Project 6 Report

Theoretically Optimal Strategy

and Technical Indicators

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Abstract—In this project, the Theoretically Optimal Strategy (TOS) is conducted, and five technical indicators are introduced. The results show that TOS beats the benchmark with 6.7 times more profit. Price/SMA ratio (P/SMA), price rate of change (ROC), golden/death cross (GDC), Bollinger Bands® (BB), and percentage price oscillator (PPO) are used to generate buy and sell signals. New indicators that return computational value, which can trigger a buy/sell signal are derived from the original indicators, and the thresholds for signals are also defined for future use.

1 THEORETICALLY OPTIMAL STRATEGY

1.1 Experiment design

In the Theoretically Optimal Strategy (TOS), the future trend of the price is available, so the trading decision is based on the next-day price change.

Apply TOS to the adjusted closing price of JPM (January 1, 2008 – December 31, 2009) with starting cash of $ 100,000. The legal positions are 1000 shares long, 1000 shares short, and 0 shares. No transaction costs are considered.

In order to gain as much profit as possible, set a position of 1000 shares long/short if the stock price begins to rise/drop the next day. Hold the position until the price trend reverses.

1.2 Benchmark

Buy 1000 shares of JPM with starting cash of $ 100,000 and hold the position in the entire timespan (January 1, 2008 – December 31, 2009) without any trades.

1.3 Results

TOS is more profitable than the benchmark (Fig. 1). The final TOS portfolio value is $ 678610.0 – it's 6.7 times higher than the benchmark value ($101230.0).
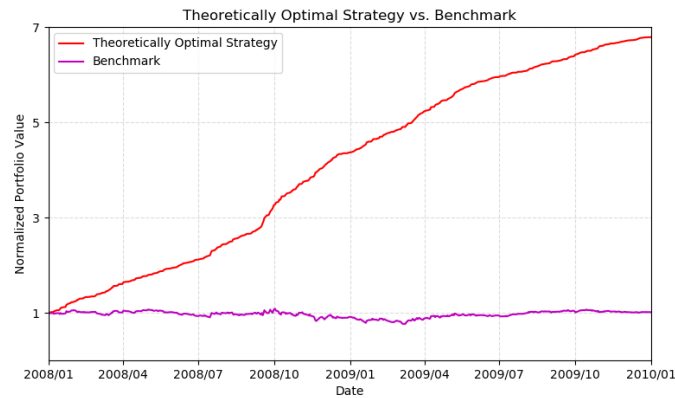

Figure 1—Normalized portfolio values of TOS and benchmark

Statistics also show that TOS is better than the benchmark (table 1). TOS has higher cumulative returns and average daily returns and is less volatile (smaller standard deviation) than the benchmark.

Table 1—Statistics of TOP and benchmark.

Name	Cumulative Return	Mean of Daily Return	Standard Deviation of Daily Return
TOS	5.786100	0.003817	0.004548
Benchmark	0.012300	0.000168	0.017004

2 TECHNICAL INDICATORS

Technical analysis is the predicting of future prices based on the manipulation of past data. For an overbought situation, the price will drop, and hence a sell signal; for an oversold situation, the price will rise, and hence a buy signal. Technical indicators are mathematical calculations derived from historical market data and offer technical analyses to forecast future price movement.

Five technical indicators are applied to the adjusted closing price of JPM, and the results cover the same timespan as that in 1.1. The indicators are the ratio of price to simple moving average (P/SMA), price rate of change (ROC), golden/death cross (GDC), Bollinger Bands® (BB), and percentage price oscillator (PPO).

2.1 Simple moving average and exponential moving average

The simple moving average (SMA) is a technical indicator used to identify the trend of a stock price. It is like the mean of a price list, but SMA is a "moving" mean, which is calculated based on the length of the list and the window size (i.e., the number of days for a look-back period). "The averaging window is moved over the data, shifting it by one time step after each calculation."[1] SMA smooths out volatility and is easy to understand.

The exponential moving average (EMA) is like SMA but applies more weight to current data. Therefore, EMA reacts more significantly to the most recent price change than a corresponding SMA. Since SMA moves slower than EMA, SMA is a better long-term indicator, while EMA is preferable for short terms.

$$EMA_{today} = Price_{today} \times \frac{Smoothing}{1 + Days} + EMA_{yesterday} \times (1 - \frac{Smoothing}{1 + Days})$$

Where the most common choice for the smoothing index is $Smoothing = 2$.[2]

In this project, neither SMA nor EMA is used as a direct technical indicator, but both are important components of the technical indicators used in this study.

2.2 Incidents of price rise and drop

Four incidents (two price uptrends and two price downtrends) are used to demonstrate how to apply technical indicators in real cases. On May 1, 2008 and October 12, 2009, the price began a downtrend, and on July 14, 2008 and March 9, 2009, the price began an uptrend.

In Fig. 2 to 6, the vertical blue dashed lines emphasize the four incidents.

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[1] http://www.statistics4u.com/fundstat_eng/cc_moving_average.html

[2] https://www.investopedia.com/terms/e/ema.asp

2.3 Indicator 1 – Price/SMA Ratio

The ratio of price to an SMA (P/SMA) is a detrended form of SMA and portrays the fluctuations of the trends represented by the moving average (Charles, 2011).

Since price changes faster than SMA, P/SMA is more sensitive than moving averages and indicates an overbuy/oversell early. When the current price is significantly higher/lower than SMA, it implies the probability of overvalued/undervalued stocks and hence reflects an expectation that the price will fall/rise. In this project, P/SMA < 0.95 and > 1.05 are used as the thresholds for a buy and sell signal respectively.
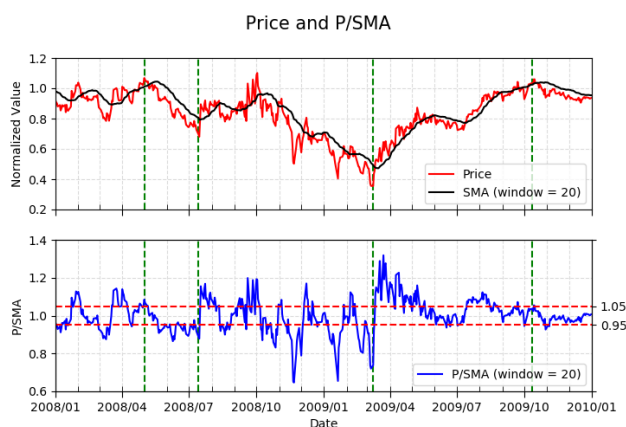

Figure 2—Price and price/SMA ratio (window size = 20)

Fig. 2 illustrates that at the beginning of May 2008, P/SMA peaked beyond 1.05, which was a sell signal - the price decreased afterward. At the beginning of March 2009, P/SMA dropped below 0.95, which was a buy signal, and then the price started to rise. P/SMA also points out the uptrend (July 2008) and downtrend (October 2009) of the price.

2.4 Indicator 2 – Price Rate of Change

The price rate of change (ROC) is a momentum oscillator that measures the percentage change between the current price and the previous price.

$$ROC_t = \frac{Price_t - Price_{t-n}}{Price_{t-n}} \times 100$$

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ROC > 0 confirms an uptrend, while ROC < 0 implies a downtrend; ROC hovers near 0 when the price is consolidating. [3, 4] ROC < 0 followed by ROC > 0 is a buy signal, and ROC > 0 followed by ROC < 0 is a sell signal.

Fig. 3 shows that ROC worked well on the upward price in July 2008 and March 2009 with a crossover of zero line from negative to positive. ROC crossed over zero from positive to negative after (6 to 9 days lagging) the price began a downtrend in May 2008 and October 2009.
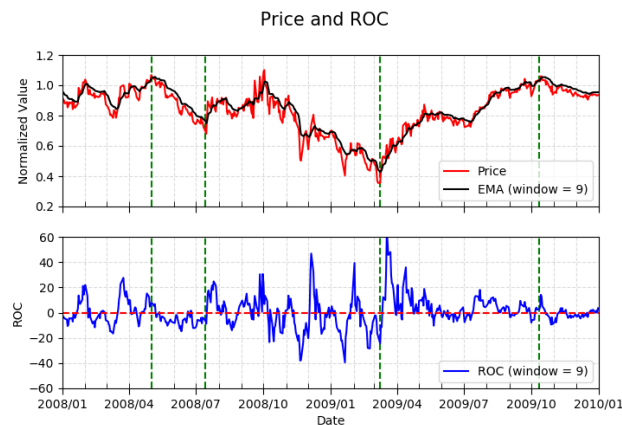

Figure 3—Price and price rate of change (window size = 9)

2.5 Indicator 3 – Golden/Death Cross

A golden/death cross is used to determine a long-term bull/bear market going forward. A golden cross appears when the short-term moving average is above the long-term moving average, indicating an uptrend. The opposite of a golden cross is a death cross, which happens when the short-term moving average drops below the long-term moving average, indicating a downtrend. [5]

A golden/death cross value (GDV) returning the difference between EMA_{15} and SMA_{50} is calculated as:

$$GDV = EMA_{15} - SMA_{50}$$

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[3] https://www.investopedia.com/terms/p/pricerateofchange.asp

[4] https://www.investopedia.com/terms/r/rateofchange.asp

[5] https://www.investopedia.com/terms/d/deathcross.asp - toc-death-cross-vs-golden-cross

Where the golden/death cross is based on the crossover of the 15-day EMA (short-term) and the 50-day (long-term) SMA.[6] It's a golden cross (a buy signal) when GDV < 0 followed by GDV > 0 and a death cross (a sell signal) when GDV > 0 followed by GDV < 0.
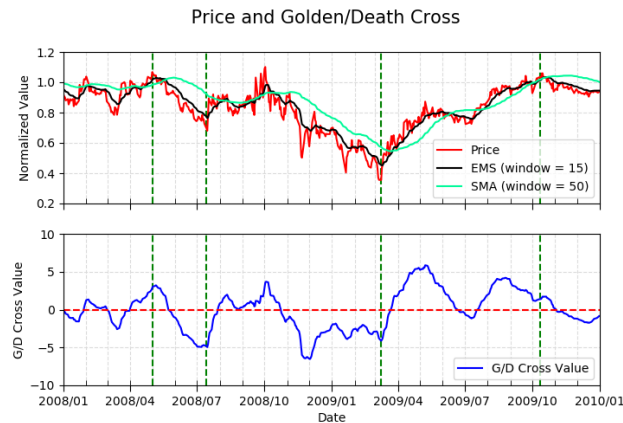

Figure 4—Price and golden/death cross

Fig. 4 presents that based on the four incidents examined in this project, a golden/death cross signals a price uptrend/downtrend with a lagging window of 10 – 20 days. In other words, a golden/death cross appears 10 to 20 days after the price starts an increasing/decreasing trend. All indicators are "lagging", and no single indicator can truly predict the future.[7] Indicators have advantages and disadvantages, so using an indicator confirmed with other indicators is better than operating with one indicator.

Nonetheless, Fig. 4 also shows that GDV reaches the local maximum/minimum value as the price reverses its current trend. Therefore, define a GDV index that represents the local maximum/minimum of GDV, GDV index = - 1.0 means a local minimum and hence a buy signal; GDV index = 1.0 for a local maximum and hence a sell signal. In this project, GDV index generating buy/sell signals successfully captured the four incidents (results are based on an examination of the return values of the GDV index).

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[6] https://learn.bybit.com/strategies/golden-cross-trading-strategies/

[7] https://www.investopedia.com/terms/g/goldencross.asp

2.6 Indicator 4 – Bollinger Bands®

Bollinger Bands® were developed by John Bollinger and contain three lines: an SMA line, an upper band, and a lower band. The upper/lower band is 2 times of standard deviations above/below the SMA line. When the price reaches the upper band, it indicates a sell signal; on the other hand, when the price touches the lower band, it's a buy signal. In this project, a Bollinger Bands® value (Tucker, 2015) is calculated as:

$$BBV = \frac{Price - SMA}{2 \times Std}$$

Where Std is the standard deviation. BBV < -1, a buy signal; BBV > 1, a sell signal.

BBV captured the price rise in July 2008 and March 2009 (BBV < - 1) but failed to signal the rest incidents. If set the threshold to ± 0.95, BBV can successfully trigger a sell signal for the price drop in May 2008 but still fail the price drop in October 2009. Notably, the price drop in October 2009 is a "weak" incident (a slight change in the big picture) compared to the other three, and most indicators in this project performed better on the other three incidents than on this one.
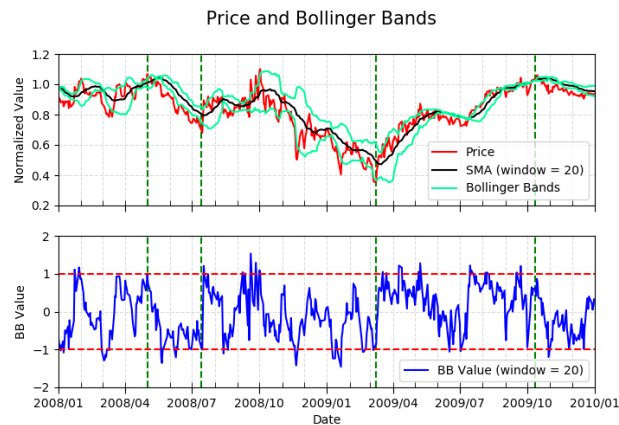

Figure 5—Price and Bollinger Bands®

2.7 Indicator 5 – Percentage Price Oscillator

The percentage price oscillator (PPO) is a momentum indicator that presents the relationship between the 12-day EMA and the 26-day EMA.

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In the meantime, the 9-day EMA of PPO is the signal and moves slower than PPO.[8]

$$PPO = \frac{EMA_{12\ days} - EMA_{26\ days}}{EMA_{26\ days}} \times 100$$

$$PPOD = PPO - signal$$

It's a buy signal when PPO crosses above the signal line, i.e. PPOD changes from negative to positive. It is a sell signal when PPO crosses below the signal line, i.e., PPOD changes from positive to negative.

PPOD captured all incidents although it was a little bit behind the price change (Fig. 6). In May 2008 and October 2009, PPOD changed from positive to negative, generating a sell signal as the price dropped. In July 2008 and March 2009, PPOD changed from negative to positive, generating a buy signal as the price surged.
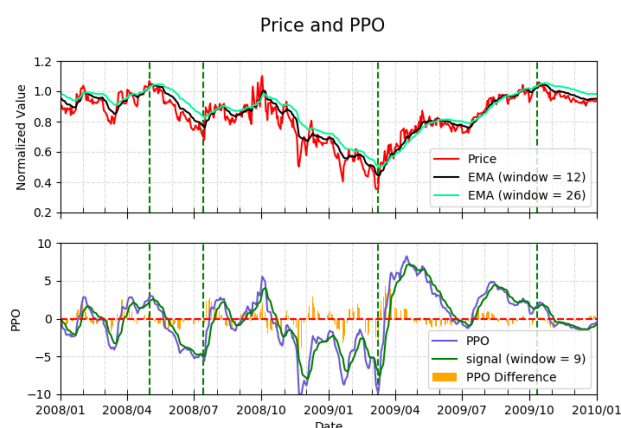

Figure 6—Price and percentage price oscillation

3 CONCLUSION

As a "peeking-into-future" strategy, TOS beats the benchmark of holding a position and is 6-7 times more profitable than the benchmark in this project.

Five technical indicators are introduced and developed for future testing. Each indicator has a threshold for a buy/sell signal:

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[8] https://www.investopedia.com/terms/p/ppo.asp

1) Buy signals: P/SMA < 0.95, ROC < 0 followed by ROC > 0, GDV index = - 1, BBV < - 0.95, and PPOD < 0 followed by PPOD > 0.

2) Sell signals: P/SMA > 1.05, ROC > 0 followed by ROC < 0, GDV index = 1, BBV > 0.95, and PPOD > 0 followed by PPOD < 0.

Different settings of the parameters and window sizes in an indicator will change its performance. Although there are standard or most used settings, there are no "best settings" that can be generalized to each case. Besides, indicators might not be sensitive enough to capture "weak" incidents, and improved settings will be helpful to enhance their overall performance. Therefore, adjusting parameters or thresholds is an important process for a better outcome. The thresholds of buy/sell signals in this project will be examined and subject to necessary changes while applying them to future projects.

Furthermore, one indicator does not work efficiently on its own, e.g., SMA is more sensitive than moving averages (SMA, EMA, etc.) but also gives more false signals for trend developments.[9] Each indicator has its downsides, so combing different indicators makes it secure to a better result.

However, more indicators do not guarantee a more beneficial prediction. Carefully selecting, examining, and developing the indicators to study historical market data is a key component of technical analysis.

4 REFERENCES

1. Charles D. Kirkpatrick (2011). Time the Markets: Using Technical Analysis to Interpret Economic Data. Revised Edition. Pearson Education, United Kingdom.
2. T. Balch (2005). A Few Indicators: Bollinger Bands. Lecture of Technical Analysis, Georgie Institute of Technology. Georgie, United States of America.

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[9] https://altfins.com/knowledge-base/price-sma-crossovers/