Trading Strategy Evaluation

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Abstract-Three indicators: percent B, Percentage Price Oscillator and Stochastic Oscillator are used to build a Manual Strategy and Strategy Learner to generate trade signals. The Strategy Learner is a Random Forest Based Trader. The in-sample data is used to train the learner and out-of-sample data is used to evaluate the performance of the learner. 50 days before the start date of the in-sample data is used to calculate indicators values, and 50 days after the end date of the in-sample data is used to produce Y labels to train the Strategy Learner. Two experiments are conducted. In experiment I, different performance of Manual Strategy, Strategy Learner, and benchmark with in-sample and out-of-sample data are compared. In experiment II, how impacts affect the Strategy Learner is explored and its different performances with different impacts are compared.

1 INDICATOR OVERVIEW

1.1 Percent B

The %B Indicator measures a security's price in relation to the upper and lower Bollinger Bands. It can be used to identify overbought or oversold conditions and gauge trend strength. Here is how %B is calculated:

$$\%B = \frac{price(t) - Lower\ Band}{Upper\ Band - Lower\ Band}$$

Where: Lower Band = SMA – 2 x RSTD, Upper Band = SMA + 2 x RSTD

And SMA is the simple moving average for a chose window period, and RSTD is the rolling standard deviation in this window period. The default window size chosen to calculate %B is 20. If %B >=1, it generates a sell signal. If %B <=0, it generates a buy signal.

1.2 Percentage Price Oscillator

The Percentage Price Oscillator (PPO) is a momentum oscillator that measures the difference between two moving averages as a percentage of the larger moving average. It's used to identify price trend direction, momentum, and potential buy and sell signals. The PPO is shown with a signal line, a histogram, and a centerline.

$$PPO = \frac{12\_day\ EMA - 26\_day\ EMA}{26\_day\ EMA} \times 100$$

Signal Line = 9_day EMA of PPO

PPO Histogram: PPO – Signal Line

Usually, the signal line crossovers are used to generate buy and sell signals. To make PPO indicator work for both the Manual Strategy and the Random Forest Based Learner, a ratio is calculated to measure the difference between PPO and signal line:

$$Ratio = \frac{PPO}{Signal\ Line}$$

1.3 Stochastic Oscillator

Stochastic Oscillator is a momentum indicator that shows the speed and momentum of price movement. Usually, this is how %K and %D calculated:

$$\%K = \frac{(Current\ Close - Lowest\ Low)}{(Highest\ High - Lowest\ Low)} \times 100$$

$$\%D = 3 - day\ SMA\ of\ \%K$$

Lowest Low = lowest low for the look back period

Highest High = highest high for the look back period

%D is a 3-day simple moving average of %K. This indicator has two parameters: look back period and smoothing which is number of days used to calculate moving average of %K.

2 MANUAL STRATEGY

2.1 Generate Signals

All three indicators return a numeric variable. In the Manual Strategy, all the numeric variables are converted into categorical variables which have -1, 0, and 1 representing "sell", "nothing", and "buy" respectively.

For %B,

if %B >= 1.1, then -1

else if %B <= 0, then 1

else: 0

For PPO, a bullish crossover happens when PPO crosses above the signal line from below. A bearish crossover happens when PPO crosses below the signal line from above. Since ratio = ppo/ signal line.

If 1.01 <= ratio <= 1.1 and ratio[t] > ratio[t+1]: ppo_signal[t] = -1

else if 1.01 <= ratio <= 1.1 and ratio[t] < ratio[t+1]: ppo_signal[t] = 1

else if 0.9 <= ratio <= 0.99 and ratio[t] > ratio[t+1]: ppo_signal[t] = -1

else if 0.9 <= ratio <= 0.99 and ratio[t] < ratio[t+1]: ppo_signal[t] = 1

PPO indicator generates a buy signal if the ratio is in the range [1.01, 1.1] or [0.9, 0.99] when the ppo values are increasing which means the ppo is in an uptrend. This is around the time when bullish cross happens. PPO indicator generates a sell signal if the ratio is in the range [1.01, 1.1] or [0.9, 0.99] when the ppo values are decreasing which means the ppo is in a downtrend. This is around the time when bearish cross happens.

For Stochastic Oscillator, %D is used to generate buy and sell signals.

if %D >= 90, then -1

else if %D <= 20, then 1

else: 0

These three indicators are combined to generate a trade signal. If any two indicators generate a buy signal, the Manual Strategy generates an overall buy signal. If any one indicator generates a sell signal, the Manual Strategy generates a sell signal. It's rare that two or more than two indicators generate a sell signal at the same time. So, a sell signal from any indicator means an overall sell signal. To avoid too many overall sell signals, the thresholds are raised in the indicators to generate less sell signals. This can avoid false signals and reduce transaction costs caused by commission and impacts.

The Manual Strategy takes the overall signals and makes orders.

If overall_signal[t] = 1:

If I am in cash, then buy 1000 shares.

Else if I am in a short position holding -1000 shares, buy 2000 shares.

Else if I am in a long position holding 1000 shares, do nothing.

If overall_signal[t] = -1:

If I am in cash, then sell 1000 shares.

Else if I am in a short position holding -1000 shares, do nothing.

Else if I am in a long position holding 1000 shares, sell 2000 shares.

Usually holding a short position is very risky, the strategy needs to take more information into account, not the trading signal alone, to decide whether entering a short position or not. However, the in-sample period is from January 1st, 2008, to December 31st, 2009, which is during the 2008 financial crisis. The stock market is very choppy. It is a range bound market. Stock prices go up and down a lot. It's very volatile. Therefore, the Manual Strategy works for this market. If the market is in a strong uptrend, this strategy will not work. More information and more research is needed to decide whether to enter a short position.

2.2 Compare Performances

The Manual Strategy outperforms JPM benchmarks for the in-sample and out-of-sample period. During the in-sample period, the Manual Strategy enters long positions 8 times and short positions 8 times. The Manual Strategy generates very accurate trading signals, enters, and exits positions at a very good time until 3/14/2009. The portfolio value increases significantly during this period. However, the Manual Strategy enters and stays in a short position when the stock is in an uptrend after 3/14/2009 which causes the portfolio to lose some of its gains. There are several transactions in December 2009, but it doesn't change the portfolio value a lot. Overall, the Manual Strategy performance beats the benchmark during in-sample period. Please see the chart below:

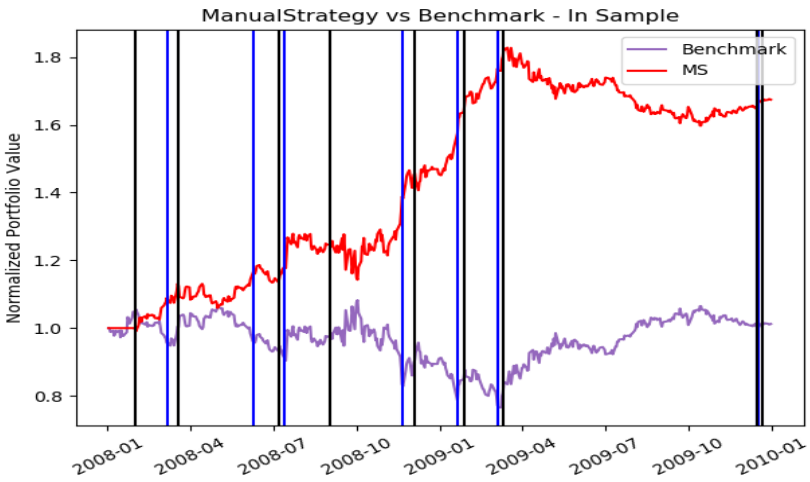

Figure 1—Manual Strategy vs Benchmark: In-Sample

In Table 1 below are different values of the indicator parameters with corresponding in-sample and out-of-sample cumulative returns from the Manual Strategy. The values in bold are the optimized parameters.

Table 1—Parameter Values in Manual Strategy Indicators

%B	PPO			Stochastic Oscillator		In-Sample CR	Out-of-Sample CR
windows	short	long	Signal-line	period	smoothing		
50	14	35	9	25	3	0.587987	0.149133
40	14	40	9	25	3	0.672452	0.196006
40	**14**	**35**	**9**	**25**	**3**	**0.674417**	**0.213163**
35	14	35	9	25	3	0.584369	0.285692
40	12	26	9	25	3	0.653645	0.145937

During the out-of-sample period, the Manual Strategy enters long positions and short positions 13 times and 12 times respectively. The Manual Strategy generates accurate signals, enters, and exits positions at good times most of the time. It enters a short position on 2/11/2010 and holds the short position when the stock broke its resistance and started to go up in November 2010. This causes the portfolio to lose some of its gains. Overall, the manual strategy performance beats the benchmark during out-of-sample period too. Please see the chart below:

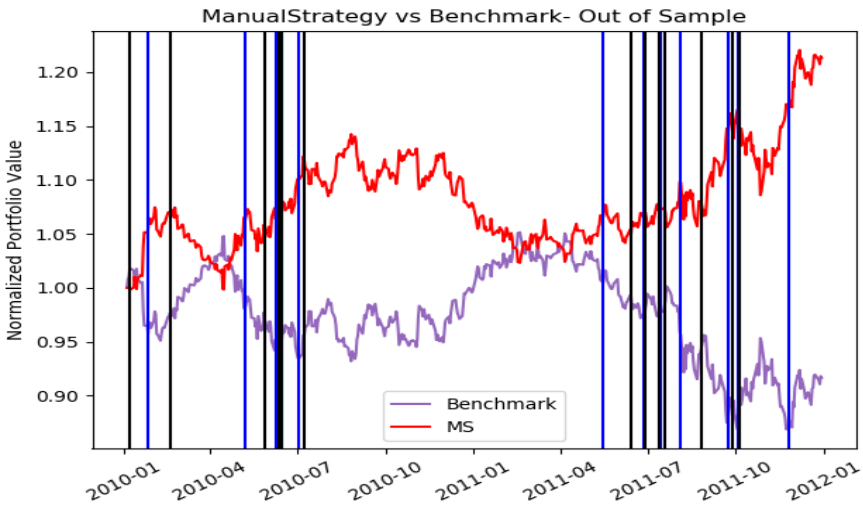

Figure 2—Manual Strategy vs Benchmark: Out-of-Sample

From Table 2 below, we can see that during out-of-sample period, the Manual Strategy has higher Cumulative Return, Mean of Daily Return, Sharpe Ratio than the Benchmark. It also has lower Standard Deviation than the Benchmark which means lower investment risk following the Manual Strategy.

Table 2—MS and Benchmark portfolio Statistics: in-sample and out-of-sample

	in-sample		out-of-sample	
	Manual Strategy	Benchmark	Manual Strategy	Benchmark
Cumulative Return	0.674417	0.012325	0.213163	-0.083579
STDEV of Daily Returns	0.011652	0.017041	0.007418	0.0085
Mean of Daily Returns	0.001091	0.000169	0.000412	-0.000137
Sharpe Ratio	1.486241	0.157205	0.880951	-0.256657

Though the Manual Strategy outperforms benchmark with both in-sample and out-of-sample data, it has higher Cumulative Return, Mean of Daily Return, Sharpe Ratio with in-sample data than out-of-sample data. The Standard Deviation of Daily Return is lower with in-sample data too. This is because the Manual Strategy looks at the in-sample stock price and indicator values produced by the in-sample data to build the logic. Thresholds and parameters are tuned and adjusted in the indicators to make sure the Manual Strategy works well with the in-sample data. However, the Manual Strategy hasn't seen the out-of-sample data, and how well can the strategy generalize to new unseen data is uncertain. Therefore, the Manual Strategy has better performance with in-sample data than with out-of-sample data.

3 STRATEGY LEARNER

The Strategy Learner is a Random Forest-Based Trader. Three indicators: percent B, Percentage Price Oscillator and Stochastic Oscillator, are used as features. The learner returns 1, 0 and -1

representing “buy”, “nothing”, and “sell” respectively. Therefore, the Random Forest-Based Trader is a classification model. x_train is constructed with indicators and y labels are constructed based on N-day returns. Therefore, x_train is the values returned by the indicators. Y labels are -1, 0, and 1.

3.1 Standardize X_train

All the three indicators return continuous variables, but they have very different value ranges. To improve model performance, reduce the impact of outliers, and ensure that the data is on the same scale, all the indicators are standardized.

Standardization is a feature scaling method where the values are centered around the mean with a unit standard deviation. This means that the mean of the attribute becomes zero, and the resultant distribution has a unit standard deviation.

Here’s the formula for standardization:

$$X' = \frac{X - \mu}{\sigma}$$

μ is the mean of the feature values and σ is the standard deviation of the feature values.

Standardization preserves the relationship between the data points. So the learner is less sensitive to outliers.

3.2 Construct Y Labels

Y labels for the training phase are classified based on N-day return. Impacts are taken into consideration when calculating returns so the learner can generate better trading signals. Since the impact works in different directions for buying and selling, returns for buying and selling are calculated separately, then the returns for buying (ret_buy) are compared with the buying threshold YBUY and the returns for selling (ret_sell) are compared with the selling threshold YSELL. If ret_buy is greater than YBUY, the learner returns 1 for a buying signal. If ret_sell is less than YSELL, the learner returns -1 for a selling signal.

Here’s the pseudo code for the calculation of y:

```
for each day:
    ret_buy = (prices[t+N] * (1 + self.impact) / prices - 1)
    ret_sell = (prices[t+N] * (1- self.impact) / prices - 1)
   if ret_buy > YBUY:   y_train[t] = 1    # long
  else if ret_sell  < YSELL: y_train[t] = -1     # short
```

3.3 Parameters

OptimizeLearner.py is implemented to find the best parameters for the Strategy Learner. The intertools module is imported and intertools.product() is used for parameter Grid-Search. The parameters are also tuned manually. Some parameter value ranges are provided to the OptimizeLearner when some parameter values that produce good results are found. Parameter

values returned by OptimizeLearner are tested with the Strategy Learner, and then new ranges are provided to the OptimizeLearner, back and forth, until the best parameter values that give best performance are found.

There are two hyperparameters in the Random Forest Classification model: leaf size and bag size. If the leaf size is smaller than 5, the model will overfit, so leaf size is set to 5 to avoid overfitting and make sure the model is sensitive to price changes. The bag size is set to 40 to make sure the number of bags is sufficiently large for the error rate to settle down. Meanwhile, the learner doesn't perform very well with leaf size bigger than 5.

In Table 3 below are different values of the indicator parameters, N-day look ahead, YBUY, and YSELL with corresponding in-sample and out-of-sample cumulative returns from the Strategy Learner.

Table 3—Parameter Values in Strategy Learner Indicators

	%B	PPO			Stochastic Oscillator		N-day	YBUY	YSELL	In-Sample CR	Out-of-Sample CR
	windows	short	long	Signal-line	period	smoothing					
1	**15**	**10**	**30**	**6**	**14**	**3**	**8**	**0.038**	**-0.04**	**1.017628**	**-0.157821**
2	15	10	30	6	14	3	8	0.038	-0.044	1.257251	-0.126981
3	20	14	35	9	20	3	7	0.038	-0.038	1.387839	-0.151755
4	5	10	30	6	10	2	15	0.04	-0.04	0.406817	-0.441069
5	20	14	35	9	20	3	11	0.038	-0.038	0.449738	-0.275772

The first set (values in bold) are the optimized parameters for the Strategy Learner. Set 2, 3, 4 didn't generalize very well. They fail one or more test cases. Set 2 and 3 are very interesting cases. After YSELL is changed from -0,044 in set 2 to -0.04 in set 1, the learner passes all the tests, and the performance only decreases a little bit. Set 3 has the best performance, but it fails the Sine-Noise test, and when one or two parameters are changed, it passes all the tests, but the performance decreases significantly, like set 5. There are many other parameter values are tried, but they are way off so not worth reporting.

4 EXPERIMENT 1

4.1 Experimental Hypothesis

The benchmark uses a simple strategy which is buy and hold which works well in a market with strong uptrend. However, during the in-sample period, JPM doesn't have a strong long-term uptrend. Therefore, the indicators and strategies can help the learner identify good times for entering and exiting positions. So, the Manual Strategy is assumed to outperform the benchmark.

For Strategy Learner, it will outperform the benchmark for in-sample data because the model is trained with the same data. The learner has seen the y labels that are used to train it. Models usually have a low in-sample error rate.

Most importantly, the Strategy Learner is assumed to outperform the Manual Strategy with in-sample data because the in-sample-data was used to train the model, to tune the parameters. Theoretically, the in-sample error rate can be reduced to zero as the model complexity increases with fine-tuned parameters.

4.2 Experiment Results

From Table 5 below, we can see that both Strategy Learner and Manual Strategy outperform the benchmark during in-sample period. They have higher Cumulative Return, Mean Daily Return and Sharpe Ration. They also have a lower Standard Deviation of Daily Return than the benchmark.

Meanwhile, the Strategy Learner outperforms the Manual Strategy during in-sample period. It has higher Cumulative Return, Mean Daily Return and Sharpe Ratio. It also has a lower Standard Deviation of Daily Return than the Manual Strategy.

Table 5—MS, SL and Benchmark portfolio Statistics: in-sample and out-of-sample

	in-sample			out-of-sample		
	Manual Strategy	Strategy Learner	Benchmark	Manual Strategy	Strategy Learner	Benchmark
Cumulative Return	0.674417	1.017628	0.012325	0.213163	-0.157821	-0.083579
STDEV of Daily Returns	0.011652	0.010725	0.017041	0.007418	0.009195	0.0085
Mean of Daily Returns	0.001091	0.001451	0.000169	0.000412	-0.000299	-0.000137
Sharpe Ratio	1.486241	2.147337	0.157205	0.880951	-0.516547	-0.256657

It is very clear that the Strategy Learner outperforms the Manual Strategy which outperforms the benchmark in Figure 3 below.

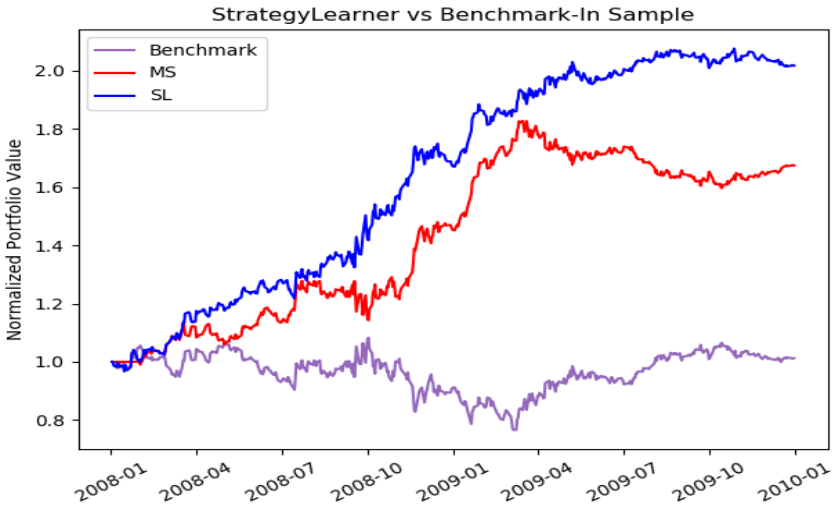

Figure 3—Manual Strategy, Strategy Learner vs Benchmark: In-Sample

We would expect this relative result every time with in-sample data. This is because the Strategy Learner is trained on in-sample data. It looks at the in-sample stock price and builds Y labels based on N-day returns. The Strategy Learner has seen all the Y labels, so it's supposed to generate more accurate signals than Manual Strategy. Meanwhile, because the Manual Strategy looks at the in-sample stock price and the indicators values to come up with a good rule to generate trading signals, it can make better trades than buying and holding. Therefore, we can always expect that the Strategy Learner will outperform the Manual Strategy which will outperform the benchmark.

During out-of-sample period, the Manual Strategy beats the benchmark while the Strategy Learner does not outperform the benchmark.

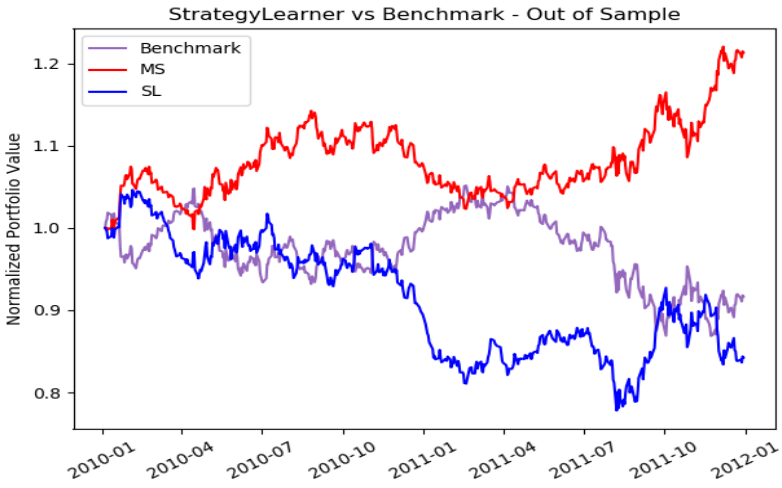

Figure 4—Manual Strategy, Strategy Learner vs Benchmark: Out-Of-Sample

5 EXPERIMENT 2

5.1 Experimental Hypothesis

A bigger impact means the price the stock prices move against us more which decreases the cumulative returns of the portfolio and increases trading risks. Therefore, a hypothesis about how impact affect the portfolio can be made:

As impact goes up, Cumulative Return, Mean of Daily Return and Sharpe Ratio go down, but Standard Deviation of Daily Returns goes up.

5.2 Experiment Results

From Table 6 below, we can tell that the Cumulative Return and Sharpe Ratio decrease significantly while the impact increases in general. If the impact is big, we will end up with buying at a much higher price and selling at a much lower price. It reduces the portfolio value and the chance for us to make a profit through each transaction.

The Standard Deviation of Daily Return measures the volatility of a stock. Higher Standard Deviation means higher risk. Standard Deviation of Daily Return increases as impact increases, which is the same as saying it is riskier to buy or sell a stock if the impact is big.

Table 6—CR, STDEV of Daily Return, SR, and Number of Trades of SL with Different Impacts

	Impacts			
	0.001	0.01	0.05	0.1
Cumulative Return	1.417539	0.524082	-4.76091	-1.42073
STDEV of Daily Return	0.009448	0.012598	0.323309	0.351614
Sharpe Ratio	3.019944	1.153573	-0.680239	-0.731608
Number of Trades	290	340	504	504

The Strategy Learner generates different numbers of trades when it takes different impacts into account. As for why the number of trades increases as the impact increases is not clear. We need more time and research to explain why this is happening.

It is obvious that the portfolio values decrease significantly as the impact increases from Figure 5 below:

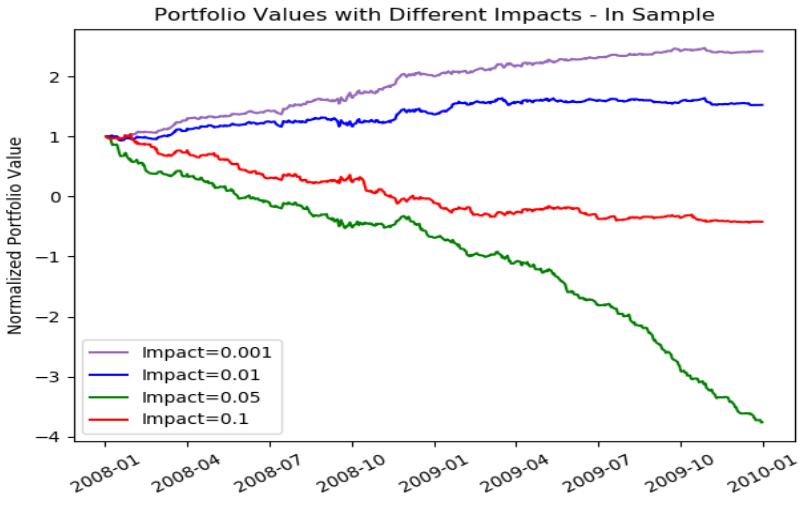

Figure 5—Portfolio Values with Different Impacts: In-Sample

6 REFERENCES

1. Stockcharts.com
2. Investopedia.com