A Comparative Study on Predictive Performance of Bollinger Band Indicator: An Indian Market View

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ABSTRACT

Purpose: The principal agenda of this research is to analyze if Bollinger Band indicator is more profitable than MACD and RSI, post removal of data snooping bias and inculcation of transaction costs, over a period of 10 years.

Design/Methodology/Approach: The study makes use of secondary data that is quantitative in nature. The data includes EOD closing prices of Nifty-50 index and that of the technical indicators (Bollinjer Band, MACD, RSI) from 2011 to 2020.

Findings: The research results indicate that the Bollinger Band indicator performed better than MACD and RSI. Both statistically, and in terms of ROI, the returns generated by the subject were superior to its counterparts.

Research Implications: The results of this paper offer genuine, unbiased performance of the Bollinger Band indicator. Therefore, these findings may be useful to retail traders who use technical analysis and investment advisors, broking firms, etc. that offer trading recommendations based on technical analysis.

Originality/Value: There exist very few research studies dedicated to the Bollinger Band indicator, and even fewer that offer unbiased performance reviews of the indicator, that is true to actuality.

Key Words: *Bollinger Band, Technical Analysis, MACD, RSI, Momentum Trading, Reversal Trading, etc.*

1. Introduction

Finance, as a discipline. has always been forward-looking. The numbers that one sees today are not based on historical information, or even current data, for that matter. It is rather, an indicative of the future expectations associated with the asset. An optimistic view may inflate the value of the asset, which on the flip side, may witness negative action if expected otherwise. The opinion one holds on an asset, be it affirmative or negative, is strongly affected by the probability of it behaving in an explicit manner as it did in the past. It is this probability that drives the valuation of the asset in a particular direction, thereby either complementing or contradicting the expectations. To achieve the aforementioned, modern-day financial analysis offers a wide range of tools and techniques for the user to choose from, and Technical Analysis (thereby TA) is one of the popular techniques that is commonly used by all categories of traders and investors.

1.1 Introduction to TA

TA, as defined by Murphy (1999), refers to the study of market action, primarily through the use of charts, for the purpose of forecasting future price trends. Since its inception in the 18th century, TA has come a long way and has now evolved into a highly sophisticated tool for forecasting the price of financial securities (Nelly & Weller, 2011). In the initial years of practice, TA included the manual study of candlestick charts formed by the interaction between price levels and volume. This scenario, however, changed with the emergence of IT in the field of finance. Currently, TA offers a wide variety of automated tools, commonly referred to as technical indicators, that have simplified the process of valuation and forecasting to a great deal. These indicators act as a decision support system for the traders and investors, in the selection and execution of trades. One such indicator, that has been around for a long time but whose prime potential is yet to be discovered is Bollinger Band (hereafter BB) indicator.

1.2 Introduction to BB indicator

Developed by a famous American trader, John Bollinger, the Bollinger Bands indicator was designed to discover trade opportunities, that provide traders and investors, with a higher probability of success. In his book, *Bollinger on Bollinger Bands (2001)*, the author discussed for the first time, the construction and implementation of the Bollinger Bands indicator. The indicator is composed of 3 lines, namely the Upper Band (thereafter UB), the Middle Band (thereafter MB), and the Lower Band (thereafter LB). The MB is a simple moving average (SMA) of 20-period, and the UB and LB are typically $\pm$ 2 σ (standard deviations) from the MB. The formulas for calculation of the Bollinger Bands indicator are as follows:

Middle Band (MB) = 20-day simple moving average (SMA)
Upper Band (UB) = 20-day SMA + (20-day standard deviation of price x 2)
Lower Band (LB) = 20-day SMA - (20-day standard deviation of price x 2)

The indicator was primarily designed to capture stocks that had entered over-bought and over-sold trading zones, thereby giving the traders an opportunity to take a reverse position in the market. But, with the passage of time, the application of BB underwent an immense transformation and now the indicator can also be used to pick scrips that are witnessing strong momentum play and stocks that are about to take a strong leap, post an extended phase of consolidated (neutral) movement.

Owing to the fact that there exist multiple renditions of BB indicator, it becomes increasingly difficult for traders and investors to select the most appropriate version that offers them the highest possible return. Thus, with an intention to identify the most profitable version of the BB indicator and assess its performance against other popular indicators (MACD & RSI), the researcher intends to conduct an internal and external performance review of the BB indicator. Through the means of this research, the researcher aims at answering the most fundamental question pertaining to the profitability of the BB indicator and its ability to supersede the performance of other popular technical indicators (MACD & RSI).

2. Review of Literature

BB has been one of the most popular technical indicators amongst traders, owing to its ease of application and its proficiency to yield generous returns. The same, however, cannot be said about the popularity of this indicator within the research community. Most of the research on TA is centered around indicators like Moving Averages, MACD, RSI DMAC, etc. and BB indicator has been left relatively unattended. The limited researches that have been conducted to date, are more inclined in favor of technical indicator-based trading disciplines. Analogical reviews directed by Mishra (2016), Ling & Ruzita (2017) & Macchiarulo (2018), ruled in favor of technical indicators

of the likes of BB for having an appreciative impact on the overall portfolio returns. Also, Azizan & M'ng (2010), who developed an advanced model called Bollinger Bands Z-Test, and Cohen (2020), who tested the Bollinger Band's breakout strategy on US ETFs, suggested that BB offered superior returns in comparison to conventional trading techniques. These views, however, were contradicted by the findings posted by Balsara, Chen & Zheng (2009) upon pegging BB indicator against the B&H strategy. Abbey & Doukas (2012), upon examining the performance of technical indicators (including Bollinger Bands) stated that the discipline was not profitable.

Application of such investigative research on more contemporary asset classes such as currency swaps, by Maliheh (2012), and on crypto-currencies (Bitcoins) by Resta, Pagnottoni & De Giuli (2020), suggest that the BB indicator performed exceedingly well against the B&H system. The recent studies dedicated to analyzing the efficiency of technical indicators have been based on algorithmic trading systems (ATS). Gold (2019), Vezeris, Kyrgos & Bizergianidou (2020), upon examining the impact of indicator-based ATS on portfolio returns, concluded that the portfolio returns witnessed significant improvement. Similar investigations were conducted by Macedo, Godinho & Alves (2020), Chaudhuri, Ghosh & Singh (2017), on generic trading models based on TA indicators. The results stated that the indicator-based models offered an edge to the traders and can be used to generate above-average profits. As an extension of their previous research, Chaudhuri, Ghosh & Singh (2017) developed a more sophisticated ATS model based on deep machine learning techniques, only to discover that such trading models are indeed more profitable than traditional trading systems such as B&H. The research directed by Sousa & Alonso (2020), proved the effectiveness of TA by developing a neural network system based on technical indicators and applying it to stock prices of selected US stocks. Thus, from the aforementioned, it can be stated that the existing literature builds a majoritarian view suggesting that the indicators-based trading systems possess an innate ability to beat the benchmark indices.

Even though such detailed research has been conducted to date, the fact that there exist no more grey areas cannot be said. Upon a thorough investigation of the existing literature, it was discovered that the results achieved through such studies often get contaminated by the existence of data snooping bias in time series data. Thus, detection and elimination of this bias is of utmost importance, which has been taken into consideration only in a handful of research. In addition to this, transaction charges (STT, DP charges, Brokerage, Gov. Taxes) that often take a toll on the profitability of trading strategies, have been left out of scope in a considerable amount of studies. Also, the time frame under scrutiny is of extreme importance in context to stock market-related research. Charles Dow and George Charles Selden, in their book "*Scientific Stock Speculation*" 1920, suggested that markets undergo cycles of uptrends and downtrends extending over a period of nearly 6-7 years. Thus, for any research to get a holistic view on the performance of any trading indicator in both market situations, it becomes highly important to select a time frame that ensures the inclusion of all cycles that the markets may possibly witness. This, however, cannot be said to be true for a majority of research works that have been dedicated to this cause. The studies that have been conducted till date, have addressed the aforementioned variables to a certain degree, however, not comprehensively under one research. Also, most of the studies have considered Bollinger Bands as a trend following indicator in their investigation, thereby, disregarding its application as a trend reversal indicator as well. Owing to this, there exists a dilemma pertaining to the profitability of Bollinger Bands. This research aims at bringing together all the above-mentioned variables under the preview of one single investigation to deliver a conclusive judgment regarding the efficiency and effectiveness of the BB indicator.

3. Research Objectives

- To analyze whether Bollinger Bands, when used as a momentum indicator, offer better returns than the RSI and MACD indicator, post removal of biases, the inclusion of transaction costs, and over a 10 years period.
- To analyze whether Bollinger Bands, when used as a reversal indicator, offer better returns than the RSI and MACD indicator, post removal of biases, the inclusion of transaction costs, and over a 10 years period.
- To analyze which rendition of Bollinger Bands (usage as a momentum indicator/ usage as a reversal indicator) offers the best relative returns, post removal of biases, the inclusion of transaction costs, and over a 10 years period.

3.1 Research Questions

- Does Bollinger Bands, when used as a momentum indicator, offer better returns than the RSI and MACD indicator, post removal of biases, the inclusion of transaction costs, and over a 10 years period?
- Does Bollinger Bands, when used as a reversal indicator, offer better returns than the RSI and MACD indicator, post removal of biases, the inclusion of transaction costs, and over a 10 years period?
- Which rendition of Bollinger Bands (usage as a momentum indicator/ usage as a reversal indicator) offers the best relative returns, post removal of biases, the inclusion of transaction costs, and over a 10 years period?

3.2 Research Hypothesis

- H_1: (**Null**): Bollinger Bands indicator, when used as a momentum indicator, does not offer superior returns than MACD indicator.
- H_2: (**Null**): Bollinger Bands indicator, when used as a momentum indicator, does not offer superior returns than RSI indicator.
- H_3: (**Null**): Bollinger Bands indicator, when used as a reversal indicator, does not offer superior returns than MACD indicator.
- H_4: (**Null**): Bollinger Bands indicator, when used as a reversal indicator, does not offer superior returns than RSI indicator.
- H_5: (**Null**): There is no significant difference in the returns offered by various renditions of Bollinger Bands indicator i.e. when used as a momentum indicator, reversal indicator and breakout indicator.

4. Research Methodology

4.1 Research Type

This research is explanatory in nature as aims to illustrate the performance of BB technical indicator against popular technical indicators and the profitability generated by them in terms of ROI.

4.2 Logic of Inquiry

The research makes use of the deductive approach, wherein the applicability of the BB technical indicator has been tested. The data used in the research is thus, quantitative in nature.

4.3 Source of Research Data

The study makes use of secondary data that comprises of end of the day (EOD) values of the adjusted closing price and traded volume of the BB technical indicators, along with that of MACD and RSI indicator. The research data spans over a period of 10 years, starting from January 1,

2011, to December 31, 2020. The data for the purpose of this research has been gathered from the following web sources:

- www.nseindia.com (official website of the National Stock Exchange)
- www.investing.com (stock market analysis freeware)
- www.prowessiq.cmie.com (a`ccessed through Auro University's virtual library)

4.4 Procedure of Data Analysis

The primary step in the data analysis phase of the research begins with preparing the data for analysis. For this purpose, the data (returns generated by the indicators) was subjected to statistical tests such as Levene's test, Mann-Whitney-U-test in order to identify and eliminate data snooping bias. Post this, real-time transactions charges were computed and were inculcated with the data. Finally, comparative assessments were made between the variables using Mann-Whitney U-test to understand the variability in their returns.

4.5 Trading Parameters

Trading parameters refer to the set of rules and guidelines that have been applied while trade selection and execution. It forms the underlying logic behind the use of a technical indicator while trading. (*refer Annexures: Exhibit-1*)

5.   Research Analysis

The foremost agenda of the paper was to identify and eliminate of data snooping bias, if it exists. For the purpose of achieving the aforementioned, the entire research data was divided into two equal time sections i.e. 2011-15 (referred to as in-sample) and 2016-20 (referred to as out-sample). Post this, a test of normality was conducted in order to verify the suitability of statistical tools to be used for the examination of bias. Thus, at a confidence threshold of 95%, the results of the K-S (Kolmogorov-Smirnov) Test of normality revealed that BB, when used as a momentum indicator and BB when used as a reversal indicator, had a p-value of 0.00919 and 0.00214 respectively. The results dictate that both the data sets are non-normally distributed, owing to which Mann-Whitney U-test, a non-parametric test, was applied on the data so collected.

Prior to the deployment of the Mann-Whitney U-test, an important assumption of the equality of variance was validated through the application of Levene's test on the in-sample and out-sample. The results of the Levene's test confirm that there exists homogeneity in the variances of the in-sample and out-sample for both renditions of the BB indicator i.e. as a momentum indicator and as a reversal indicator, thereby sufficing the fundamental criteria for application of non-parametric tests. (*refer Annexures: Exhibit-2*)

The Mann-Whitney U-test was then deployed to assess if any statistically significant difference exists between the distribution of in-sample and out-sample data, for both the renditions of the BB indicator. The hypothesis for the test is as follows:

H_0: There is no significant difference between the returns generated during the in-sample and out-sample data.

H_1: There is a significant difference between the returns generated during the in-sample and out-sample data.

The results of the test suggest that the for a confidence level of 95% (Alpha = 0.05) the calculated p-value of the test statistic is greater than critical p-value (0.05) for the data in both cases i.e. BB when used as a momentum indicator and BB when used as a reversal indicator. This suggests that the null hypothesis (H_0) cannot be rejected as there is not enough evidence to support otherwise,

stating that there is no statistically significant difference between the in-sample and out-sample data. Evidence, thus proposes, that the data snooping bias, which generally exists in time series data, thereby affecting its validity, does not exist in the aforementioned data sets that have been scrutinized under this research. (*refer Annexures: Exhibit-3*)

The next step in line, is the computation of the transaction charges (thereby TC) and to analyze their impact on the returns obtained by both versions of the BB indicator. The TC imposed by Zerodha Securities Pvt. Ltd., India's biggest broker in terms of market share (18.33%) and the foremost discount broker of the country, were taken into consideration. The overall transaction cost comprises of the following charges:

Table-1: (Components of Transaction Charges)

Charge	Basis of Implementation
Brokerage	Rs. 40 per trade
Security Transaction Tax (STT)	0.005% of total traded value
Exchange Transaction Tax (ETT)	0.002% of the total traded value
Clearing Charges	--NIL--
GST	18% of Brokerage + ETT
SEBI Charges	0.001% of total traded value
Stamp Duty	0.002% of total traded value
Total Transaction Charges	**0.01036% of total traded value + Rs.47.2**

The implementation of the Mann-Whitney U-Test on returns exclusive of TC and returns inclusive of TC reveals that at a confidence threshold of 95% (Alpha= 0.05), there exists no statistically significant difference between the two data sets. This submits that the current TCs do not affect the trading results to an extent that deems a trading discipline unfit for practice. This was not the case previously as, many of the existing research studies, that have considered the implication of TC, have ruled against TA being a profitable discipline. The most common translation states that TA is profitable prior to the inclusion of transaction costs, thereby making it gainful only in theory and not in practice. The introduction of a discount brokerage system in the Indian markets has reduced the impact that transaction costs had on the returns generated by a retail trader, thus making the markets more competitive and efficient.

Following the elimination of bias and inclusion of TC, the research presses forward with the internal comparative evaluation between BB momentum and BB reversal, and thereafter external comparison with MACD and RSI indicator.

5.1 Comparison of returns generated by BB momentum and BB reversal
5.11 Statistical Comparison
Statistical comparison between the two versions of BB aims at identifying a superior strategy out of the two. Considering the fact that a trader may not be able to function on both renditions of the indicator simultaneously, it becomes excessively important to identify an application that has an edge over the other. To verify if there is any statistically significant difference between the performance of the two strategies, the Mann-Whitney U-test was applied, post confirmation of homogeneity of variance through the Levene's test (p-value = 0.77 at a confidence level of 95%). The results of the Mann-Whitney U-test reveal that the returns generated by the BB momentum strategy and the BB reversal strategy carry no statistical difference, and are at par with each other.

At a confidence threshold of 95%, there is not enough evidentiary support to dismiss the null hypothesis, stating the aforementioned. This reflects upon the fact that statistically both the renditions of BB indicator are equally profitable and a trader may opt for any of the strategies that suits his/her trading style. This dilemma can further be fixed by introducing the element of volatility into the picture. Khan, Waqas & Hassan (2017), through their research on the impact of volatility on momentum returns, suggested that the two variables are inversely related i.e. increase in volatility has a shrinking effect on the momentum returns generated by the stocks. Thus, if the trading volatility remains high, as suggested by the volatility index (VIX), one must opt for BB reversal strategy. However, if the markets are riding low on volatility and have been trending in a definite direction, the BB momentum strategy may prove to be more profitable. (*refer Annexures: Exhibit-4)*

5.12 Comparison of ROI
The quantum of returns generated by the two interpretations of the BB indicator suggest that they are not too far apart. The decade long performance of the BB reversal strategy inches ahead by a mere 3.5% in comparison to the BB momentum strategy. (*refer Annexures: Exhibit-5)*

The variability in the annual returns of the two strategies may be attributed to the fact that they belong to different schools of thought. The BB momentum strategy banks on the continuation of a set trend, whereas, the BB reversal strategy seemingly looks for termination of the ongoing trend and emergence of the opposite one. In addition to this, the two trading systems perform quite differently in varying market conditions, and their performance is deeply influenced by the ongoing market trend and the degree of volatility experienced by the market.

5.2 Comparison of returns generated by BB momentum with MACD & RSI indicator
5.21 Statistical Comparison
MACD & RSI have been one of the top pics amongst the traders, owing to their precision and versatility of usage. The majority of research that has been conducted around the subject of Technical Analysis, centers around these two technical indicators. Thus, comparative performance review of the BB indicator (momentum) against the MACD and RSI indicator is of great importance. In context to the BB momentum and the MACD indicator, the p-value at a confidence level of 95% suggests a p-value (0.2032) that is greater than 0.05. Owing to this, the null hypothesis cannot be rejected and it can be concluded that, statistically, BB momentum does not offer superior returns than the MACD indicator. Converse to this, the p-value for the test between BB momentum and RSI lands at 0.0079, suggesting that there exists a significant difference in the performance of the two disciplines and that BB momentum is indeed capable of generating greater returns than the RSI indicator. (*refer Annexures: Exhibit-6)*

5.22   Comparison of ROI
The BB momentum strategy has yielded far better results than its counterparts. The MACD & RSI trading disciplines proved to be more profitable in the initial years of the decade, but, as the volatility of the markets went up, it exposed the shortcomings of the two indicators. The BB momentum system offered positive returns 80% of the time, whereas the MACD & RSI could achieve this feat only 50% of the time. The quantum of returns generated by the BB momentum strategy is more closely related to the returns generated by the index, in comparison to that of MACD & RSI. Thus, it can be stated that the BB momentum is more successful in capturing the tone of the market than its competitors. (*refer Annexures: Exhibit-7)*

5.3   Comparison of returns generated by BB reversal and MACD & RSI indicator
5.31 Statistical Comparison

BB, MACD, and RSI belong to a category of indicators that are quite flexible in their applicability. They can not only be used to ride an ongoing trend but also to detect a probable trend switching that occurs at the end of every bull or bear rally. Thus, with an intent to test the abilities of the aforementioned indicators in capturing peaks and valley, the Mann-Whitney U-test was brought into service. At a confidence level of 95%, the results of the test proposed that, there exists a statistically significant difference between the performance of BB reversal strategy and MACD, RSI. With a p-value of 0.00006 for the test between BB reversal and MACD and 0.00084 for the test between BB reversal and RSI, the evidence dictates that null hypothesis must be rejected and alternate hypothesis, stating superiority in performance of BB reversal over the other indictors has been reinforced. The plausible justification of the above results lies within the fact that MACD is an indicator that is based on moving averages. This provides MACD a bit more stability and reliability in context to others, but takes away its ability to respond quickly to changing market conditions. On the flip side, RSI holds an edge over other technical indicators as it is more agile and responds almost instantaneously, owing to its composition that is based on OHLC (open-high-low-close) price levels. This, however, brings down the stability factor to a great extent as RSI may indicate trend reversal even when it is just a temporary correction. The BB indicator, carries in itself, the best of both worlds. It is steadier than RSI and a lot swifter than MACD, which is what brands it more profitable than the two indicators, when used in solitude. *(refer Annexures: Exhibit-8)*

5.32   Comparison of ROI

The year-on-year comparison of the data shows that BB reversal strategy has been more consistent in offering positive annual returns in comparison to MACD & RSI. It is this tenacity of the indicator that has led to it outperforming its counterparts. Out of the 10 years of assessment, BB reversal has offered negative returns only in 30% of the case, with a maximum drawdown of 12.7%. On the flip side, for both RSI & MACD the proportion of profitable and non-profitable years has been equal. The quantum of return generated by BB reversal surpassed the others owing to the fact that it offers its traders a healthy risk-reward ratio. The amount of risk per unit of return is a lot smaller for BB reversal than the MACD & RSI indicator. For every 1% risk assumed by a trader, the BB reversal fetched a 1.5% return. This aspect is further reinforced by the fact that out of the 81 trades that were conducted over a period of 10 years, only 37 proved to be profitable, giving this strategy a win rate of just 45.6%. Even with an unfavorable strike rate, the trading system managed to generate an average return of 0.83% per trade. *(refer Annexures: Exhibit-9)*

Findings & Conclusion

BB as a technical indicator is versatile enough to be used by intraday traders and long-term traders alike, and simple enough to not require any specialized knowledge for implementation. It presents a potent blend of alertness and agility, thereby making it highly compatible with almost all trading styles and asset classes. Upon investigation, it was found that the indicator's performance has been particularly impressive when pegged against other popular indicators such as MACD and RSI. Almost every single time the Bollinger Band has been able to beat its counterparts with a considerable margin. This comparative performance review over the last decade suggests that banking entirely on a trend following indicator such as MACD or on a price oscillator of the likes of RSI may not be enough to be profitable in the market. A wholistic indicator such as the BB has an innate edge over other trading meters, which becomes more visible when observed over a longer time duration i.e. 5 years or more. An additional advantage associated with the BB indicator is that it requires very little effort from the trader's perspective to identify and execute winning trades. On one side where MACD and RSI demand considerable experience and skill on the trader's part, BB takes care or most aspects of trading by itself i.e. ensuring a healthy reward as against a

minimalistic risk factor. Thus, in totality, it can rightly be stated that the BB indicator, when compared statistically and on the basis of ROI, is a cut above the traditionally popular indicators such as MACD and RSI.

Scope for Further Research

- The study takes into consideration 10 years of duration for the purpose of analysis. This duration can further be enlarger for a more comprehensive investigation.
- The research restricts itself to two major renditions of BB indicator i.e. as a momentum indicator and as a reversal indicator. The ability of the BB indicator to act as a profitable breakout indicator can be taken up in a future research investigation.
- The study takes into consideration two major indicators i.e. MACD and RSI for comparative evaluation of the BB indicator. Similar research may be conducted by pegging BB against other popular indicators such as the Moving Averages indicator, DMAC (Dual Moving Average Crossover) indicator, Super-Trend indicator, etc.

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Annexures

Exhibit-1 (Trading Parameters)

1. **Bollinger Bands as a Momentum Indicator –**
   a. **Buy/Long Trade**
   - A buy trade is initiated when any part of the full body of a positive EOD (1-day) candlestick touches the upper band of the Bollinger Bands indicator and the upper and lower bands experience a divergence.
   - The trade is squared off once the middle line is breached from the upper side, on a closing basis.
   - The stop loss of the trade lies at the middle line of the Bollinger Bands, on a closing basis.
   - Algorithm: $Buy = Close_n > UB_n$ And $Close_n > Open_n$ And $(UB_n - LB_n) > (UB_{n-1} - LB_{n-1})$

   b. **Sell/Short Trade**
   - A sell trade is initiated when any part of the full body of a negative EOD (1-day) candlestick touches the lower band of the Bollinger Bands indicator and the upper and lower bands experience a divergence.
   - The trade is squared off once the middle line is breached from the lower side, on a closing basis.
   - The stop loss of the trade lies at the middle line of the Bollinger Bands, on a closing basis.
   - Algorithm: $Sell = Close_n < LB_n$ And $Close_n < Open_n$ And $(UB_n - LB_n) > (UB_{n-1} - LB_{n-1})$

2. **Bollinger Bands as a Reversal Indicator –**
   a. Buy/Long Trade
   - A buy trade is initiated once an EDO candle re-enters the bands, on a closing basis, post a candle that offers close below the lower band.
   - The stop loss is triggered if a candle closes below the low of the candle on which the trade has been initiated, on a closing basis.
   - The trade is squared off once the middle line is breached from the upper side, on a closing basis.
   - Algorithm: $Buy = Open_n < LB_n$ And $Close_n < LB_n$ And $Close_n > Open_n$

b. Sell/Short Trade

- A sell trade is initiated once an EDO candle re-enters the bands, on a closing basis, post a candle that offers close above the upper band.
- The stop loss is triggered if a candle closes above the high of the candle on which the trade has been initiated, on a closing basis.
- The trade is squared off once the middle line is breached from the lower side, on a closing basis.
- Algorithm: $Sell = Open_n > UB_n$ And $Close_n > UB_n$ And $Close_n < Open_n$

Exhibit-2: (Result of Levene's Test)

BB as a Momentum Indicator		BB as a Reversal Indicator	
f-ratio value	1.381	f-ratio value	0.648
p-value	0.2426	p-value	0.425

Exhibit-3 (Results of Mann-Whitney U-Test for In/Out Sample)

BB as a Momentum Indicator				BB as a Reversal Indicator			
In-Sample		**Out-Sample**		**In-Sample**		**Out-Sample**	
Rank Sum	2460.5	Rank Sum	2390.5	Rank Sum	1460.5	Rank Sum	1860.5
Mean of Ranks	48.25	Mean of Ranks	50.86	Mean of Ranks	38.43	Mean of Ranks	43.27
Expected Sum of Ranks	2524.5	Expected Sum of Ranks	2326.5	Expected Sum of Ranks	1558	Expected Sum of Ranks	1763
Expected Mean of Ranks	49.5	Expected Mean of Ranks	49.5	Expected Mean of Ranks	41	Expected Mean of Ranks	41
U-value	1262.5	U-value	1134.5	U-value	914.5	U-value	719.5
Expected U-value	1198.5	Expected U-value	1198.5	Expected U-value	817	Expected U-value	817
Combined Sample				**Combined Sample**			
Sum of Ranks	4851			Sum of Ranks	3321		
Mean of Ranks	49.5			Mean of Ranks	41		
Standard Deviation	140.62			Standard Deviation	105.67		
U-value	1134.5			U-value	719.5		
Z-value	0.451			Z-value	0.918		
P-value	0.652			P-value	0.357		

Exhibit-4 (Comparison between BB-momentum strategy & BB-reversal strategy)

BB (Reversal)		BB (Momentum)	
Rank Sum	7591.5	Rank Sum	8518.5
Mean of Ranks	93.72	Mean of Ranks	86.92
Expected Sum of Ranks	7290	Expected Sum of Ranks	8820

Expected Mean of Ranks	90	Expected Mean of Ranks	90
U-value	3667.5	U-value	4270.5
Expected U-value	3969	Expected U-value	3969
Combined Sample			
Sum of Ranks	16110		
Mean of Ranks	90		
Standard Deviation	345.065		
U-value	3667.5		
Z-value	0.8723		
P-value	0.3843		

Exhibit-5 (Year-on-Year ROI Comparison of BB Momentum & BB Reversal)

Year	BB (Momentum)	BB (Reversal)
2011	9.21%	8.28%
2012	3.30%	9.25%
2013	1.33%	-12.70%
2014	16.70%	20.07%
2015	-14.47%	-0.99%
2016	0.38%	3.32%
2017	6.21%	22.48%
2018	8.12%	-2.43%
2019	-5.40%	3.16%
2020	43.05%	16.07%

Exhibit-6 (Comparison between BB-momentum strategy MACD & RSI)

BB (Momentum)		MACD		BB (Momentum)		RSI	
Rank Sum	12405	Rank Sum	17241	Rank Sum	8859.5	Rank Sum	4835.5
Mean of Ranks	126.58	Mean of Ranks	118.9	Mean of Ranks	90.4	Mean of Ranks	72.17
Expected Sum of Ranks	11956	Expected Sum of Ranks	17690	Expected Sum of Ranks	8134	Expected Sum of Ranks	5561
Expected Mean of Ranks	122	Expected Mean of Ranks	122	Expected Mean of Ranks	83	Expected Mean of Ranks	83
U-value	6656	U-value	7554	U-value	2557.5	U-value	4008.5
Expected U-value	7105	Expected U-value	7105	Expected U-value	3283	Expected U-value	3283
Combined Sample				**Combined Sample**			

Sum of Ranks	29646	Sum of Ranks	13695
Mean of Ranks	122	Mean of Ranks	83
Standard Deviation	537.528	Standard Deviation	301.379
U-value	6656	U-value	2557.5
Z-value	0.834	Z-value	2.405
P-value	0.2032	P-value	0.0079

Exhibit-7 (Year-on-Year Return Comparison of BB Momentum & MACD/RSI)

Year	BB (Momentum)	MACD	RSI
2011	9.21%	25.81%	6.51%
2012	3.30%	10.07%	10.03%
2013	1.33%	-1.68%	-6.11%
2014	16.70%	-4.48%	-2.05%
2015	-14.47%	-3.16%	20.97%
2016	0.38%	-16.13%	5.41%
2017	6.21%	-2.18%	-12.88%
2018	8.12%	16.59%	-2.89%
2019	-5.40%	11.57%	16.5%
2020	43.05%	17.25%	-22.99%

Exhibit-8 (Comparison between BB-reversal strategy MACD & RSI)

BB (Reversal)		MACD		BB (Reversal)		RSI	
Rank Sum	11014.5	Rank Sum	14636.5	Rank Sum	6850.5	Rank Sum	4175.5
Mean of Ranks	135.98	Mean of Ranks	100.94	Mean of Ranks	84.57	Mean of Ranks	62.32
Expected Sum of Ranks	9193.5	Expected Sum of Ranks	16457.5	Expected Sum of Ranks	6034.5	Expected Sum of Ranks	4991.5
Expected Mean of Ranks	113.5	Expected Mean of Ranks	113.5	Expected Mean of Ranks	74.5	Expected Mean of Ranks	74.5
U-value	4051.5	U-value	7693.5	U-value	1897.5	U-value	3529.5
Expected U-value	5872.5	Expected U-value	5872.5	Expected U-value	2713.5	Expected U-value	2713.5
Combined Sample				**Combined Sample**			
Sum of Ranks	25651			Sum of Ranks	11026		
Mean of Ranks	113.5			Mean of Ranks	74.5		
Standard Deviation	471.35			Standard Deviation	259.586		
U-value	4051.5			U-value	1897.5		

Z-value	3.8622	Z-value	3.141
P-value	0.00006	P-value	0.00084

Exhibit-9 (Year-on-Year Return Comparison of BB Reversal & MACD/RSI)

Year	BB (Reversal)	MACD	RSI
2011	8.28%	25.81%	6.51%
2012	9.25%	10.07%	10.03%
2013	-12.70%	-1.68%	-6.11%
2014	20.07%	-4.48%	-2.05%
2015	-0.99%	-3.16%	20.97%
2016	3.32%	-16.13%	5.41%
2017	22.48%	-2.18%	-12.88%
2018	-2.43%	16.59%	-2.89%
2019	3.16%	11.57%	16.5%
2020	16.07%	17.25%	-22.99%