Quantitative Trading Analysis with Python

Section 2: Strategy Implementation

EXFINSIS
www.exfinsis.com

Course Disclaimer

- **Course Objective.** This course has an educational and informational purpose and doesn't constitute any type of trading or investment advice. All content, including code and data, is presented with no guarantee of exactness or completeness.
- **Investment Risk and Uncertainty.** All course content and conclusions are based on hypothetical historical back-testing and not real trading with the possibility of future outliers not previously observed within these time series. Past performance doesn't guarantee future returns. Investment risk and uncertainty can possibly lead to its total loss for unleveraged products and even larger for leveraged ones.
- **Responsibility Disclaimer.** The instructor is not responsible for any damages caused by using course content for trading or investment decisions; exclusively transferring all this responsibility to the student. Recommending that the student does own due-diligence based on several scenarios, assumptions and consult a certified financial advisor before taking any trading or investment decision.
- **Non-endorsement.** The instructor doesn't endorse any particular trading strategy and associated stock or investment vehicle. Some are from recent inception and haven't been exposed to a major market correction. Investment vehicles have risk considerations such as liquidity, tracking error, replicating index unpredictability, note issuer credit risk, among others. Therefore, recommending again student does own due-diligence and consult a certified financial advisor before taking any trading or investment decision.

EXFINSIS
www.exfinsis.com

Strategy Implementation

- **Strategy implementation** consists of quantitative trading strategy identification, defining strategy indicators based on its category and frequency, identifying trading signals these generate and outlining trading rules that accompany them.

EXFINSIS
www.exfinsis.com

Strategy Identification

- **Strategy identification** consists of defining its category and frequency.

EXFINSIS
www.exfinsis.com

Strategy Categories

- **Strategy categories** consist of profit identification opportunities. Main categories include trend-following and mean-reversion.
  - **Trend-following trading strategies** consist of identifying asset prices uptrends, downtrends and their momentum which is the tendency of raising or falling prices to keep on doing so. These patterns are generally observed in short-term periods of one year or less.
  - **Mean-reversion trading strategies** consist of identifying asset prices deviations from their statistical mean and oversold or overbought areas which indicate asset prices reversal. These patterns are generally observed in long-term periods of three to five years.

EXFINSIS
www.exfinsis.com

Strategy Frequencies

- **Strategy frequencies** consist of transactions regularity. Main frequencies are low, high and ultra-high.
  - **Low frequency trading** consists of inter-day transaction regularity.
  - **High frequency trading** consists of intra-day transaction regularity up to the minute.
  - **Ultra-high frequency trading** consists of intra-day transaction regularity up to the second or millisecond.

EXFINSIS
www.exfinsis.com

Strategy Indicators

- **Strategy indicators** consist of identifying trend-following or mean-reversion asset price patterns. Main indicators include single or multiple, lagging, leading or statistical arbitrage technical indicators.

EXFINSIS
www.exfinsis.com

Trend Following Lagging Indicators

- **Trend-following lagging indicators** consist of identifying asset prices uptrends and downtrends.

- An example of these would be **simple moving average** overlay.

$$sma_k(c)_t = \frac{1}{k}\sum_{i=0}^{k-1} c_{t-i}$$

Trend Following Leading Indicators

- **Trend-following leading indicators** consist of identifying asset prices uptrends, downtrends and their momentum which is the tendency of raising or falling asset prices to keep on doing so.

- An example of these would be **moving averages convergence divergence** centered oscillator.

- Gerald Appel. "*Technical Analysis: Powerful Tools for Active Investors*". FT Press. 2005

EXFINSIS
www.exfinsis.com

Trend Following Leading Indicators

- Technical indicator is calculated through following steps:
- a. Short-term and long-term smoothing calculations.

$$ema_{12}(c)_t = \frac{2}{12+1}(c_t - ema_{12}(c)_{t-1}) + ema_{12}(c)_{t-1}$$

$$ema_{12}(c)_1 = sma_{12}(c)_1$$

$$ema_{26}(c)_t = \frac{2}{26+1}(c_t - ema_{26}(c)_{t-1}) + ema_{26}(c)_{t-1}$$

$$ema_{26}(c)_1 = sma_{26}(c)_1$$

EXFINSIS
www.exfinsis.com

Trend Following Leading Indicators

- b. Moving average convergence/divergence indicator calculation.

$$macd_{12,26}(c)_t = ema_{12}(c)_t - ema_{26}(c)_t$$

- c. Moving average convergence/divergence indicator smoothing calculation.

$$sig_9\big(macd_{12,26}(c)\big)_t = ema_9(macd_{12,26}(c))_t$$

- d. Moving average convergence/divergence indicator histogram calculation.

$$macd_{12,26,9}(c)_t = macd_{12,26}(c)_t - sig_9\big(macd_{12,26}(c)\big)_t$$

EXFINSIS
www.exfinsis.com

Mean Reversion Lagging Indicators

- **Mean-reversion lagging indicators** consist of identifying asset prices deviations from their statistical mean which indicate asset prices reversal.

- An example of these would be **Bollinger bands®** overlays.

- John Bollinger. "Using Bollinger Bands". *Technical Analysis of Stocks & Commodities*. 1992

$$mbb_{20,2}(c)_t = sma_{20}(c)_t$$

$$ubb_{20,2}(c)_t = mbb_{20,2}(c)_t + 2sd_{20}(c)_t$$

$$lbb_{20,2}(c)_t = mbb_{20,2}(c)_t - 2sd_{20}(c)_t$$

EXFINSIS
www.exfinsis.com

Mean Reversion Leading Indicators

- **Mean-reversion leading indicators** consist of identifying asset prices deviations from their statistical mean and oversold or overbought areas which indicate asset prices reversal.

- An example of these would be **relative strength index** bounded oscillator.

- J. Welles Wilder Jr. "New Concepts in Technical Trading Systems". *Commodities Magazine (now Futures Magazine)*. 1978

EXFINSIS
www.exfinsis.com

Mean Reversion Leading Indicators

- Technical indicator is calculated through following steps:
- a. Average gain and loss calculation.

$$ag_{14}(\Delta c^+)_t = \frac{13ag_{14}(\Delta c^+)_{t-1} + \Delta c^+{}_t}{14}$$

$$ag_{14}(\Delta c^+)_1 = \frac{1}{14} \sum_{i=0}^{14-1} \Delta c^+{}_{t-i}$$

$$al_{14}(|\Delta c^-|)_t = \frac{13al_{14}(|\Delta c^-|)_{t-1} + |\Delta c^-|_t}{14}$$

$$al_{14}(|\Delta c^-|)_1 = \frac{1}{14} \sum_{i=0}^{14-1} |\Delta c^-{}_{t-i}|$$

EXFINSIS
www.exfinsis.com

Mean Reversion Leading Indicators

- b. Relative strength calculation.

$$rs_{14}(c)_t = \frac{ag_{14}(\Delta c^+)_t}{al_{14}(|\Delta c^-|)_t}$$

- c. Relative strength index calculation.

$$rsi_{14}(c)_t = 100 - \left(\frac{100}{1 + rs_{14}(c)_t}\right)$$

EXFINSIS
www.exfinsis.com

Mean Reversion Statistical Arbitrage Indicators

- **Mean-reversion statistical arbitrage indicators** consist of identifying asset prices deviations from their statistical mean which indicate asset prices reversal after testing time series is mean stationary.

- An example of indicator would be **z-score**.

- Main mean stationary tests are **augmented Dickey-Fuller** and **autocorrelation functions**.

- Statistical arbitrage is done through following steps:

- a. Level time series mean stationary tests.

Mean Reversion Statistical Arbitrage Indicators

- **Augmented Dickey-Fuller test** consists of evaluating whether time series is mean stationary with null hypothesis that it has a unit root and is not stationary.

- David A. Dickey and Wayne A. Fuller. "Distribution of the Estimators for Autoregressive Time Series with a Unit Root". *Journal of the American Statistical Association*. 1979

$$\Delta c_t = \alpha + \beta t_t + \gamma c_{t-1} + \delta \Delta c_{t-1} + e_t$$

- **Test: γ coefficient p-value:**
  - *If γ coefficient p-value < 0.05: mean stationary time series with 95% of statistical confidence.*
  - *If γ coefficient p-value > 0.05: higher differentiation order needed for mean stationary time series with 95% of statistical confidence.*

EXFINSIS
www.exfinsis.com

Mean Reversion Statistical Arbitrage Indicators

- Normal and partial autocorrelation functions (ACF and PACF).

$$\rho(c_t, c_{t-l}) = \frac{\sigma^2(c_t, c_{t-l})}{\sigma^2(c_t)}$$

$$\rho_p(c_t, c_{t-l}) = \alpha_l \; ; c_t = \alpha_1 c_{t-1} + \cdots + \alpha_l c_{t-l} + e_t$$

- *Test: ACF and PACF bars within upper and lower bands:*
  - *If all ACF and PACF bars within upper and lower bands: mean stationary time series with 95% of statistical confidence.*
  - Upper and lower bands = $\pm \frac{1.96}{\sqrt{n}}$

EXFINSIS
www.exfinsis.com

Mean Reversion Statistical Arbitrage Indicators

- b. Log differentiate time series if level is not mean stationary and test again. Prices log differentiation approximates their arithmetic rate of return under specific circumstances.

$$\Delta log(c_t) = log(c_t) - log(c_{t-1}) \sim r_t = \frac{c_t}{c_{t-1}} - 1$$

Mean Reversion Statistical Arbitrage Indicators

- c. Calculate z-score technical indicator.

- **Individual z-score indicator** calculation corresponds to difference between mean stationary time series and its rolling mean divided by its rolling standard deviation.

$$z_{21}(c)_t = \frac{c_t - \mu_{21}(c)_t}{\sigma_{21}(c)_t}$$

EXFINSIS
www.exfinsis.com

Strategy Signals

- **Strategy signals** consist of comparing asset prices, indicators or their components. Main trading strategy signals are **crossovers** and **thresholds**.
  - **Crossover signals** consist of comparing when asset prices, indicators or their components cross above or below each other.
  - **Threshold signals** consist of comparing when asset prices, indicators or their components cross above or below a specified band or centerline.

EXFINSIS
www.exfinsis.com

Double SMA Crossover Signal

- **Double simple moving average crossover signal** consists of comparing when slow indicator crosses above or below fast one.

- Double crossover trading signals:

- Buy signal: $sma_5(c)_{t-1} < sma_{20}(c)_{t-1} \rightarrow sma_5(c)_t > sma_{20}(c)_t$
- Sell signal: $sma_5(c)_{t-1} > sma_{20}(c)_{t-1} \rightarrow sma_5(c)_t < sma_{20}(c)_t$

EXFINSIS
www.exfinsis.com

MACD Signal Crossover

- **Moving average convergence/divergence signal crossover** consists of comparing when indicator histogram crosses above or below its centerline.

- Centerline crossover trading signals:

- Buy signal: $macd_{12,26,9}(c)_{t-1} < 0 \rightarrow macd_{12,26,9}(c)_t > 0$
- Sell signal: $macd_{12,26,9}(c)_{t-1} > 0 \rightarrow macd_{12,26,9}(c)_t < 0$

EXFINSIS
www.exfinsis.com

BB Crossover Signal

- **Bollinger bands® crossover signal** consists of comparing when asset price crosses above or below indicator bands.

- Bands Crossover Trading Signals:

- Buy signal: $c_{t-1} > lbb_{20,2} (c)_{t-1} \rightarrow c_t < lbb_{20,2} (c)_t$
- Sell signal: $c_{t-1} < ubb_{20,2} (c)_{t-1} \rightarrow c_t > ubb_{20,2} (c)_t$

EXFINSIS
www.exfinsis.com

RSI Bands Threshold Signal

- **Relative strength index bands threshold signal** consists of comparing when indicator reaches certain banded threshold.

- Bands threshold trading signals:

- Buy signal: $rsi_{14}(c)_{t-1} > +30 \rightarrow rsi_{14}(c)_t < +30$
- Sell signal: $rsi_{14}(c)_{t-1} < +70 \rightarrow rsi_{14}(c)_t > +70$

EXFINSIS
www.exfinsis.com

Z-Score Bands Threshold Signal

- **Z-Score bands threshold signal** consists of comparing when indicator reaches certain banded threshold.

- Bands threshold trading signals:

- Buy signal: $z_{21}(c)_{t-1} > -2 \rightarrow z_{21}(c)_t < -2$
- Sell signal: $z_{21}(c)_{t-1} < 2 \rightarrow z_{21}(c)_t > 2$

Strategy Rules

- **Strategy rules** consist of transaction orders for owning or not owning asset based on associated buy or sell signals. This corresponds to entering or exiting a long-only type of position. Main trading orders include **market**, **limit** and **stop**.

- **Market order** is implemented at current asset price.

- **Limit order** is implemented at specified asset price.
  - A buy limit order is implemented at specified asset price or less.
  - A sell limit order is implemented at specified asset price or more.

Strategy Rules

- **Stop order** consists of specified threshold related to initial trade asset price where a market or limit order is activated.
  - o A buy stop order threshold is specified above initial trade asset price.
  - o A sell stop order threshold is specified below initial trade asset price.
  - o Stop order threshold where market order is activated is known as **stop-market** and when limit order is activated as **stop-limit**.
    - Sell stop-market order is also known as **stop-loss**.