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# A Statistical Analysis of the Predictive Power of Japanese Candlesticks

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# A STATISTICAL ANALYSIS OF THE PREDICTIVE POWER OF JAPANESE CANDLESTICKS

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***Japanese Candlesticks is a technique for plotting past price action of a specific underlying such as a stock, index or commodity using open, high, low and close prices. These candlesticks create patterns believed to forecast future price movement. Although the candles' popularity has increased rapidly over the last decade, there is still little statistical evidence about their effectiveness over a large number of occurrences. In this work, we analyze the predictive power of the Shooting Star and Hammer patterns using over six decades of historical data of the S&P 500 index. In our studies, we found out that historically these patterns have offered little forecasting reliability when using closing prices but were highly reliable when using high price for the Shooting Star and low price for the Hammer.***

Keywords: Japanese Candlesticks, Shooting Star, Hammer, Stock market forecasting

## INTRODUCTION

Technical Analysis is a popular method used in the financial industry to predict future price movements of financial securities. It is the study of market action, primarily through the use of charts, for the purpose of forecasting future price trends (Murphy, 1999). Charts are drawn using historical prices and may contain additional information such as volume and open interest. This technical methodology relies on three main assumptions: #1. Market action discounts everything. All relevant information that affects price of the security is already discounted in the market price. #2. Prices move in trends. #3. History repeats itself.

Based on assumption #1, the technician only relies on charts since it is all that it is required to forecast future prices. It follows from assumptions #2 and #3 that by studying past data using charts, it is possible to forecast future price trends. Historically, the technical approach has suffered its fair share of criticism. Probably the most well-known example is the Efficient-market hypothesis (EMH), which states that it is not possible to consistently achieve returns superior to those of the market on a risk-adjusted basis by using publicly available information (Fama, 1970). While the validity of EMH has been questioned repeatedly, it is not our purpose to prove or disprove this hypothesis.

Although it is difficult to find scientific evidence for the efficiency of technical analysis, it is hard to argue the immense popularity that it enjoys in the investment community. Popular financial websites such as Yahoo! Finance (Yahoo! Finance, n.d.), Google Finance (Google Finance, n.d.), MSN Money (MSN Money, n.d.), and CNN Money (CNN Money, n.d.) offer stock charts with a wide variety of technical indicators. In addition, those websites allow plotting multiple styles of charts that use not only closing prices but also incorporate other prices. One of the most popular styles is Japanese Candlesticks, which are candles created using open, high, low and closing prices. When these candlesticks are drawn on a chart, they display patterns believed to be useful in forecasting temporary tops, bottoms, continuations and reversals. The effectiveness of Japanese Candlesticks is the focus of our work.

Although there is extensive literature on Japanese Candlesticks, most of it is generally vague and does not provide any statistical evidence on the validity of the patterns. On the other hand, the studies that do offer statistical evidence mostly concentrate on specific stocks over a short period of time (usually few years), instead of a highly liquid index over a long period of time (over a decade). The advantage of using a highly liquid index such as the S&P500 is that no single participant has large enough capital to influence price movement for long periods. In our study, we analyze the performance of two one-candle patterns: the Shooting Star, which is believed to forecast a temporary top and the Hammer, which is believed to forecast a temporary bottom. Our study is based on over 60 years of historical data on the S&P500 index, which is the most followed index by the media as well as analysts, and widely believed to be a leading indicator of the health of the US economy.

## JAPANESE CANDLESTICKS

Japanese Candlesticks were initially developed in Japan around the 18th century; used by Japanese investors to forecast the price fluctuations of rice. Although Japanese Candlesticks Charts have been used in Japan for over 200 years, they were virtually unknown in the West until 1990 when they were introduced by Steve Nison (Nison, The Candlestick Course, 2003). Following Nison's introduction and the rise of the World Wide Web, Japanese Candlesticks have enjoyed increased popularity. Today, they are commonly included in most software packages and websites for technical stock analysis.

A daily Japanese Candlestick (Nison, Japanese Candlestick Charting Techniques, 2001) is formed by using 4 prices. These prices are the open, high, low and close for that particular day. The open and close prices determine the candle body, which is represented by a box. The high and low determine the candle's upper and lower shadows respectively, which are shown as thin vertical lines above and below the candlestick body. Figure 1 shows three sample candlesticks. In Figure 1(a), the closing price is higher than the opening price, thus the candlestick body is white (or green). Shown in Figure 1(b), the closing price is lower than the opening price, thus the candlestick body is black (or red). A special case appears in Figure 1(c), where the opening price equals the closing price, this is referred to as *Doji*.

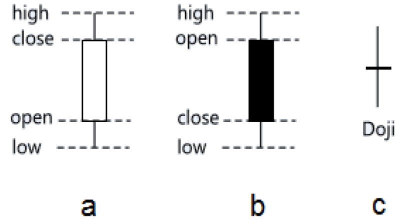


*Figure 1.* Sample Candlesticks.

With this terminology, the most basic pattern that can be defined consists of only one candle. This one-candle pattern is based on the body length and its position. Figure 2 shows several one-candle patterns. Starting from the leftmost pattern, the first one is known as Shooting Star (a), which is made of a small body at the bottom and a large upper shadow, the Hammer (b) has a small body at the top and a large lower shadow, the Doji (c) has a tiny body usually appearing near the middle of the candle with the exceptions of the Gravestone Doji (d) for which its body appears at the bottom and the Hanging Man (e) whose body appears at the top.

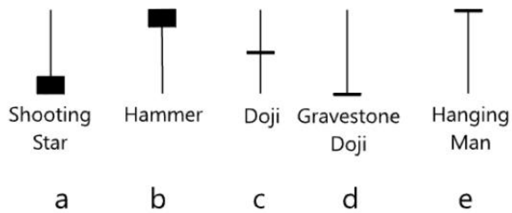


*Figure 2.* One Candle Patterns

More complex patterns involving multiple candles are possible as shown in Figure 3. For instance, the *Bullish Engulfing pattern,* which consists of a small dark candle *engulfed* by a subsequent large white candle whose body covers the previous small dark candle. Conversely, a *Bearish Engulfing pattern* is a small white candle engulfed by a large dark candle.

A pattern believed to forecast an uptrend is referred to as “bull” or “bullish” pattern while a pattern believed to forecast a downtrend is referred to as “bear” or “bearish” pattern. This terminology comes from Wall Street since market participants expecting a rise in prices are called “bulls” and participants expecting a fall are called “bears”.

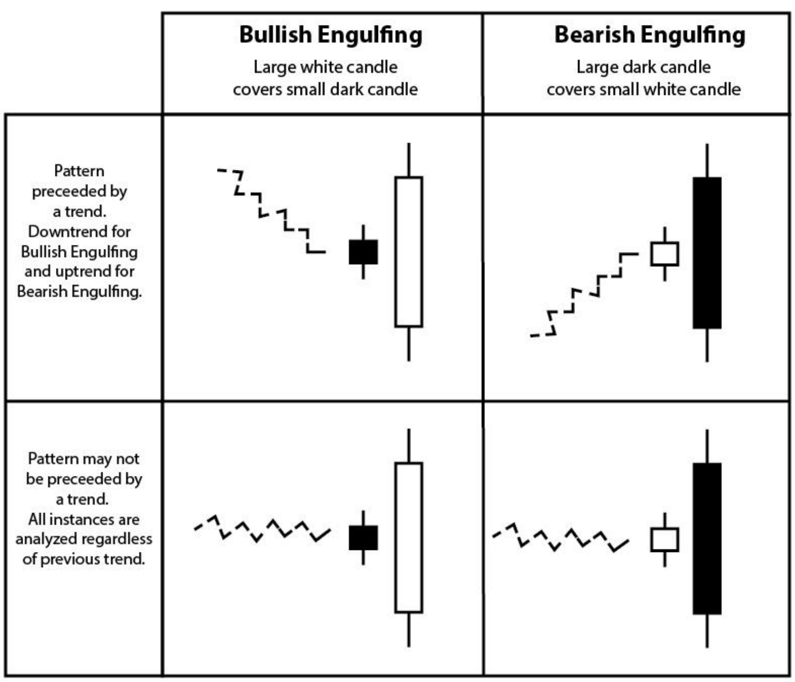


*Figure 3.* Bullish and Bearish Engulfing patterns

According to much of the literature, the significance of candlestick patterns is dependent upon the previous trend (Nison, Japanese Candlestick Charting Techniques, 2001). For instance, a Shooting Star in an uptrend is believed to forecast a top or resistance area, since prices have been consistently moving up but finished near the bottom of the day failing to establish a new high. In contrast, a Shooting Star in a sideways trend is believed to possess little predictive value. Figure 3 shows examples of two-candle patterns and the prior trend necessary to give validity to the pattern.

The literature also attaches significance to a Bullish Engulfing pattern occurring after a downtrend. This pattern is believed to indicate a bottom or support area and therefore, a trend reversal is likely. The opposite pattern is the Bearish Engulfing, which consists of an uptrend followed by a small white candle and a large dark candle. As its name implies, this patterns indicates a top or a resistance area. In this work, we study the patterns when they are preceded by a trend and also in all instances (regardless of trend).

There are several other Japanese Candlestick patterns that consist of two, three, and even four candlesticks. Popular patterns include *Morning Star*, *Evening Star*, *Dark Cloud Cover*, *Hammer*, *Piercing*, *Three Black Crows*, and *Three White Soldiers* (Nison, The Candlestick Course, 2003).

## LITERATURE REVIEW

Many studies have been done to answer the question "Are Japanese Candlesticks an effective tool for forecasting future price action in the stock market?" This is not a simple question due to the fact that academicians are skeptical of technical analysis, while professional and retail traders rely heavily on technical indicators for predicting future prices and trends.

Examination of the literature to determine if there is a consensus concerning whether or not Japanese candlesticks are effective market predictors yielded mix results. There were some studies that had a positive result, but for limited markets, or just for certain patterns. For example, Lu, et. al. (Lu, Shiu, & Liu, 2012) investigated six different candlestick patterns using the Taiwan 50 component stocks. Using an adjusted t-test and the binomial test, they find that three bullish reversal patterns, i.e. the Bullish Engulfing, the Bullish Harami, and the Piercing, "have significant predictive power in the Taiwan stock market." They also examined three bearish patterns, but these did not show the predictive power of the bullish patterns.

In another study, Zhu (Zhu, Atri, & Yegen, 2015) concludes that certain candlestick patterns are effective for certain kinds of stocks in the Chinese exchanges. Specifically, in this study, the Bearish Harami and cross signals are effective in predicting reversals for stocks of low liquidity. Bullish Harami, Engulfing and Piercing patterns are seen to work well when applied to highly liquid, small companies' stocks.

Xie et al. (Xie, Zhao, & Wang, 2012) challenged the academic skepticism and claim to have demonstrated that candlesticks do provide predictive power based on past performance using S&P 500 data.

Another investigation yielding mixed results was that of Chmielewski, et al (Chmielewski, Janowicz, Kaleta, & Orlowski, 2015), who applied k-nearest neighbor classifier techniques to candlestick patterns for the Warsaw, Poland market. They conclude that, in general, there was no evidence to suggest candlesticks could be used to make a profit. However, evidence does indicate that there are some situations for which the opposite can occur; and that practicing traders can use candlesticks for their trading tactics differently from the way that academic studies are conducted.

On the negative side; in a seminal case study, Horton (Horton, 2009) examines candlesticks as a method of technical analysis for 349 stocks from Commodity Systems Inc. (CSI), with 349 randomly selected companies. Their study involved use of the following bull market candlesticks: Three White Soldiers, Three Inside Up, Three Outside Up, Morning Star; and the following bear market candlesticks: Three Black Crows, Three Inside Down, Three Outside Down, and Evening Star. They analyzed these as they related to a 3-day moving average (for uptrends and downtrends). The main conclusion of this study was that these candlestick charting methods had no value for trading individual stocks.

Prado, et al (Prado, Ferneda, Morais, Luiz, & Matsura, 2013) replicated a study performed on the U.S. Market, and applied these to the Brazilian market. Not only was no statistical evidence found to confirm predictive power, at least one pattern's analysis showed its trend was contrary to the original interpretation of the pattern. A few patterns showed predictive power in the markets of their intended use, but not in the Brazilian market.

Another study develops a mathematical definition scheme to enable objective and computerized identification of candles. Fock et al (Fock, Klein, & Zwergel, 2005) use this scheme to examine intra-day market performance. Even without taking transaction costs into account the results reflect poorly for the effective use of candles. In most cases, the results were not significantly better than results for a benchmark with randomized transactions. This was confirmed by Duvinage et al (Duvinage, Mazza, & Petitjean, 2013), who examined the predictive power of candlesticks at the 5-minute interval for the 30 constituents of the DJIA index. They found no evidence that candlesticks outperform the buy-and-hold method, after transaction costs are considered.

## OVERVIEW OF THE STUDY

The focus of our study was to examine the predictive capability of the Shooting Star and Hammer, which are patterns determined by a single candle as shown in Figure 2(a) and Figure 2(b). The Shooting Star preceded by an uptrend is believed to forecast a market top, while the Hammer preceded by a downtrend is believed to forecast a market bottom. According to Nison (Nison, The Candlestick Course, 2003), when the market begins by rallying after the open but fails to make a new high due to a sell off and by the end of the trading session finishes near the opening price, it is a sign that the market participants are bearish and a downtrend is imminent, in which case the Shooting Star pattern is formed. Conversely, when the market sells off after the open but rallies toward the end of the trading session and closes near the open, it is a sign that the market participants are bullish and an uptrend is imminent, in which case a Hammer pattern is formed.

In order to test the predictive power of the Shooting Star and Hammer patterns, we created a computer program using C# to find all instances of both patterns in the S&P500 index by using historical data from 1950 to 2017. This program provides a graphical user interface (GUI) that allows the user to find multiple candlestick patterns by reading a CSV (comma separated values) file with historical prices. In addition, it allows the user to specify multiple parameters such as the candle's body length in relation to the entire candle's length, period of time, trend's strength, etc. For our study, we used historical data of the S&P 500 index from Yahoo finance.

The S&P 500 is a widely followed index comprised of 500 leading companies in the United States. Every time a candle pattern was found, we determined the previous trend as well as high and low prices following the candle to find out if it was a top (for the Shooting Star) or bottom (for the Hammer) for the next 5, 7 and/or 10 days. After finding the candle pattern and obtaining the success/failure of each instance found, we compared the results against those for all candles to determine whether using the candle pattern provided a statistical advantage of picking a top or bottom than simply using any random candle.

Although there is abundant literature on Japanese Candlesticks, these sources typically provide vague definitions rather than precise concepts. For instance, although a Doji candle is strictly defined as a candle where open and close prices are equal, there are instances in which those two prices are separated by only few cents. Should those instances be also considered a Doji and if so, how close should the two prices be? A similar situation occurs with the Shooting Star since it is suggested that the candle body should be small but there is no precise definition of how small. To further complicate matters, this pattern is often studied when it is preceded by an uptrend, but there is little information of what qualifies as an uptrend. Is it a 7-day uptrend, 10-day uptrend, 1-month uptrend? Should all the previous candles be rising or only some of them?

In order to perform our studies, we defined the following parameters for the candle patterns and trends.

A. Parameter definitions:

High (H). The highest traded price for the day.
Low (L). The lowest traded price for the day.
Open (O). The opening price for the day.
Close (C). The closing price for the day.

Lower Shadow (LS) = MIN(O, C) – L
Upper Shadow (US) = H - MAX(O, C)
Body (B) = ABS(O – C)
Whole Candle (WC) = H – L

**Shooting Star.** A candle for which the body is less than or equal to 25% of the entire candle, and the lower shadow is less than or equal to 5 percent of the entire candle length. Formally, B/WC <= .25 AND LS/WC <= .05

**Hammer.** A candle for which the body is less than or equal to 25% of the entire candle, and the upper shadow is less than or equal to 5 percent of the entire candle length. Formally, B/WC <= .25 AND US/WC <= .05

**Moving Average.** The n-Day Moving Average (n-Day MA) is the average of the closing prices for n consecutive days.

**Uptrend.** We consider a sequence of n candles to be in an uptrend when the n-day MA increases for least 70% of the n days.

**Downtrend.** We consider a sequence of n candles to be in a downtrend when the n-day MA decreases for least 70% of the n days.

**Regardless of trend or No Trend.** Any sequence of n days that it is either an uptrend, downtrend or sideways (neither of both).

**Success/Failure of Shooting Star pattern.** The Shooting Star over a period of n days is considered successful if:

- Closing price success (CLOSE criterion). The Shooting Star's close is higher than or equal to the highest close for the next n days. Otherwise, it is considered a failure.
- High price success (HIGH Criterion). The Shooting Star's high is higher than or equal to the highest close for the next n days. Otherwise, it is considered a failure.

As an example, the 5-day Shooting Star using the CLOSE criterion is expected to be a top for the next 5 trading days so that no other subsequent day can close higher than the closing price of the Shooting Star pattern to be considered a success. Similarly, the 10-day Shooting Star using the HIGH criterion is expected to be a top for the next 10 trading days so that no other subsequent day can close higher than the highest price of the Shooting Star pattern to be considered a success.

**Success/Failure of Hammer pattern.** The Hammer over a period of n days is considered successful if:

- Closing price success (CLOSE criterion). The Hammer's close is lower than or equal to the lowest close for the next n days. Otherwise, it is considered a failure.
- Low price success (LOW criterion). The Hammer's low is lower than or equal to the lowest close for the next n days. Otherwise, it is considered a failure.

As an example, the 5-day Hammer using the CLOSE criterion is expected to be a low for the next 5 trading days so that no other subsequent day can close lower than the closing price of the Hammer pattern to be considered a success. Similarly, the 10-day Hammer using the LOW criterion is expected to be a low for the next 10 trading days so that no other subsequent day can close lower than the lowest price of the Shooting Star pattern to be considered a success.

## STATISTICAL ANALYSIS

The focus of our study was to examine the predictive capability of Japanese candlesticks by examining the Shooting Star and Hammer patterns, which have been given significance in the literature. For example: *a Shooting Star in an uptrend is hypothesized to forecast a temporary top price and thus, price will move downward afterwards*. In order to test that hypothesis, we wanted to compare the instances of this pattern with past data and perform a statistical analysis to determine the truth of the hypothesis.

In this study, we analyzed the Shooting Star in scenarios in which there were uptrends, as well as all scenarios. Likewise we analyzed the Hammer in scenarios in which there were downtrends, as well as all scenarios.

The next section contains the analysis for the Shooting Star forecasting a top, based on 5-, 7- and 10-day future days, and a comparison with forecasting a top randomly without using a candle signal. By random, we mean, using all days, we compare against the actual tops, as a proportion of the total number of data points. Similarly we present analysis for the Hammer forecasting a bottom, based on 5-, 7- and 10-day future days, and compare with forecasting a bottom randomly without using a candle pattern signal.

A. Descriptive Analysis

The important data used in the statistical analysis is summarized in Appendix A. The two criteria used are the HIGH/LOW for Shooting Star and Hammer respectively as well as the CLOSE. The HIGH criterion of the Shooting Star, expects the High price of the candle pattern to serve as a temporary top while the CLOSE criterion assumes the Close price of the candle pattern would serve as the temporary top (no closing price for the future n days can be higher than the top). In the case of the Hammer, the LOW criterion expects the Low price of the candle pattern to serve as a temporary bottom while the CLOSE criterion assumes the Close price of the candle pattern would serve as a temporary bottom (no closing price for the future n days can be lower than the bottom).

The data suggests that both the Shooting Star and Hammer candles are effective when the HIGH criterion for Shooting Star is used and the LOW criterion for Hammers. When using the CLOSE criterion neither the Shooting Star nor the Hammer appear to be effective.

Beginning with the Shooting Star, when using the CLOSE criterion, we observe that the proportion of successes for the candle is typically lower than, or comparable to, the proportion of successes for all days, regardless of trend (Table 1) and with trend (Table 2). By contrast, from

| | | Number of tops (successes) | Total Number of observations | Proportion of tops (successes) |
|---|---|---|---|---|
| **5 Day** | All days | 3560 | 16635 | 0.214007 |
| | Shooting Star | 76 | 161 | 0.47205 |
| **7 Day** | All days | 2933 | 16631 | 0.176357 |
| | Shooting Star | 64 | 161 | 0.397516 |
| **10 Day** | All days | 2363 | 16625 | 0.142135 |

| | | | | |
|---|---|---|---|---|
| | Shooting Star | 46 | 161 | 0.285714 |

Table 3 and Table 4 when the HIGH criterion is used the Shooting Star success proportions are markedly higher than the corresponding success proportions for all days (5-, 7- and 10-day) with trend and regardless of trend.

The proportions in

Figure 4 also bear these out—the success proportions using the HIGH criterion are markedly higher for the Shooting Star especially under the 5- and 7-day and to a lesser extent the 10-day (both regardless of trend and with trend). Likewise, bundling into one all the success rates by moving average (5-, 7 -and 10- day), we see using boxplots ()

Figure 5) that when the CLOSE criterion is used the Shooting Star success proportions are comparable to the success proportions of all days, this is regardless of trend and with trend. In fact the medians of the boxplots for the Shooting Star (with the CLOSE criterion) are lower than the medians for the boxplots for the proportions for all days (with the CLOSE criterion). However when the HIGH criterion is used we see the boxplots for the Shooting Star are much higher than those for all days (with the HIGH criterion)—in fact the tail of the Shooting Star boxplot is higher than the head of the corresponding boxplot for all days (again, regardless of trend, and with trend).

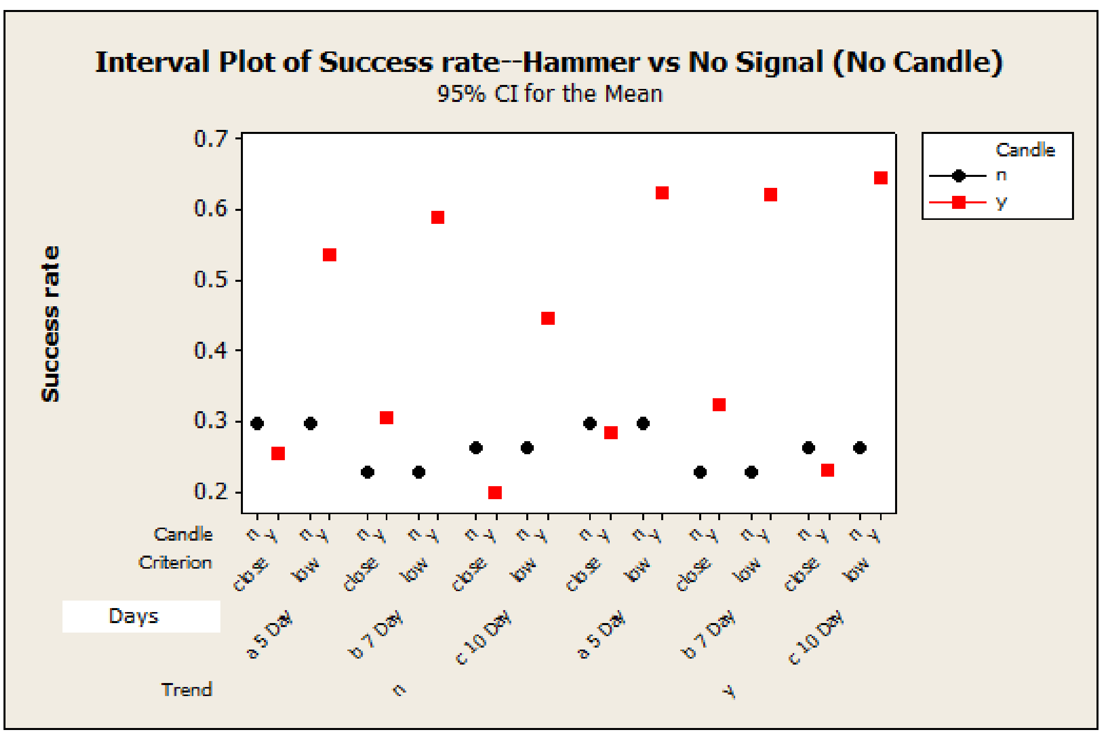


*Figure 4.* Plots of success rates for Shooting Star vs success rates with no signal (all days)

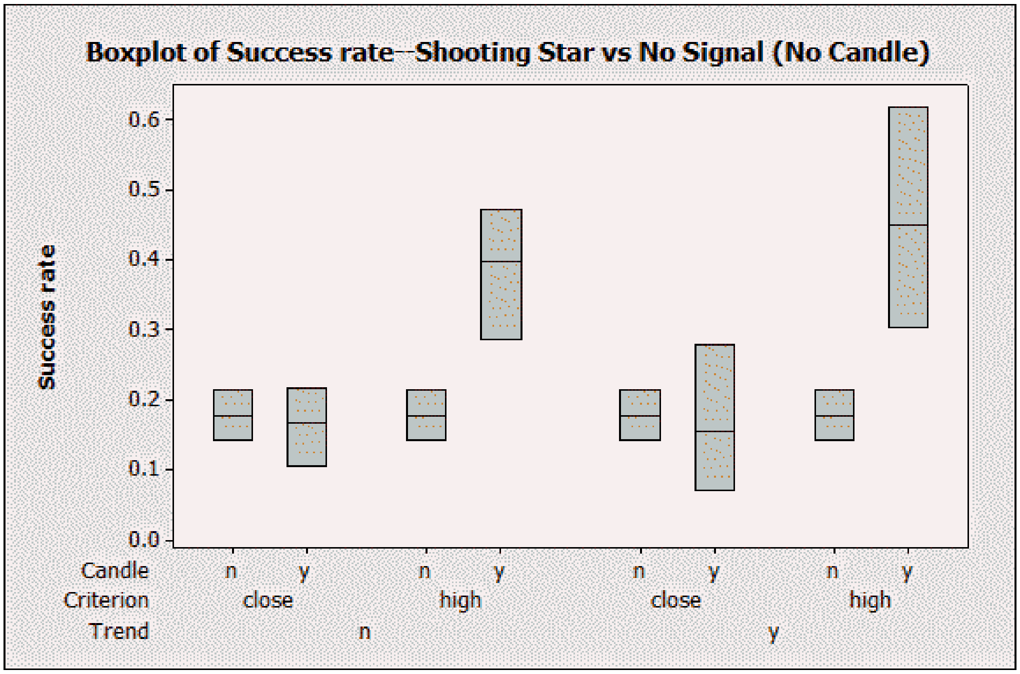


*Figure 5.* Boxplots of success rates for Shooting Star vs success rates with no signal (bundled into one across 3-, 5-, 7- and 10-days)

A similar situation occurs with the Hammer signal. The Hammer appears effective when using the LOW criterion and not effective when using the CLOSE criterion. For the Hammer, looking at the proportion of successes when using the CLOSE criterion, we see from Table 5 and Table 6 that the proportion of successes for the candle is typically lower than, or comparable to, the proportion of successes for all days, regardless of trend (Table 5) and with trend (Table 6). By contrast, when the LOW criterion is used the Hammer candle success proportions are markedly higher than the corresponding success proportions across all 5, 7 and 10-day regardless of trend (Table 7) as well as with trend (Table 8).

The proportions in

Figure 6 also bear these out—the success proportions using the LOW criterion are markedly higher for the Hammer especially when there is a trend (for all 5, 7 and 10-days) and regardless of trend with the 5 and 7 days and to a lesser extent even the 10-day. Likewise, bundling into one all the success rates (5-, 7 -and 10- day), we see using boxplots (

Figure 7) that when the CLOSE criterion is used the Hammer success proportions are comparable to the success proportions of all days, this is regardless of trend and with trend. In fact the median of the boxplots for the Hammer are lower than the median for the boxplots for the proportions for all days when the CLOSE criterion is used and when there is no trend. The median under the CLOSE criterion when there is a trend is only marginally higher for the Hammer candle boxplot than that for the boxplot for success with not candle. However when the LOW criterion is used we see the boxplots for the Hammer are much higher than those for all days—in fact the tail of Hammer boxplot is higher than the head of the corresponding boxplot for all days (again, regardless of trend, and with trend).

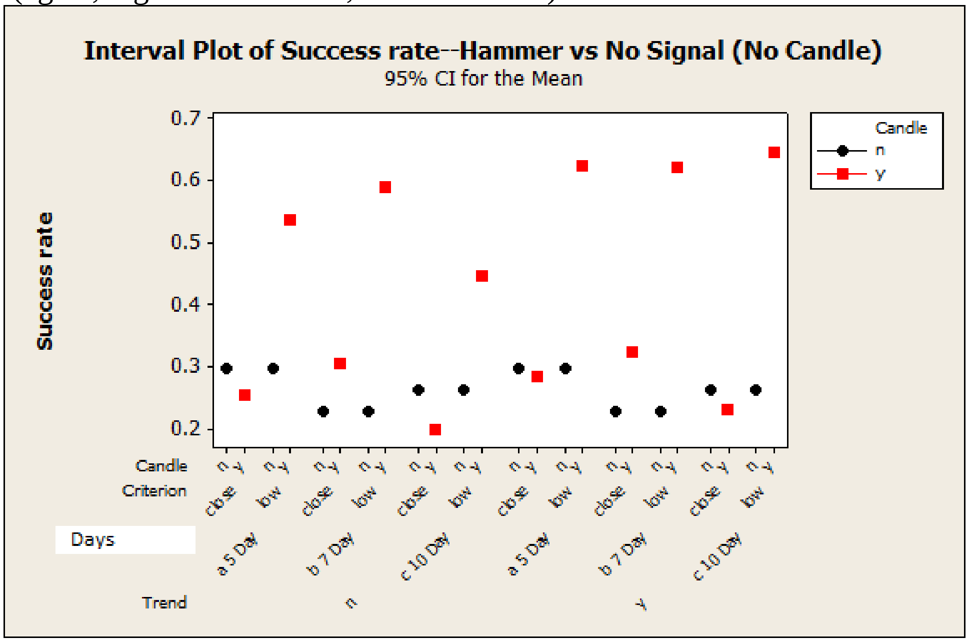


*Figure 6.* Plots of success rates for Hammer vs success rates with no signal (all days)

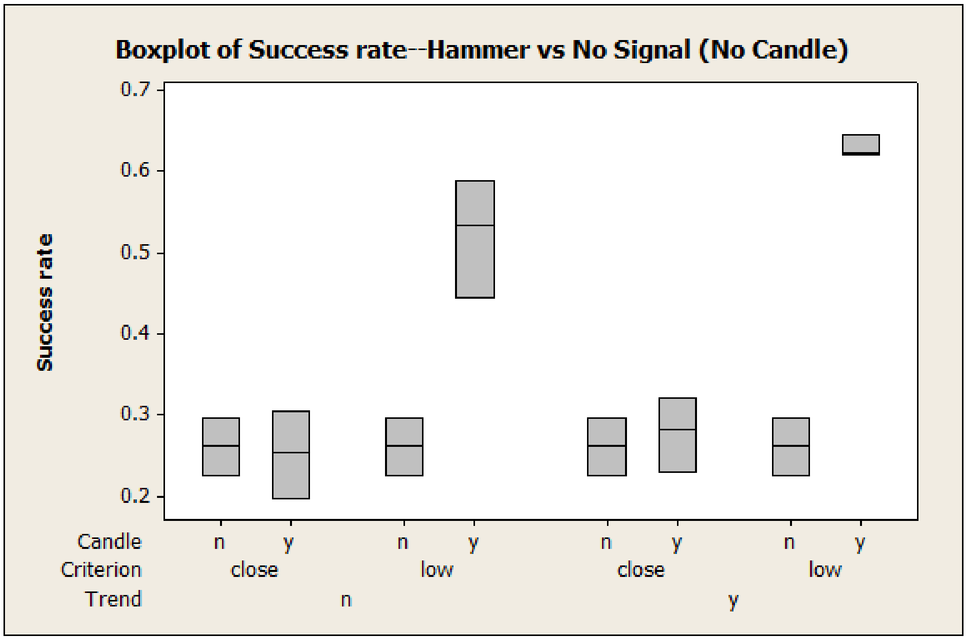


*Figure 7.* Boxplots of success rates for Hammer vs success rates with no signal (bundled into one across 3-, 5-, 7- and 10-day

B. Inferential Analysis

1. Tests for independence between candle signals

We conducted nonparametric chi-squared tests for both the Shooting Star candle as a bearish signal and the Hammer candle as a bullish signal. We tested whether the appearance of a top was dependent on the Shooting Star signal or not. Likewise we tested whether the appearance of a bottom was dependent on the Hammer signal or not.

In the case of tops and the Shooting Star the hypotheses are:

$H_0$: tops are independent of the Shooting Star
$H_a$: tops are dependent on the Shooting Star

In the case of bottoms and the Hammer the hypotheses are:

$H_0$: bottoms are independent of the Hammer
$H_a$: bottoms are dependent on the Hammer

For example, consider the Shooting Star 5-day, regardless of trend (CLOSE). We see that there are 161 Shooting Star observations of which 35 successfully signaled a top for the next 5 days. Using a chi-squared test, we investigated whether this is independent or not of the Shooting Star signal by using all 16,635 candles for which 3,560 were tops for 5 days. The nonparametric chi-squared test for independence comparing 35 successful Shooting Star signals out of a total of 161 Shooting Star signals against 3,560 days that are tops out of a total of 16,635 days yields a p-value of 0.9939 (Figure 8) suggesting that tops are independent of the Shooting Star pattern.

The tests are summarized in Figure 8 for the Shooting Star pattern and Figure 9 for the Hammer pattern. We see that when the CLOSE criterion is used, neither the Shooting Star nor the Hammer results are significant. However when the HIGH criterion is used, tops do appear to significantly depend on the Shooting Star. Likewise when the LOW criterion is used bottoms do appear to significantly depend on the Hammer.

| **$H_0$ : tops are independent of the Shooting Star pattern**<br>**$H_a$ : tops are dependent on the Shooting Star pattern** | **p-value regardless of trend (CLOSE)** | **p-value with uptrend (CLOSE)** | **p-value regardless of trend (HIGH)** | **p-value with uptrend (HIGH)** |
|---|---|---|---|---|
| **5 Day** | 0.9939 | 0.2445 | 5.464e-15 | 2.21e-15 |
| **7 Day** | 0.8549 | 0.7514 | 6.486e-1 | 4.071e-09 |
| **10 Day** | 0.2265 | 0.1862 | 4.227e-07 | 0.001126 |

*Figure 8.* Chi-square tests for independence of tops on Shooting Star candle pattern regardless of trend and with uptrend

| **$H_0$ : bottoms are independent of the Hammer pattern<br>$H_a$ : bottoms are dependent on the Hammer pattern** | **p-value regardless of trend (CLOSE)** | **p-value with downtrend (CLOSE)** | **p-value regardless of trend (LOW)** | **p-value with downtrend (LOW)** |
|---|---|---|---|---|
| **5 Day** | 0.8224 | 0.6927 | < 2.2e-16 | 9.717e-11 |
| **7 Day** | 0.8036 | 0.7584 | < 2.2e-16 | 1.099e-13 |
| **10 Day** | 0.2835 | 1 | < 2.2e-16 | 1.478e-11 |

*Figure 9.* Chi-square tests for independence of bottoms on Hammer candle pattern regardless of trend and with downtrend

2. Tests for comparing success proportions between candle signals and no signals

We also conducted tests of proportions both parametric and nonparametric. We tested whether the proportion of successes with the candle pattern is greater than the proportion of tops, in the Shooting Star case, and whether the proportion of success with the candle pattern is greater than the proportion of bottoms, in the Hammer case. The hypotheses, for both the Shooting Star and Hammer signals are:

$H_0$: success proportion for candle pattern = success proportion without using candle pattern
$H_a$: success proportion for candle pattern > success proportion without using candle pattern

For example, consider again the Shooting Star 5-day without trend (CLOSE). We see that there are 161 Shooting Star observations of which 35 successfully signaled a top giving a success proportion of r1 = 0.217391. Using a nonparametric test, we determined whether this is greater than the proportion for all 16,635 trading days, where 3,560 tops were found, giving a rate of appearance of tops ("success proportion") of r2 = 0.214007. The nonparametric tests for proportions comparing 35 successful Shooting Star signals out of a total of 161 Shooting Star signals against 3,560 days that are tops out of a total of 16,635 trading days yields a p-value of 0.4582 (See Figure 10) suggesting that the proportion of successes with the Shooting Star is no more than the ordinary proportion of tops.

The nonparametric tests are summarized in Figure 10 for the Shooting Star and Figure 11 for the Hammer. We see that when the CLOSE criterion is used, neither the proportion of successes for the Shooting Star, nor the proportion of successes for the Hammer, is higher than the proportion of all tops, in the case of the Shooting Star, or higher than the proportion of all bottoms, in the case of the Hammer. However, when the HIGH criterion is used, the proportion of successes of the Shooting Star is significantly higher than the proportion of successes for all days. Likewise, when the LOW criterion is used, the proportion of successes with the Hammer are significantly higher than the proportion of successes for all days.

| **$H_0$ : success proportion for Shooting Star = success proportion without Shooting Star $H_a$: success proportion for Shooting Star > success proportion without Shooting Star** | **p-value regardless of trend (CLOSE)** | **p-value with uptrend (CLOSE)** | **p-value regardless of trend (HIGH)** | **p-value with uptrend (HIGH)** |
|---|---|---|---|---|
| **5 Day** | 0.4582 | 0.09422 | 7.107e-16 | 2.41e-16 |
| **7 Day** | 0.6488 | 0.6795 | 7.873e-14 | 6.077e-10 |
| **10 Day** | 0.9077 | 0.9351 | 8.99e-08 | 0.0002693 |

*Figure 10.* Tests for proportions for Shooting Star

| **$H_0$ : success proportion for Hammer = success proportion without Hammer $H_a$ : success proportion for Hammer > success proportion without Hammer** | **p-value regardless of trend (CLOSE)** | **p-value with downtrend (CLOSE)** | **p-value regardless of trend (LOW)** | **p-value with downtrend (LOW)** |
|---|---|---|---|---|
| **5 Day** | 0.296723 | 0.304 | < 2.2e-16 | 1.859e-11 |
| **7 Day** | 0.6269 | 0.3337 | < 2.2e-16 | 1.671e-14 |
| **10 Day** | 0.877 | 0.4826 | < 2.2e-16 | 1.958e-12 |

*Figure 11.* Tests for proportions for Hammer

3. How high success proportion would be considered effective for a candle

In the preceding analysis we found success proportions for the Shooting Star and Hammer patterns using 5, 7 and 10-days, with and regardless of trends (uptrend in the case of the Shooting star, and downtrend in the case of the Hammer). The analysis showed that the proportion of successes for the Shooting Star was statistically lower than the actual proportion of days that were tops overall, approximately 16,600 days sampled when the CLOSE criterion was used, but statistically higher than the actual proportion of days that were tops overall when the HIGH criterion was used. Likewise the proportion of successes for the Hammer was statistically lower than the actual proportion of days that were bottoms overall with approximately 16,000 days sampled, when the CLOSE criterion was used, but statistically higher than the actual proportion of days that were bottoms overall when the LOW criterion was used. In this section we take a different view and begin by explaining the difference with the previous analysis.

In the previous approach, we looked to detect candle patterns and then find out how successful these patterns were in signaling downturns (tops) in the case of the Shooting Star and upturns (bottoms) in the case of the Hammer. We then compared these results with the overall proportion of days that were tops out of the total number of days in the case of the Shooting Star. The analysis for the Hammer was similar. More specifically, the failure for the Shooting Star can be measured by the frequency of the following scenarios,

1) A top arises, but it is not preceded by the appearance of a Shooting Star
2) A Shooting Star appears but it is not followed by a top

In the previous analysis, by comparing the proportion of Shooting Star success with the proportion of all tops we essentially looked at scenario 1). Proponents of candle strategies may argue that scenario 1) should not be used to dispute technical strategies such as the use of candlesticks. The argument is that a top may or may not be signaled by a candle pattern such as the Shooting Star—and that is fine. However, if a Shooting Star candle is detected, then it is expected to signal a top which corresponds to scenario 2). The argument is that a candle such as a Shooting Star should be assessed on how good the signal is once it appears, since this is due to specific circumstances that make the candle pattern to be created and are the cause of the trend reversal. In some sense then, where a candle appears should be considered "distinguished," or "special." For example, consider, the Shooting Star success proportion for the 5-day regardless of trend and the same for the Hammer, which are respectively $r_1 = 35/161 = 0.217391$ (Table 1) and $r_2 = 88/289 = 0.304498$ (Table 5) when the CLOSE criterion is used. Proponents of candle strategies may argue that these are significant success proportions, against, say other conceivable trading strategies. We show that this is not in fact the case when the CLOSE criterion is used for candles, but that there is strong evidence for significant success proportions when the HIGH criterion is used in the case of the Shooting Star candle and when the LOW criterion is used in the case of the Hammer candle.

The second scenario above suggests that all the instances where the candle pattern appears must be distinguished. So for example in the 5-day regardless of trend, there are 161 appearances of the Shooting Star, and 289 appearances of the Hammer. Proponents of candles would argue that the 161 instances where the Shooting Star appeared and where the 289 instances where the Hammer appeared are distinguished. We show that statistically these signals do not appear at distinguished instances when the CLOSE criterion is used for the candle signal. We randomly selected 161 days out of the total 16,635 days and considered what proportion of them signaled tops to compare against the actual 161 Shooting Star appearances. We repeated this over 50 iterations. Likewise we randomly selected 289, days out of the total 16,635 days and considered what proportion of them signaled bottoms to compare against the actual 289 Hammer appearances, again repeating over 50 iterations. The results are summarized in Appendix B (Table 9 - Table 14) for 5-, 7- and 10-day with CLOSE criterion and HIGH and LOW criteria for the Shooting Star and Hammer respectively.

In this study, we conducted nonparametric tests (permutation tests) for proportions. In the case of the Shooting Star the hypotheses are:

$H_0$: probability that a candle instance detects top = probability that a random instance detects top

$H_a$: probability that a candle instance detects top > probability that a random instance detects top

For the Hammer, the hypotheses are:

$H_0$: probability that a candle instance detects bottom = probability that a random instance detects bottom
$H_a$: probability that a candle instance detects bottom > probability that a random instance detects bottom

In the case where the CLOSE criterion was used, we tested against the worst rate with random signal assignment (minimum success rate) as shown in the highlighted rows of Table 15 and Table 16. Observe that in every case for the Shooting Star and Hammer (5, 7, or 10-day, with trend or regardless of trend), the lowest random placement success ratio is greater than the corresponding candle pattern success ratio. This means that all p-values for the CLOSE criterion are comparable to 0.5 and closer in fact to 1. We see then, using the data in Table 15 and Table 16, that there is no evidence to support the claim that the instance where a Shooting Star or Hammer candle pattern arises is more likely to signal a top or bottom respectively than randomly assigning instances of signals when the CLOSE criterion is used for the candle.

Consider the same study, except now using the HIGH criterion for the Shooting Star, and the LOW criterion for the Hammer. There is good evidence to support the claim that the instance where a Shooting Star or Hammer candle arises is more likely to signal a top or bottom respectively than randomly assigning instances of signals. For evidence to this effect we would ideally like that the candle pattern success ratio be better or at least equal than the best rate with random signal assignment (maximum success rate), which are the highlighted rows in Table 17 and **Error! Reference source not found.**. Observe that this is the case for the Hammer (**Error! Reference source not found.**) in every scenario (5, 7, or 10-day, with trend or regardless of trend). In the case of the Shooting Star (Table 17), this only the case for the 5-day with trend. Nevertheless the success ratios for the Shooting Star with HIGH criterion are comparable to the maximum success ratios with random assignments and are better than every median success ratio for random assignments.

Afterwards, we summarize the test results for comparing the candle success ratios with HIGH criterion for the Shooting Star and LOW criterion for the Hammer. We then test against the corresponding maximum success ratio, median success ratio, and minimum success ratio for the random assignments. Clearly the p-values should decrease as we test against the maximum, median and minimum random assignment success ratios. The results for the Shooting Star are shown in Table 18. We see that the p-value is not significant in any case when testing against the maximum success rate. However the p-value is significant when testing against the median success rate for the 5 and 7 day (with trend or regardless of trend). The Shooting Star does not appear significant when using the HIGH criterion for the 10-day (neither with trend nor regardless of trend).

Table 19 shows the results for the Hammer. We see that the p-value is significant in some cases even when testing against the maximum success rate (e.g. 10-Day with trend) and it is always significant when testing against the median success rate (with trend or regardless of trend).

## SUMMARY

In this work, we have examined various statistical methods to determine if two of the most popular Japanese candlestick patterns, namely Shooting Star and Hammer, have predictive significance.

In our studies, we found out that when using the closing price of the Shooting Star to determine a temporary top (5, 7 or 10 subsequent days), the pattern's reliability was no better than that of using a randomly chosen candle. On the other hand, if we instead use the high price of the Shooting Star as a temporary top, the predictive power was significantly better than when using a randomly chosen candle. A similar outcome occurred with the Hammer pattern. When we used the closing price of the Hammer as a temporary bottom, its predictive power was no better than that of a randomly chosen candle. However, when we selected the Hammer's low as a temporary bottom, the pattern's reliability clearly outperformed that of a randomly selected candle.

Future work may include an application of trading strategies to measure the profitability of the Hammer and Shooting Star candlestick patterns across bullish and bearish patterns. This would involve the incorporation of a performance measure to determine if returns superior to those of the general market can be achieved. This method would allow out-of-sample tests to be performed, which can help measure the predictive ability of the technique.

Additionally, as we only used historical data of the S&P500 index, more studies may be conducted to determine the candles patterns' reliability in other markets such as commodities, interest rates, precious metals or even foreign markets.

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# Appendix A
## Summary of Data used in Statistical Analysis

| | | Number of tops (successes) | Total Number of observations | Proportion of tops (successes) |
|---|---|---|---|---|
| **5 Day** | All days | 3560 | 16635 | 0.214007 |
| | Shooting Star | 35 | 161 | 0.217391 |
| **7 Day** | All days | 2933 | 16631 | 0.176357 |
| | Shooting Star | 27 | 161 | 0.167702 |
| **10 Day** | All days | 2363 | 16625 | 0.142135 |
| | Shooting Star | 17 | 161 | 0.10559 |

*Table 1.* Shooting Star observations vs all days (no signal) regardless of trend CLOSE

| | | Number of tops (successes) | Total Number of observations | Proportion of tops (successes) |
|---|---|---|---|---|
| **5 Day** | All days | 3560 | 16635 | 0.214007 |
| | Shooting Star | 19 | 68 | 0.279412 |
| **7 Day** | All days | 2933 | 16631 | 0.176357 |
| | Shooting Star | 11 | 71 | 0.15493 |
| **10 Day** | All days | 2363 | 16625 | 0.142135 |
| | Shooting Star | 4 | 56 | 0.071429 |

*Table 2.* Shooting Star observations vs all days (no signal) with trend CLOSE

| | | Number of tops (successes) | Total Number of observations | Proportion of tops (successes) |
|---|---|---|---|---|
| **5 Day** | All days | 3560 | 16635 | 0.214007 |
| | Shooting Star | 76 | 161 | 0.47205 |
| **7 Day** | All days | 2933 | 16631 | 0.176357 |
| | Shooting Star | 64 | 161 | 0.397516 |
| **10 Day** | All days | 2363 | 16625 | 0.142135 |
| | Shooting Star | 46 | 161 | 0.285714 |

*Table 3.* Shooting Star observations vs all days (no signal) regardless of trend HIGH

| | | Number of tops (successes) | Total Number of observations | Proportion of tops (successes) |
|---|---|---|---|---|
| **5 Day** | All days | 3560 | 16635 | 0.214007 |
| | Shooting Star | 42 | 68 | 0.617647 |
| **7 Day** | All days | 2933 | 16631 | 0.176357 |
| | Shooting Star | 32 | 71 | 0.450704 |
| **10 Day** | All days | 2363 | 16625 | 0.142135 |
| | Shooting Star | 17 | 56 | 0.303571 |

*Table 4.* Shooting Star observations vs all days (no signal) with trend HIGH

| | | Number of tops (successes) | Total Number of observations | Proportion of tops (successes) |
|---|---|---|---|---|
| **5 Day** | All days | 4936 | 16635 | 0.296724 |
| | Hammer | 88 | 289 | 0.304498 |
| **7 Day** | All days | 4355 | 16631 | 0.26186 |
| | Hammer | 73 | 288 | 0.253472 |
| **10 Day** | All days | 3766 | 16625 | 0.226526 |
| | Hammer | 57 | 288 | 0.197917 |

*Table 5.* Hammer observations vs all days (no signal) regardless of trend CLOSE

| | | Number of tops (successes) | Total Number of observations | Proportion of tops (successes) |
|---|---|---|---|---|
| **5 Day** | All days | 4936 | 16635 | 0.296724 |
| | Hammer | 28 | 87 | 0.321839 |
| **7 Day** | All days | 4355 | 16631 | 0.26186 |
| | Hammer | 24 | 85 | 0.282353 |
| **10 Day** | All days | 3766 | 16625 | 0.226526 |
| | Hammer | 11 | 48 | 0.229167 |

*Table 6.* Hammer observations vs all days (no signal) with trend CLOSE

| | | Number of tops (successes) | Total Number of observations | Proportion of tops (successes) |
|---|---|---|---|---|
| **5 Day** | All days | 4936 | 16635 | 0.296724 |
| | Hammer | 170 | 289 | 0.588235 |
| **7 Day** | All days | 4355 | 16631 | 0.26186 |
| | Hammer | 154 | 288 | 0.534722 |
| **10 Day** | All days | 3766 | 16625 | 0.226526 |
| | Hammer | 128 | 288 | 0.444444 |

*Table 7.* Hammer observations vs all days (no signal) regardless of trend LOW

| | | Number of tops (successes) | Total Number of observations | Proportion of tops (successes) |
|---|---|---|---|---|
| **5 Day** | All days | 4936 | 16635 | 0.296724 |
| | Hammer | 54 | 87 | 0.62069 |
| **7 Day** | All days | 4355 | 16631 | 0.26186 |
| | Hammer | 53 | 85 | 0.623529 |
| **10 Day** | All days | 3766 | 16625 | 0.226526 |
| | Hammer | 31 | 48 | 0.645833 |

*Table 8.* Hammer observations vs all days (no signal) with trend LOW

## Appendix B

| Trend | | | Regardless of Trend | | |
|---|---|---|---|---|---|
| Top | No-Top | Success Proportion | Top | No-Top | Success Proportion |
| 24 | 44 | 0.3529 | 63 | 98 | 0.3913 |
| 25 | 43 | 0.3676 | 59 | 102 | 0.3665 |
| 28 | 40 | 0.4118 | 55 | 106 | 0.3416 |
| 21 | 47 | 0.3088 | 50 | 111 | 0.3106 |
| 26 | 42 | 0.3824 | 55 | 106 | 0.3416 |
| 22 | 46 | 0.3235 | 61 | 100 | 0.3789 |
| 21 | 47 | 0.3088 | 62 | 99 | 0.3851 |
| 28 | 40 | 0.4118 | 63 | 98 | 0.3913 |
| 27 | 41 | 0.3971 | 60 | 101 | 0.3727 |
| 22 | 46 | 0.3235 | 51 | 110 | 0.3168 |
| 27 | 41 | 0.3971 | 61 | 100 | 0.3789 |
| 23 | 45 | 0.3382 | 50 | 111 | 0.3106 |
| 25 | 43 | 0.3676 | 53 | 108 | 0.3292 |
| 22 | 46 | 0.3235 | 61 | 100 | 0.3789 |
| 27 | 41 | 0.3971 | 74 | 87 | 0.4596 |
| 28 | 40 | 0.4118 | 63 | 98 | 0.3913 |
| 27 | 41 | 0.3971 | 68 | 93 | 0.4224 |
| 28 | 40 | 0.4118 | 67 | 94 | 0.4161 |
| 29 | 39 | 0.4265 | 58 | 103 | 0.3602 |
| 30 | 38 | 0.4412 | 66 | 95 | 0.4099 |
| 27 | 41 | 0.3971 | 76 | 85 | 0.4720 |
| 29 | 39 | 0.4265 | 64 | 97 | 0.3975 |
| 34 | 34 | 0.5000 | 61 | 100 | 0.3789 |
| 28 | 40 | 0.4118 | 63 | 98 | 0.3913 |
| 22 | 46 | 0.3235 | 62 | 99 | 0.3851 |
| 27 | 41 | 0.3971 | 64 | 97 | 0.3975 |
| 27 | 41 | 0.3971 | 67 | 94 | 0.4161 |
| 28 | 40 | 0.4118 | 58 | 103 | 0.3602 |
| 26 | 42 | 0.3824 | 65 | 96 | 0.4037 |
| 24 | 44 | 0.3529 | 59 | 102 | 0.3665 |
| 26 | 42 | 0.3824 | 72 | 89 | 0.4472 |
| 31 | 37 | 0.4559 | 52 | 109 | 0.3230 |
| 21 | 47 | 0.3088 | 80 | 81 | 0.4969 |
| 25 | 43 | 0.3676 | 57 | 104 | 0.3540 |
| 24 | 44 | 0.3529 | 67 | 94 | 0.4161 |
| 27 | 41 | 0.3971 | 60 | 101 | 0.3727 |
| 24 | 44 | 0.3529 | 59 | 102 | 0.3665 |
| 24 | 44 | 0.3529 | 57 | 104 | 0.3540 |
| 25 | 43 | 0.3676 | 57 | 104 | 0.3540 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | 24 | 44 | 0.3529 | 68 | 93 | 0.4224 |
| | 23 | 45 | 0.3382 | 64 | 97 | 0.3975 |
| | 29 | 39 | 0.4265 | 62 | 99 | 0.3851 |
| | 23 | 45 | 0.3382 | 59 | 102 | 0.3665 |
| | 30 | 38 | 0.4412 | 70 | 91 | 0.4348 |
| | 28 | 40 | 0.4118 | 58 | 103 | 0.3602 |
| | 29 | 39 | 0.4265 | 64 | 97 | 0.3975 |
| | 30 | 38 | 0.4412 | 58 | 103 | 0.3602 |
| | 31 | 37 | 0.4559 | 63 | 98 | 0.3913 |
| | 34 | 34 | 0.5000 | 64 | 97 | 0.3975 |
| | 26 | 42 | 0.3824 | 60 | 101 | 0.3727 |
| Low | 21 | 47 | 0.3088 | 50 | 111 | 0.3106 |
| High | 34 | 34 | 0.5000 | 80 | 81 | 0.4969 |
| Average | 26.32 | 41.68 | 0.3871 | 61.8 | 99.2 | 0.3839 |
| Median | 27 | 41 | 0.3971 | 61.5 | 99.5 | 0.3820 |

*Table 9.* Iterations Shooting Star (Tops) 5 day

| Trend | | | Regardless of Trend | | |
|---|---|---|---|---|---|
| Top | No-Top | Success Proportion | Top | No-Top | Success Proportion |
| 22 | 49 | 0.3099 | 53 | 108 | 0.3292 |
| 22 | 49 | 0.3099 | 51 | 110 | 0.3168 |
| 21 | 50 | 0.2958 | 57 | 104 | 0.3540 |
| 31 | 40 | 0.4366 | 46 | 115 | 0.2857 |
| 25 | 46 | 0.3521 | 47 | 114 | 0.2919 |
| 20 | 51 | 0.2817 | 40 | 121 | 0.2484 |
| 21 | 50 | 0.2958 | 58 | 103 | 0.3602 |
| 24 | 47 | 0.3380 | 53 | 108 | 0.3292 |
| 26 | 45 | 0.3662 | 47 | 114 | 0.2919 |
| 14 | 57 | 0.1972 | 51 | 110 | 0.3168 |
| 17 | 54 | 0.2394 | 48 | 113 | 0.2981 |
| 24 | 47 | 0.3380 | 54 | 107 | 0.3354 |
| 25 | 46 | 0.3521 | 57 | 104 | 0.3540 |
| 23 | 48 | 0.3239 | 61 | 100 | 0.3789 |
| 22 | 49 | 0.3099 | 49 | 112 | 0.3043 |
| 23 | 48 | 0.3239 | 56 | 105 | 0.3478 |
| 18 | 53 | 0.2535 | 56 | 105 | 0.3478 |
| 18 | 53 | 0.2535 | 55 | 106 | 0.3416 |
| 20 | 51 | 0.2817 | 50 | 111 | 0.3106 |
| 24 | 47 | 0.3380 | 58 | 103 | 0.3602 |
| 23 | 48 | 0.3239 | 48 | 113 | 0.2981 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | 21 | 50 | 0.2958 | 55 | 106 | 0.3416 |
| | 23 | 48 | 0.3239 | 56 | 105 | 0.3478 |
| | 21 | 50 | 0.2958 | 50 | 111 | 0.3106 |
| | 21 | 50 | 0.2958 | 47 | 114 | 0.2919 |
| | 22 | 49 | 0.3099 | 53 | 108 | 0.3292 |
| | 27 | 44 | 0.3803 | 44 | 117 | 0.2733 |
| | 34 | 37 | 0.4789 | 58 | 103 | 0.3602 |
| | 24 | 47 | 0.3380 | 46 | 115 | 0.2857 |
| | 22 | 49 | 0.3099 | 47 | 114 | 0.2919 |
| | 26 | 45 | 0.3662 | 62 | 99 | 0.3851 |
| | 19 | 52 | 0.2676 | 63 | 98 | 0.3913 |
| | 22 | 49 | 0.3099 | 47 | 114 | 0.2919 |
| | 22 | 49 | 0.3099 | 66 | 95 | 0.4099 |
| | 27 | 44 | 0.3803 | 47 | 114 | 0.2919 |
| | 13 | 58 | 0.1831 | 44 | 117 | 0.2733 |
| | 21 | 50 | 0.2958 | 43 | 118 | 0.2671 |
| | 20 | 51 | 0.2817 | 49 | 112 | 0.3043 |
| | 20 | 51 | 0.2817 | 51 | 110 | 0.3168 |
| | 23 | 48 | 0.3239 | 51 | 110 | 0.3168 |
| | 18 | 53 | 0.2535 | 62 | 99 | 0.3851 |
| | 21 | 50 | 0.2958 | 48 | 113 | 0.2981 |
| | 22 | 49 | 0.3099 | 46 | 115 | 0.2857 |
| | 25 | 46 | 0.3521 | 44 | 117 | 0.2733 |
| | 22 | 49 | 0.3099 | 51 | 110 | 0.3168 |
| | 23 | 48 | 0.3239 | 52 | 109 | 0.3230 |
| | 17 | 54 | 0.2394 | 56 | 105 | 0.3478 |
| | 23 | 48 | 0.3239 | 55 | 106 | 0.3416 |
| | 38 | 33 | 0.5352 | 51 | 110 | 0.3168 |
| | 24 | 47 | 0.3380 | 51 | 110 | 0.3168 |
| Low | 13 | 58 | 0.1831 | 40 | 121 | 0.2484 |
| High | 38 | 33 | 0.5352 | 66 | 95 | 0.4099 |
| Average | 22.48 | 48.52 | 0.3166 | 52 | 109 | 0.3217 |
| Median | 22 | 49 | 0.3099 | 51 | 110 | 0.3168 |

*Table 10.* Iterations Shooting Star (Tops) 7 day

84

| Trend | | | Regardless of Trend | | |
|---|---|---|---|---|---|
| Top | No-Top | Success Proportion | Top | No-Top | Success Proportion |
| 18 | 38 | 0.3214 | 53 | 108 | 0.3292 |
| 12 | 44 | 0.2143 | 51 | 110 | 0.3168 |
| 14 | 42 | 0.2500 | 57 | 104 | 0.3540 |
| 22 | 34 | 0.3929 | 46 | 115 | 0.2857 |
| 19 | 37 | 0.3393 | 47 | 114 | 0.2919 |
| 22 | 34 | 0.3929 | 40 | 121 | 0.2484 |
| 14 | 42 | 0.2500 | 58 | 103 | 0.3602 |
| 16 | 40 | 0.2857 | 53 | 108 | 0.3292 |
| 17 | 39 | 0.3036 | 47 | 114 | 0.2919 |
| 9 | 47 | 0.1607 | 51 | 110 | 0.3168 |
| 14 | 42 | 0.2500 | 48 | 113 | 0.2981 |
| 16 | 40 | 0.2857 | 54 | 107 | 0.3354 |
| 11 | 45 | 0.1964 | 57 | 104 | 0.3540 |
| 8 | 48 | 0.1429 | 61 | 100 | 0.3789 |
| 15 | 41 | 0.2679 | 49 | 112 | 0.3043 |
| 19 | 37 | 0.3393 | 56 | 105 | 0.3478 |
| 13 | 43 | 0.2321 | 56 | 105 | 0.3478 |
| 11 | 45 | 0.1964 | 55 | 106 | 0.3416 |
| 14 | 42 | 0.2500 | 50 | 111 | 0.3106 |
| 15 | 41 | 0.2679 | 58 | 103 | 0.3602 |
| 14 | 42 | 0.2500 | 48 | 113 | 0.2981 |
| 20 | 36 | 0.3571 | 55 | 106 | 0.3416 |
| 15 | 41 | 0.2679 | 56 | 105 | 0.3478 |
| 20 | 36 | 0.3571 | 50 | 111 | 0.3106 |
| 15 | 41 | 0.2679 | 47 | 114 | 0.2919 |
| 12 | 44 | 0.2143 | 53 | 108 | 0.3292 |
| 11 | 45 | 0.1964 | 44 | 117 | 0.2733 |
| 18 | 38 | 0.3214 | 58 | 103 | 0.3602 |
| 18 | 38 | 0.3214 | 46 | 115 | 0.2857 |
| 14 | 42 | 0.2500 | 47 | 114 | 0.2919 |
| 20 | 36 | 0.3571 | 62 | 99 | 0.3851 |
| 21 | 35 | 0.3750 | 63 | 98 | 0.3913 |
| 12 | 44 | 0.2143 | 47 | 114 | 0.2919 |
| 15 | 41 | 0.2679 | 66 | 95 | 0.4099 |
| 12 | 44 | 0.2143 | 47 | 114 | 0.2919 |
| 9 | 47 | 0.1607 | 44 | 117 | 0.2733 |
| 13 | 43 | 0.2321 | 43 | 118 | 0.2671 |
| 8 | 48 | 0.1429 | 49 | 112 | 0.3043 |
| 10 | 46 | 0.1786 | 51 | 110 | 0.3168 |
| 15 | 41 | 0.2679 | 51 | 110 | 0.3168 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | 12 | 44 | 0.2143 | 62 | 99 | 0.3851 |
| | 17 | 39 | 0.3036 | 48 | 113 | 0.2981 |
| | 12 | 44 | 0.2143 | 46 | 115 | 0.2857 |
| | 20 | 36 | 0.3571 | 44 | 117 | 0.2733 |
| | 12 | 44 | 0.2143 | 51 | 110 | 0.3168 |
| | 14 | 42 | 0.2500 | 52 | 109 | 0.3230 |
| | 23 | 33 | 0.4107 | 56 | 105 | 0.3478 |
| | 12 | 44 | 0.2143 | 55 | 106 | 0.3416 |
| | 13 | 43 | 0.2321 | 51 | 110 | 0.3168 |
| | 19 | 37 | 0.3393 | 51 | 110 | 0.3168 |
| Low | 8 | 48 | 0.1429 | 23 | 138 | 0.1429 |
| High | 23 | 33 | 0.4107 | 56 | 105 | 0.3478 |
| Average | 14.9 | 41.1 | 0.2661 | 42.64 | 118 | 0.2648 |
| Median | 14 | 42 | 0.2500 | 42 | 119 | 0.2609 |

*Table 11.* Iterations Shooting Star (Tops) 10 day

| Trend | | | Regardless of Trend | | |
|---|---|---|---|---|---|
| Top | No-Top | Success Proportion | Top | No-Top | Success Proportion |
| 33 | 54 | 0.3793 | 142 | 147 | 0.4913 |
| 44 | 43 | 0.5057 | 137 | 152 | 0.4740 |
| 40 | 47 | 0.4598 | 141 | 148 | 0.4879 |
| 48 | 39 | 0.5517 | 135 | 154 | 0.4671 |
| 39 | 48 | 0.4483 | 136 | 153 | 0.4706 |
| 44 | 43 | 0.5057 | 127 | 162 | 0.4394 |
| 43 | 44 | 0.4943 | 150 | 139 | 0.5190 |
| 39 | 48 | 0.4483 | 154 | 135 | 0.5329 |
| 47 | 40 | 0.5402 | 144 | 145 | 0.4983 |
| 37 | 50 | 0.4253 | 136 | 153 | 0.4706 |
| 39 | 48 | 0.4483 | 125 | 164 | 0.4325 |
| 39 | 48 | 0.4483 | 140 | 149 | 0.4844 |
| 35 | 52 | 0.4023 | 132 | 157 | 0.4567 |
| 39 | 48 | 0.4483 | 123 | 166 | 0.4256 |
| 35 | 52 | 0.4023 | 142 | 147 | 0.4913 |
| 47 | 40 | 0.5402 | 130 | 159 | 0.4498 |
| 47 | 40 | 0.5402 | 147 | 142 | 0.5087 |
| 39 | 48 | 0.4483 | 144 | 145 | 0.4983 |
| 45 | 42 | 0.5172 | 136 | 153 | 0.4706 |
| 52 | 35 | 0.5977 | 152 | 137 | 0.5260 |
| 40 | 47 | 0.4598 | 141 | 148 | 0.4879 |
| 46 | 41 | 0.5287 | 135 | 154 | 0.4671 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | 48 | 39 | 0.5517 | 139 | 150 | 0.4810 |
| | 39 | 48 | 0.4483 | 130 | 159 | 0.4498 |
| | 38 | 49 | 0.4368 | 140 | 149 | 0.4844 |
| | 48 | 39 | 0.5517 | 152 | 137 | 0.5260 |
| | 36 | 51 | 0.4138 | 147 | 142 | 0.5087 |
| | 42 | 45 | 0.4828 | 150 | 139 | 0.5190 |
| | 50 | 37 | 0.5747 | 153 | 136 | 0.5294 |
| | 43 | 44 | 0.4943 | 138 | 151 | 0.4775 |
| | 45 | 42 | 0.5172 | 145 | 144 | 0.5017 |
| | 44 | 43 | 0.5057 | 139 | 150 | 0.4810 |
| | 40 | 47 | 0.4598 | 141 | 148 | 0.4879 |
| | 45 | 42 | 0.5172 | 152 | 137 | 0.5260 |
| | 41 | 46 | 0.4713 | 147 | 142 | 0.5087 |
| | 51 | 36 | 0.5862 | 135 | 154 | 0.4671 |
| | 42 | 45 | 0.4828 | 132 | 157 | 0.4567 |
| | 52 | 35 | 0.5977 | 144 | 145 | 0.4983 |
| | 35 | 52 | 0.4023 | 143 | 146 | 0.4948 |
| | 46 | 41 | 0.5287 | 148 | 141 | 0.5121 |
| | 40 | 47 | 0.4598 | 143 | 146 | 0.4948 |
| | 37 | 50 | 0.4253 | 137 | 152 | 0.4740 |
| | 44 | 43 | 0.5057 | 142 | 147 | 0.4913 |
| | 44 | 43 | 0.5057 | 132 | 157 | 0.4567 |
| | 41 | 46 | 0.4713 | 156 | 133 | 0.5398 |
| | 36 | 51 | 0.4138 | 161 | 128 | 0.5571 |
| | 38 | 49 | 0.4368 | 132 | 157 | 0.4567 |
| | 44 | 43 | 0.5057 | 151 | 138 | 0.5225 |
| | 37 | 50 | 0.4253 | 146 | 143 | 0.5052 |
| | 51 | 36 | 0.5862 | 140 | 149 | 0.4844 |
| Low | 33 | 54 | 0.3793 | 123 | 166 | 0.4256 |
| High | 52 | 35 | 0.5977 | 161 | 128 | 0.5571 |
| Average | 42.28 | 44.72 | 0.4860 | 141.28 | 148 | 0.4889 |
| Median | 42 | 45 | 0.4828 | 141 | 148 | 0.4879 |

*Table 12.* Hammer (Bottoms) 5 day

| Trend | | | Regardless of Trend | | |
|---|---|---|---|---|---|
| Top | No-Top | Success Proportion | Top | No-Top | Success Proportion |
| 39 | 46 | 0.4588 | 102 | 186 | 0.3542 |
| 35 | 50 | 0.4118 | 121 | 167 | 0.4201 |
| 30 | 55 | 0.3529 | 135 | 153 | 0.4688 |
| 37 | 48 | 0.4353 | 119 | 169 | 0.4132 |
| 34 | 51 | 0.4000 | 132 | 156 | 0.4583 |
| 44 | 41 | 0.5176 | 125 | 163 | 0.4340 |
| 40 | 45 | 0.4706 | 127 | 161 | 0.4410 |
| 37 | 48 | 0.4353 | 125 | 163 | 0.4340 |
| 37 | 48 | 0.4353 | 131 | 157 | 0.4549 |
| 39 | 46 | 0.4588 | 134 | 154 | 0.4653 |
| 45 | 40 | 0.5294 | 133 | 155 | 0.4618 |
| 33 | 52 | 0.3882 | 130 | 158 | 0.4514 |
| 42 | 43 | 0.4941 | 136 | 152 | 0.4722 |
| 44 | 41 | 0.5176 | 134 | 154 | 0.4653 |
| 33 | 52 | 0.3882 | 131 | 157 | 0.4549 |
| 42 | 43 | 0.4941 | 134 | 154 | 0.4653 |
| 34 | 51 | 0.4000 | 117 | 171 | 0.4063 |
| 37 | 48 | 0.4353 | 129 | 159 | 0.4479 |
| 30 | 55 | 0.3529 | 119 | 169 | 0.4132 |
| 41 | 44 | 0.4824 | 132 | 156 | 0.4583 |
| 37 | 48 | 0.4353 | 126 | 162 | 0.4375 |
| 32 | 53 | 0.3765 | 121 | 167 | 0.4201 |
| 35 | 50 | 0.4118 | 109 | 179 | 0.3785 |
| 34 | 51 | 0.4000 | 127 | 161 | 0.4410 |
| 39 | 46 | 0.4588 | 120 | 168 | 0.4167 |
| 36 | 49 | 0.4235 | 125 | 163 | 0.4340 |
| 38 | 47 | 0.4471 | 126 | 162 | 0.4375 |
| 39 | 46 | 0.4588 | 138 | 150 | 0.4792 |
| 39 | 46 | 0.4588 | 133 | 155 | 0.4618 |
| 45 | 40 | 0.5294 | 124 | 164 | 0.4306 |
| 38 | 47 | 0.4471 | 123 | 165 | 0.4271 |
| 33 | 52 | 0.3882 | 111 | 177 | 0.3854 |
| 37 | 48 | 0.4353 | 123 | 165 | 0.4271 |
| 41 | 44 | 0.4824 | 124 | 164 | 0.4306 |
| 32 | 53 | 0.3765 | 111 | 177 | 0.3854 |
| 35 | 50 | 0.4118 | 130 | 158 | 0.4514 |
| 27 | 58 | 0.3176 | 115 | 173 | 0.3993 |
| 36 | 49 | 0.4235 | 128 | 160 | 0.4444 |
| 37 | 48 | 0.4353 | 128 | 160 | 0.4444 |
| 35 | 50 | 0.4118 | 128 | 160 | 0.4444 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | 40 | 45 | 0.4706 | 137 | 151 | 0.4757 |
| | 34 | 51 | 0.4000 | 132 | 156 | 0.4583 |
| | 35 | 50 | 0.4118 | 127 | 161 | 0.4410 |
| | 32 | 53 | 0.3765 | 112 | 176 | 0.3889 |
| | 39 | 46 | 0.4588 | 117 | 171 | 0.4063 |
| | 37 | 48 | 0.4353 | 129 | 159 | 0.4479 |
| | 34 | 51 | 0.4000 | 130 | 158 | 0.4514 |
| | 34 | 51 | 0.4000 | 128 | 160 | 0.4444 |
| | 40 | 45 | 0.4706 | 123 | 165 | 0.4271 |
| | 39 | 46 | 0.4588 | 124 | 164 | 0.4306 |
| Low | 27 | 58 | 0.3176 | 102 | 186 | 0.3542 |
| High | 45 | 40 | 0.5294 | 138 | 150 | 0.4792 |
| Average | 36.84 | 48.16 | 0.4334 | 125.5 | 163 | 0.4358 |
| Median | 37 | 48 | 0.4353 | 127 | 161 | 0.4410 |

*Table 13.* Hammer (Bottoms) 7 day

| Trend | | | Regardless of Trend | | |
|---|---|---|---|---|---|
| Top | No-Top | Success Proportion | Top | No-Top | Success Proportion |
| 19 | 29 | 0.3958 | 112 | 176 | 0.3889 |
| 20 | 28 | 0.4167 | 104 | 184 | 0.3611 |
| 15 | 33 | 0.3125 | 121 | 167 | 0.4201 |
| 13 | 35 | 0.2708 | 119 | 169 | 0.4132 |
| 16 | 32 | 0.3333 | 120 | 168 | 0.4167 |
| 24 | 24 | 0.5000 | 116 | 172 | 0.4028 |
| 22 | 26 | 0.4583 | 104 | 184 | 0.3611 |
| 23 | 25 | 0.4792 | 120 | 168 | 0.4167 |
| 19 | 29 | 0.3958 | 101 | 187 | 0.3507 |
| 12 | 36 | 0.2500 | 90 | 198 | 0.3125 |
| 22 | 26 | 0.4583 | 104 | 184 | 0.3611 |
| 18 | 30 | 0.3750 | 112 | 176 | 0.3889 |
| 20 | 28 | 0.4167 | 118 | 170 | 0.4097 |
| 24 | 24 | 0.5000 | 111 | 177 | 0.3854 |
| 19 | 29 | 0.3958 | 101 | 187 | 0.3507 |
| 16 | 32 | 0.3333 | 100 | 188 | 0.3472 |
| 19 | 29 | 0.3958 | 106 | 182 | 0.3681 |
| 16 | 32 | 0.3333 | 101 | 187 | 0.3507 |
| 17 | 31 | 0.3542 | 109 | 179 | 0.3785 |
| 15 | 33 | 0.3125 | 104 | 184 | 0.3611 |
| 15 | 33 | 0.3125 | 95 | 193 | 0.3299 |
| 16 | 32 | 0.3333 | 109 | 179 | 0.3785 |
| 16 | 32 | 0.3333 | 104 | 184 | 0.3611 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | 16 | 32 | 0.3333 | 101 | 187 | 0.3507 |
| | 20 | 28 | 0.4167 | 118 | 170 | 0.4097 |
| | 18 | 30 | 0.3750 | 98 | 190 | 0.3403 |
| | 13 | 35 | 0.2708 | 111 | 177 | 0.3854 |
| | 14 | 34 | 0.2917 | 128 | 160 | 0.4444 |
| | 18 | 30 | 0.3750 | 113 | 175 | 0.3924 |
| | 21 | 27 | 0.4375 | 110 | 178 | 0.3819 |
| | 17 | 31 | 0.3542 | 102 | 186 | 0.3542 |
| | 19 | 29 | 0.3958 | 109 | 179 | 0.3785 |
| | 18 | 30 | 0.3750 | 93 | 195 | 0.3229 |
| | 17 | 31 | 0.3542 | 100 | 188 | 0.3472 |
| | 18 | 30 | 0.3750 | 100 | 188 | 0.3472 |
| | 17 | 31 | 0.3542 | 104 | 184 | 0.3611 |
| | 20 | 28 | 0.4167 | 93 | 195 | 0.3229 |
| | 15 | 33 | 0.3125 | 108 | 180 | 0.3750 |
| | 18 | 30 | 0.3750 | 117 | 171 | 0.4063 |
| | 20 | 28 | 0.4167 | 123 | 165 | 0.4271 |
| | 16 | 32 | 0.3333 | 104 | 184 | 0.3611 |
| | 23 | 25 | 0.4792 | 120 | 168 | 0.4167 |
| | 21 | 27 | 0.4375 | 93 | 195 | 0.3229 |
| | 14 | 34 | 0.2917 | 97 | 191 | 0.3368 |
| | 15 | 33 | 0.3125 | 107 | 181 | 0.3715 |
| | 21 | 27 | 0.4375 | 109 | 179 | 0.3785 |
| | 21 | 27 | 0.4375 | 126 | 162 | 0.4375 |
| | 22 | 26 | 0.4583 | 104 | 184 | 0.3611 |
| | 19 | 29 | 0.3958 | 112 | 176 | 0.3889 |
| | 18 | 30 | 0.3750 | 104 | 184 | 0.3611 |
| Low | 12 | 36 | 0.2500 | 90 | 198 | 0.3125 |
| High | 24 | 24 | 0.5000 | 128 | 160 | 0.4444 |
| Average | 18.1 | 29.9 | 0.3771 | 107.7 | 180 | 0.3740 |
| Median | 18 | 30 | 0.3750 | 106.5 | 182 | 0.3698 |

*Table 14.* Hammer (Bottoms) 10 day

## Appendix C

| | | Trend | | | No Trend | | |
|---|---|---|---|---|---|---|---|
| | Shooting Star | 5 Day MA | 7 Day MA | 10 Day MA | 5 Day MA | 7 Day MA | 10 Day MA |
| Candle | Total # of Observations | 68 | 71 | 56 | 161 | 161 | 161 |
| | Total # of Tops detected | 19/68 | 11/71 | 4/56 | 35/161 | 27/161 | 17/161 |
| No Candle (50 random instances of total # of observations) | Total # of Tops detected (lowest instance) | 21/68 | 13/71 | 8/56 | 50/161 | 40/161 | 23/161 |
| | Total # of Tops detected (median instance) | 27/68 | 22/71 | 14/56 | 61.5/161 | 51/161 | 42/161 |
| | Total # of Tops detected (highest instance) | 34/68 | 38/71 | 23/56 | 80/161 | 66/161 | 56/161 |

*Table 15.* Shooting Star (Close) against 50 iterations of random instances

| | | Trend | | | No Trend | | |
|---|---|---|---|---|---|---|---|
| | Hammer | 5 Day MA | 7 Day MA | 10 Day MA | 5 Day MA | 7 Day MA | 10 Day MA |
| Candle | Total # of Observations | 87 | 85 | 48 | 289 | 288 | 288 |
| | Total # of Bottoms detected | 28/87 | 24/85 | 11/48 | 88/289 | 73/288 | 57/288 |
| No Candle (50 random instances of total # of observations) | Total # of Bottoms detected (lowest instance) | 33/87 | 27/85 | 12/48 | 123/289 | 102/288 | 90/288 |
| | Total # of Bottoms detected (median instance) | 42/87 | 37/85 | 18/48 | 141/289 | 127/288 | 106.5/288 |
| | Total # of Bottoms detected (highest instance) | 52/87 | 45/85 | 24/56 | 161/289 | 138/288 | 128/288 |

*Table 16.* Hammer (Close) against 50 iterations of random instances

| | | Trend | | | No Trend | | |
|---|---|---|---|---|---|---|---|
| | Shooting Star | 5 Day MA | 7 Day MA | 10 Day MA | 5 Day MA | 7 Day MA | 10 Day MA |
| Candle | Total # of Observations | 68 | 71 | 56 | 161 | 161 | 161 |
| | Total # of Tops detected | 42/68 | 32/71 | 17/56 | 76/161 | 54/161 | 46/161 |
| No Candle(50 random instances of total # of observations) | Total # of Tops detected (highest instance) | 34/68 | 38/71 | 23/56 | 80/161 | 66/161 | 56/161 |
| | Total # of Tops detected (median instance) | 27/68 | 22/71 | 14/56 | 61.5/161 | 51/161 | 42/161 |
| | Total # of Tops detected (lowest instance) | 21/68 | 13/71 | 8/56 | 50/161 | 40/161 | 23/161 |

*Table 17.* Shooting Star (High) against 50 iterations of random instances

| | | Trend | | | No Trend | | |
|---|---|---|---|---|---|---|---|
| | Hammer | 5 Day MA | 7 Day MA | 10 Day MA | 5 Day MA | 7 Day MA | 10 Day MA |
| Candle | Total # of Observations | 87 | 85 | 48 | 289 | 288 | 288 |
| | Total # of Bottoms detected | 54/87 | 53/85 | 31/48 | 170/289 | 154/288 | 128/288 |
| No Candle (50 random instances of total # of observations) | Total # of Bottoms detected (highest instance) | 52/87 | 45/85 | 24/56 | 161/289 | 138/288 | 128/288 |
| | Total # of Bottoms detected (median instance) | 42/87 | 37/85 | 18/48 | 141/289 | 127/288 | 106.5/288 |
| | Total # of Bottoms detected (lowest instance) | 33/87 | 27/85 | 12/48 | 123/289 | 102/288 | 90/288 |

*Table 18.* Hammer (low) against 50 iterations of random instances

<table>
<tr><td colspan="2" rowspan="2">$H_0$: probability that a candle instance detects top = probability that a random instance detects top<br><br>$H_a$: probability that a candle instance detects top > probability that a random instance detects top</td><td colspan="3">Trend</td><td colspan="3">No Trend</td></tr>
<tr><td>5 Day MA</td><td>7 Day MA</td><td>10 Day MA</td><td>5 Day MA</td><td>7 Day MA</td><td>10 Day MA</td></tr>
<tr><td>Candle</td><td>Total # of Tops detected</td><td>42/68</td><td>32/71</td><td>17/56</td><td>76/161</td><td>54/161</td><td>46/161</td></tr>
<tr><td rowspan="6">No Candle (50 random instances of total # of observations)</td><td rowspan="2">Total # of Tops detected (highest instance)</td><td>34/68</td><td>38/71</td><td>23/56</td><td>80/161</td><td>66/161</td><td>56/161</td></tr>
<tr><td>p=0.0622</td><td>p=0.7999</td><td>p=0.8318</td><td>p=0.6315</td><td>p=0.5527</td><td>p=0.8564</td></tr>
<tr><td rowspan="2">Total # of Tops detected (median instance)</td><td>27/68</td><td>22/71</td><td>14/56</td><td>61.5/161</td><td>51/161</td><td>42/161</td></tr>
<tr><td>p=0.0019</td><td>p=0.0265</td><td>p=0.2134</td><td>p=0.0452</td><td>p=0.0225</td><td>p=0.2633</td></tr>
<tr><td rowspan="2">Total # of Tops detected (lowest instance)</td><td>21/68</td><td>13/71</td><td>8/56</td><td>50/161</td><td>40/161</td><td>23/161</td></tr>
<tr><td>p=0.0001</td><td>p=0.0001</td><td>p=0.0165</td><td>p=0.001</td><td>p=0</td><td>p=0.0001</td></tr>
</table>

*Table 18.* Shooting star (high) against 50 iterations of random instances: Tests for probability of a successful Hammer instance is greater than a probability of success for a random signal instance when using the high criterion for the Shooting Star

| $H_0$: probability that a candle instance detects bottom = probability that a random instance detects bottom<br>Ha: probability that a candle instance detects bottom > probability that a random instance detects bottom | | Trend | | | No Trend | | |
|---|---|---|---|---|---|---|---|
| | | 5 Day MA | 7 Day MA | 10 Day MA | 5 Day MA | 7 Day MA | 10 Day MA |
| Candle | Total # of Bottoms detected | 54/87 | 53/85 | 31/48 | 170/289 | 154/288 | 128/288 |
| No Candle (50 random instances of total # of observations) | Total # of Bottoms detected (highest of 50 instances) | 52/87 | 45/85 | 24/56 | 161/289 | 138/288 | 128/288 |
| | | p=0.4408 | p=0.0777 | p=0.0494 | p=0.5644 | p=0.0806 | p=0.4634 |
| | Total # of Bottoms detected (median of 50 instances) | 42/87 | 37 | 18/48 | 141/289 | 127/288 | 106.5/288 |
| | | p=0.0001 | p=0.004 | p=0.0021 | p=0.0054 | p=0.0091 | p=0.0377 |
| | Total # of Bottoms detected (lowest of 50 instances) | 33/87 | 27/85 | 12/48 | 123/289 | 102/288 | 90/288 |
| | | p=0 | p=0 | p=0 | p=0 | p=0 | p=0.0004 |

*Table 19.* Hammer (low) against 50 iterations of random instances: Tests for probability of a successful Hammer instance is greater than a probability of success for a random signal instance when using the low criterion for the Hammer candle