

# Exploring The VIX using Automated Trading Strategies

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## Abstract

This study consists of two major sections: a background analysis of stocks in the biotech and pharmaceutical industry, and the creation and evaluation of trading strategies. The first section investigates some technical aspects of historical stock data as well as their correlation with investor sentiment. This section aims to answer how the Chicago Board Options Exchange's volatility index (VIX) can be used to predict stock movement. The second section covers the creation and evaluation of trading strategies based on the VIX. Software is developed that dynamically creates different trading methods through simulation. These methods are then tested over a three month period. Ultimately, the goal of this study is to assess the value of the VIX as a tool for stock prediction.

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## **Introduction**

In the early twentieth century Henry Poor was walking down the financial district with John D. Rockefeller. When asked about the future of Standard Oil stocks, Rockefeller is said to have replied, “Young man, I think they will fluctuate” (Wall Street Journal, 18 Oct. 1922). While this quote appears shallow at face value, it is profound in how incredibly applicable it is to global economies today. Within the stock market, fluctuation is a way of life. Prices waver as a result of countless influences and it is difficult, especially for the inexperienced, to see the broader patterns of stock movement. Those who find success in trading are the ones who are able to exploit this volatility in their favor.

To begin to understand the inherent volatility of the market, it is important to understand the nature of the traders involved. While automation accounts for a large and growing percentage of trades, human emotion is still deeply rooted in the system. Greed and fear play a significant role in stock behavior. This is where the VIX comes in to play as potentially a very special indicator; a way of capturing some of this human emotion into a simple index.

## **VIX**

In 1993 the Chicago Board Options Exchange created a volatility index with the ticker symbol VIX (Investopedia, 16 Apr. 2018). The VIX aims to predict the volatility of the S&P 500 index options over the next thirty days. Commonly known as the “fear gauge”, the VIX is popular for its ability to capture the sentiment of investors in the market. When investors are scared and the market is “bearish” the VIX will rise and when the market is “bullish” the VIX will fall. It is disputed whether or not the VIX can be used as a method of prediction or if it is simply a reflection of the market.

The VIX is a noteworthy indicator because it gives a representation of far more than just technical details. Many political, social, and economic events are displayed through investor sentiment. Theoretically, this gives the VIX an advantage over other technical indicators when it comes to price prediction. This study attempts to show the potential of the VIX to be used as an indicator.

## **Technical Indicators**

The significance of technical indicators is a heavily disputed topic by new and experienced traders alike. While some see them as shortcuts to success, others question just how well they can distill the intricacies of the market in their basic calculation. A large part of their criticism comes from the reality that they are not absolute. Specifically, they offer a suggestion of what is more likely to happen, but offer no guarantee. Because of this, it is important to recognize that indicators are only as valuable as their user's understanding of them.

## **Efficient Market Hypothesis**

Developing on this idea, some speculate that the market itself is impossible to beat. Theorized in the 1960's by Eugene Fama, the Efficient Market Hypothesis (EMH) suggests that all of the determinative information, which could potentially be used for prediction, is already built into the current share price. As a result, technical analysis and exploitation of a stock is useless. There are three variations of the EMH known as "weak", "semi-strong", and "strong" which increase the extent of the theory (Maverick, 26 Mar. 2015). In the "weak" variation, stock price is a manifestation of all historical data and, subsequently, technical analysis yields no predictive information. The "semi-strong" variation adds that any form of fundamental analysis from public knowledge is also included in the market, making only insider information

significant. Finally the “strong” variation includes insider information in the system, making it impossible to for investors to achieve anything other than normal market returns (Maverick, 26 Mar. 2015). While many agree with the concept of the EMH, it is disputed how well the theory performs in practice. This study recognizes the existence of some form of the EMH but aims to disprove its absolute nature.

Ultimately, the goal of this study is to identify the relationships that stocks have with the VIX and to develop a successful trading strategy around this information. In order to begin to tackle this problem, a historical analysis of stock data must be performed.

## **Sample Stocks**

The time period being used for the historical analysis begins on 2/6/2006 and ends on 9/8/2017. This data set of 2918 days was chosen because it contains enough points to be statistically significant and it also contains the entry, crash, and recovery of the 2008 housing bubble. The stocks that have been chosen to be examined focus in on the biotech and pharmaceutical sectors of the market in particular. Both individual stocks as well as Exchange Traded Funds (ETF) were selected to give adequate coverage of the market.

## **Beta**

Calculated through regression analysis, beta gives an indication of a stocks volatility compared to the market. A beta value greater or less than 1 demonstrates that the stock is more or less volatile than the market, respectively. When trading, beta is a helpful statistic to consider because it provides some insight on the risk of an investment. In this study, beta provides a general indication of the stock’s behavior before doing any technical analysis. Stocks with a higher beta have higher movement and are potentially more exploitable with trading strategies.

## Selected Stocks

### **IBB – iShares NASDAQ Biotechnology Index – ETF**

**Description:** IBB is an Exchange Traded Fund that tracks many biotech and pharmaceutical companies on the NASDAQ market. IBB weights companies by their market cap, focusing primarily on the top Large-cap stocks that it covers. This ETF was selected because of its focus on big name companies and its stability.

**Total Assets:** 9.27B

**Beta (3y):** 1.39

### **XBI – SPDR S&P Biotech – ETF**

**Description:** XBI covers a broad range of small-cap and micro-cap stocks, and is very resistant to single points of failure. This ETF was selected because it provides a different form of coverage of the biotech sector.

**Total Assets:** 4.7B

**Beta (3y):** 1.74

### **FBIOX – SPDR S&P Biotech – ETF**

**Description:** FBIOX invests the majority of its resources in companies participating in research, development, and distribution. This ETF was chosen to add further diversity to the sample.

**Total Assets:** 8.94B

**Beta (3y):** 1.5



**CELG** – Celgene Corporation

**Description:** CELG is a Biopharmaceutical company that develops treatments for cancer and inflammatory diseases. This stock was chosen as it is a major biotech company.

**Market Cap:** 64.5B

**Beta (3y):** 1.4

**GILD** – Gilead Sciences, Inc.

**Description:** GILD is a Biopharmaceutical company that researches and develops treatments for diseases and infections without suitable cures. GILD was selected as it is a large and consistently growing company in the biotech sector.

**Market Cap:** 98.8B

**Beta (3y):** 1.38

**BIIB** – Biogen, Inc.

**Description:** BIIB is a biopharmaceutical company that develops treatments for neurological and autoimmune diseases. BIIB was selected to add an additional biopharmaceutical to the sample.

**Market Cap:** 56.1B

**Beta (3y):** 1.07

**AMGN – Amgen, Inc.**

**Description:** AMGN develops a wide range of human therapeutics. AMGN was selected as it is one of the largest companies in the biotech sector.

**Market Cap:** 123.2B

**Beta (3y):** 1.64

**REGN – Regeneron Pharmaceuticals, Inc.**

**Description:** REGN researches, develops, and commercializes treatments for major medical conditions. REGN was selected because of its rapid growth and volatile behavior.

**Market Cap:** 34.3B

**Beta (3y):** 1.60

**INCY – Incyte Corp**

**Description:** INCY is a biopharmaceutical company researches, develops, and commercializes treatments for various medical conditions. INCY was selected because it's explosive behavior.

**Market Cap:** 13.56B

**Beta (3y):** 1.06

**VRTX** – Vertex Pharmaceuticals, Inc.

**Description:** VRTX researches, develops, and commercializes treatments for major medical conditions. VRTX was selected to add an additional pharmaceutical company to the sample.

**Market Cap:** 39.16B

**Beta (3y):** 1.95

**AZN** – AstraZeneca, PLC.

**Description:** AZN is a biopharmaceutical company researches and develops treatments for tumors as well as cardiovascular diseases. AZN was chosen to further diversify biopharmaceuticals in the study.

**Market Cap:** 86.4B

**Beta (3y):** 0.64

## General Analysis

We will begin with a basic analysis on the returns of each stock. Figure 1 shows a few simple yet meaningful statistics. First, variance is an important statistic to take into account when investing. The less sure the outcome of an investment, the worse that investment is. It should be noted that in its calculation variance gives increased weight to values the further they are from the mean, essentially making outliers stand out further. Skewness and kurtosis describe the shape of the data, and are useful for gleaning additional information about the stock. For example two stocks can have the same mean of returns and standard deviation, but have much different skewness and kurtosis. This can be seen in the comparison between REGN and INCY. These stocks have very similar mean of returns and standard deviation but have much different levels of skewness.

<b>Fund</b>	<b>Mean Returns</b>	<b>Variance</b>	<b>Standard Deviation</b>	<b>Skewness</b>	<b>Kurtosis</b>	<b>Reward-to-Variability Ratio</b>
<b>IBB</b>	0.061	2.274	1.508	-0.112	2.650	0.02680
<b>XBI</b>	0.075	3.364	1.834	0.007	2.767	0.02235
<b>FBIOX</b>	0.066	2.587	1.608	-0.096	2.954	0.02533
<b>CELG</b>	0.095	4.710	2.170	0.228	7.344	0.02015
<b>GILD</b>	0.080	3.684	1.919	-0.133	7.686	0.02163
<b>BIIB</b>	0.093	4.838	2.199	-0.921	22.035	0.01926
<b>AMGN</b>	0.049	2.782	1.668	0.579	7.676	0.01770
<b>REGN</b>	0.164	9.588	3.097	0.720	7.390	0.01706
<b>INCY</b>	0.173	12.816	3.580	-0.082	11.432	0.01354
<b>VRTX</b>	0.104	11.042	3.323	4.806	77.930	0.00938
<b>AZN</b>	0.025	2.645	1.626	-0.190	9.374	0.00927

**Figure 1: General Statistics of Stock Returns**

From an initial viewing of this data, a few things become apparent. While pharmaceuticals such as REGN and INCY have the highest mean returns, they also have a higher volatility making them a higher risk investment. Despite the ETFs IBB and FBIOX having lower mean returns, they boast the lowest variance resulting in an excellent reward to variability ratio. Just as would be expected, ETF's have the highest risk reward ratio, making them strong investments. While this shows ETF's as more predictable funds, it does not yet inform us about how they can be traded.

## Plotting Mean Vs Variance

Comparing the mean of returns versus the variance of the stock reveals a direct correlation. High earners such as INCY and REGN have a correspondingly high variance. The ETF's, on the other hand, have low variance corresponding with their low activity. A linear trend line of the data matches fairly well yielding an  $r^2$  value 0.76.

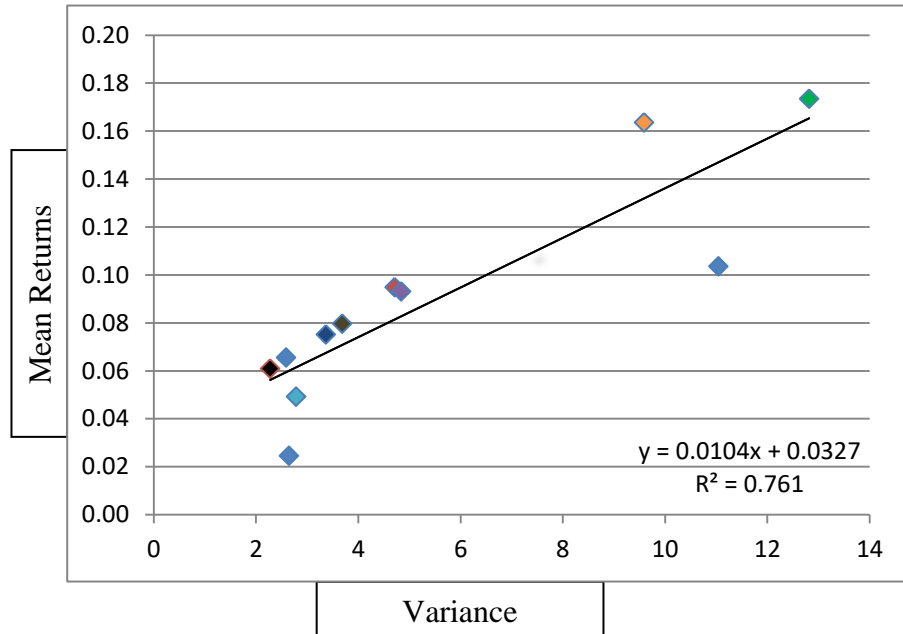


Figure 2: Variance vs Mean Returns

Stock	Variance	Mean Returns
IBB	2.274	0.061
ETF XBI	3.364	0.075
FBIOX	2.587	0.066
CELG	4.710	0.095
GILD	3.684	0.080
BIIB	4.838	0.093
AMGN	2.782	0.049
REGN	9.588	0.164
INCY	12.816	0.173
VRTX	11.042	0.104
AZN	2.645	0.025

## Correlation Matrix

Through the use of a correlation matrix we can better understand how each stock behaves in comparison to one another. In Figure 3 we see the ETF's have a very high correlation with each other. This is an expected result as these funds track very similar portions of the market and thus have very similar behavior. ETF's are also much more resilient to fluctuation as they are much less affected by intra-company affairs. The stocks AZN and VRTX have extremely poor correlations with many of the other stocks, making them potentially much more difficult to predict with a general strategy.

Stock	IBB	FBIOX	XBI	CELG	GILD	BIIB	AMGN	REGN	INCY	VRTX	AZN
<b>IBB</b>	1	0.9591	0.9257	0.7165	0.6493	0.6419	0.6876	0.6540	0.6233	0.5675	0.4884
<b>FBIOX</b>	0.9591	1	0.9524	0.6993	0.6461	0.6452	0.6905	0.6129	0.6112	0.5605	0.4656
<b>XBI</b>	0.9257	0.9524	1	0.6439	0.5586	0.5835	0.5859	0.6065	0.6186	0.5358	0.4368
<b>CELG</b>	0.7165	0.6993	0.6439	1	0.5586	0.4844	0.5437	0.4361	0.4312	0.4051	0.3522
<b>GILD</b>	0.6493	0.6461	0.5586	0.5515	1	0.4376	0.4503	0.4114	0.3731	0.3449	0.3550
<b>BIIB</b>	0.6419	0.6452	0.5835	0.4844	0.4376	1	0.4866	0.4151	0.3759	0.3594	0.3387
<b>AMGN</b>	0.6876	0.6905	0.5859	0.5437	0.4866	0.4503	1	0.4274	0.3957	0.3382	0.3825
<b>REGN</b>	0.6540	0.6129	0.6065	0.4361	0.4114	0.4151	0.4274	1	0.4460	0.3455	0.3088
<b>INCY</b>	0.6233	0.6112	0.6186	0.4312	0.3731	0.3759	0.3957	0.4460	1	0.3442	0.3028
<b>VRTX</b>	0.5675	0.5605	0.5358	0.4051	0.3449	0.3594	0.3382	0.3455	0.3442	1	0.2731
<b>AZN</b>	0.4884	0.4656	0.4368	0.3522	0.3550	0.3387	0.3825	0.3088	0.3028	0.2731	1

**Figure 3: Correlation Matrix**

## **Linear Regression Analysis**

Now that the general behavior of our stocks is understood, their VIX relationship needs to be examined. It is expected that there will be a negative correlation between the VIX and the stock price. As investor fear rises, the stock price decreases. The higher this negative correlation, the more useful the VIX will be as an indicator for predicting stock price. Figure 4 shows a linear regression analysis between the change in stock price and change in the VIX. Here we find a strong negative VIX correlation with every stock. It is important to note that a constant greater than 2.037 means it is significant with greater than 95% confidence. Values deemed significant are highlighted in green. In figure 4, IBB, FBIOX, and XBI are again found to have the most significant correlations with the VIX while VRTX, INCY, and REGN have much lower ratings. Based on these findings, trading strategies developed around the VIX will perform noticeably better on ETF's than their counterparts.



<b>FUND</b>	<b>Constant</b>	<b><math>\Delta</math> VIX</b>
<b>IBB</b>	0.0944	-0.1220
	(4.30)	(-42.42)
<b>FBIOX</b>	0.1000	-0.1258
	(4.18)	(-40.20)
<b>XBI</b>	0.1121	-0.1347
	(3.98)	(-36.57)
<b>CELG</b>	0.1303	-0.1293
	(3.64)	(-27.56)
<b>GILD</b>	0.1104	-0.1122
	(3.47)	(-26.93)
<b>BIIB</b>	0.1256	-0.1185
	(3.38)	(-24.37)
<b>AMGN</b>	0.0764	-0.0992
	(2.78)	(-27.51)
<b>REGN</b>	0.2066	-0.1569
	(3.91)	(-22.64)
<b>INCY</b>	0.2240	-0.1844
	(3.67)	(-23.10)
<b>VRTX</b>	0.1435	-0.1457
	(2.47)	(-19.18)
<b>AZN</b>	0.0507	-0.0957
	(1.88)	(-27.14)

**Figure 4: Regression Statistics of Returns vs VIX**

## Plotting Stocks vs the VIX

Plotting stocks against the VIX give a good visual indication of the relationship. It can clearly be seen when the VIX successfully reflects the behavior of a stock and when it does not. Often the stock and the VIX act as reflections of each other. However, there are also some situations where the stock fluctuations are completely unnoticed in the VIX and vice-versa. In the Figures below, behavior that suggests strong correlation is highlighted in green, and behavior that suggests poor correlation is highlighted in red.

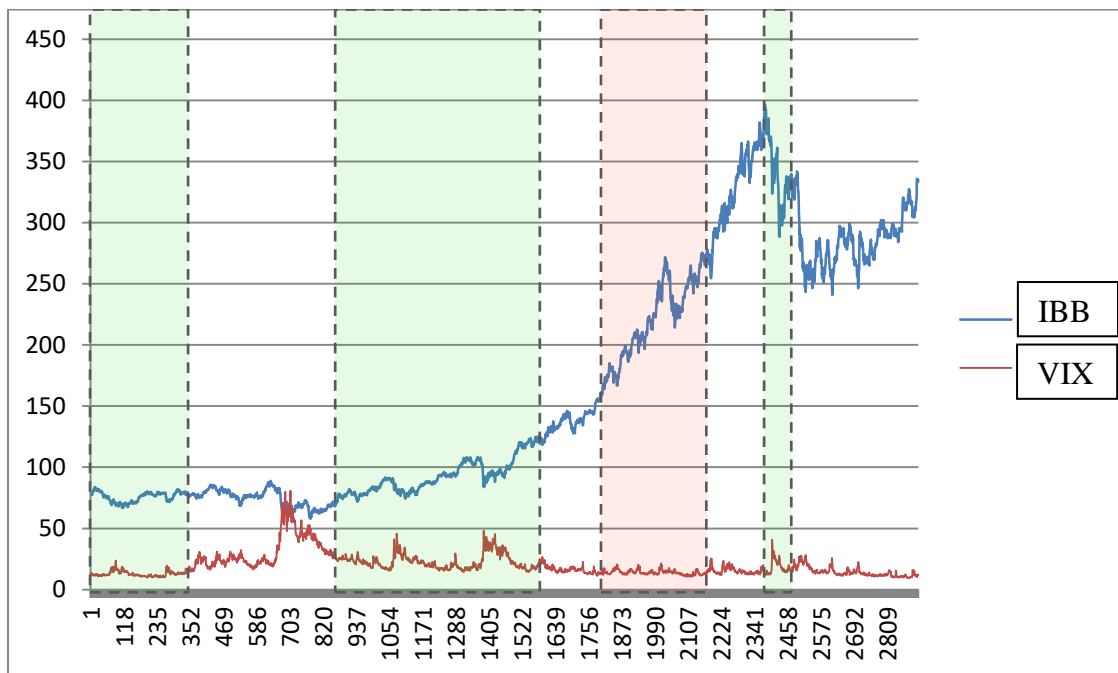


Figure 5: IBB vs VIX

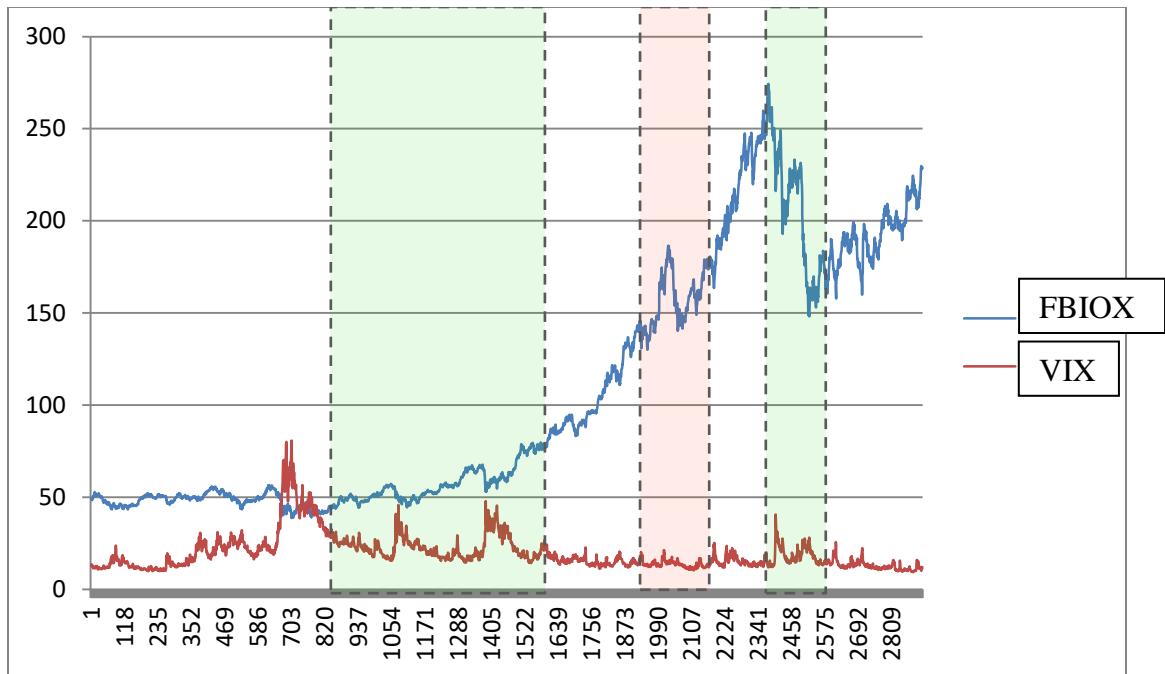


Figure 6: FBIIX vs VIX

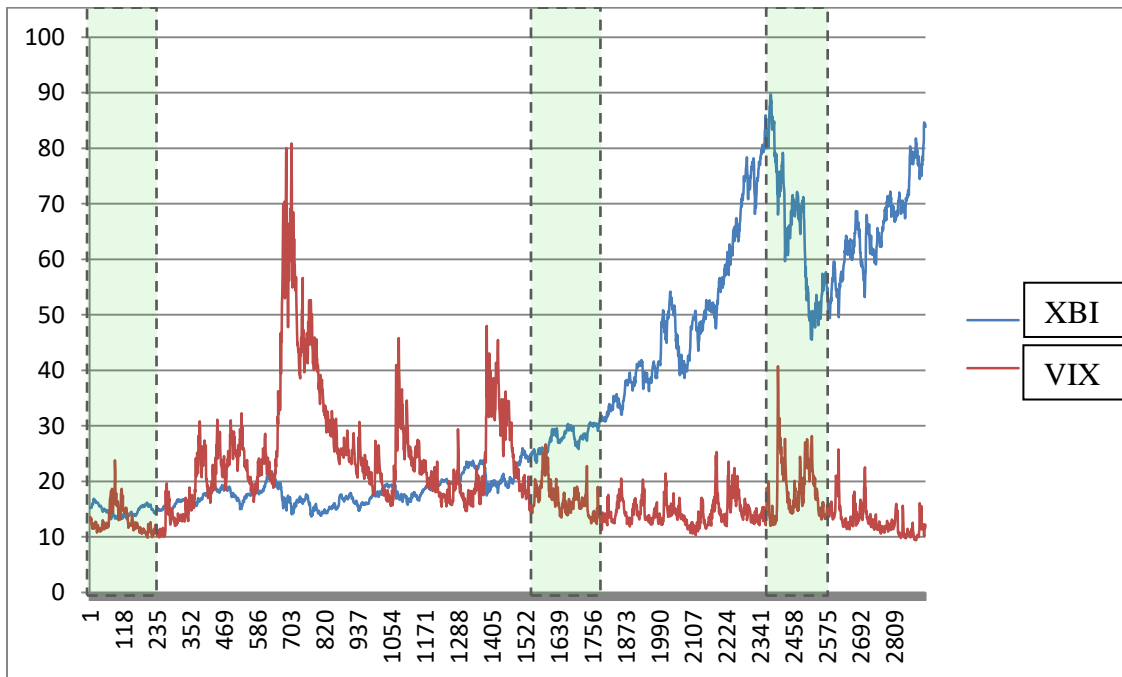
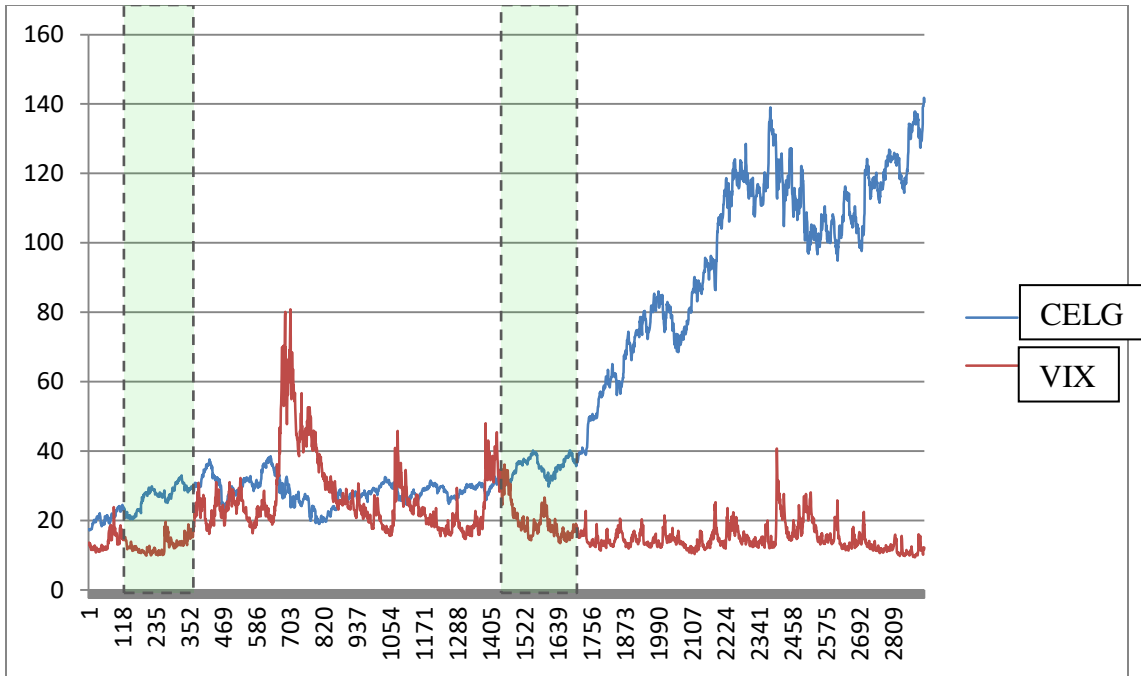
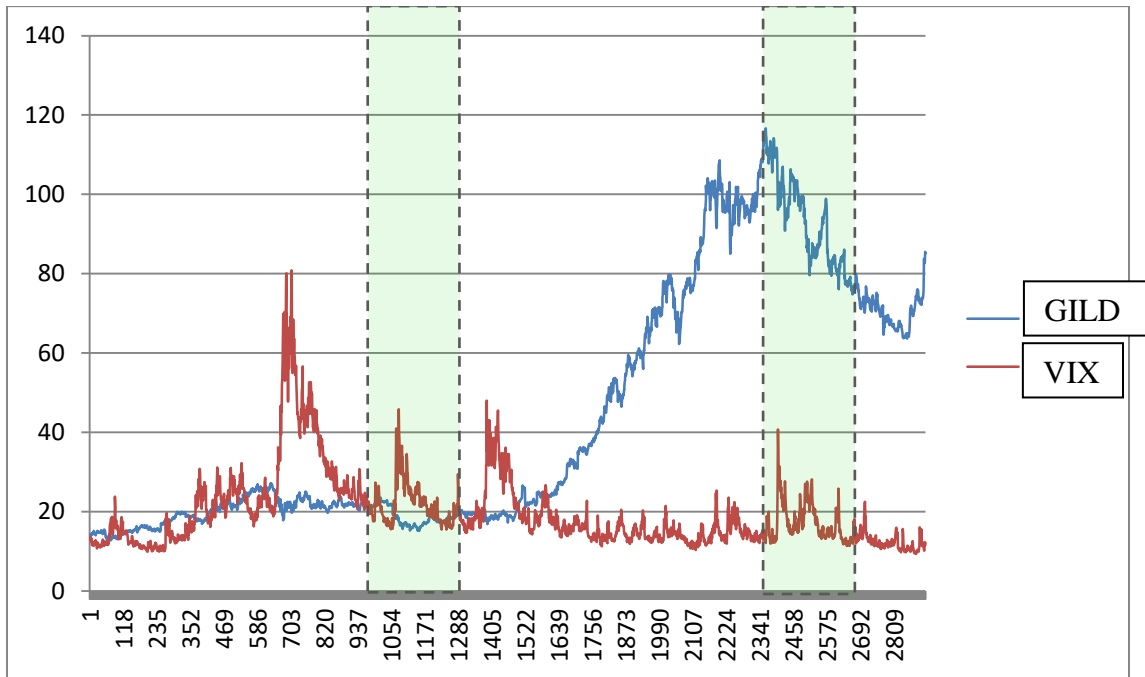


Figure 7: XBI vs VIX



**Figure 8: CELG VS VIX**



**Figure 9: GILD vs VIX**

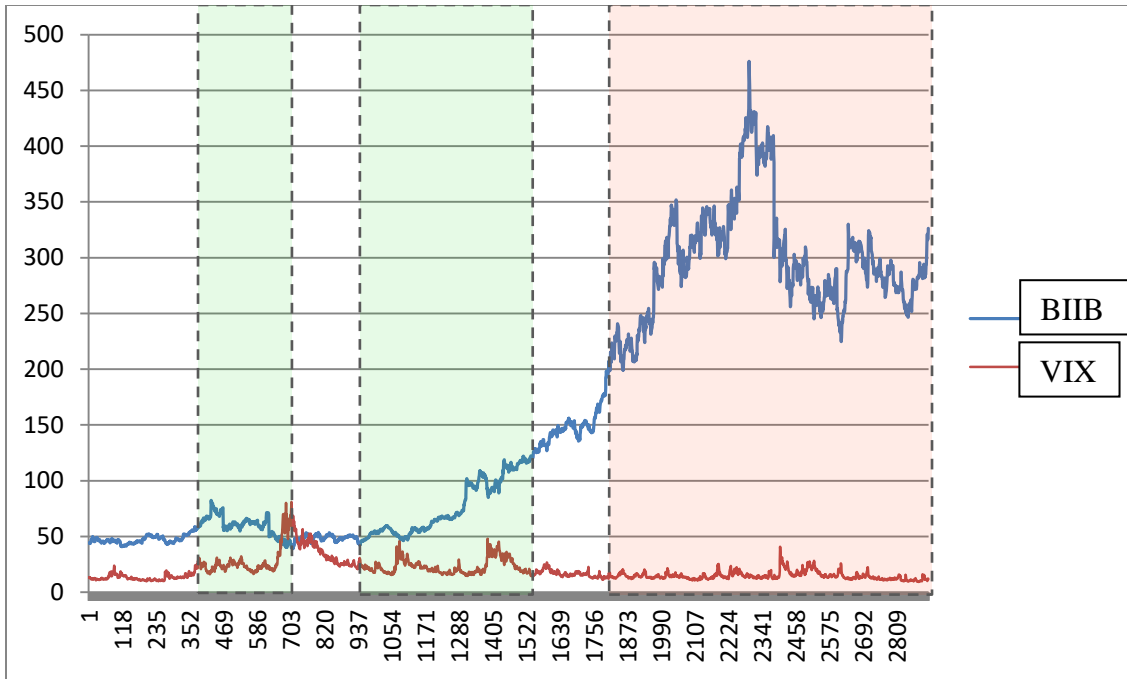


Figure 10: BIIB vs VIX

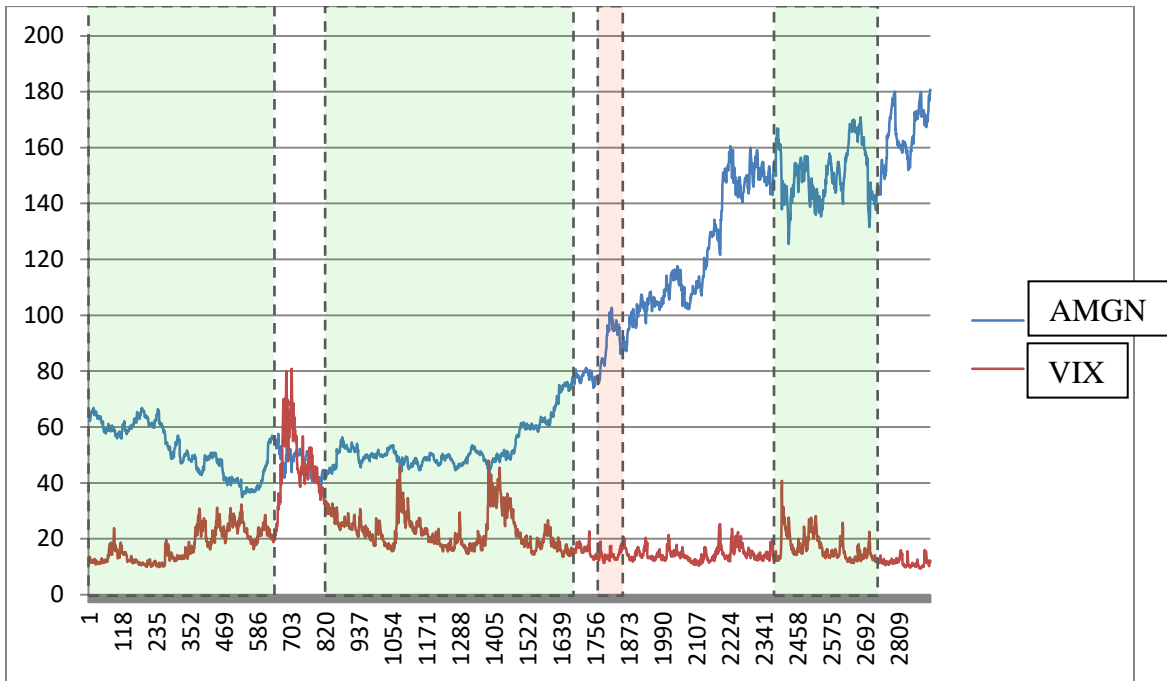


Figure 11: AMGN vs VIX

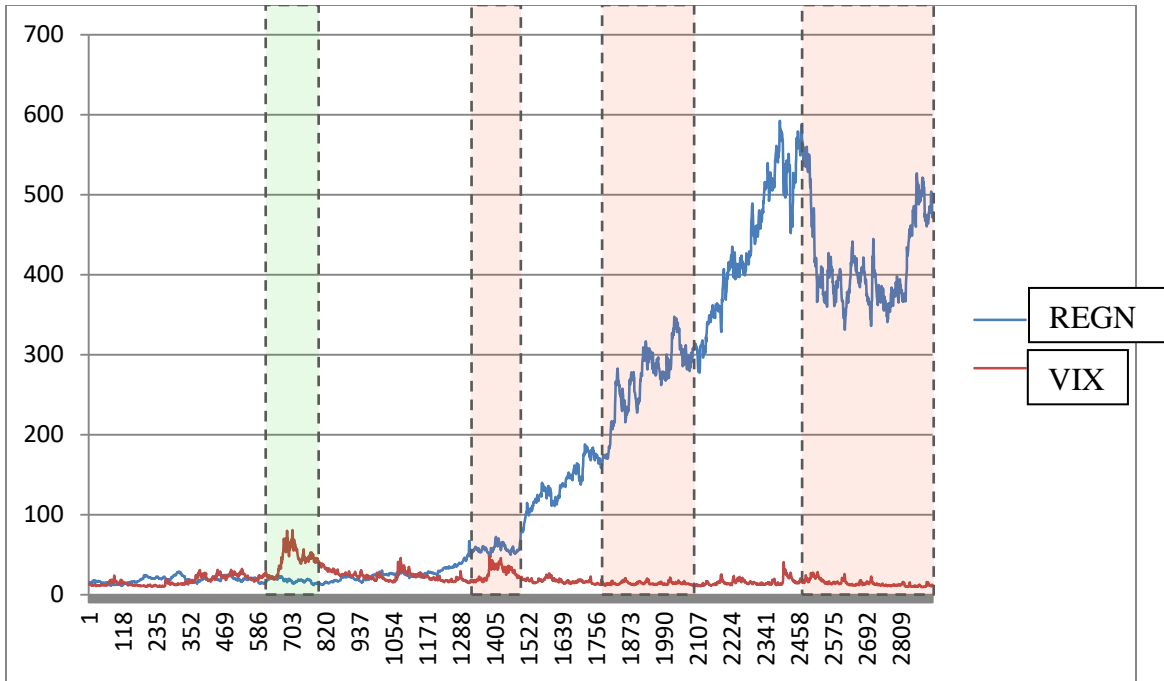


Figure 13: REGN vs VIX

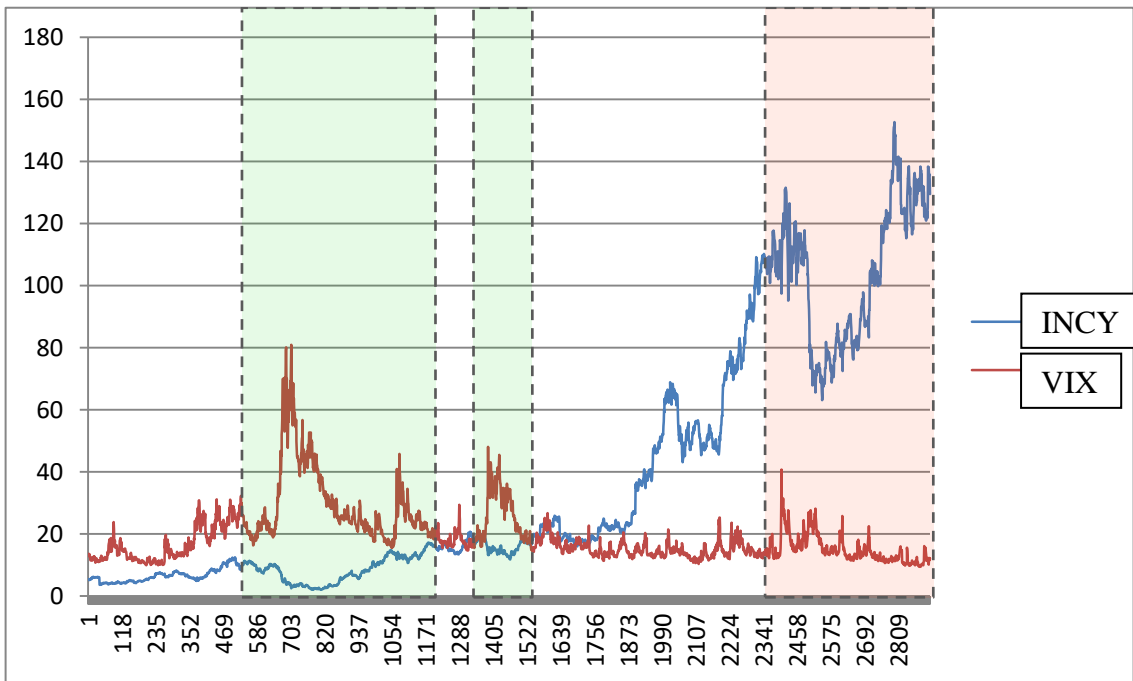


Figure 12: INCY vs VIX

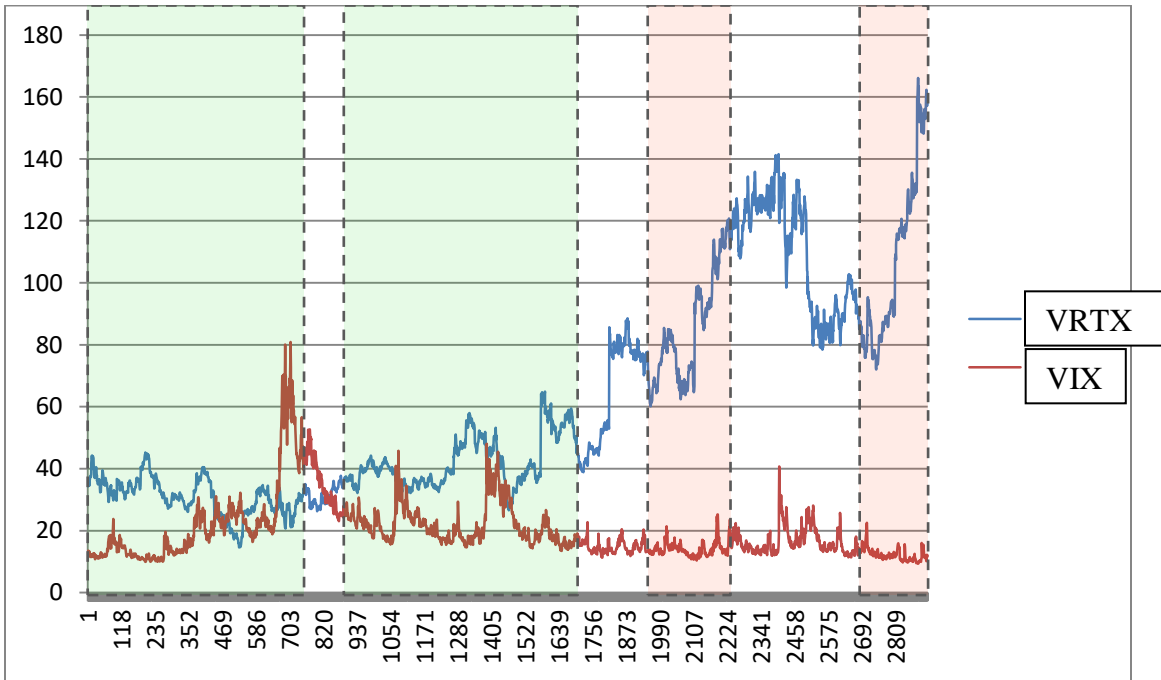


Figure 14: VRTX vs VIX

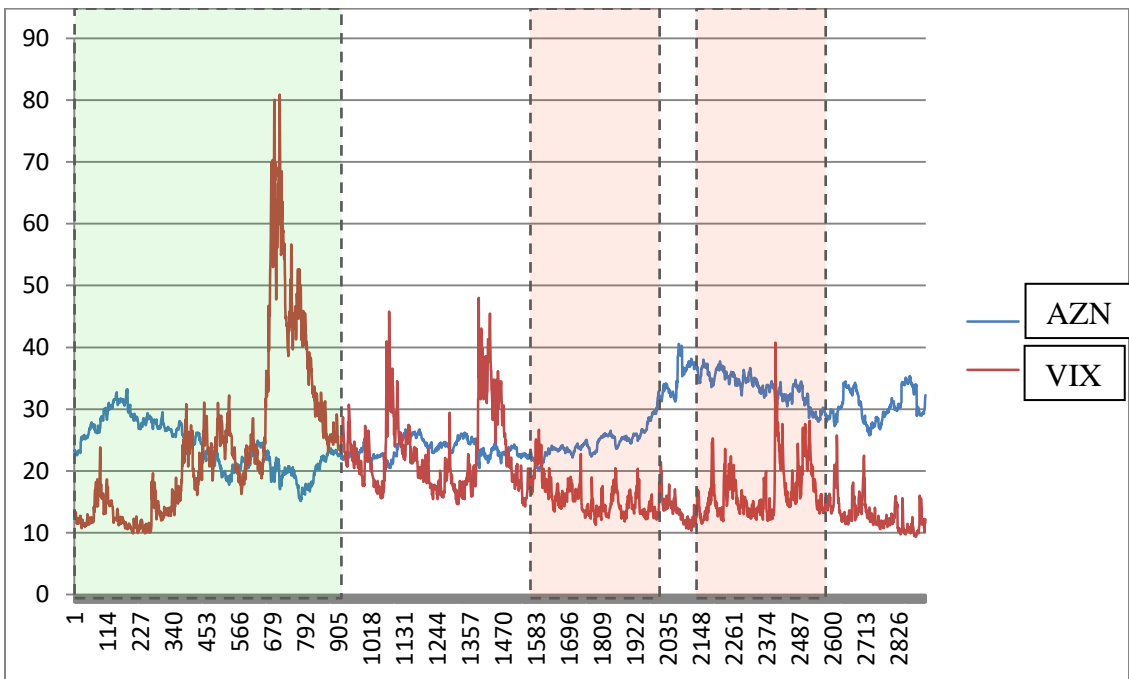


Figure 15: AZN vs VIX

## Creating a Trading Program

Now that we have found these stocks to have a meaningful correlation with the VIX, we can use this knowledge to develop a strategy for trading. While the VIX inherently contains some information about investor sentiment on a macro scale, our trading system will not be able to predict any impactful future events, especially specific to each stock. For example our trading strategy will have no way of knowing about upcoming financial reports, government legislation, or new breakthrough cancer drugs. Ultimately, our trading strategy focuses on the technical aspects of trading rather than the fundamentals.

To create a trading strategy we must define the rules to buy and sell a stock. In order to improve accuracy, the weights of each rule can be adjusted relative to each other through simulation. To begin we will define a few somewhat arbitrary rules that can be improved in the future. The goal here is to establish the problem space and the program will help locate optimal strategies within the environment. In order to evaluate the VIX trading strategy, additional trading strategies will be created using other technical indicators. This gives us more contexts to evaluate the VIX trading strategy.

### RSI

The Relative Strength Index (RSI) is a popular technical indicator that describes the recent performance of a stock and its current momentum. Generally, a value greater than 70 indicates that a stock price is overbought and a value lower than thirty indicates that a stock is oversold (StockCharts.com, 9 Oct. 2017). While the RSI can lead to false signals, it can be effective at highlighting trends when used in conjunction with other indicators.



## **Moving Average**

The two primary types of moving averages are the Simple Moving Average (SMA) and the Exponential Moving Average (EMA). Moving averages are basic methods used to reduce noise in stock data, revealing larger scale trends. EMAs are similar to SMAs in their calculation, but give heavier weighting to more recent data. This allows them to respond more quickly to rapid changes and breakouts. Moving averages of different lengths (10 day, 20 day, 60 day) are used in conjunction with each other to find buy and sell signals. When the indicators cross one another it represents a potential place to make a trade. In our trading program, SMAs and EMAs are used for pattern recognition in VIX and stock data.

## **On Balance Volume**

On balance volume (OBV) is a momentum indicator that focuses on volume rather than price. The theory of OBV is based on the basic idea that large changes in volume without changes in stock price are a sign of significant future price movement. Its calculation simply involves adding volume on days where the stock price goes up and subtracting when it goes down.

## Trading Rules

The following are the initial VIX trading rules used by all five trading strategies.

- **Buy** If the VIX low is above its 10 day simple moving average
- **Sell** if the VIX high is below its 10 day simple moving average
- **Buy** if the VIX close is more than 10% above its 10 day exponential moving average
- **Sell** if the VIX high is more than 10% below its 10 day exponential moving average
- **Buy** if the VIX close is less than 13
- **Sell** if the VIX close is more than 25
- **Buy** if the VIX has gone up more than 9% in one day
- **Sell** if the VIX has gone down more than 9% in one day

Below are additional indicators used in methods one, two, and three.

### Simple Moving Average

- **Buy** if the 5 day SMA of the stock price crosses above the 10 day SMA
- **Sell** if the 5 day SMA of the stock price crosses below the 10 day SMA

### RSI Rules

- **Sell** if the RSI is above 65
- **Buy** if the RSI is below 35

### On Balance Volume Rules

- **Buy** If the slope of the stocks 10 day SMA is moving upwards more than 7% and the slope of the 10 day SMA of the on balance volume is within 5% of the stocks slope
- **Sell** If the slope of the stocks 10 day SMA is moving upwards more than 7% and the slope of the 10 day SMA of the on balance volume is not within 5% of the stocks slope

- **Sell** If the slope of the stocks 10 day SMA is moving downwards more than 7% and the slope of the 10 day SMA of the on balance volume is within 5% of the stocks slope
- **Buy** If the slope of the stocks 10 day SMA is moving upwards more than 7% and the slope of the 10 day SMA of the on balance volume is not within 5% of the stocks slope
- **Sell** if the difference between the two slopes is greater than 5% and the OBV is moving downwards
- **Buy** if the difference between the two slopes is greater than 5% and the OBV is moving upwards

## **Trading Program**

The program developed is able to import the data for each stock and simulate trading based on that data. The data is first processed in Excel to calculate the indicators and is then imported into the program. Built into the program is a \$7.00 commission fee on each trade. This discourages the program from optimizing for trading strategies with many hundreds of trades. By default the program starts with \$5000.00 of currency.

## **Weighting**

The rules were implemented as seen above but a variable weighting system was implemented alongside to change the impact of each rule at runtime. When the rules are met, the given weight is added to the score that will determine to buy or sell. Because of this variable weighting system, weights can be set to negative values. This gives the program an extremely wide range of options when optimizing. Some rules may turn out to work in the opposite direction than we intended. The program is setup with 14 different weights. Unfortunately, due to the limits of processing power, every combination of these weights cannot be tested. The user must instead manually adjust one variable at a time.

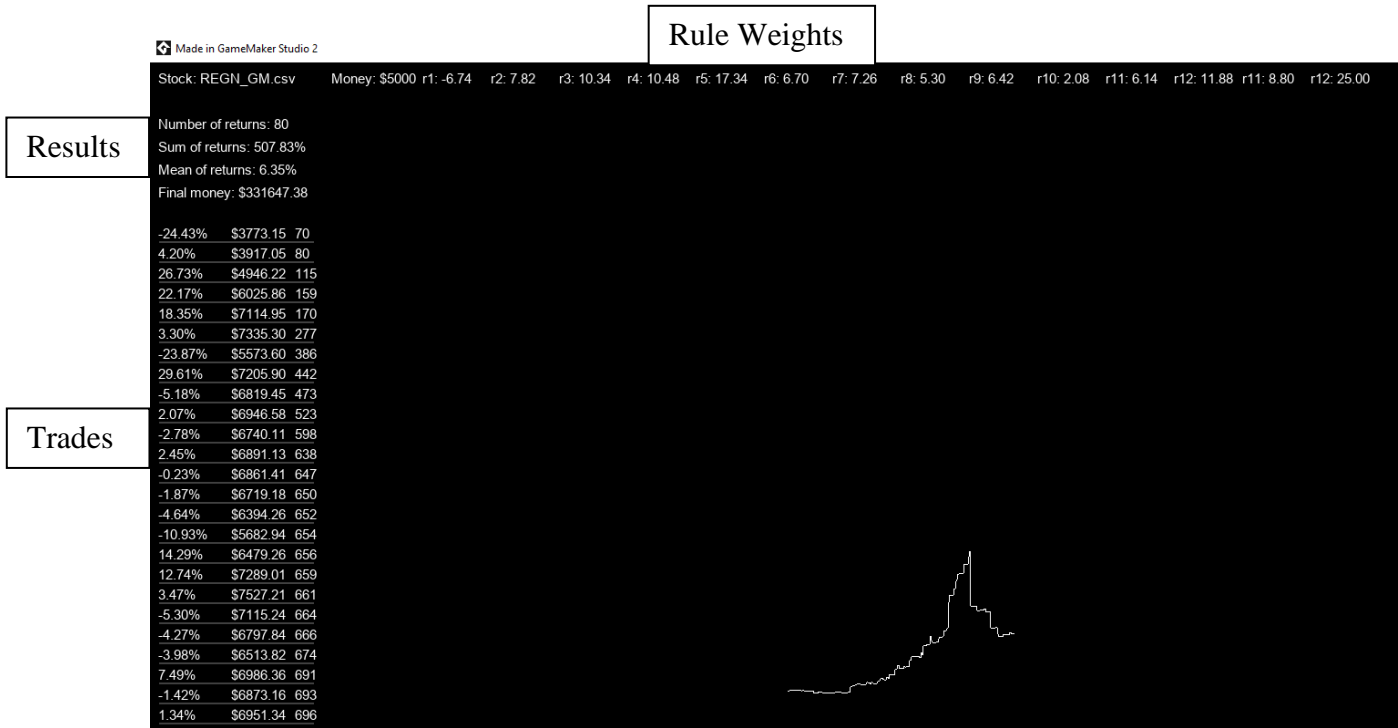


Figure 16: Trading Program Interface

Stock: REGN\_GM.csv

Number of returns: 80  
Sum of returns: 507.83%  
Mean of returns: 6.35%  
Final money: \$331647.38

-24.43%	\$3773.15	70
4.20%	\$3917.05	80
26.73%	\$4946.22	115
22.17%	\$6025.86	159
18.35%	\$7114.95	170
3.30%	\$7335.30	277
-23.87%	\$5573.60	386
29.61%	\$7205.90	442
-5.18%	\$6819.45	473
2.07%	\$6946.58	523
-2.78%	\$6740.11	598
2.45%	\$6891.13	638
-0.23%	\$6861.41	647
-1.87%	\$6719.18	650
-4.64%	\$6394.26	652
-10.93%	\$5682.94	654
14.29%	\$6479.26	656
12.74%	\$7289.01	659
3.47%	\$7527.21	661
-5.30%	\$7115.24	664
-4.27%	\$6797.84	666
-3.98%	\$6513.82	674
7.49%	\$6986.36	691
-1.42%	\$6873.16	693
1.34%	\$6951.34	696
0.83%	\$6994.91	721
6.63%	\$7443.89	724
1.92%	\$7572.85	731
1.99%	\$7709.58	752

% returns—Money—Day

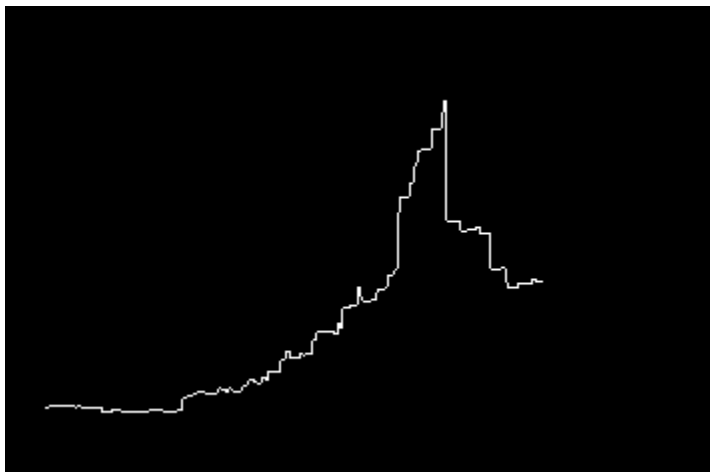


Figure 17: Simulated Returns of Variable Weighting

### Algorithm Optimization

After the user chooses a variable the software iterates through a range of that variable and displays the results. This allows the user to clearly see the influence of the given metric on the returns of the stock. This example shows the optimization of the weight of the programs sell threshold. Selling too much obviously yields poor returns but not selling enough has similar effects. The software is able to quickly find the happy medium. The accuracy is adjustable but by default the program tests 100 points along a predetermined range. This optimization takes around five seconds. Increasing the accuracy linearly increases the processing time.

## Optimizing for Individual Stocks vs All Stocks

Different stocks often have very different behavior from one another. This is a culmination of financial reports, insider trading, global market activity, legislation, etc. As can be seen in figure 4, different stocks also have largely varying correlations with the VIX. The goal is to take advantage of the commonalities in stock movements to create a globally successful strategy.

The program is able to go through historical data and test the weighting of a given rule to find the value that produces maximum income. If we attempt to optimize for GILD for example, the program will only take GILD's behavior into account when optimizing the variable. This can be problematic when optimizing for two stocks that have noticeably different behavior. Take VRTX and AZN from figure 3 for example. As we can see from the correlation matrix, the stocks have a correlation of 0.2730. Obviously, an optimal strategy for VRTX would look quite different from an optimal strategy for AZN. This raises a fundamental question. Which method has more accurate results? Optimizing for unique stocks on an individual basis or developing a single strategy that has optimal returns over a large variety of sample stocks. Due to scope, all of the created strategies were one size fits all. Given these conditions, six methods of variable weighting were developed to find the optimal trading strategy. The weighting that provides the highest return and lowest variance between stocks is the optimal strategy.

<b>Method</b>	<b>Description</b>
<b>Method One</b>	Weights equally optimized around every stock. Those weights applied to every stock. Used the VIX rules as well as the additional indicators.
<b>Method Two</b>	Weights optimized around the ETF IBB. Those weights applied to every stock. Used the VIX rules as well as the additional indicators.
<b>Method Three</b>	Weights optimized around the ETF XBI. Those weights applied to every stock. Used the VIX rules as well as the additional indicators.
<b>Method Four</b>	Weights optimized around a random selection of multiple stocks. Used the VIX rules as well as the additional indicators.
<b>Method Five</b>	Weights optimized around the ETF XBI and ETF IBB. Those weights applied to every stock. Used only the VIX rules to trade.
<b>Method Six</b>	Weights optimized around the INCY. Those weights applied to every stock. Used only the VIX rules to trade.

**Figure 18: Methods**

**Output**

The weights in Figure 19 are the output of simulation. Highlighted in bold are rules that the program gave similar weights to across different strategies. Figures 20 and 21 show the simulated profits of the trading strategies over the eight year period.



**R1:** Buy if VIX low above VIX SMA

**R2:** Sell if VIX high above VIX SMA

**R3:** Buy if VIX is 10% above EMA

**R4:** Sell if VIX is 10% below EMA

**R5:** VIX buy threshold

**R6:** VIX sell threshold

**R7:** VIX slope buy

**R8:** VIX slope sell

**R9:** RSI Sell threshold

**R10:** RSI Buy threshold

**R11:** Buy when the 5 day SMA of the stock crosses above its 10 day SMA

**R12:** Sell when the 5 day SMA of the stock crosses below its 10 day SMA

**R13:** Buy threshold

**R14:** Sell threshold

	<b>R1</b>	<b>R2</b>	<b>R3</b>	<b>R4</b>	<b>R5</b>	<b>R6</b>	<b>R7</b>	<b>R8</b>	<b>R9</b>	<b>R10</b>	<b>R11</b>	<b>R12</b>	<b>R13</b>	<b>R14</b>
<b>Method One</b>	10.6	11.18	<b>-10.1</b>	-1.14	-2.82	<b>2.36</b>	<b>10.9</b>	11.32	3.70	8.10	<b>17.36</b>	4.9	20.1	21.5
<b>Method Two</b>	-3.38	-0.72	<b>-4.08</b>	8.10	7.68	-15	<b>18.04</b>	3.76	<b>7.82</b>	3.48	<b>15.1</b>	15.5	20	20
<b>Method Three</b>	16.22	-6.46	<b>-4.08</b>	18.88	-15	<b>3.90</b>	<b>12.44</b>	-15	<b>13.84</b>	-3.1	<b>14.54</b>	-15	29.2	30.5
<b>Method Four</b>	18.7	-15	6.14	-15	-15	8.66	<b>12.44</b>	3.34	<b>16.22</b>	-7.3	<b>11.74</b>	-15	29.2	30.5
<b>Method Five</b>	-5.2	0.68	<b>-6.88</b>	16.22	9.64	<b>0.26</b>	<b>12.02</b>	5.44	-	-	-	-	15.4	14.7
<b>Method Six</b>	8.38	-15	7.96	-15	9.22	<b>0.54</b>	<b>8.1</b>	9.94	-	-	-	-	20.4	14.3

**Figure 19: Trading Strategy Weights**

While these strategies were created through different means, some patterns arose in the weighting from the software. Using the dataset, the program seems to strongly favor buying when the VIX has spiked down more than 9%. The program also places high significance on buying when the stock's 5 day SMA crosses above its 10 day SMA. Additionally selling when the RSI is above 70 is also a consistent method. In contrast, the VIX above its 10 day EMA is a sign not to buy the stock.

Stock	No Strategy	Method One	Diff	Method Two	Diff
AZN	\$ 12,349	\$ 6,470	-48%	\$ 8,023	-35%
VRTX	\$ 19,993	\$ 57,139	186%	\$ 34,748	74%
INCY	\$ 107,367	\$ 37,336	-65%	\$ 116,454	8%
REGN	\$ 137,181	\$ 190,850	39%	\$ 239,211	74%
AMGN	\$ 13,963	\$ 9,403	-33%	\$ 5,896	-58%
BIIB	\$ 30,271	\$ 33,156	10%	\$ 33,978	12%
GILD	\$ 30,250	\$ 17,157	-43%	\$ 15,839	-48%
CELG	\$ 35,369	\$ 70,707	100%	\$ 20,590	-42%
XBI	\$ 25,984	\$ 28,354	9%	\$ 35,872	38%
IBB	\$ 20,616	\$ 34,510	67%	\$ 39,989	94%
<b>Total</b>	<b>\$ 433,343</b>	<b>\$ 485,082</b>	<b>12%</b>	<b>\$ 550,600</b>	<b>27%</b>

Figure 20: Earnings of Simulated Strategies over Historical Period Group A

Method Three	Diff	Method Four	Diff	Method Five	Diff	Method Six	Diff
\$ 7,616	-38%	\$ 5,791	-53%	\$ 12,561	2%	\$ 11,530	-7%
\$ 26,469	32%	\$ 10,820	-46%	\$ 50,748	154%	\$ 20,349	2%
\$ 68,253	-36%	\$ 349,795	226%	\$ 736,039	586%	\$ 677,462	531%
\$ 262,191	91%	\$114,026	-17%	\$ 957,953	598%	\$ 301,593	120%
\$ 17,844	28%	\$11,921	-15%	\$ 21,221	52%	\$ 26,242	88%
\$ 30,970	2%	\$ 1,854	-94%	\$ 23,204	-23%	\$ 41,285	36%
\$ 24,986	-17%	\$ 46,828	55%	\$ 32,724	8%	\$ 41,762	38%
\$ 28,754	-19%	\$ 84,276	138%	\$ 67,025	90%	\$ 58,669	66%
\$ 43,206	66%	\$ 21,395	-18%	\$ 58,928	127%	\$ 35,124	35%
\$ 1,322	52%	\$ 19,454	-6%	\$ 41,224	100%	\$ 36,208	76%
<b>\$ 541,611</b>	<b>25%</b>	<b>\$ 666,160</b>	<b>54%</b>	<b>\$ 2,001,627</b>	<b>362%</b>	<b>\$ 1,250,224</b>	<b>189%</b>

Figure 21 : Earnings of Simulated Strategies over Historical Period Group B

### Three Month Test

The six methods were put to the test over a three month period. Biotech performed very poorly in these months, along with the market in general. However, all methods were successful in having higher cumulative returns rather than no trading strategy at all. There was, however, a very large variance in returns when compared to the reference. The trading strategies produced by the program receive the benefits of high profits at the cost of high volatility. All methods were consistently successful in trading the ETF's. The software is able to exploit the consistency of the ETF's making them regularly better than the reference. Low correlation stocks, on the other hand, such as AZN, GILD, and AMGN are not traded well by the software. Methods five and six, which were entirely VIX based trading strategies, performed on the same if not higher level than the multi-indicator strategies. Despite the three month testing period being short, it shows the VIX as a potentially powerful method of prediction.

Stock	No Strategy	Method One	Diff	Method Two	Diff3
AZN	\$ 5,104	\$ 4,948	-3%	\$ 5,161	1%
VRTX	\$ 5,053	\$ 5,452	8%	\$ 5,476	8%
INCY	\$ 3,994	\$ 4,538	14%	\$ 3,702	-7%
REGN	\$ 3,938	\$ 4,209	7%	\$ 4,190	6%
AMGN	\$ 5,068	\$ 5,379	6%	\$ 5,218	3%
BIIB	\$ 5,245	\$ 5,262	0%	\$ 5,085	-3%
GILD	\$ 4,961	\$ 5,357	8%	\$ 4,789	-3%
CELG	\$ 3,641	\$ 3,973	9%	\$ 4,668	28%
XBI	\$ 4,963	\$ 5,083	2%	\$ 5,188	5%
IBB	\$ 4,894	\$ 5,307	8%	\$ 5,547	13%
<b>Total</b>	<b>\$ 46,861</b>	<b>\$ 49,508</b>	<b>6%</b>	<b>\$ 49,024</b>	<b>5%</b>

Figure 22: Three Month Returns Group A

Method Three	Diff	Method Four	Diff	Method Five	Diff	Method Six	Diff
\$ 5,286	4%	\$ 5,232	3%	\$ 5,328	4%	\$ 5,369	5%
\$ 6,200	23%	\$ 5,867	16%	\$ 5,670	12%	\$ 5,849	16%
\$ 4,512	13%	\$ 4,512	13%	\$ 4,962	24%	\$ 4,690	17%
\$ 4,354	11%	\$ 4,317	10%	\$ 4,972	26%	\$ 4,834	23%
\$ 5,494	8%	\$ 5,332	5%	\$ 5,334	5%	\$ 5,320	5%
\$ 5,258	0%	\$ 4,179	-20%	\$ 4,870	-7%	\$ 4,850	-8%
\$ 5,327	7%	\$ 5,032	1%	\$ 5,054	2%	\$ 4,996	1%
\$ 4,074	12%	\$ 4,068	12%	\$ 4,539	25%	\$ 4,372	20%
\$ 5,919	19%	\$ 5,601	13%	\$ 5,495	11%	\$ 5,357	8%
\$ 5,516	13%	\$ 5,177	6%	\$ 5,289	8%	\$ 3,950	-19%
\$ 51,940	11%	\$ 49,317	5%	\$ 51,513	10%	\$ 49,587	6%

Figure 23: Three Month Returns Group B

## Conclusion

Even in its most basic form, the efficient market hypothesis claims that technical analysis is ineffective. This study works to disprove that blanket statement. While the trial period was brief, it far exceeded the natural movement of the market. If nothing else, these results serve as an additional example of when technical trading strategies succeed.

While the developed software focused on the automated discovery and creation of trading strategies, it could potentially be augmented to receive real-time ticker information and trade automatically. The use of computational analysis in this project offers only a brief glimpse into the extensive world of financial automation. With rapid developments in artificial intelligence and computing, it seems almost inevitable that the market will become more and more automated in the future. This raises the question of how heavy automation effects market efficiency.

Analysis revealed the VIX to have a meaningful correlation with stock price. More importantly, that correlation was used as a tool for prediction. Furthermore, the trading strategies

based entirely off of the VIX outperformed trading strategies with other traditional indicators. The VIX is not merely a reflection of the market but is a collection of information that can be exploited.

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## Source Code

Below is a large sample of the source code of the created program. The code is responsible for the simulation and optimization of the trading strategies.

```
//end the application if the user presses escape
if (keyboard_check_pressed(vk_escape)) game_end();
if (keyboard_check(vk_shift)) {
    scroll_mod = 3
} else if (keyboard_check(vk_control)) {
    scroll_mod = 0.3;
} else {
    scroll_mod = 1;
}
if (keyboard_check_pressed(vk_enter)) {
    if (simulate == 0) {
        step = 0;
    }
}
```

```

        highest_returns = 0;
        simulate = 1;
    }
}
if (keyboard_check(ord("W"))) scroll -= 10*scroll_mod;
if (keyboard_check(ord("S"))) scroll += 10*scroll_mod;
if (keyboard_check_pressed(vk_left)) {state--;flash=1;delay=0;}
if (keyboard_check_pressed(vk_right)) {state++;flash=1;delay=0;}
state = clamp(state,0,15);
scroll = clamp(scroll,0,10000);

if (delay > 30) {
    delay = 0;
    if (flash) {
        flash = 0;
    } else {
        flash = 1;
    }
}

switch (state) {
    case 0:
        if (keyboard_check(vk_up)) {
            stock++;update=1;
            stock = clamp(stock,0,ds_list_size(stocks)-1);
            grid = script0(working_directory+ds_list_find_value(stocks,stock));}
        if (keyboard_check(vk_down)) {
            stock--;update=1;
            stock = clamp(stock,0,ds_list_size(stocks)-1);
            grid = script0(working_directory+ds_list_find_value(stocks,stock));}
        break;
    case 1:
        if (keyboard_check(vk_up)) {starting_money += 40*scroll_mod;update=1};
        if (keyboard_check(vk_down)) {starting_money -= 40*scroll_mod;update=1};
        break;
    case 2:
        if (keyboard_check(vk_up)) {rating1 += 0.1*scroll_mod;update=1};
        if (keyboard_check(vk_down)) {rating1 -= 0.1*scroll_mod;update=1};
        break;
    case 3:
        if (keyboard_check(vk_up)) {rating2 += 0.1*scroll_mod;update=1};
        if (keyboard_check(vk_down)) {rating2 -= 0.1*scroll_mod;update=1};
        break;
    case 4:
        if (keyboard_check(vk_up)) {rating3 += 0.1*scroll_mod;update=1};
        if (keyboard_check(vk_down)) {rating3 -= 0.1*scroll_mod;update=1};
        break;
    case 5:

```

```

        if (keyboard_check(vk_up)) {rating4 += 0.1*scroll_mod;update=1 };
        if (keyboard_check(vk_down)) {rating4 -= 0.1*scroll_mod;update=1 };
        break;
case 6:
        if (keyboard_check(vk_up)) {rating5 += 0.1*scroll_mod;update=1 };
        if (keyboard_check(vk_down)) {rating5 -= 0.1*scroll_mod;update=1 };
        break;
case 7:
        if (keyboard_check(vk_up)) {rating6 += 0.1*scroll_mod;update=1 };
        if (keyboard_check(vk_down)) {rating6 -= 0.1*scroll_mod;update=1 };
        break;
case 8:
        if (keyboard_check(vk_up)) {rating7 += 0.1*scroll_mod;update=1 };
        if (keyboard_check(vk_down)) {rating7 -= 0.1*scroll_mod;update=1 };
        break;
case 9:
        if (keyboard_check(vk_up)) {rating8 += 0.1*scroll_mod;update=1 };
        if (keyboard_check(vk_down)) {rating8 -= 0.1*scroll_mod;update=1 };
        break;
case 10:
        if (keyboard_check(vk_up)) {rating9 += 0.1*scroll_mod;update=1 };
        if (keyboard_check(vk_down)) {rating9 -= 0.1*scroll_mod;update=1 };
        break;
case 11:
        if (keyboard_check(vk_up)) {rating10 += 0.1*scroll_mod;update=1 };
        if (keyboard_check(vk_down)) {rating10 -= 0.1*scroll_mod;update=1 };
        break;
case 12:
        if (keyboard_check(vk_up)) {rating11 += 0.1*scroll_mod;update=1 };
        if (keyboard_check(vk_down)) {rating11 -= 0.1*scroll_mod;update=1 };
        break;
case 13:
        if (keyboard_check(vk_up)) {rating12 += 0.1*scroll_mod;update=1 };
        if (keyboard_check(vk_down)) {rating12 -= 0.1*scroll_mod;update=1 };
        break;
case 14:
        if (keyboard_check(vk_up)) {rating13 += 0.1*scroll_mod;update=1 };
        if (keyboard_check(vk_down)) {rating13 -= 0.1*scroll_mod;update=1 };
        break;
case 15:
        if (keyboard_check(vk_up)) {rating14 += 0.1*scroll_mod;update=1 };
        if (keyboard_check(vk_down)) {rating14 -= 0.1*scroll_mod;update=1 };
        break;
}

if (update) {
    update = 0;
    delay = 0;

```

```

money = starting_money;
number_of_returns = 0;
total_returns = 0;
stored_buy_price = 0;
bought = 0
count4 = 0;
ds_list_clear(returns);
ds_list_clear(dates);
ds_list_clear(money_returns);
var len = ds_grid_height(grid);
for (var i=0;i<len;i++) {

    var vix_open = ds_grid_get(grid,0,i);
    var vix_close = ds_grid_get(grid,1,i);
    var vix_high = ds_grid_get(grid,2,i);
    var vix_low = ds_grid_get(grid,3,i);
    var vix_sma = ds_grid_get(grid,4,i);
    var vix_ema = ds_grid_get(grid,5,i);
    var stock_close = ds_grid_get(grid,6,i);
    var stock_volume = ds_grid_get(grid,7,i);
    var stock_obv = ds_grid_get(grid,8,i);
    var stock_rsi = ds_grid_get(grid,9,i);
    var stock_sma5 = ds_grid_get(grid,10,i);
    var stock_sma10 = ds_grid_get(grid,11,i);
    var obv_sma10 = ds_grid_get(grid,12,i);

    if (stock_close > 0) {
        count4++;
        trade = 0;
        buy_rating = 0;
        sell_rating = 0;

        if (vix_low > vix_sma) {
            buy_rating += rating1;
        }
        if (vix_high < vix_sma) {
            sell_rating += rating2;
        }

        var percent_diff = ((vix_close - vix_ema)/vix_ema)*100;
        if (percent_diff > 10) {
            buy_rating += (percent_diff/20)*rating3;
        }
        if (percent_diff < -10) {
            sell_rating -= (percent_diff/20)*rating4;
        }
    }
}

```



```

if (vix_close < 13) {
    buy_rating += 0.5*(13-vix_close)*rating5;
}

if (vix_close > 25) {
    sell_rating += 0.5*(vix_close-25)*rating6;
}

if (extra_indicators) {
    if (stock_rsi > 65) {
        sell_rating += (0.2*(stock_rsi-65)*rating9);
    }

    if (stock_rsi < 35) {
        buy_rating += (0.2*(35-stock_rsi)*rating10);
    }
}

if (i > 0) {
    var vix_close_prev = ds_grid_get(grid,1,i-1);
    var vix_change = ((vix_close - vix_close_prev)/vix_close_prev)*100;
    if (vix_change > 9) {
        buy_rating += 0.2*(vix_change-9)*rating7;
    }
    if (vix_change < -9) {
        sell_rating -= 0.2*(vix_change+9)*rating8;
    }

    if (extra_indicators) {
        var stock_sma5_prev = ds_grid_get(grid,10,i-1);
        var stock_sma10_prev = ds_grid_get(grid,11,i-1);
        if (stock_sma5 > stock_sma10 && stock_sma5_prev < stock_sma10_prev) {
            buy_rating += rating11;
        } else if (stock_sma5 < stock_sma10 && stock_sma5_prev > stock_sma10_prev) {
            sell_rating += rating12;
        }
    }
}

if (extra_indicators) {
    if (i > 9) {
        var slopea1 = stock_sma10;
        var slopea2 = ds_grid_get(grid,11,i-10);
        var slopeb1 = obv_sma10;
        var slopeb2 = ds_grid_get(grid,12,i-10);
        var stock_slope = ((slopea1-slopea2)/slopea2)*100;
        var obv_slope = ((slopeb1-slopeb2)/slopeb2)*100;
    }
}

```

```

var slope = 7;
var diff = 5;
if (stock_slope > slope) {
    if (abs(stock_slope - obv_slope) < diff) {
        buy_rating += 3;
    } else if (obv_slope < stock_slope) {
        sell_rating += 3;
    }
} else if (stock_slope < -slope) {
    if (abs(stock_slope - obv_slope) < diff) {
        sell_rating += 3;
    } else if (obv_slope > stock_slope) {
        buy_rating += 3;
    }
} else {
    if (abs(stock_slope - obv_slope) < diff) {

    } else if (obv_slope > stock_slope) {
        buy_rating += 3;
    } else if (obv_slope < stock_slope) {
        sell_rating += 3;
    }
}
}

if (i==0 && bought == 0) {
    stored_buy_price = stock_close;
    bought = 1;
    money -= 7;
} else if (((i >= 113) || (sell_rating > rating14)) && bought == 1) {
    bought = 0;
    percent_return = ((stock_close-stored_buy_price)/stored_buy_price)*100;
    ds_list_add(returns,percent_return);
    ds_list_add(dates,i);
    money += (percent_return/100)*money;
    ds_list_add(money_returns,money);
    money -= 7;
}

}

}

for (var i=0;i<ds_list_size(returns);i++) {
    number_of_returns++;
    var ret = ds_list_find_value(returns,i);

```

```

        total_returns += ret;
    }

    mean_returns = total_returns/number_of_returns;
}

delay++;

if (simulate) {
    delay = 0;
    count = 0;
    simulate = 0;
    update = 1;

    var r1 = rating1;
    var r2 = rating2;
    var r3 = rating3;
    var r4 = rating4;
    var r5 = rating5;
    var r6 = rating6;
    var r7 = rating7;
    var r8 = rating8;
    var r9 = rating9;
    var r10 = rating10;
    var r11 = rating11;
    var r12 = rating12;
    var r13 = rating13;
    var r14 = rating14;

    range1 = -15;
    range2 = 20;

    switch (state) {
        case 14:
            range1 = 5;
            range2 = 30;
            break;
        case 15:
            range1 = 5;
            range2 = 30;
            break;
    }

    for (var i=range1;i<range2;i+=(range2-range1)/accuracy) {

        switch (state) {
            case 2:
                r1 = i;

```

```
        break;
    case 3:
        r2 = i;
        break;
    case 4:
        r3 = i;
        break;
    case 5:
        r4 = i;
        break;
    case 6:
        r5 = i;
        break;
    case 7:
        r6 = i;
        break;
    case 8:
        r7 = i;
        break;
    case 9:
        r8 = i;
        break;
    case 10:
        r9 = i;
        break;
    case 11:
        r10 = i;
        break;
    case 12:
        r11 = i;
        break;
    case 13:
        r12 = i;
        break;
    case 14:
        r13 = i;
        break;
    case 15:
        r14 = i;
        break;
}

money = starting_money;
number_of_returns = 0;
total_returns = 0;
stored_buy_price = 0;
bought = 0
ds_list_clear(returns);
```

```

ds_list_clear(dates);
ds_list_clear(money_returns);
var len = ds_grid_height(grid);
for (var j=0;j<len;j++) {
    var vix_open = ds_grid_get(grid,0,j);
    var vix_close = ds_grid_get(grid,1,j);
    var vix_high = ds_grid_get(grid,2,j);
    var vix_low = ds_grid_get(grid,3,j);
    var vix_sma = ds_grid_get(grid,4,j);
    var vix_ema = ds_grid_get(grid,5,j);
    var stock_close = ds_grid_get(grid,6,j);
    var stock_volume = ds_grid_get(grid,7,j);
    var stock_obv = ds_grid_get(grid,8,j);
    var stock_rsi = ds_grid_get(grid,9,j);
    var stock_sma5 = ds_grid_get(grid,10,j);
    var stock_sma10 = ds_grid_get(grid,11,j);
    var obv_sma10 = ds_grid_get(grid,12,j);
    if (stock_close > 0) {
        trade = 0;
        buy_rating = 0;
        sell_rating = 0;

        if (vix_low > vix_sma) {
            buy_rating += r1;
        }
        if (vix_high < vix_sma) {
            sell_rating += r2;
        }

        var percent_diff = ((vix_close - vix_ema)/vix_ema)*100;
        if (percent_diff > 10) {
            buy_rating += (percent_diff/20)*r3;
        }
        if (percent_diff < -10) {
            sell_rating -= (percent_diff/20)*r4;
        }

        if (vix_close < 13) {
            buy_rating += 0.5*(13-vix_close)*r5;
        }

        if (vix_close > 25) {
            sell_rating += 0.5*(vix_close-25)*r6;
        }

        if (extra_indicators) {
            if (stock_rsi > 65) {

```

```

        sell_rating += (0.2*(stock_rsi-65)*r9);
    }

    if (stock_rsi < 35) {
        buy_rating += (0.2*(35-stock_rsi)*r10);
    }
}

if (j > 0) {
    var vix_close_prev = ds_grid_get(grid,1,j-1);
    var vix_change = ((vix_close - vix_close_prev)/vix_close_prev)*100;
    if (vix_change > 9) {
        buy_rating += 0.2*(vix_change-9)*r7;
    }
    if (vix_change < -9) {
        sell_rating -= 0.2*(vix_change+9)*r8;
    }

    if (extra_indicators) {
        var stock_sma5_prev = ds_grid_get(grid,10,j-1);
        var stock_sma10_prev = ds_grid_get(grid,11,j-1);
        if (stock_sma5 > stock_sma10 && stock_sma5_prev < stock_sma10_prev) {
            buy_rating += r11;
        } else if (stock_sma5 < stock_sma10 && stock_sma5_prev > stock_sma10_prev) {
            sell_rating += r12;
        }
    }
}

if (extra_indicators) {
    if (j > 9) {
        var slopea1 = stock_sma10;
        var slopea2 = ds_grid_get(grid,11,j-10);
        var slopeb1 = obv_sma10;
        var slopeb2 = ds_grid_get(grid,12,j-10);
        var stock_slope = ((slopea1-slopea2)/slopea2)*100;
        var obv_slope = ((slopeb1-slopeb2)/slopeb2)*100;
        var slope = 7;
        var diff = 5;
        if (stock_slope > slope) {
            if (abs(stock_slope - obv_slope) < diff) {
                buy_rating += 3;
            } else if (obv_slope < stock_slope) {
                sell_rating += 3;
            }
        } else if (stock_slope < -slope) {
            if (abs(stock_slope - obv_slope) < diff) {
                sell_rating += 3;
            }
        }
    }
}

```

```

        } else if (obv_slope > stock_slope) {
            buy_rating += 3;
        }
    } else {
        if (abs(stock_slope - obv_slope) < diff) {

            } else if (obv_slope > stock_slope) {
                buy_rating += 3;
            } else if (obv_slope < stock_slope) {
                sell_rating += 3;
            }
        }
    }
}

if (buy_rating > r13 && bought == 0) {
    stored_buy_price = stock_close;
    bought = 1;
    money -= 7;
} else if (((i == len) || (sell_rating > r14)) && bought == 1) {
    bought = 0;
    percent_return = ((stock_close - stored_buy_price) / stored_buy_price) * 100;
    ds_list_add(returns, percent_return);
    ds_list_add(dates, i);
    money += (percent_return / 100) * money;
    ds_list_add(money_returns, money);
    money -= 7;
}
}

}

for (var w=0; w<ds_list_size(returns); w++) {
    number_of_returns++;
    var ret = ds_list_find_value(returns, w);
    total_returns += ret;
}

mean_returns = total_returns / number_of_returns;
graph[count] = money / 600;
count++;

if (money > highest_returns) {
    highest_returns = money;
    rating1 = r1;
    rating2 = r2;
    rating3 = r3;
}

```

```
rating4 = r4;  
rating5 = r5;  
rating6 = r6;  
rating7 = r7;  
rating8 = r8;  
rating9 = r9;  
rating10 = r10;  
rating11 = r11;  
rating12 = r12;  
rating13 = r13;  
rating14 = r14;
```

```
}
```

```
}
```

```
}
```