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CHAPTER 1: INTRODUCTION

The advent of machine learning has transformed our current technological landscape. Technology has allowed humans to make rational decisions on whether to buy or sell financial instruments. Backtesting is one such method and offers intriguing possibilities.

What is Backtesting?

Backtesting is the process of testing the effectiveness of a trading strategy through the use of historical data. Backtesting is founded upon the premise that securities, historically, move in relatively similar patterns. Given market trends, traders employ backtests to forecast economic movements and assess the risk of their strategies. Backtests allow traders to solidify their convictions and make informed, calculated decisions.

In order to assess the validity of trading strategies, backtests examine not only profitability and risk but also volatility, return, and market exposure, as shown in Figure 1. Backtests attempt to ensure that traders incur greater wins than losses by issuing profitable exit and entry signals. They establish lucrative dynamics because they are founded upon the basis that historically ineffective trades are likely to yield similar results. Equally, past trades that rendered profit may have similar outcomes, too. This dichotomy allows for the opportunity for traders to make profits, an exciting prospect.

> **Common Backtesting Measures**
>
> **Volatility** - A measure of variance of a trading price over a period of time
> **Return** - Gain or loss on an investment over a specified period of time
> **Risk-Adjusted Return** - Financial performance, or return, adjusted for risk
> **Market Exposure** - The amount invested in a particular market sector or industry
>
> **Figure 1**

An effective backtester will analyze trading strategies like market trends, swings, and conditions. Traders will understand the expected market movements, which provides certainty around their trading approach. Movements are anticipated from the following:

(1) Economic Events (**news**-driven triggers)
(2) Price Movements (**price**-driven triggers)
(3) External News Resources and Events

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When coupled with various triggers (macro news, price action, external events, etc.) and market reactions, backtesting strategies allow traders to optimize other metrics like stop losses, profit targets, duration of trades, and volatility, among others.

From the aforementioned movements, backtesting programs can construct risk/reward ratios for each trade. Ratios can be continuously kept profitable by the implementation of stop losses. If rewards far outweigh the risk, traders may have their strategies supported or contradicted, with both scenarios providing valuable information. When they use their trade plans in tandem with the historical market data provided by backtesters, traders may effectively revise their strategies for the future based on past market conditions. Although past performance cannot be used to predict future results, historical market reactions provide a systematic approach for traders to test and analyze their strategies.

While traders utilize and implement the analysis provided by backtests, the backtester itself is constructed by programmers. They perform simulations on instruments (stocks, bonds, ETFs, currencies, and commodities) to assess market movements and returns. An effective backtesting model has a representative sample of instruments and, oftentimes, requires a census of all economic events. The created backtester will ideally identify trends in the data such as correlations between economic releases or market movements and bullish/bearish patterns. The backtester may also be coded to identify patterns using key level zones, support and resistance levels, trendlines, and Fibonacci retracements. Signals the backtester produces ultimately go through rigorous tests to determine their statistical validity. A specialized backtester will conduct the required market analysis, which optimizes the time spent by traders and analysts.

> **Key Idea**
>
> **"Signals the backtester produces, ultimately, go through rigorous tests to determine their statistical validity."**
>
> **Figure 2**

The strategies a backtester uses to issue signals can be generated from historical data using a training and test set. The training set is constructed of data divided over a specific period; on the other hand, the test set consists of slightly fewer data points over a more recent period of time. The trading strategy may be hypothesized by using only the training set. Then, the strategy will be applied to the test set to view its effectiveness.

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If the strategy produces a portfolio with a profit over time, then the strategy is effective. This process of simulating historical data to generate equity curves is a common way to backtest and evaluate the effectiveness of a strategy.

What is an Equity Curve?

An equity curve is a graphical representation of the financial performance of a trading account over time. Moving averages may be applied to a trader's equity curve. A common rule is to stop trading if the equity curve falls below the moving average. Once the curve is above the moving average, traders may resume.

Backtesting platforms allow traders to see a visual representation of their equity curve for each implemented strategy. A sample equity curve is shown below:
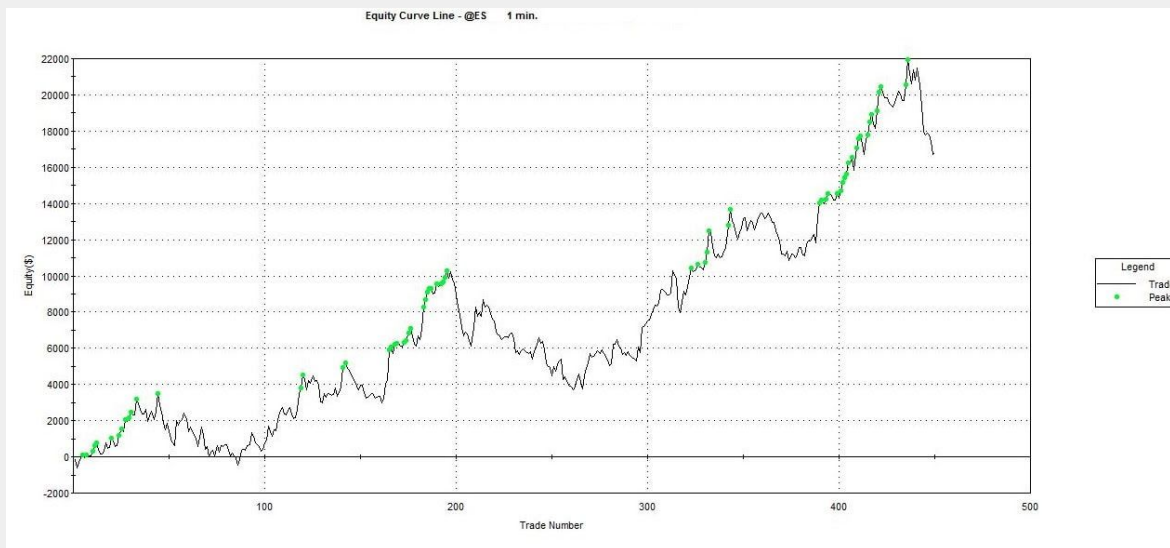

Figure 3

In a study conducted by Seeking Alpha, researchers devised a backtesting strategy given the following funds: IVE, IVW, IJK, and IJJ. They constructed countless algorithms in an attempt to outperform the S&P 500 Index, a standard benchmark for the success of the market. The rules of the algorithm they found particularly effective was to invest, during each month, in two out of the four funds that achieved the highest 3-month performance. This algorithm is their trading strategy. The development of a strategy typically begins with an idea of the future conditions of a market. This idea is stress tested against past market conditions using a backtest. If the strategy proves futile, traders will stress test another strategy. If there is both low volatility and risk associated with a given strategy, traders may choose to implement it. The program would

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automatically set stop-losses and profit targets throughout the course of the study. The backtested model, as shown in green in Figure 3, resulted in cumulative returns of 267.11% since 2000. This strategy outperformed the S&P 500, which has cumulative returns of 143.45% since 2000 and is shown in blue. Intuitively, by analyzing historical results, **backtesting software grants traders the ability to make informed decisions about a future market.**

Figure 4
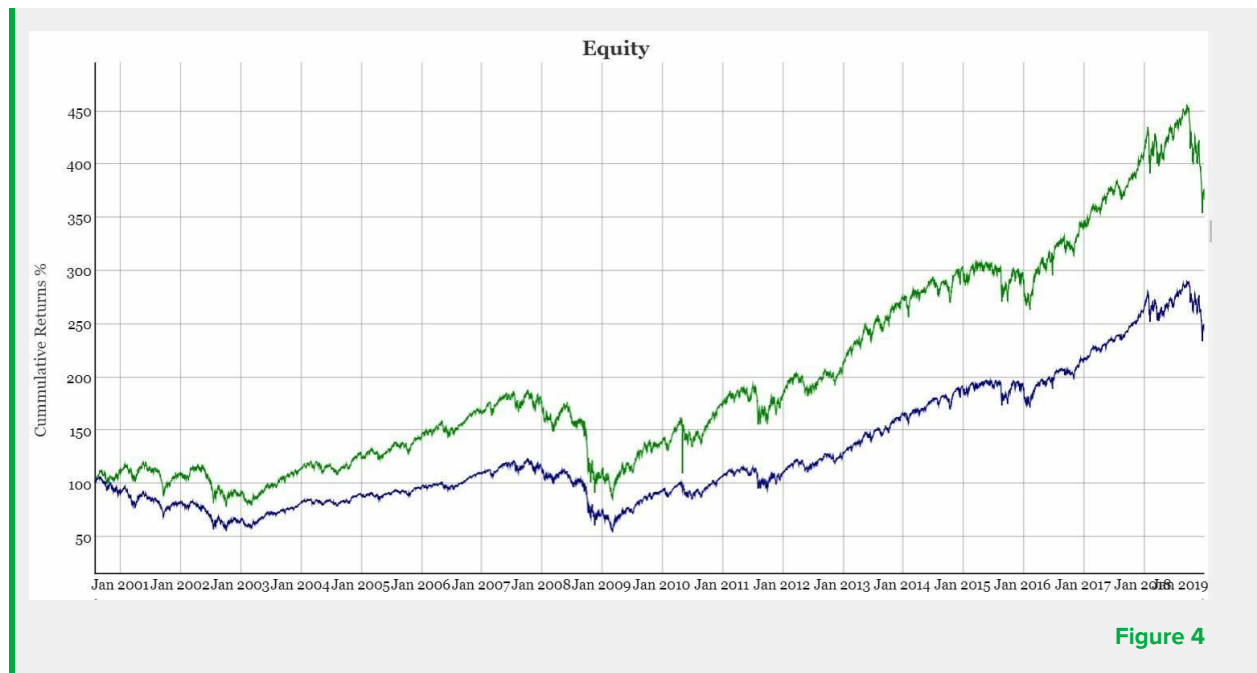
Why Do Traders Perform Backtests?

Historically, backtests have been performed by institutional traders, money managers, and investment companies. These investors have high amounts of capital to construct backtesting models and develop their strategies. They backtest to estimate and mitigate risk. However, backtesting technology has recently become accessible to retail traders.

Backtesting is a form of validation to prove to traders that their strategies have been historically effective. In turn, their confidence may rise after experiencing positive results. Even during periods of losses or economic downturn, backtesting may inspire confidence due to profits in the long-term, **which makes backtesters both physical and psychological tools.** Traders will acknowledge yet endure short-term losses, as their proven, backtested strategies will render profits over time. **Those who backtest have an**

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advantage over those who completely disregard historical fluctuations or information from other avenues like economic reports.

   Backtesting is an effective mechanism to filter out emotion while trading. Oftentimes, our opinions on market movements are driven by personal biases. An academic journal article written by researchers of Claremont Graduate University found that traders exhibited elevated dopamine levels while trading. Backtesting allows us to ground our opinions in concrete data and follow a systematic process. Subsequently, traders may accurately follow signals without an inherent personal bias to forge informed decisions.

The Dunning-Kruger Effect

   Although backtesting may not confirm results or profits, testing from historical data may serve as a validation tool for traders. The division between confirmation and validation is best visualized by the Dunning-Kruger Effect, which is shown in Figure 5. This effect measures a person's competence against the confidence of their competence or ability. Those with low competence are expected to have high confidence. This seemingly paradoxical relationship was understood by researchers from Cornell University who coined the phrase "inflated self-assessments." A steep decline follows the peak level of confidence, which may be symbolic of a large loss in trading. However, once a person reaches an average level of competence, the person's confidence level is positively correlated with their competence level. The Dunning-Kruger Effect applies to backtesting in the sense that those who wholeheartedly rely on backtests for their trades may experience high volatility in their results; in short, they have a low competence but high confidence in the system. Those who validate their assessments with a backtester, as well as understand the statistics behind it, on the other hand, may reap the rewards. Ultimately, they may earn the status of an "expert" trader.
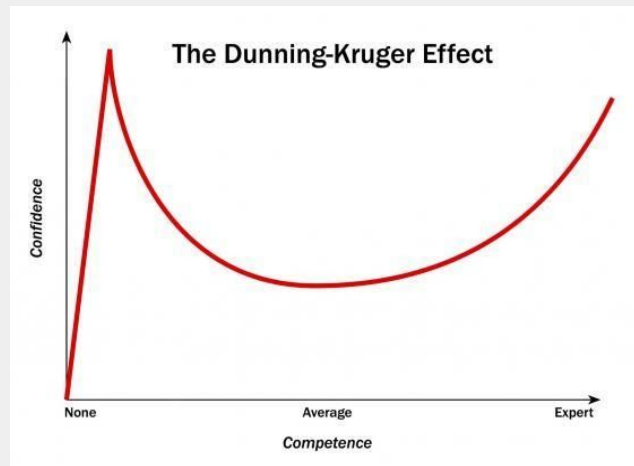
The Dunning-Kruger Effect

Figure 5

Backtester Components

Internal backtesting systems often have core similarities in terms of components. The five most prominent components of backtesting modules are explained in this section.

(1) Data Handler

A data handler is essentially a master database of historical and live market data. The interface contains data on financial securities such as stock and futures prices. The data must be live, as even the slightest pip movement may alter the backtester's recommendations.

Common database systems include PostgreSQL, MySQL, and SQL, as well as HDF5 for storing larger files. These systems store tick data, which are upward and downward movements in price levels by the pip, and bid-ask spread information, which is the amount that the asking price exceeds the bidding price. Advanced data handlers take into account dividends and forward and backward adjusted stock prices. In order to limit survivorship bias, which is discussed in Chapter 3, data handlers must include delisted securities. Once the data is compiled, the time zones of the exchanges must be verified and standardized.

(2) Entry Event Generator

An entry event is a signal generated based on market data, news, or additional sources. Once new information is received from the data handler, the coded prediction mechanism produces trading signals. For example, the system may recommend

purchasing the S&P 500 Index, which classifies as an entry event. In doing so, the prediction mechanism will perform an optimization to limit risk and minimize cost. The backtester may have a risk management system to dismiss signals under specific circumstances. An example of a dismissal parameter the system might consider is a pre-defined level of bid-ask spread width, which could increase the execution costs and limit traders' ability to quickly exit a position.

(3) Strategy

Backtester providers typically construct a system that offers the ability to connect with multiple data sources. The strategy, which is comparable to the brain of the system, encompasses the core rules that traders use to trade and test. In order to provide realistic estimated returns, the backtester must consider fees and slippage of trade execution prices, among other scenarios.

(4) Result Metrics

In order to generate a robust trading infrastructure, several performance metrics must be identified and examined. Backtest programs often have live indicators of the values of these metrics, which are generated from the three prior backtesting components. These metrics can help traders analyze their performance and decide whether to execute trades. The explanations of the key result metrics are described below in Figure 6.

Key Metrics Explanations

General:

PnL - The profits and losses of a trader in a given portfolio

Stop Loss - An instruction to sell an asset once it reaches a particular price point

Entry Price - The price at which a trader buys an asset

Profit Target - An instruction to exit a trade once it reaches a particular price point

Trade Duration - The total duration of a trade, which includes the trade's time unit

Max Drawdown - The maximum loss from a peak

Reward-Risk Ratio - The reward of a trade per unit of change of maximum risk

Advanced:

Average Latency - The time for a market data system to collect information

Alpha - Measures a given stock's performance relative to a benchmark index

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Beta - Measures a given security's correlation to the market

Benchmark Comparison - The standard performance of securities

Cost per Trade - The amount a broker charges per trade

Figure 6

(5) Optimization Model

An optimization model defines the ideal parameters to utilize for a trading strategy. Optimization is conducted on the signal to entry (triggers) and the execution, which consists of the stop loss, time in the market, and profit targets, among other metrics shown in Figure 6. Backtesting platforms conduct optimization to tune each variable to identify the most profitable and sustainable combinations. For instance, a trader may find that trading at 10 A.M. is particularly effective. However, the trader wants to optimize the profits gained, so the person backtests all possible times that the market is open. The backtester may discover that the ideal time to trade under the person's particular strategy is 11 A.M., in fact. The trader has effectively tuned and optimized the time variable through the use of a backtester. The model could optimize many internal variables of the execution strategy. This is a very simplistic example and is provided strictly to illustrate the concept of optimization. When optimization is run on all possible variables (time of day, stop loss, profit targets, etc.) to generate a model, the tuned variables increase the liquidity of trades and maximize the trader's efficiency.

CHAPTER 2: WHICH STRATEGIES CAN BE BACKTESTED?

In this section, we explore the types of strategies that can be backtested to deliver value to traders. We will differentiate the following triggers for backtesting strategies:

(1) **News**-driven triggers - a prescheduled economic event as a trigger for trades.
(2) **Price**-driven triggers - a price movement in one market triggering a move in the same or another market.
(3) External news - an unscheduled, unexpected piece of news that triggers a trade.

Economic Events (News-Driven Triggers)

Economic events are accessible through an economic calendar, a tool that tracks worldwide economic events released by government agencies. The economic calendar is repeatedly updated through live feeds and provides pure statistics of the event without ancillary analysis. Government agencies' release of data has a profound impact on the Foreign Exchange (or Forex) Market, which determines the exchange rates for currencies across the globe. Events are scheduled in advance, whether it be speakers of the Federal Open Market Committee or of government councils. Traders, therefore, have access to the same information as large investment companies and trading firms. They may analyze economic indicators to evaluate their impact on movements in the Forex market.

In order to effectively analyze economic events, traders must be able to read economic calendars. An example of an economic calendar is shown below in Figure 7. The calendar shows all the details of the release from the release time to the country and currency that this event belongs to. Each economic event is ranked in terms of importance and volatility as a first, second, or third tier event. Third tier (!!!) data are the most important and frequently monitored by traders, as they have the highest potential impact on the currencies and commodities market for the particular country. Traders can leverage this market reaction to make profitable trading decisions. Many economic calendars have an option to filter economic data, so traders may choose to view only tier three data. Economic calendars will automatically update the actual values of the events. If there is a deviation from the actual and expected release values, traders can capitalize on the volatility in the Forex and Futures markets to make a profit. To learn more about economic events, reference this eBook.

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Event from Economic Calendar

Prev (previous) - the value of the economic events from a previous release.

Exp (expected) - the expected value of the economic event and is based on the previously released data.

Actual - the actual, updated value of the economic event.

Figure 7

Traders can evaluate economic reports to generate a return by analyzing the expected and actual release values. For Manufacturing PMI in the United States, as shown in Figure 7, the expectation is 48.0 and the actual number is 49.6. Many tend to believe that an increase of 1.6 is relatively insignificant. However, the expectation for this event is accurate on a regular basis. This deviation by 1.6 is unexpected and constitutes a magnitude of surprise of **Much Stronger**.

Given the deviation, traders must be able to identify instruments and markets to trade. Backtesters can allow traders to test historical outcomes for similar United States Manufacturing PMI releases and evaluate the impact on other instruments like oil and gold. The live newsfeed of economic events can be stored in the backtester's data handler. Given certain economic releases and forecasts, the backtester can provide traders with historical results after certain events. For example, given a magnitude of surprise of **Much Stronger** for the United States Manufacturing PMI, the backtester may notify traders that 8 out of 10 times the EUR/USD increased following this event. The backtester will generate a news-driven trade idea for EUR/USD with a historical success

ratio. The backtester's strategy tools will then develop the risk/reward ratio, profit target, and stop loss recommendations to determine both worthwhile and unreasonable trades.

Traders find economic events enticing because of their volatility and correlation with various asset classes such as currencies. Effective backtesters can analyze economic calendars for traders and provide them with robust analysis of the Forex market.

Backtesting can be done either by programming in python, other coding languages, or by using user interface products like BetterTrader's backtesting system. These preprogrammed tools are limited in comparison to self-programmed software, but they are readily available and do not require knowledge of coding. To further explore news-driven triggers, read this case study on the unemployment rate and its effect on the S&P 500.

Price Movements (Price-Driven Triggers)

The concept of leading and following markets can be applied to generate price-driven triggers for market instruments. The movement of the following market directly correlates, either positively or negatively, with the movement of the leading market. For example, oil may be the leading market for the S&P 500, which is the following market. If the price of oil dramatically rises, traders may expect the price of the S&P 500 Index to rise, too. Therefore, a rise in oil prices presents traders with an opportunity to purchase the S&P 500 and earn profits. Instead of presuming the direction of the S&P 500, traders can conduct an educated analysis of oil prices.

Traders gain a competitive trading edge by analyzing price-driven triggers. However, the role of the leading and following markets are often ambiguous; oil prices do not always positively correlate with the S&P 500. In fact, the S&P 500 can be the leading market and oil the following market in certain situations, or the two variables can have no correlation at all. For any given leading market, there may be multiple following markets. Backtesting allows traders to discover statistically significant relationships and correlations between leading and following markets. For example, given that the S&P 500 moved up 30 points during the last fifteen times that oil moved up by $1.5, if the S&P 500 moves up by 30 points, then it is beneficial for traders to analyze the price of oil. Backtesters analyze these price movements of market instruments and generate informed trade ideas. Similar to price-driven trade ideas, the backtester generates a

risk/reward ratio, profit target, stop loss for each leading and following market relationship that it identifies.

> **Key Idea**
>
> **"Traders gain a competitive trading edge by analyzing price-driven triggers."**
>
> **Figure 8**

Traders do not have to predict price movements. Trading the follower can give traders a competitive edge. Instead of trying to simply trade oil or the S&P 500, traders can identify a correlation between two instruments, one of which is the lagging market and reacts slower than the leading. Then, trades become substantially easier because traders are following proven historical techniques. The idea of a backtester is to signal over time when trades work and when they stop to work. Automated tools can identify multiple following markets and notify traders when there is no longer a statistical relationship between two variables.

External News Resources and Events

Twitter has become a medium for influential people to share their opinions on markets and world events. Their opinions may cause short-term positive or negative spikes in the market. For example, a study conducted by *Barron's* found that days where Donald Trump tweeted more than 35 times correlated with downtrends for the S&P 500. Following its slight falls, the market tends to recover and produce slight gains. This concept of unexpected volatility is illustrated in Figure 9. As shown in Figure 10, on days where Trump tweets more than twenty times, the S&P 500 experiences an average daily loss of 0.03%. After a ten-day period, the market recovers and experiences an average gain of roughly 0.21%. Trump's tweets about tariffs and the United States Federal Reserve cause the market to fall exponentially higher than other subjects. Correlation should not be mistaken for causation, as there could be confounding variables that lead to the fall of the S&P 500. Kristina Hooper, a chief market strategist for Invesco, believes that Trump's tweets are "in the same category as economic data and other daily news." While traders should consider Trump's tweets, Hooper does not believe that the traders should focus on the volatility that follows.

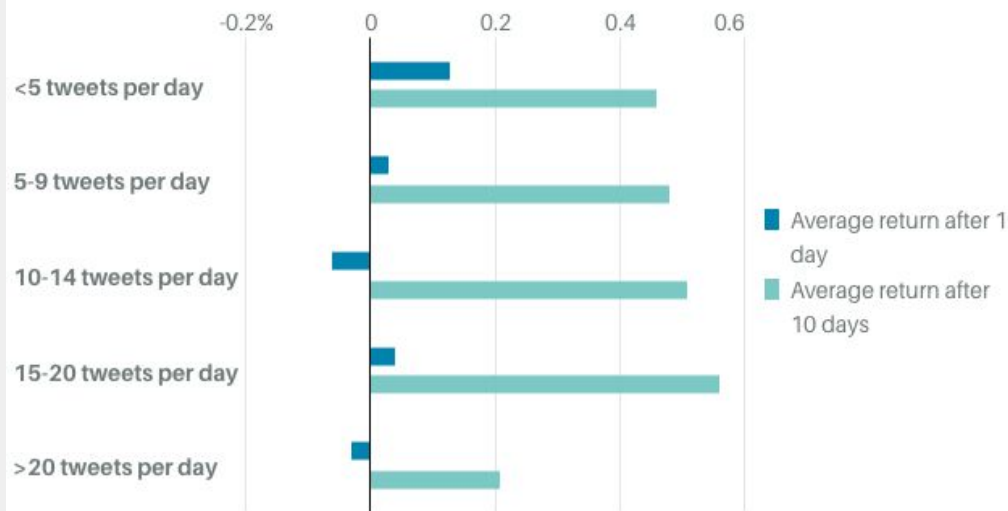**Unexpected Volatility Following Donald Trump's Tweet**

Figure 9

Donald Trump's Tweets and the S&P 500

Source: *Barron's*

Figure 10

In recent news, Elon Musk tweeted that he believed the Tesla stock price was too high, as seen in Figure 11. Subsequently, Tesla's share price fell as much as 12%. External news sources like Twitter can have an extensive impact on market conditions. Other influential Twitter sources besides Trump and Musk include Finance News, Bloomberg Markets, Holger Zschaepitz, Saxo Bank, and John J. Handy. Backtesting platforms can create a live Twitter feed so that traders may analyze tweets in real-time. BetterTrader's Twitter Scanner gives traders voice customized notifications on nonscheduled news that can impact the markets.

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Elon Musk's Tweet

Elon Musk ✓
@elonmusk

Tesla stock price is too high imo

8:11 AM · May 1, 2020 · Twitter for iPhone

Figure 11

CHAPTER 3: BACKTESTING PITFALLS

When attempting to backtest their strategies, traders may experience common pitfalls that skew their data, forgoing potential gains or experiencing losses. To avoid skewed data, backtests must preemptively adjust for non-material data points which skew the larger data set.

Expected Value

The expected value should not be the sole variable used to describe a set of data. Instead, traders should also focus on volatility, skew, and max drawdown. An article written by The Wall Street Journal analyzed the average monthly percentage change for the Dow Jones Industrial Average and found that the index has the lowest average return in the month of September. Although the article insinuates that traders should short the index during September, the distribution in Figure 10 demonstrates that the index performs only marginally worse. The dichotomy between the Wall Street Journal's implication and the true value of the distribution reveals the futility of only considering one dimension of a data set. Backtesting models must take into account all metrics including standard deviation and the Sharpe ratio. Some backtesters allow traders to visualize distributions, which would mitigate the aforementioned scenario and potential losses.

The Wall Street Journal (WSJ) Graphic

Figure 10
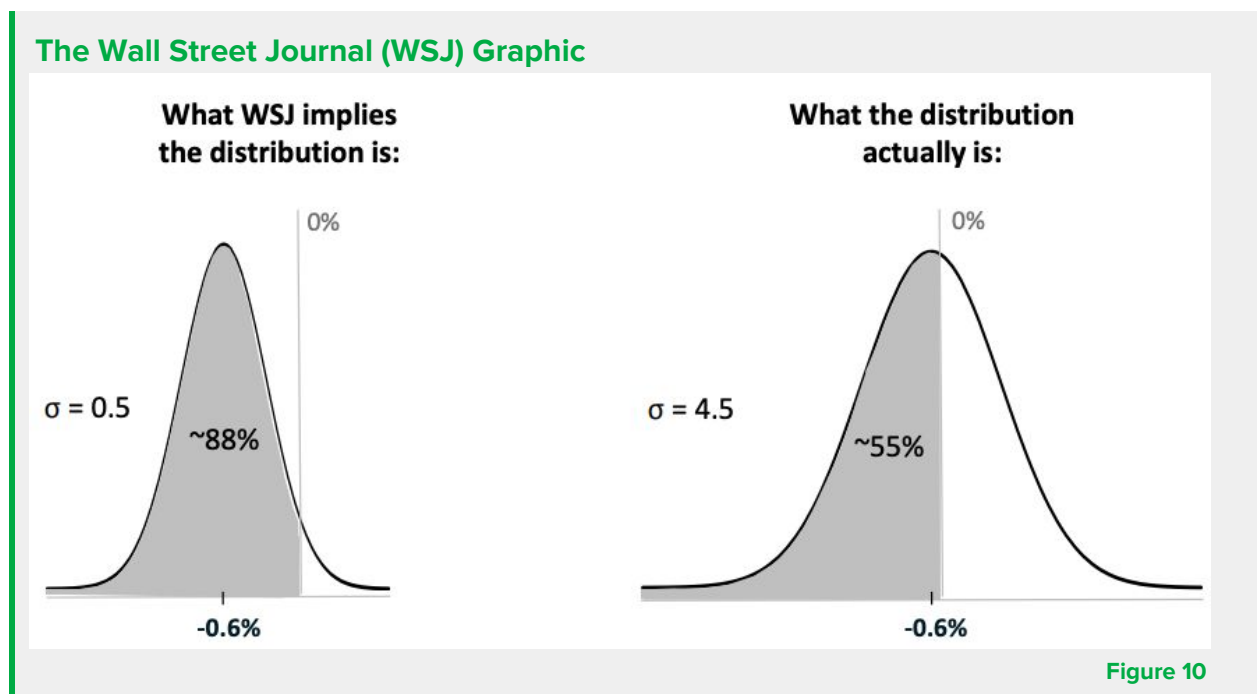
Survivorship Bias

Survivorship bias occurs when data from failed companies are excluded from a backtest. Over time, companies with consistent access to investor capital (debt or equity) are likely to stay afloat, whereas companies without such access are more prone to failure. Backtesting with successful companies may positively skew results and artificially inflate returns. For example, the S&P is continuously rebalanced. The companies that comprised the S&P in 2005 are not the same companies that are in the S&P today. In addition, mutual funds are also rebalanced over time because some companies experience poor performance. In order to mitigate survivorship bias when backtesting the S&P or mutual funds, the backtesting program will have to account for changes in all companies that once existed in the funds. In doing so, traders will conduct a holistic analysis of the instruments and limit survivorship bias.

Correlation vs. Causation

Correlation does not imply causation. Causation can only be established through perfect isolation of relevant variables. Accordingly, economic/financial analysis precludes determination of causation due to the impossibility of perfectly isolating variables. Assuming that correlation implies causation can lead to negative returns for traders. An example of a false correlation can be found in the Rolling Stone Magazine article that plotted rock music quality alongside the United States oil production (Figure 11). The two

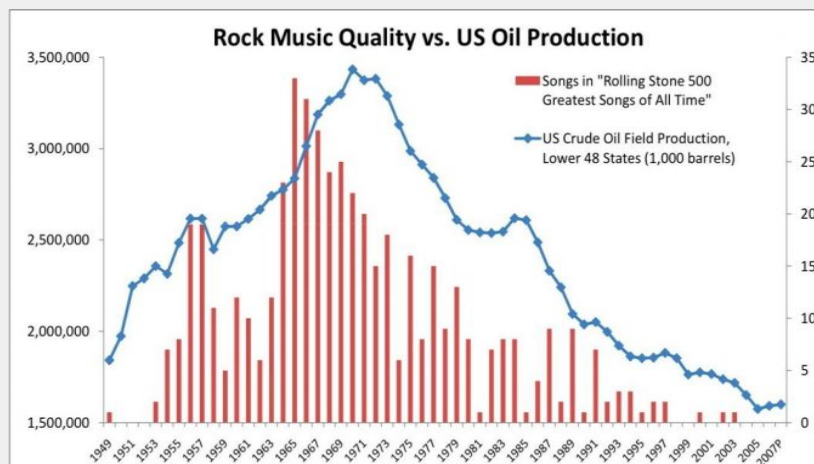**Rolling Stone Magazine Graphic**

Figure 11

variables appear to be correlated with each other, but the confounding variables reveal that there is no direct relationship between the two variables. Ultimately, backtesting software must undergo significant testing to verify statistical significance of apparent correlations.

Unrepresentative Time Period

Backtesting must be completed on data from a time period that is reflective of the current environment. Additionally, large sample sizes are required to be representative of the environment. For instance, if data is primarily selected from recessionary periods, results will not represent general market conditions. Conversely, data which is primarily selected from periods of economic growth may positively skew results. For example, Figure 12 shows the Barclays PLC 5-Year Stock Price. If a backtester implemented a strategy using a sample of data points from February to March of 2020, the strategy would be falsely understood as incredibly efficient. However, data points before February of 2020 are volatile and decline in price. Backtesting programs can bypass selecting an unrepresentative time period by collecting a simple random sample of points. A simple random sample limits inherent bias from the selection process and ensures that the strategy is performed on a representative sample of points. The strategy will then be applied an ample amount of times on many different samples of data to determine its effectiveness.

Barclays PLC 5-Year Stock Price

Figure 12

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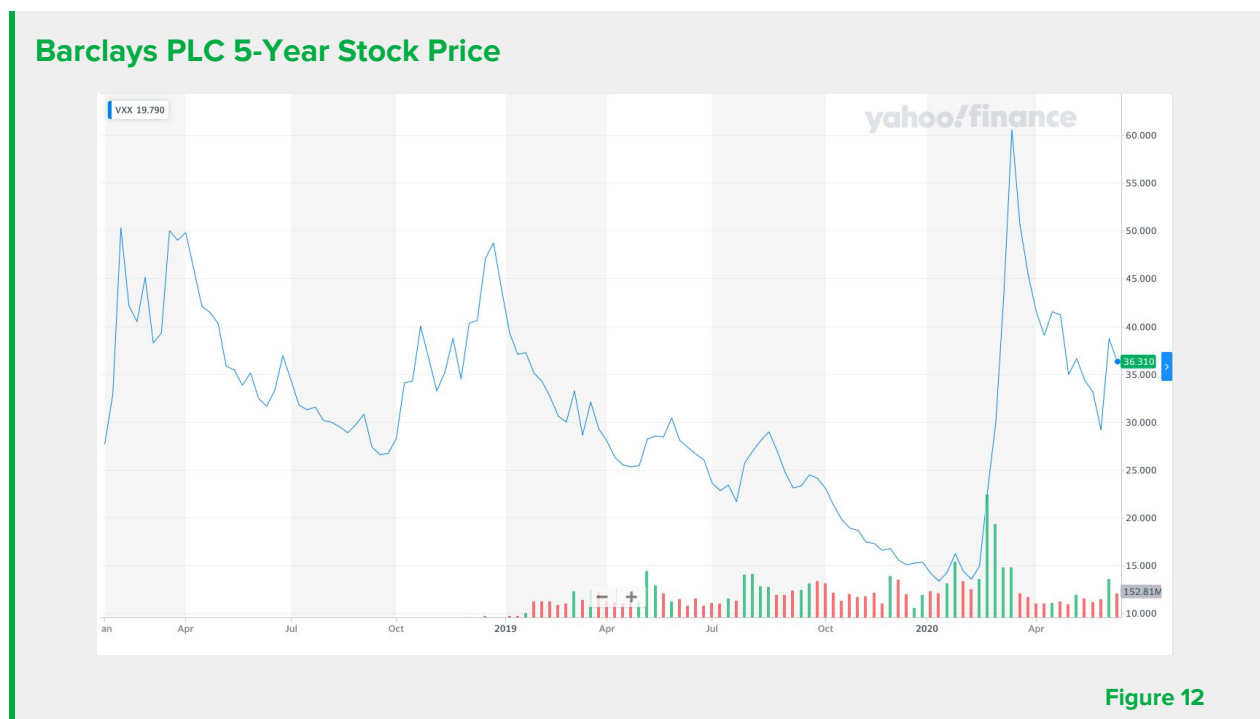
Outliers

Outliers must be properly accounted for. If outliers are representative of the current time period, then they must be included in the backtest. If outliers are not representative of the current time period, then they may be excluded from the backtest. This distinction is particularly important because including a non-representative data point or excluding a representative data point can skew results. Outliers are typically non recurring events that have significant impacts on residual plots. Backtesters may be able to test how representative the sample of data points is by eliminating the outliers and observing changes.

Overfitting and Data Mining

Overfitting occurs when a backtesting model is extrapolated to other models of similar pairs. For example, a strategy to buy the S&P 500 index when the one-week moving average is greater than the two-week moving average is particularly effective (Figure 13). However, different moving average pairs do not produce the same results. A trading strategy for when the three-week moving average is greater than the four-week moving average greatly underperforms. Backtests must statistically test each trading strategy and not extrapolate strategies onto the same set of data.

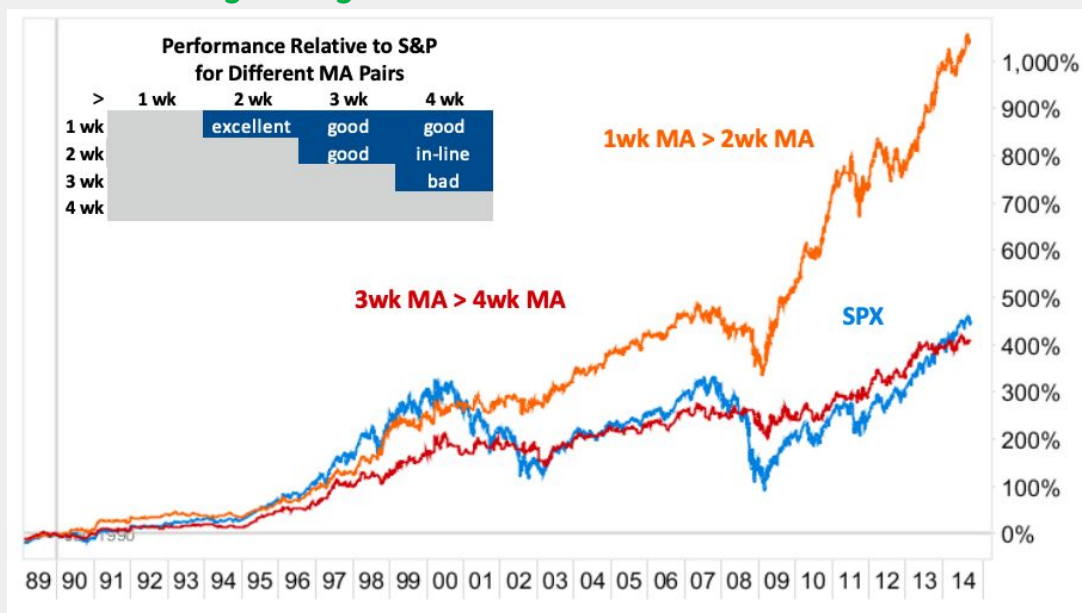### Performance of Moving Average Pairs

Figure 13

Data mining is the practice which underlies all backtesting: reviewing data to find meaningful patterns and relationships. Concurrently, data dredging describes an inappropriate practice which seeks to derive all possible relationships regardless of statistical significance and an underlying hypothesis. A given strategy can not be selected to represent all possible trading strategies. An example of data *mining* would be to construct a graph with only the colored lines shown in Figure 14. In order to avoid the bias associated with data *dredging*, back testers must consider all relationships and then determine the statistical significance of those relationships. Furthermore, traders are advised to form an independent hypothesis before conducting backtesting.

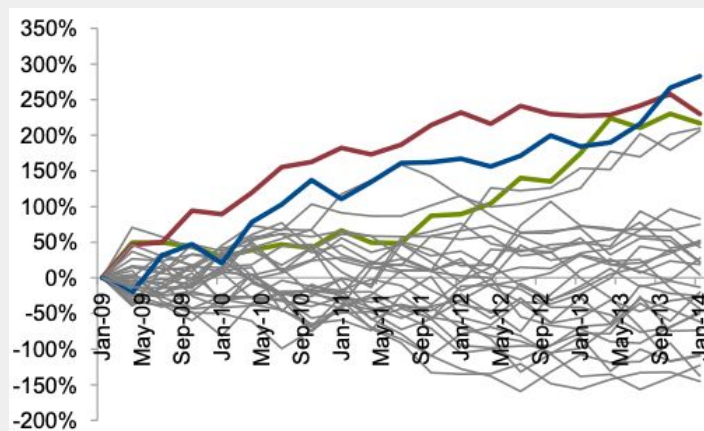**Performance of Trading Strategies**

Figure 14

Unexpected Risk

Effective backtesters will account for potential future risks in hypothetical crisis scenarios. They will stress-test strategies to determine performance in times of economic downturn, providing traders with essential information about risk. As discussed earlier, the implementation of stop-loss strategies can limit potential losses. Backtesters must also take into account more frequently-occurring risks like spread, fees/commissions, market impact, and slippage.

In-Sample Testing

In-sample testing is one of the most common yet devastating types of backtesting pitfalls; this type of testing occurs when a trader or backtesting platform fits their model onto the same set of data, the training set, then evaluates their strategy on that same

training set. To avoid this pitfall, a backtester must be programmed to construct strategies from a training set and test strategies on a sample test set.

CHAPTER 4: BACKTESTING USING MATHEMATICS

In this section, we delve into the mathematical methods used during backtesting to determine statistical significance and validity. Historical backtests perform single test strategies known as t-tests and compare trading strategies using Sharpe ratios.

Single Tests and Sharpe Ratios

In order to test if a trading strategy is profitable, statistical analysts perform statistical hypothesis tests called t-tests. The null hypothesis, the strategy simulated under, maintains that the expected returns are equal to zero. The alternative hypothesis attempts to disprove the null in favor of the belief that expected returns are different from zero. The alternative hypothesis, therefore, is two-sided. If statisticians can prove that expected returns are different from zero, they may reject the null hypothesis and accept the alternative hypothesis. In doing so, they have effectively found a profitable trading strategy that is different from zero in either the positive or negative direction.

Given a sample of data consisting of historical returns, the mean (μ) and standard deviation (σ) of the sample can be measured. The t-test assumes that the test statistic follows a normal distribution, so the distribution would contain $T - 1$ degrees of freedom. By constructing the t-test ratio, which is shown in Figure 15, statisticians may test the null hypothesis that the average return is zero; the result of the hypothesis test will deduce whether the investment strategy is statistically significant.

T-Test Ratio Formula

$$t\text{-ratio} = \frac{\hat{\mu}}{\hat{\sigma}/\sqrt{T}}$$

Figure 15

The Sharpe ratio is a metric of risk-adjusted return, taking into account both return and volatility, and is directly linked to the t-test ratio. A given trading strategy with high return and high volatility may be seen as less effective than a strategy with lower return and low volatility under the Sharpe ratio. The period and frequency of the tests between the two strategies must be standardized. Sharpe ratios allow traders to perform risk/reward analysis for their trading strategies and is an important aspect of backtesting.

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The Sharpe ratio is defined as the mean (μ) divided by the standard deviation (σ), as shown in Figure 16. Intuitively, the mean represents return and the standard deviation represents volatility. By setting the t-ratio and Sharpe Ratio equal, the Sharpe ratio can be set equal to the t-ratio/ √T. Due to the fact that the T is fixed under a normal distribution, there is a direct positive correlation between the t-ratio and Sharpe ratio; as the Sharpe ratio increases, the t-ratio increases, as well. A higher Sharpe ratio implies that there is a higher significance level for a trading strategy.

Sharpe Ratio Formula

$$\widehat{SR} = \frac{\hat{\mu}}{\hat{\sigma}}$$

Figure 16

The Sharpe ratio can be used in tandem with the t-ratio to compare trading portfolios. Portfolios with higher Sharpe ratios generate higher excess return per unit of volatility. An efficient frontier occurs when a portfolio generates higher returns for a defined level of risk, which is illustrated in Figure 17. An Inefficient frontier occurs when a portfolio is associated with higher risk and lower returns.
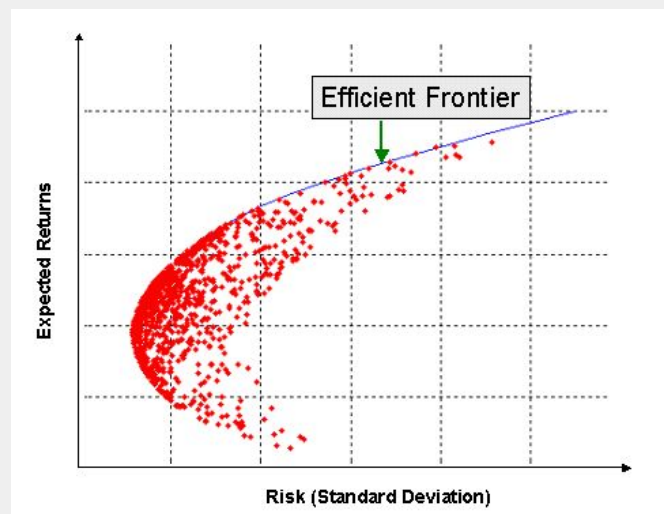
Sharpe Ratio Visual Representation

Figure 17

Each data point in Figure 17 represents a possible trading scenario. Given this model, statisticians can locate the ideal trade with the highest possible Sharpe ratio. This

process involves generating a line of tangency called the capital market line, as demonstrated in Figure 18. The tangent portfolio circled in the figure below has the highest possible Sharpe ratio. This point has the highest reward per unit of volatility and is a worthwhile investment for traders.
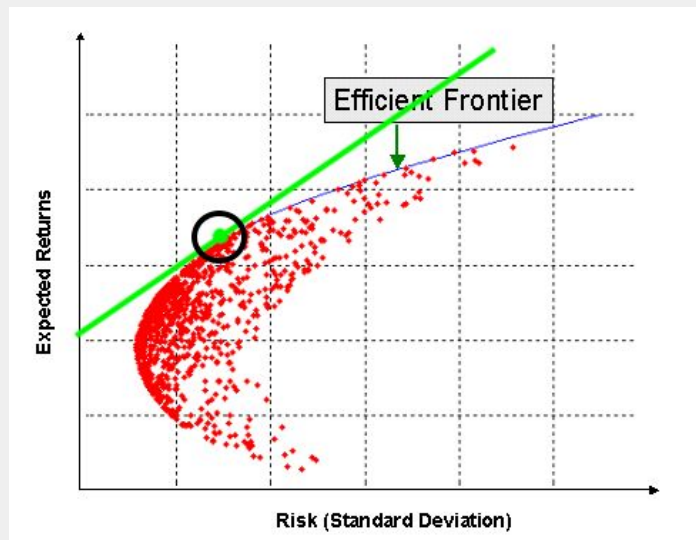
Sharpe Ratio Visual Representation

Figure 18

Efficient backtesting systems are programmed to conduct hypothesis tests and develop Sharpe Ratios for individual trades. The backtester develops optimization models using the capital market line to identify the mathematically ideal trading scenario. While the Sharpe ratio is useful in generating risk/reward ratios, it does not guarantee performance for individual traders. Backtesters must take into account economic events and price movements, too, as was discussed in Chapter 2.

CHAPTER 5: HOW TO GET THE MOST FROM BACKTESTING

Although backtesters are effective analysis tools, traders are the recipients of the analysis and must use it effectively to generate profits. Below we discuss several tools traders can utilize to maximize their profits and get the most out of their systems.

Effective Backtesting Practices

(1) Proper Money Management

Traders can ensure that they remain in the market for a long period of time by noting the exact amounts they can afford to lose at the end of each day, week, and month. Through proper money management, traders can gain vital experience, increasing their probability of long-term success.

(2) Strict Trading Algorithm

By implementing and diligently following a strict trading plan, traders can identify the exact strategies that led to a profit or loss. Strategies that produce a loss are sources of valuable information, as traders can learn to avoid them. Profitable strategies can be reimplemented in order to multiply profit.

(3) Detailed Trade Log

Traders must keep a running log of all trades using screen capture. Each trade must contain a detailed description of the entry price, stop loss, profit targets, trade duration, closing price, and realized profit. Experts cite introspection as an effective tool and recommend traders write about why they decided to make a trade, as well as the emotions they felt while trading.

> **Key Idea**
>
> **"Show me a trader with good records, and I'll show you a good trader."**
> **- Alexander Elder**
>
> **Figure 19**

(4) Demo Account Tests

Traders can test their trading strategies alongside analysis provided by backtesters by paper trading. Demo accounts serve as a psychological tool and allow

traders to develop discipline. Traders can practice sticking to their strict trading algorithm and keeping detailed trading logs with demo accounts.

(5) Continuously Improve Trading Strategy

For profitable trading strategies to remain relevant, traders must continuously improve their strategies. In doing so, traders will construct winning trade plans for long term success.

CHAPTER 6: DOES HISTORICAL PERFORMANCE GUARANTEE SUCCESS?

ALVTI Example

Past performance does not necessarily guarantee future returns. For example, ALTVI, an excess return index, was a top-selling fixed income annuity and consisted of twenty-four different futures contracts, commodities, rates, and currencies. The index generated higher returns than the S&P 500 Index (SPX) and was up about 7.2% per year since 2000 (Figure 20). After constructing an in-sample backtest, ALVTI would seem to be a profitable investment.

ALTVI vs. SPX Graph (Pre-2012)

Up 7.2% per year in up and in down markets

ALTVI

SPX
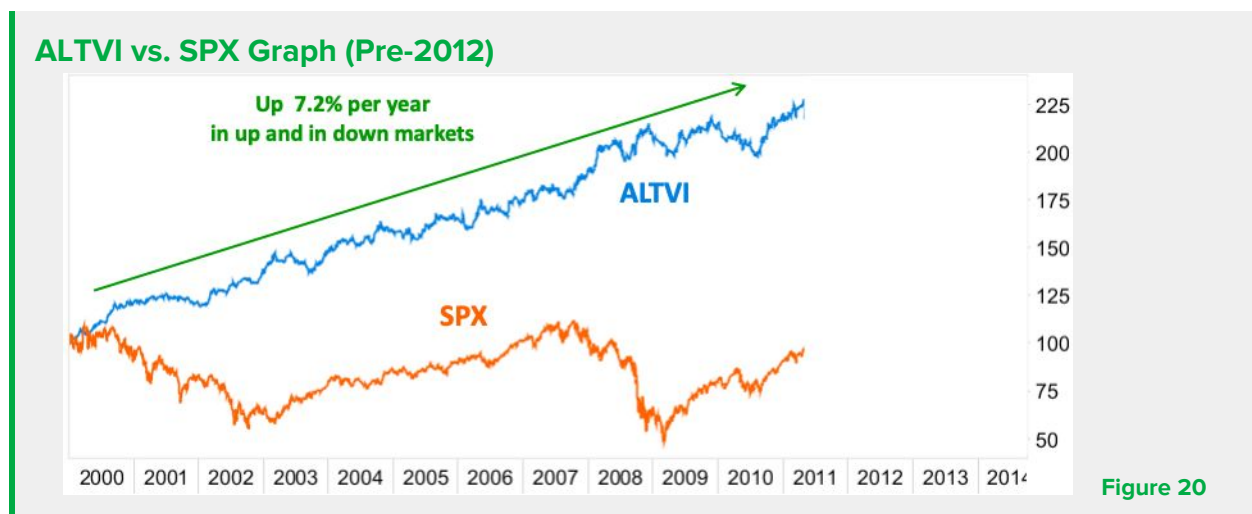
Figure 20

Although the backtest would detect that ALTVI was a profitable investment, the live data after 2012 demonstrates the unforeseen risk. Backtesting software would attempt to identify this risk by evaluating economic events and movements in leading markets, but there is no guarantee that it would detect the sudden fall. Therefore, there is always a risk associated with backtesting, as is the case with any financial trade. However, backtesters allow traders to capture positive market trends by analyzing sensitive market changes. Although, in the case of ALTVI, a trader may lose the last leg, they could backtest the strategy for roughly 11 years. Backtesters are programmed to dynamically understand when causation ceases to be a profitable strategy. Historical data is all that traders have, so they must be able to properly use it to derive the most possible value.

ALTVI vs. SPX Graph (Post-2012)

Figure 21

CHAPTER 7: BACKTESTING WITH BETTERTRADER

BetterTrader offers a specialized backtesting system that interprets market data in real-time. BetterTrader's artificial intelligence algorithms allow traders to improve their market analysis. The backtesting system avoids the aforementioned pitfalls discussed in Chapter 3.

Avoiding Backtesting Pitfalls using BetterTrader

BetterTrader's backtesting system avoids the aforementioned pitfalls discussed in Chapter 3. BetterTrader's data handler contains a complete database of historical events and developments. This database includes data on even extinct companies, thereby excluding survivorship bias. Therefore, data selected to be in the training set is representative and captures a complete picture of historical events. **The artificial intelligence algorithms account for not only expected value but also volatility, skew, and max drawdown.** As seen by the risk and historical success ratios, the backtester takes into account unexpected risk. BetterTrader's backtesting system bypasses the issues experienced by individuals and other backtesting systems.

Specification of Economic Event

BetterTrader, through the use of the economic calendar, generates event cards for every economic event. The cards specify the currency of the country the event is based in and ranks the data in tiers based on impact and volatility. **The difference between the actual and the expected release value drives the market and allows traders the opportunity to make profitable trades.** BetterTrader denotes events where the actual release value is higher than the expected value as a "stronger" event (Figure 22).
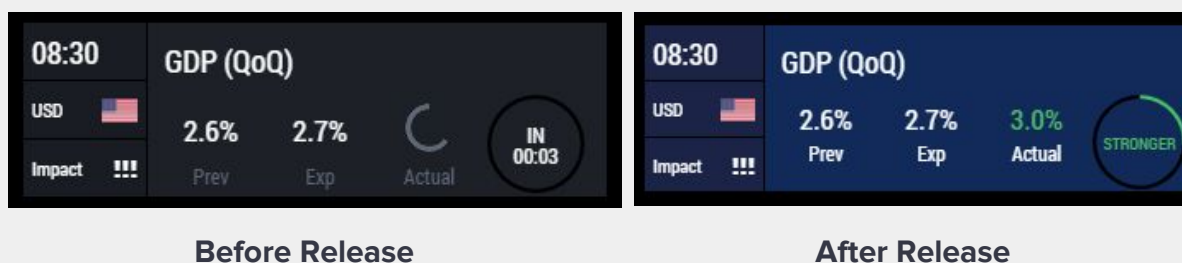
Event Cards

Before Release	After Release

Impacts of Price Actions and News

From the event cards, BetterTrader's backtesting system may generate triggers for trade ideas. For example, a trigger was generated for the S&P 500 after West Texas Oil moved up 1% thirty minutes prior. The price-driven trade idea reached its profit target eight out of nine times and reached its stop loss only once out of nine times.
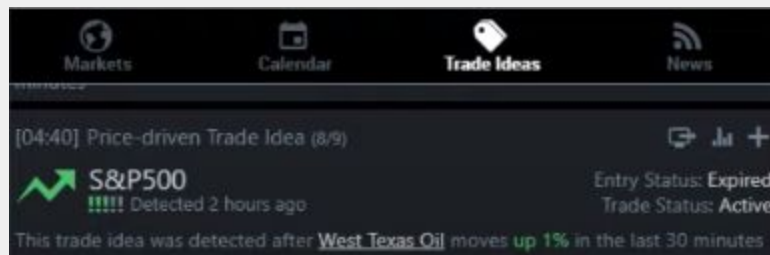
Trade Idea Triggers

Figure 23

For each trigger, BetterTrader allows traders to examine market reactions each time the trade idea happened in the past (Figure 24). By viewing the market reactions in a synthetic chart, traders can recognize patterns of the market and gain clarity on their trades.
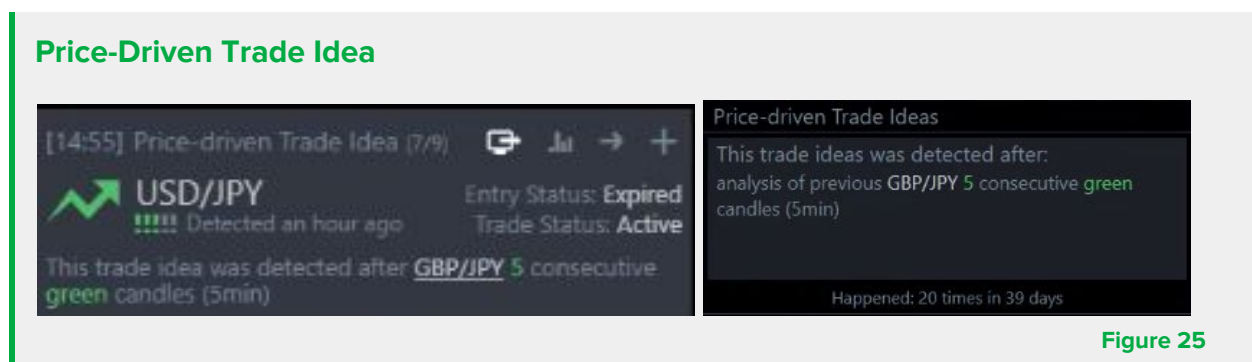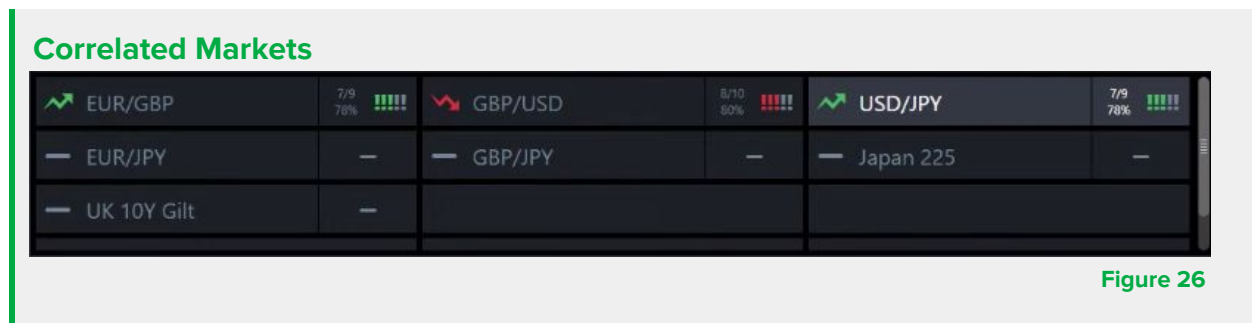
Review Previous Trades
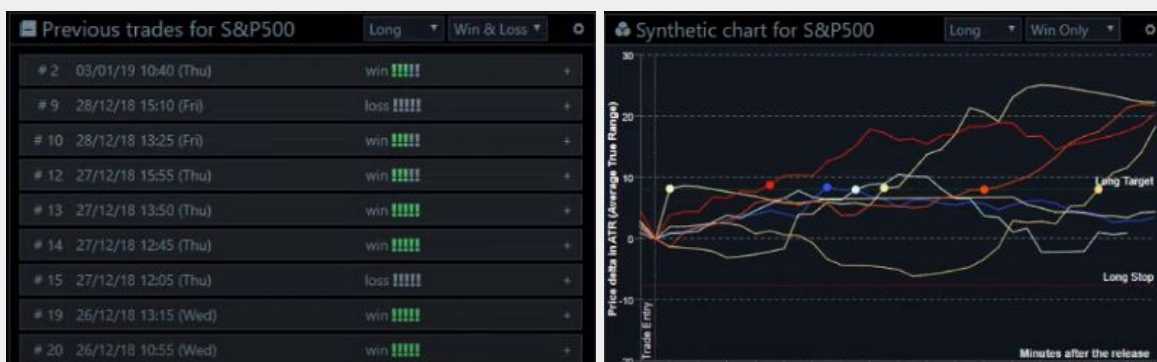
Figure 24

Backtesting Example

After GBP/JPY experienced 5 consecutive green candles, BetterTrader detected a price-driven trade idea for USD/JPY, as shown in Figure 25. Following a similar release, USD/JPY moved up seven out of nine times (78%).

Price-Driven Trade Idea

Figure 25

By analyzing correlating markets, BetterTrader provides traders with the knowledge that some instruments are not beneficial to trade following price movements. For example, Figure 26 displays that trading EUR/JPY, GBP/JPY, Japan 225, or UK 10Y Gilt following the movement of GBP/JPY is not statistically backed. The total quality of the trade is represented by the exclamation points and describes both the risk and potential profitability. BetterTrader provides customization capabilities to effectively visualize backtesting results.

**Correlated Markets**

Figure 26

BetterTrader provides the following customization capabilities to effectively visualize backtesting results: real-time chart, previous trades, latest trade, synthetic chart, and trading card. These tools allow traders with the market data needed to make trading decisions about the instrument being backtested.

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Customization Widgets

Choose a widget (learn more about widgets):

| Real-time chart | Previous trades | Latest trade | Synthetic chart | Trading card |
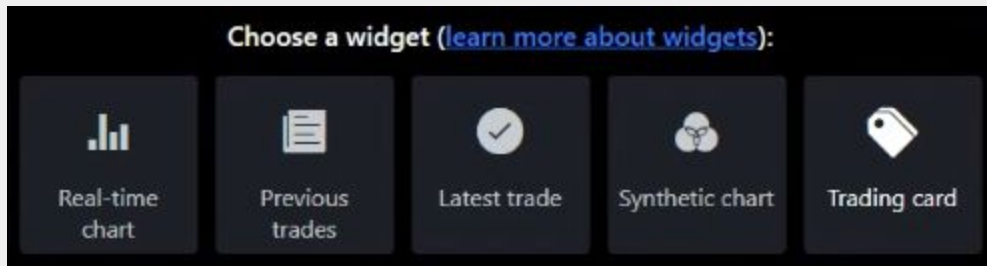
Real-time Chart

Real-time chart
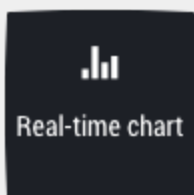
What is this widget?

Use real-time market data to keep an eye on market developments of the instrument that you are backtesting.

Benefits

1. Stay focused on the market while you're doing your research.

2. Plan in advance how you will apply that research into that market

3. Use many analysis tools to measure and analyze the trade idea yourself using your individual trading strategy

Previous Trades

Previous trades
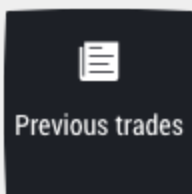
What is this widget?

See how the market reacted every single time that trade idea happened in the past.

Benefits

1. Identify when the best timing for entry and exit is.

2. Estimate what degree your loss or profit is likely to be.

3. Detect whether you should wait more after passing the profit target to gain much

more or whether you should just exit.
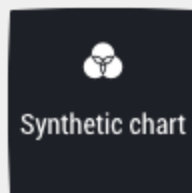
Latest Trade
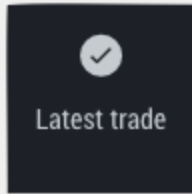
What is this widget?

See how the market reacted to any trade that was released today.

Benefits

1. Get instant results not from the past, but from today's market reaction to that specific event.

2. Detect whether today's event market reaction still correlates to its past market reaction history, and gain confidence into the next trade idea.

Synthetic Chart

What is this widget?

The synthetic chart is one of the most powerful and helpful tools traders can have. See the executive collective results of the market reaction to a specific event, all in one specific chart.

Benefits

1. See them all together - recognize the pattern of the market.

2. Get clarity and confidence on whether you should enter the market with that specific trade idea.

Trading Card

Trading card
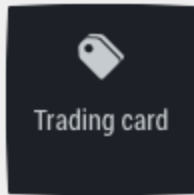
What is this widget?

A snapshot of the historical behavior for winning trades for specific trade ideas.

Trade cards include profit targets, stop loss and many other useful metrics.

Benefits

1. Get clarity for the trade iea all in one simple card.

2. Manage precisely the expectation of what is reasonable to get from this trade.

3. Keep your risk bound with well informed stop loss that is tested.

Figure 27

CHAPTER 8: NEXT STEPS

Now that you have understood the fundamentals of backtesting, we will explore a case study regarding how to:

1. Prepare for economic events
2. Analyze and react to event releases
3. React to price movements

BetterTrader's trade ideas allow traders to generate master trading strategies and provide immediate results.

Case Study: How to Prepare for Economic Events

In an all-encompassing example, we will explore the effect of the New York Empire State Manufacturing Index on both the USD/JPY (Forex) and Gold (Commodities). This same logic may apply to any economic event. Figure 28 shows the New York Empire State Manufacturing Index on a 5-year chart.

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New York Empire State Manufacturing Index 5-Year Chart

General Business Conditions
— Current — Expected ▮ U.S. recession
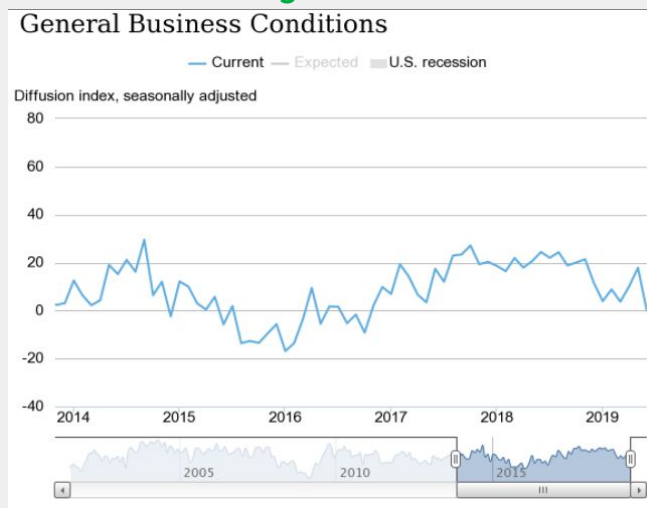
Diffusion index, seasonally adjusted

Figure 28

In economics, higher economic growth correlates with higher interest rates. Capital will, therefore, flow into the United States, which causes the United States Dollar (USD) to appreciate. However, concepts in economics seldom directly translate to market movements. Markets, a reflection of traders buying and selling assets, tend to move illogically.

The New York Empire State Manufacturing Index is the leading market and the USD/JPY pair is the following market. BetterTrader's backtester analyzed that the New York Empire State Manufacturing Index released a magnitude of surprise of "Stronger" six times since 2016. Although we may expect the USD to appreciate against the JPY following the New York Empire State Manufacturing Index being stronger than expected, USD depreciated against the JPY five out of six times (Figure 29). By strictly following economic principles, a trader may neglect profitable ventures or, in this case, lose capital.

Table of Previous Trades for USD/JPY

Figure 29

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Gold is also the following market to the New York Empire State Manufacturing Index, the leading market. Since 2016, the index release has been lower than expected, which constitutes a magnitude of surprise of "Weaker," nine times. The price of Gold went up seven out of these nine times with an average trade duration of 60 minutes. Figure 30 illustrates the impact of a weaker New York Empire State Manufacturing Index on Gold.

Trade Characteristics and Chart for Gold

Figure 30

In this scenario, the market reacts in accordance with economic principles; when there are lower economic growth rates, traders purchase gold as it is understood to be a risk-off asset. The dichotomy between the trading scenarios for USD/JPY and Gold reveal the inconsistent nature of applying economic principles to market situations. It is far more effective for traders to conduct historical analysis on an independent basis to understand expected market movements. Traders receive this exact historical analysis by using a backtester.

Backtests allow traders to prepare for economic events days in advance. If the New York Empire State Manufacturing Index release is "stronger" than expected, backtesters will instruct traders to sell the USD/JPY pair. If the index is "weaker" than expected, backtersters will instruct traders to buy Gold. **The system may also optimize the best time to buy and sell the financial instruments, maximizing reaction speeds and giving traders an edge over those who do not utilize backtesters.**

The Result

Immediate Results with BetterTrader

22%

 22% average increase in trade success

44%

 44% average fall in losses

37%

 37% average increase in confidence in client's trading strategies

Figure 31

Free Trial

BetterTrader offers a 7-day free trial so that traders may thoroughly examine how the software and data analysis tools work. We recommend following the most interesting events and choosing two to three correlating markets. Backtesting helps traders receive the appropriate analytics of markets in order to make effective and profitable decisions, as highlighted in Figure 31. The BackTester is part of the Pro Membership Plan, which includes full access to BetterTrader's Analysis tools.

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