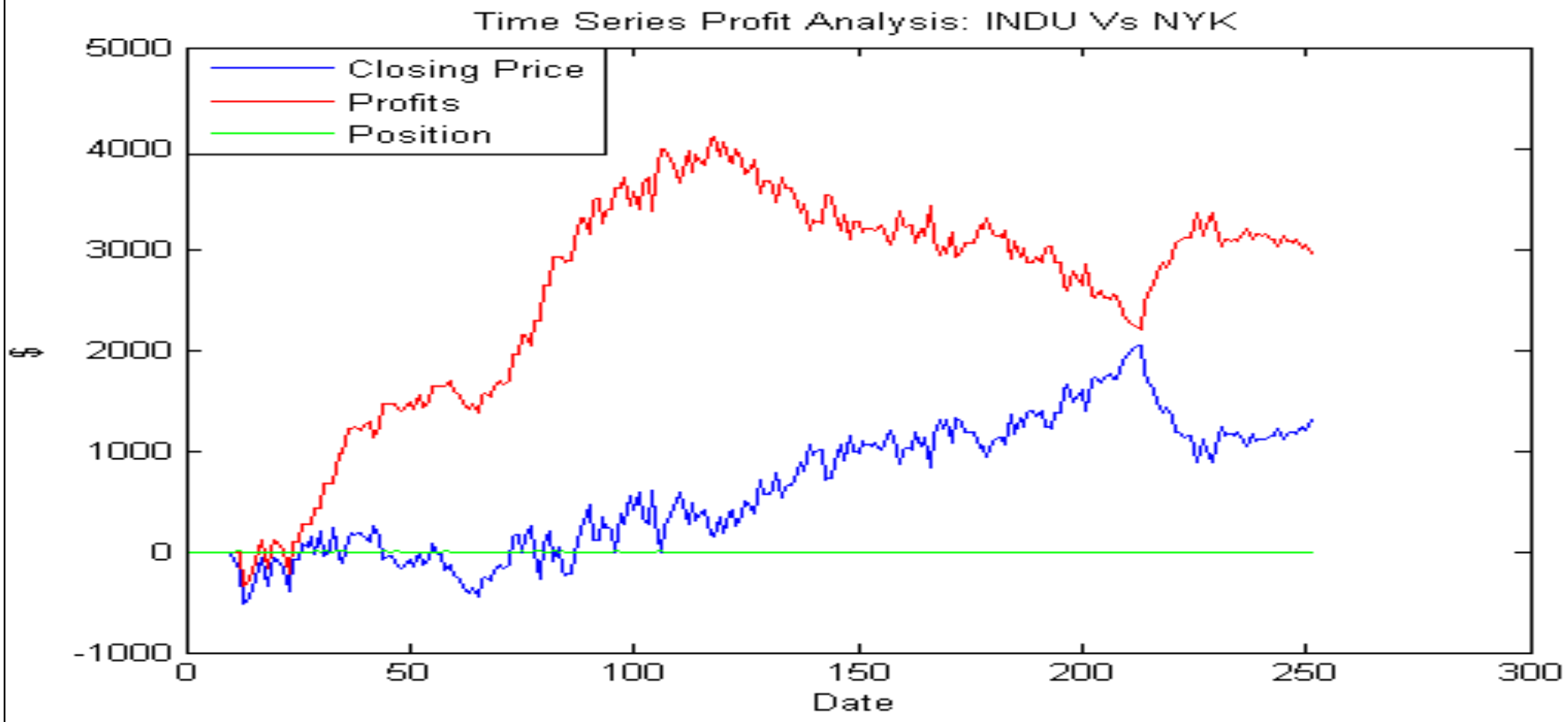
Trading Strategy III: Analysis

- Shows a higher trading activity compared to Strategy I and is consistently profitable for the pairs analyzed.
- It is an appropriate strategy for ETF.
- This implies that ETF pair trades mean-revert closely after price shocks.

4. RESULTS & ANALYSIS - INDICES

Trading Strategy I

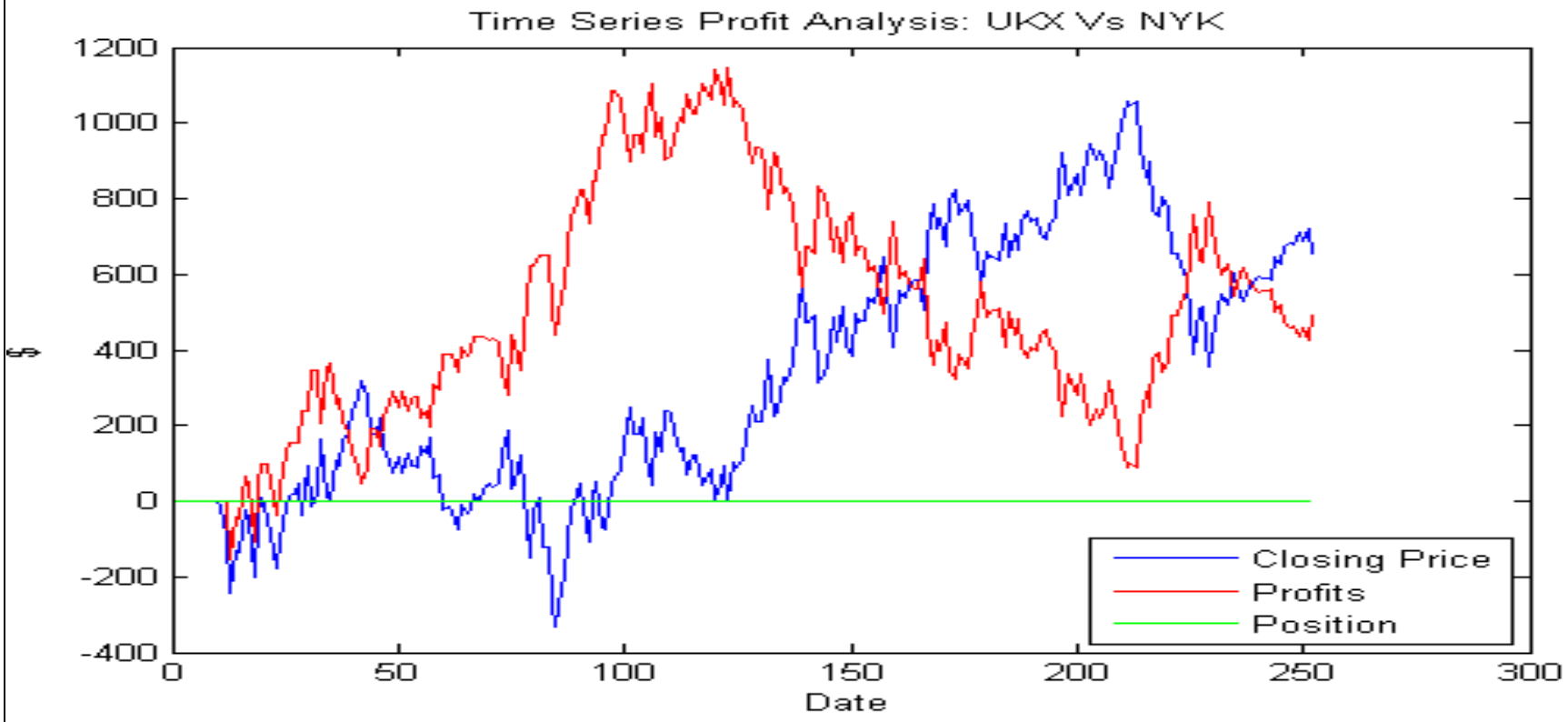
- DJIA Vs NIKKEI 225 P&L: 2948.51



4. RESULTS & ANALYSIS - INDICES

Trading Strategy I

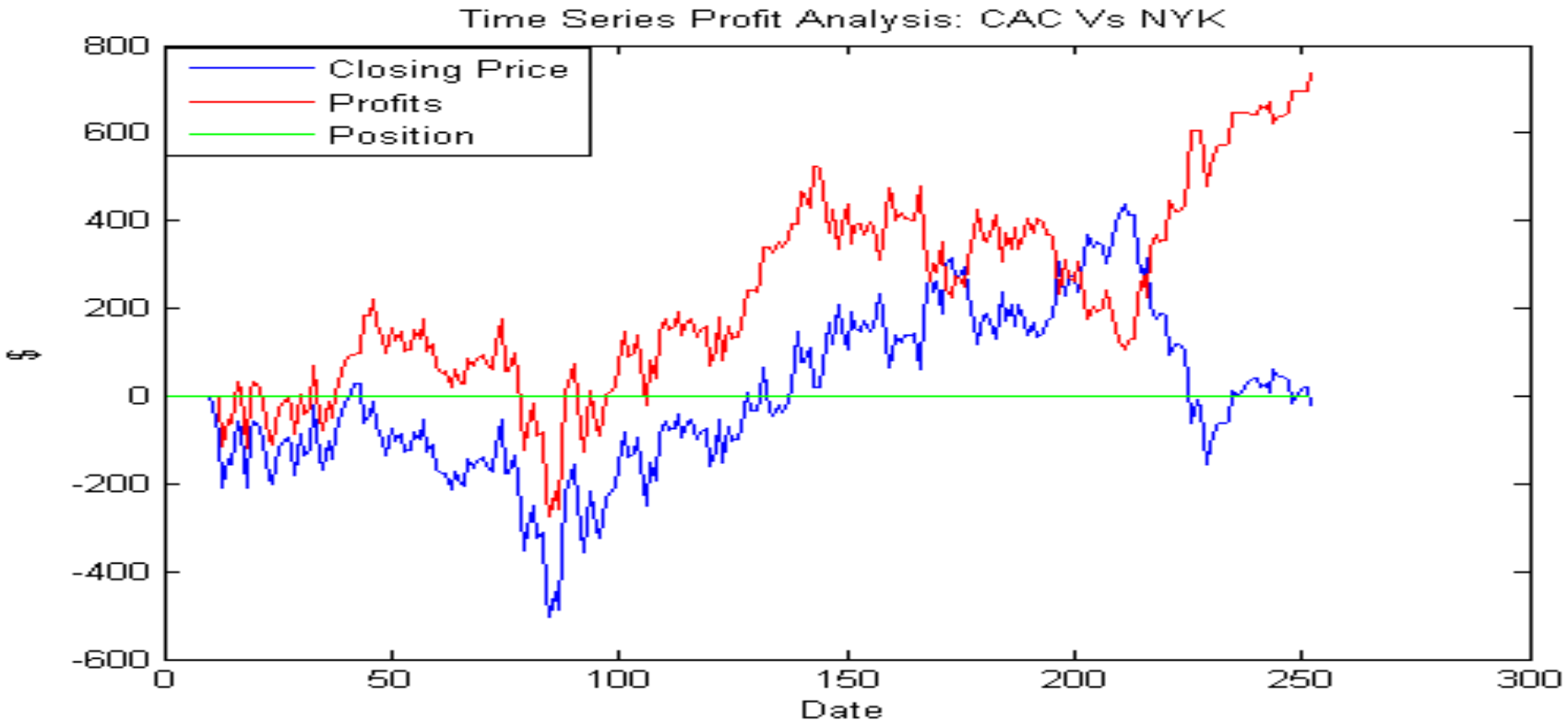
- FTSE 100 Vs NIKKEI 225 P&L: 425.30



4. RESULTS & ANALYSIS - INDICES

Trading Strategy I

- CAC 40 Vs NIKKEI 225 P&L: 425.30



4. RESULTS & ANALYSIS - INDICES

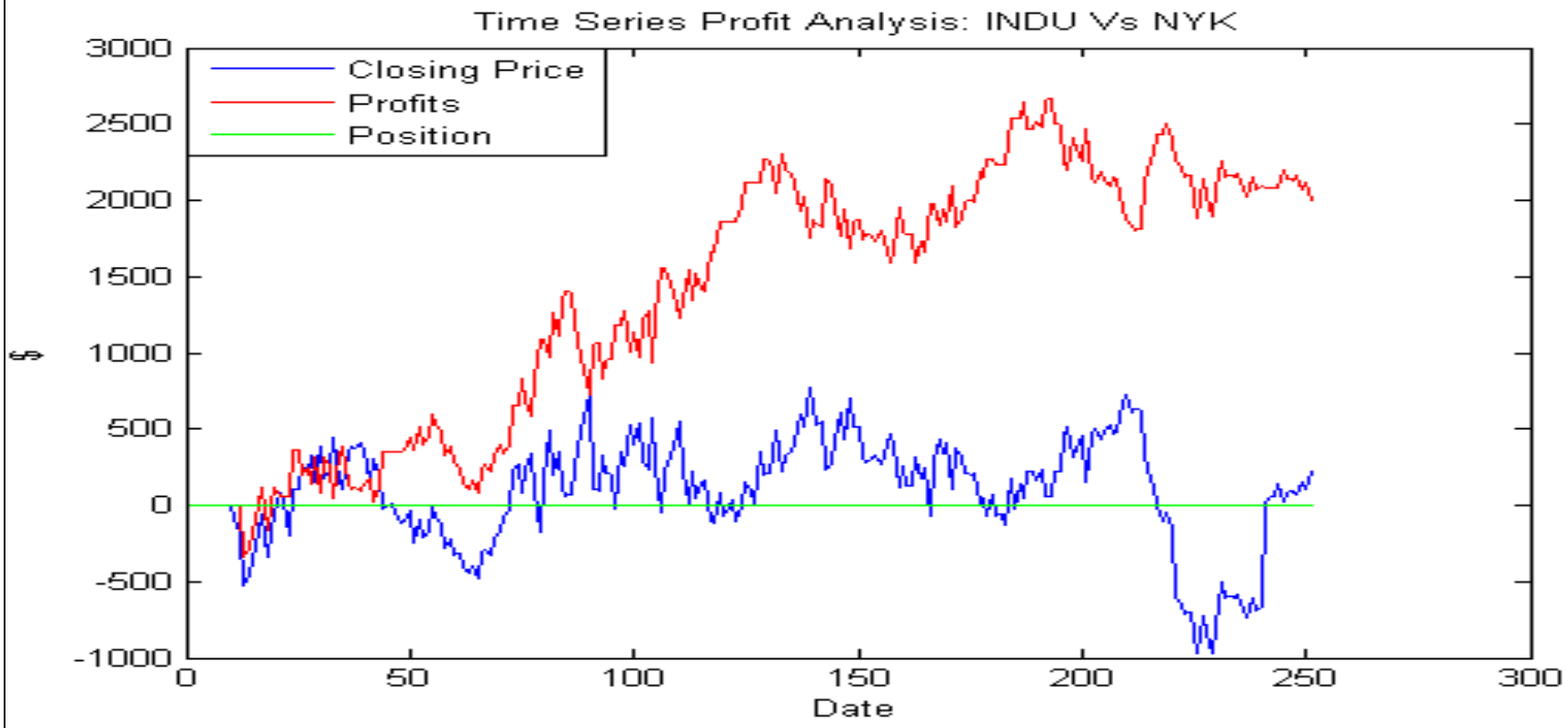
Trading Strategy I: Analysis

- Spread is not mean reverting around the historical long-term mean.
- A trading position is entered into and the position is held for prolonged period with few exit signals.
- Not a feasible trading strategy.

4. RESULTS & ANALYSIS - INDICES

Trading Strategy II

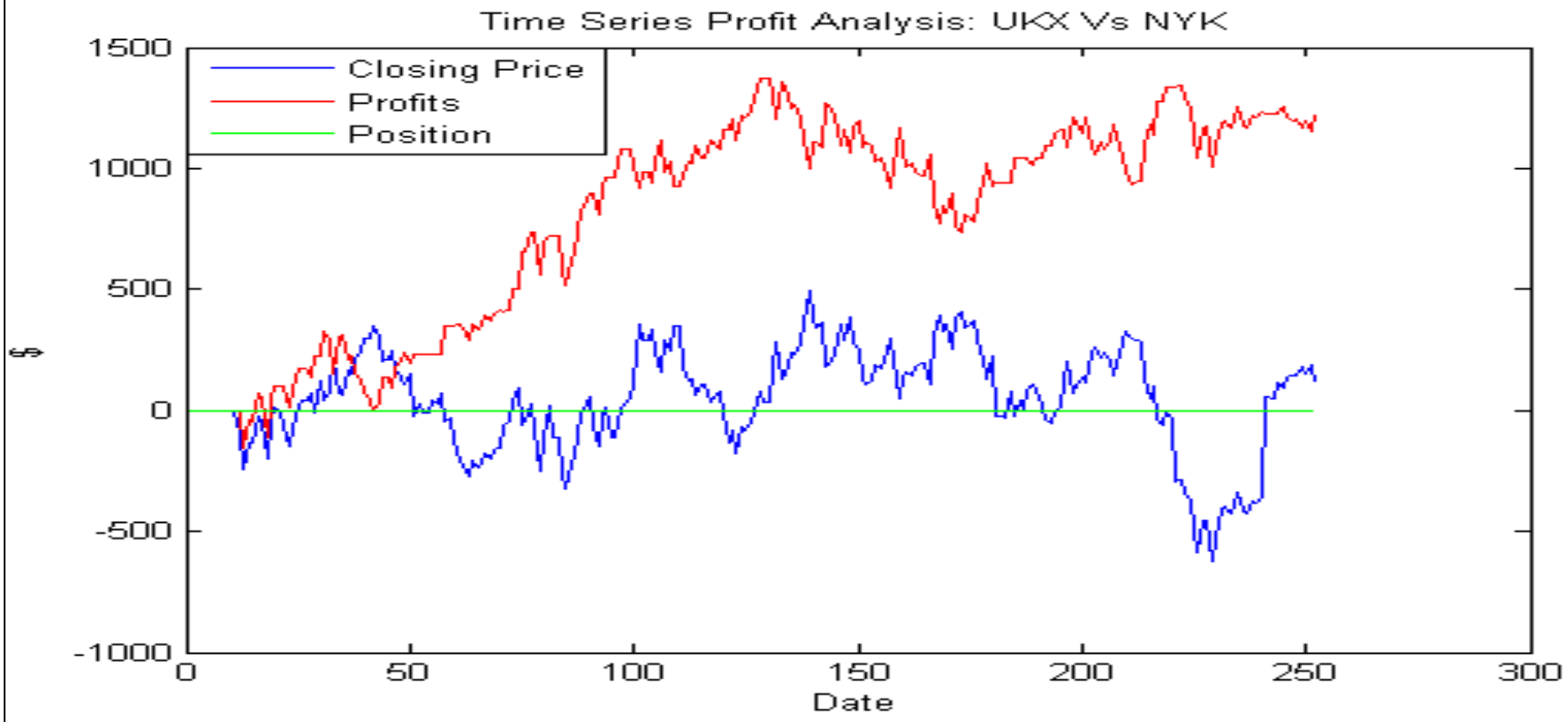
- DJIA Vs NIKKEI 225 P&L: 2002.62



4. RESULTS & ANALYSIS - INDICES

Trading Strategy II

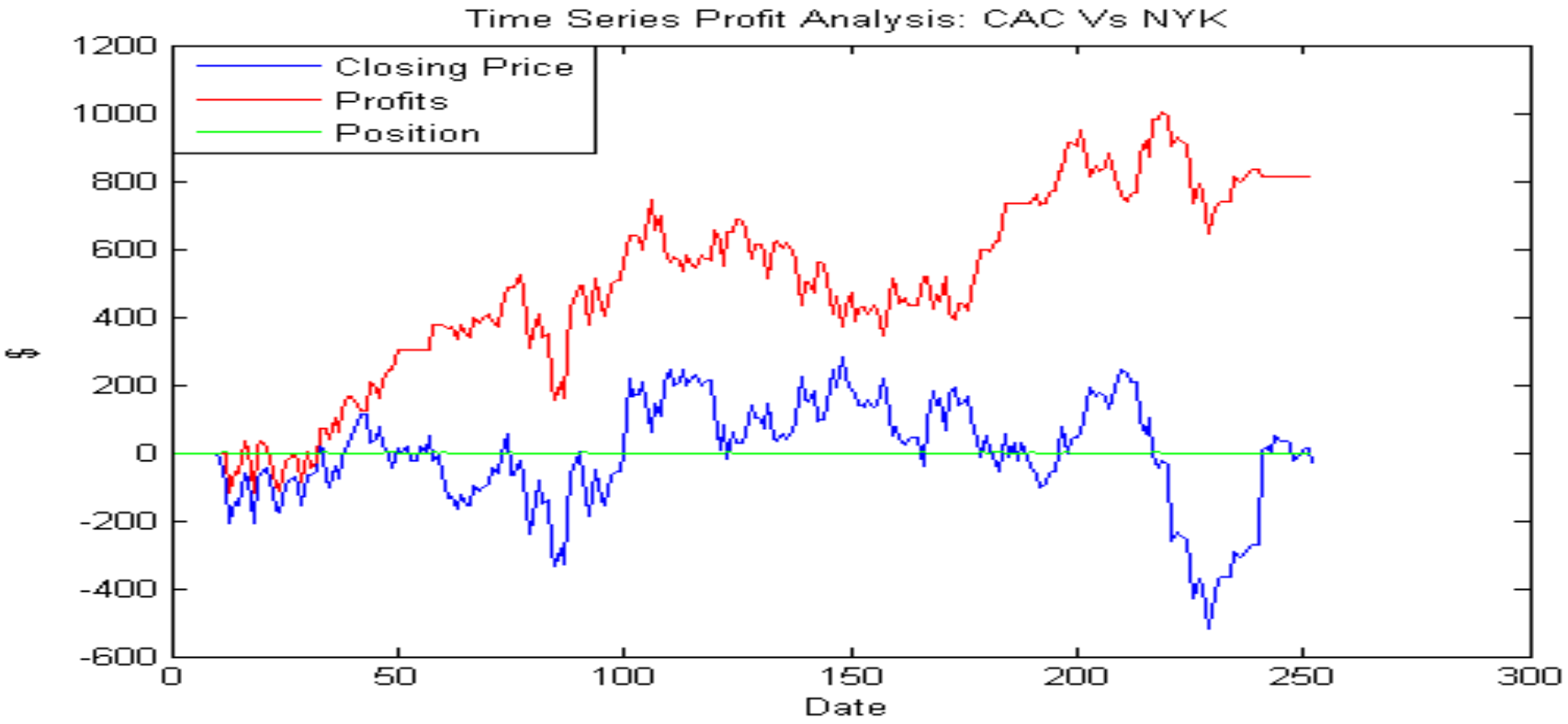
- FTSE 100 Vs NIKKEI 225 P&L: 1153.89



4. RESULTS & ANALYSIS - INDICES

Trading Strategy II

- CAC 40 Vs NIKKEI 225 P&L: 813.38



4. RESULTS & ANALYSIS - INDICES

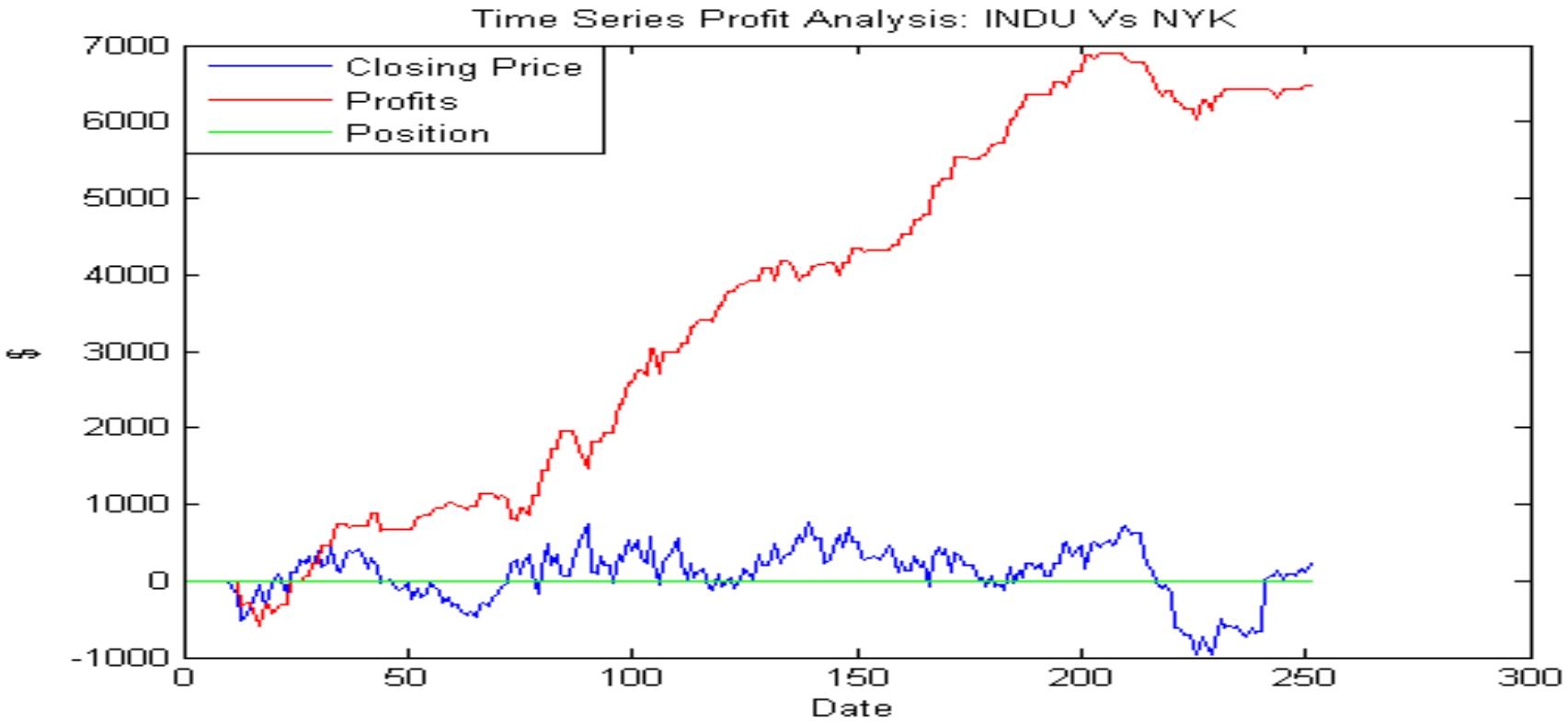
Trading Strategy II: Analysis

- Shows a higher trading activity compared to Strategy I and is consistently profitable for the pairs analyzed.
- Profits analyzed may not be accurate as the pairs are analyzed based on the spot indices and not index futures and tick value is not accounted for. However, it gives a clear indication of relative performance amongst the trading strategies.
- It is an appropriate strategy for Indices.

4. RESULTS & ANALYSIS - INDICES

Trading Strategy III

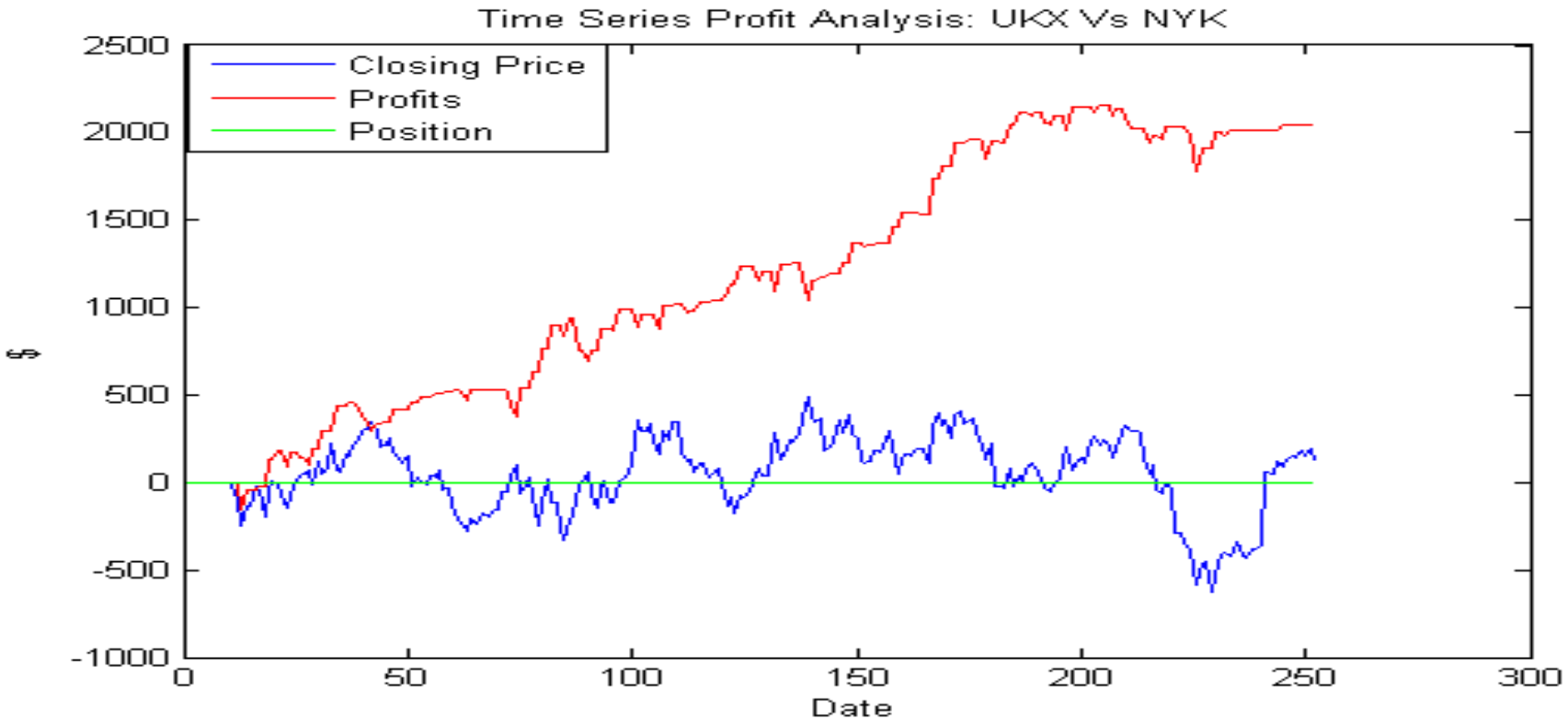
- DJIA Vs NIKKEI 225 P&L: 6471.68



4. RESULTS & ANALYSIS - INDICES

Trading Strategy III

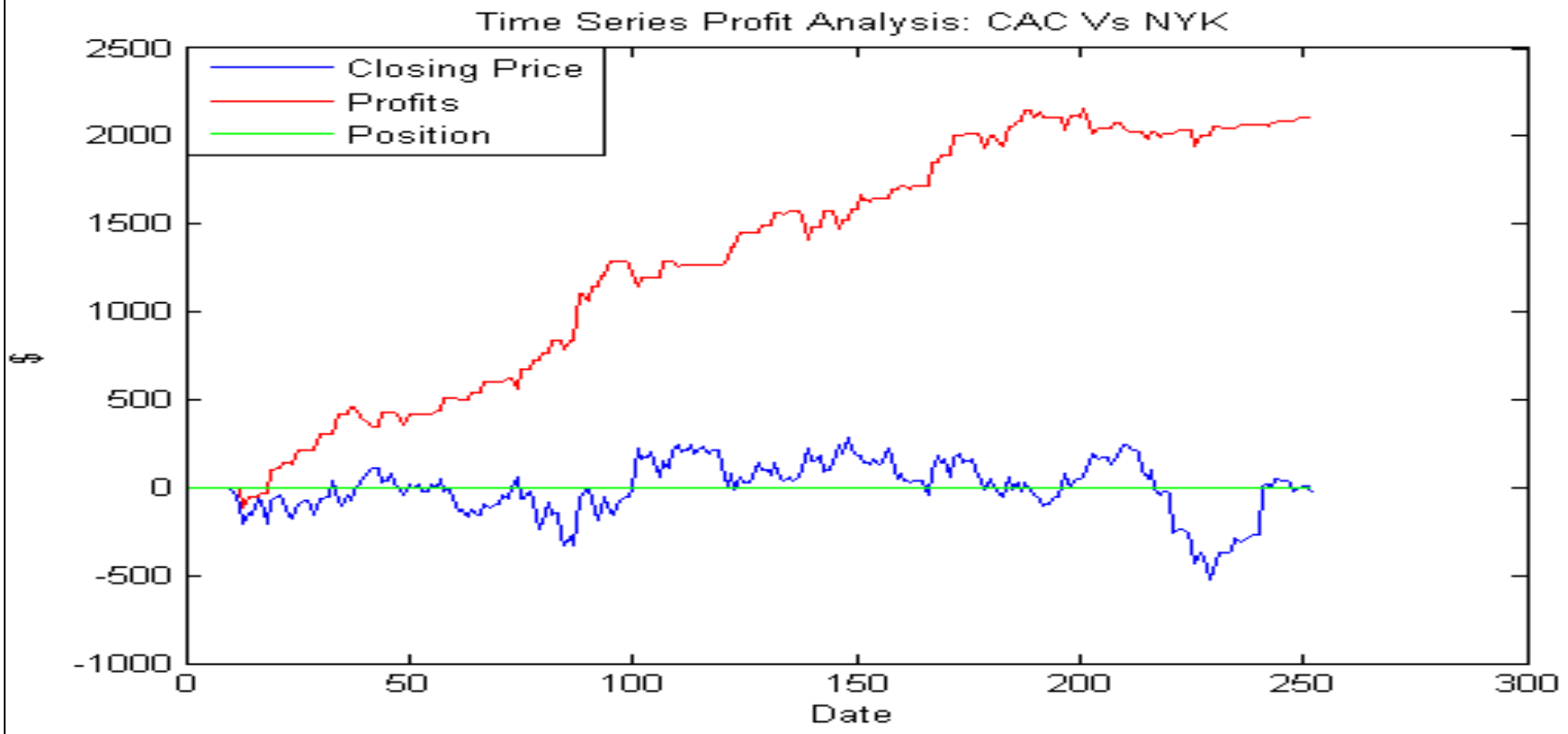
- FTSE 100 Vs NIKKEI 225 P&L: 2044.30



4. RESULTS & ANALYSIS - INDICES

Trading Strategy III

- CAC 40 Vs NIKKEI 225 P&L: 2108.45



4. RESULTS & ANALYSIS - INDICES

Trading Strategy III: Analysis

- Shows a higher trading activity compared to Strategy I and is consistently profitable for the pairs analyzed.
- Apparently this is the most profitable strategy for indices.
- This implies that Indices pair trades mean-revert closely after price shocks.

5. CONCLUSION

- The pair trading search process is most easily applicable to Equity as there are more individual assets to compare and easier to arrive at profitable pairs.
- Using the length and t-statistic of mean reversion from the search procedure is a useful indication of profitable pairs for trading.
- Pair trading performance for ETF and Indices are more consistent as compared to that of Equity.

5. CONCLUSION

- Trading Strategy I is not an appropriate trading strategy for the classes of trading instruments analyzed as there exists a stochastic drift away from the historical long-term mean.
- Trading Strategy II is the most appropriate trading strategy for Equity.
- Trading Strategy II & III are equally appropriate for ETF pair trading.
- Trading Strategy III is the most profitable trading strategy for Indices however Trading Strategy is appropriate as well.

6. REFERENCE

- Øyvind Foshaug. Implementation of Pairs Trading Strategies. Faculty of Science. Koortweg-de Vries Institute for Mathematics. Master of Science Thesis. 2010.
- Ernest Chan. Quantitative Trading: How to Build Your Own Algorithmic Trading Business.
- Haksun Li. Lecture Materials “Quantitative Trading Strategies” course in M.Sc Financial Engineering, NTU. 2011

7. APPENDICES – README FILE

- Guide to run the Pair Trading Program is available in README.txt in the "Pairs Trading" directory.
- Alternatively,

1. Open Directory : "Pairs Trading" with MATLAB
2. Run GUI.m
3. Type the ticker for Asset 1 and Asset 2
   - Both Asset 1 and Asset 2 must be from the same Asset classes
   - The ticker code can be found in the next slide
4. Choose the corresponding Asset Class for the two tickers from the drop down menu
5. Choose Strategy that we want to backtest
6. Wait for several minutes for the backtesting to complete
7. Three graphs will pop-up and Final P&L is shown in lower left corner of the window
   1. Position
   2. Price
   3. Profit
8. Close the Window before running another backtesting
9. To run a new backtesting with different strategy/ticker, repeat step 2

7. APPENDICES – README FILE

TICKER	Equity	TICKER	Equity
AAPL	Apple Inc.	VLO	Valero Energy
AMZN	Amazon.com Inc	KO	Coca Cola Co.
CSCO	Cisco Systems	K	Kellogg Co.
DELL	Dell Inc.	KFT	Kraft Foods Inc-A
EBAY	eBay Inc.	EL	Estee Lauder Cos.
GOOG	Google Inc.	F	Ford Motor
INTC	Intel Corp.	GT	Goodyear Tire & Rubber
MSFT	Microsoft Corp.	HD	Home Depot
NFLX	NetFlix Inc.	MCD	McDonald's Corp.
YHOO	Yahoo Inc.	AA	Alcoa Inc
CAT	Caterpillar Inc.	FMC	FMC Corporation
GE	General Electric	AGN	Allergan Inc
HON	Honeywell Int'l Inc.	JNJ	Johnson & Johnson
TYC	Tyco International	PFE	Pfizer Inc.
UPS	United Parcel Service	MRK	Merck & Co.
MMM	3M Co	AXP	American Express Co
BA	Boeing Company	BLK	Blackrock
FDX	FedEx Corporation	BAC	Bank of America Corp
CSX	CSX Corp.	GS	Goldman Sachs Group
GR	Goodrich Corporation	JPM	JPMorgan Chase & Co.
XOM	Exxon Mobil Corp.	LM	Legg Mason
FTI	FMC Technologies Inc.	MS	Morgan Stanley
NE	Noble Corp	NYX	NYSE Euronext
SLB	Schlumberger Ltd.	WFC	Wells Fargo
CVX	Chevron Corp.	COF	Capital One Financial

TICKER	ETF
016382	iShares Gold Trust
016383	iShares Australia Index Fund
016386	iShares MSCI Brazil Free Index Fund
016387	iShares MSCI Canada Index Fund
016389	iShares MSCI Pacific ex-Japan Index Fund
016391	iShares MSCI U.K. Index Fund
016399	iShares MSCI Germany Index Fund
016415	iShares Dow Jones Transportation Average Index
016425	iShares S&P Global energy
016428	iShares S&P Lat Am 40
016434	iShares Russell Midcap Value Index Fund
016435	iShares Russell Midcap Growth Index Fund
016442	iShares Nasdaq Biotech

TICKER	INDEX
INDU	DOW JONES INDUSTRIAL AVERAGE
SPX	S&P 500 INDEX
CCMP	NASDAQ COMPOSITE INDEX
UKX	FTSE 100 INDEC
CAC	CAC 40 INDEC
DAX	DAX INDEX
NYK	NIKKEI 225
HSI	HANG SENG INDEX
KOSPI	KOSPI INDEX
FSSTI	FTSE STRAITS TIMES INDEX