Numerical Methods for Calculating Thailand's Volatility Index

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Abstract

This financial engineering project aims to address the challenges faced by options traders in the Thai market due to limitations in size, liquidity, and understanding of the options market. Inspired by the success of the VIX in the US market, this project seeks to develop a tool to calculate Thailand's Volatility Index (TVIX) using options pricing models, numerical methods, and complex mathematical formulas. The objective is to develop a reliable TVIX that can handle the limitations of data provided by the market, move in correspondence with the market, and can be used in real practice. The scope of work includes testing and developing tools for calculating call and put options prices, implied volatility, and TVIX using Python programming language and authorized data sources from TFEX. The model's performance will be tested using datasets of all strike prices of SET50 index options from 2014 to 2023. The development of TVIX aims to attract more option traders, provide a better understanding of options, and support the growth of Thailand's options market. A final model has been developed that effectively calculates intraday TVIX using the Black-Scholes model, the Newton-Raphson method, and the VXO formula. The results of TVIX can be used as market volatility measurement since it consequently tends to rise when investors expect more uncertainty in the market. It moves in the opposite direction of the SET50 index, reflecting investors' feelings of fear about the market's future direction.

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Chapter 1
Introduction

1.1 Motivation

This project is assigned by a security company in Thailand to work on the problem of trading options in the Thai market as the options traders are facing the limitations of the size and liquidity of the market that causes difficulties in dealing with their counterparties and contract executions. Besides, there is only the SET50 index that is used as the underlying asset for options, then the number of options contracts available in each trading period are also limited. Another relevant issue is the perspective and understanding of Thai investors to the options market that might not fully comprehend the risk and advantages of trading options since it is new in Thailand. These reasons can explain how much the options market in Thailand is challenging, and somehow less attractive for the investors, thus it results in the reduction of total trading activity in the options market.

Meanwhile, developed markets such as the US, have a reliable tool called VIX (CBOE Volatility Index) created by the CBOE (Chicago Board Options Exchange) in 1993. It has been used to measure the market's expected volatility in the next 30 days and determined by the price of options on the S&P 500 index and commonly referred to as the "Fear Index" because it can imply the level of fear or anxiety in the market. Due to its ability to hedge against market volatility or speculate on market changes, the VIX has risen to be an important instrument for investors, also it is used to make trading decisions based on market sentiment and determine options prices. The VIX's creation has been a significant development for the financial industry which allows investors to have an efficient tool for managing risks and making prudent investment decisions.

According to the inspiration from the concept of VIX, this project aims to initiate a tool that is able to calculate Thailand's Volatility Index (TVIX) by applying models for options pricing, numerical methods and some complex mathematical formulas. Eventually, it would help the Thailand Futures Exchange (TFEX) to attract more option traders. All members of this project hope that the new TVIX can help Thai traders to have more understanding in options, and support Thailand's options market to be more efficient and grow faster with the belief that "The more participants the more efficient the market is, the faster the market reacts to any actions, and the more the market would expand."

1.2 Objectives

1. To develop the tool to calculate intraday Thailand's Volatility Index (TVIX)
2. To develop the TVIX of Thailand that can handle the limitations of data provided by the market.
3. To develop the TVIX of Thailand to be reliable and move mostly corresponding to the market.
4. To develop a program for calculating TVIX that can be used in real practice.

1.3 Scope of Work

The scope of this project can be listed as follows:

1. To test and develop the tool to calculate call and put options price of SET50 index options using European-style options pricing models including Black-Scholes model, Black model, and Monte-Carlo simulation.
2. To test and develop the tool to calculate Implied Volatility (IV) using numerical methods including Newton-Raphson method, Bisection method, and Secant method.
3. To develop the tool to calculate the TVIX of Thailand as the market's expected volatility based on SET50 index options.
4. To develop the tool using Python programming language.
5. To develop the tool based on TFEX and authorized sources of data only.

6. To test the model performance using call and put datasets with all strike prices of SET50 index options from 2014 to 2023.

1.4 Thesis Structure

This thesis consists of five chapters which are arranged as follows:

- Chapter 1 Introduction - refers to the motivation, objectives, scope of work, and thesis structure of this thesis.
- Chapter 2 Literature Review – proposes the literature review, various methods, models, and formulas that are relevant to this project, and comparison.
- Chapter 3 Research Methodology – explains the processes that are used to conduct the thesis including steps of choosing a model to do the options pricing, method of calculating IV until the formula for TVIX calculation together with the process of model evaluation.
- Chapter 4 Results and Discussion – shows the results obtained from the TVIX model and also discusses those results.
- Chapter 5 Conclusion and Recommendations – conclude and summarize the thesis, as well as implementations and recommendations related to the further real practice of the thesis results and model.

Chapter 2
Literature Review

This chapter primarily explains the options pricing models to calculate call and put prices, including Black-Scholes model, Black model, and Monte-Carlo simulation, along with numerical methods for calculating implied volatility (IV) using Newton and Raphson, Bisection, and Secant methods, as well as some background knowledge about CBOE Volatility Index (VIX) and CBOE S&P 100 Volatility Index (VXO).

2.1 Option Pricing Models

Option Pricing Models are mathematical models that use certain variables to calculate the theoretical value or fair value of an options. Choosing between European-style or American-style options will affect the choice for the option pricing model. Since index option pricing is taken into consideration in this project, the model must be compatible with European-style options. The selected models are the Black-Scholes model, the Black model, the Monte-Carlo simulation.

2.1.1 Black-Scholes Model

The Black and Scholes (1973) model was a significant development in theoretically estimating the option pricing problem. The Black-Scholes model is attractive since it provides a closed-form solution for pricing European-style options. With the sole exception of the volatility measure, all other variables used in the model are observed from the market and hence the model contributed to the expansion of the options markets as effective pricing technology was made available. Though the original model was developed for non-dividend paying securities in European-style options, it can be modified to price various types of options. [6]

2.1.2 Black Model

There have been various theoretical developments made to the original Black-Scholes model. One such development for the valuation of futures options is presented by Black (1976). In his calculation for options, Black made the assumption that investors would generate risk-free hedges between options and futures or forward contracts. The problem of the negative cost of carry was addressed by using 'forward prices' instead of 'spot prices' in the option pricing model. Black observed that actual forward prices not only incorporate the cost of carry but also take into account other irregularities in the market. In his proposed model, the spot price (S) in the original Black-Scholes model is replaced by the discounted value of future price (Fe^{-rt}). [6]

2.1.3 Monte-Carlo Simulation

The Monte Carlo system is typically used in equity options pricing. While Monte Carlo simulation works great for European-style options, it's harder to apply the model to value American-style options. The prices of a beginning share are simulated for each possible price path using the Stochastic Processes Simulation called Geometric Brownian Motion (GBM), and the option payoffs are determined for each path. The payoffs are also averaged and discounted to today, which provides the current value of an option. [3][19]

2.2 Numerical Methods for Implied Volatility

Implied volatility (IV) is the market's price forecast. Investors use it to forecast future price changes depending on particular characteristics. It is a proxy for market risk. It's reported in percentages and standard deviations for a certain time period. A trader can analyze historical and implied volatility to assess if an event may affect a stock's price.

In bearish stock markets, implied volatility rises when investors expect share prices to fall. While bullish investors expect prices to grow over time, reducing implied volatility. Thus, most stock investors wish to avoid and fear bearish markets.

As with the market, implied volatility fluctuates. Supply and demand affect implied volatility. A high-demand asset's price tends to climb. So does implied volatility, which increases option premium owing to its riskiness. Also, true. When supply exceeds demand, implied volatility lowers, and the option price falls. Another premium determinant is the option's time value, or how long until it expires. A short-term option has low implied volatility, whereas a long-term option has high implied volatility. The difference is the contract expiration date. Due to more time, the price has more time to advance toward the strike price.

Implied volatility measures market sentiment. It predicts an asset's movement. However, it doesn't show movement direction. Option writers calculate options contracts using implied volatility. When choosing an investment, many investors look at IV. They may invest in safer sectors or businesses during high volatility. Implied volatility is based only on price, not market fundamentals. War or natural calamities can affect implied volatility. [20]

Implied volatility is one of the important parameters and a vital component of the Black-Scholes model, an option pricing model that shall give the option's market price or market value. The implied volatility formula shall depict where the volatility of the underlying in question should be in the future and how the marketplace sees them.

Quantitative analysts use several numerical methods to calculate implied volatility, including Newton-Raphson, Secant, and Bisection methods. [7]

2.2.1 Newton-Raphson Method

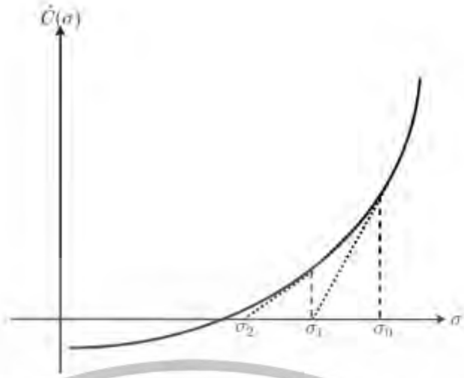

Figure 2.1: Graphical simulation of the Newton-Raphson method

[Source: On some Numerical Methods for Implied Volatility Calculation by Rosmoh Nisani, 2017]

Option traders often use the Newton–Raphson approach. This approach involves an initial guess of implied volatility, option price derived from the initial guess, options market price, and Vega in terms of initial guess.

When its criteria are met, the option's ultimate implied volatility is estimated. Initial estimated values can be acquired from other formulae, prior experience, or random. The Newton–Raphson approach is rapid and if the initial predictions are excellent, the model's efficiency is improved, hence many option traders favor it. This technique requires Vega's value. Vega may be computed analytically for European-style options. [17]

2.2.2 Secant Method

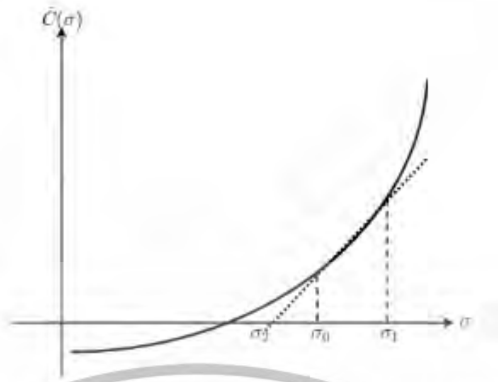

Figure 2.2: Graphical simulation of the Secant method

[Source: On some Numerical Methods for Implied Volatility Calculation by Rosmoh Nisani, 2017]

Another approach that can be used to extract implied volatility from options prices is the so-called Secant method. Some 'mathematicians', 3,000 years before Newton, developed a root–finding algorithm called the Secant method that uses a succession of roots of secant lines to approximate a root of a function. This method works similarly to the Newton–Raphson method and consequently it is just as fast as the Newton–Raphson approach. Moreover, the Secant method does not require the knowledge and computation of Vega. The necessary variables that this approach involves are the two initial guesses of volatility, the market price, the result for each iteration as the volatility, and the theoretical price for each result. When the last two results of repeated processes are closed enough then the final one would be the desired implied volatility.

This approach may not converge if the first derivative of the argument function, Vega, in this case, is near 0. Pointing out the fact that in order to perform the Secant method, two initial guesses are required, but in this instance, both guesses must be quite near to the desired value. This method involves a substantial amount of preliminary work before the commencement of iterations; otherwise, the possibility of less-than-desired outcomes exists. [17]

2.2.3 Bisection Method

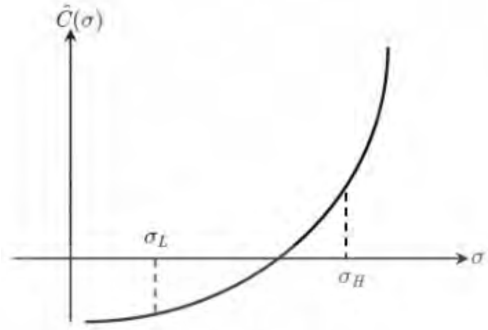

Figure 2.3: Graphical simulation of the Bisection method

[Source: On some Numerical Methods for Implied Volatility Calculation by Rosmoh Nisani, 2017]

The bisection approach has various advantages, including the fact that it always converges when the function's sign changes, which means it cannot diverge. In addition, the maximum error is constantly the difference between the upper and lower volatility boundaries. The mistakes may be reduced by increasing the number of iterations, as each iteration halves the error. The approach is significant since it can be applied without knowledge of Vega, and it can be used to determine the implied volatility of American options.

However, the approach also has a number of downsides, including slower convergence than other methods. In fact, the number of iterations required to precisely determine the root of f(x) rises if the initial higher or lower boundaries are near the real root. Furthermore, the approach only works if the sign of f(x) changes. If the root is tangent to f(x) = 0, then convergence cannot occur. Another point is that the approach only works if f(x) is continuous and real between the higher and lower bounds. Complex-valued functions are incompatible with numerical bisection, because of a discontinuity. The inefficiency of this method in comparison to the Newton-Raphson formula may make it undesirable to extract implied volatility using this technique. Additionally, the Bisection method is computationally intensive, therefore when dealing with a large number of alternatives, the computer's processing power becomes vital. [17]

2.3 CBOE Volatility Index

The CBOE Volatility Index (VIX) is widely regarded as the primary gauge for monitoring stock market volatility in the United States. Compiled by the Chicago Board Options Exchange (CBOE), this index aims to represent investors' predictions regarding short-term (30-day) volatility in the stock market.

The VIX achieves this by assessing the implied volatilities of a diverse selection of S&P 500 Index (SPX) options. It considers both puts and calls with various strike prices. When the implied volatility of SPX options increases, the VIX will correspondingly rise. Conversely, a decrease in SPX implied volatility results in a lower VIX value. This index is commonly referred to as the "fear index" or "fear gauge" due to the historical association of high volatility with bearish price movements. Nevertheless, it is more precise to describe the VIX as a measure of investors' uncertainty rather than fear.

While direct trading of the VIX is not possible, there are futures and options that can be traded. Furthermore, speculators have the option to utilize exchange-traded notes (ETNs) to speculate on future volatility.

The CBOE S&P 100 Volatility Index (VXO) is similar to the VIX, but it derives its value from the narrower S&P 100 Index (OEX) as its benchmark index. Before 2003, the VIX was based on OEX options, but the CBOE decided to switch to SPX options as they believed it would provide a broader representation of volatility expectations. The VXO is a previous volatility index that approximates the volatility swap rate under certain assumptions. It is defined based on the 1-month Black-Scholes at-the-money implied volatility, but it includes an upward bias due to an incorrect trading-day conversion. The CBOE favored the VIX over the VXO because the new VIX has a more well-known and strong economic interpretation. However, traders can still monitor the "old VIX" by tracking the progress of the renamed VXO. [13]

According to the research paper, “Volatility Index for the Thai Stock Market (TVIX)” by The Market Risk Department of a security company in Thailand (2017), the calculation of VIX for trading options in Thailand, represented by TVIX, would rather be conducted by using the methodology of VXO. The study demonstrates that VXO corresponds better to the data of current Thai option market circumstances, in which at-the-money options are more actively traded over their lifetime. [1]

Chapter 3
Research Methodology

This study adopts a quantitative research design to create a VIX for Thailand, drawing inspiration from the CBOE VIX. The research methodology encompasses the following steps.

3.1 Research Design

This study's research design is typically quantitative since all processes of calculating the volatility index of option trade in Thailand apply numerical data. In the primary steps of studying pricing models and numerical methods to come up with the best model for the approach of the volatility index of Thai option trades in the final, the historical data of all necessary elements are used to test if the models work and to evaluate the bias and errors. After the final model and the process of index calculation could be determined, the spot data of the market would be plugged into the formula of the volatility index. This strategy corresponds with the study goals of developing an index of volatility based on the Thai market that can provide additional insight into Thailand's market sentiment and risk profile for the investor.

3.2 Data Collection

The datasets used in this thesis are all secondary data that were gathered by credible sources in Thailand. First, daily settlement price of a representative sample of options contracts were collected by a securities company in Thailand, in total of 162,762 observations. The sample consists of options contracts covering underlying assets as indices, which is SET50 index options. The data consists of both call and put options with all strike prices and span a period of around nine years, from May 6, 2014, to February 20, 2023. In addition, spot prices of SET50 index, risk-free interest rates and last trading day of options were gathered from reliable financial databases, including investing.com, ThaiBMA and TFEX websites, respectively.

2.3 Data Analysis

After gathering the data for model testing, there are several steps to take including data preprocessing, model selection, model testing, model evaluation, and model refinement.

3.3.1 Data Preprocessing

Clean and preprocess the data to ensure it is in a suitable format for testing. This may involve handling missing values, fix structural errors, categorize data, or prepare data for the next steps using pivot table.

3.3.2 Model Selection

In this study, extensive research has been conducted on different pricing models for options and numerical methods to calculate implied volatility. The suitable option pricing models for this study are the Black-Scholes model, Black model, and Monte-Carlo simulation. Additionally, numerical methods such as the Newton-Raphson, Secant, and Bisection methods have been included. The formulas for calculating each pricing model and numerical methods are provided below.

Option Pricing Model: Black-Scholes Model

The Black-Scholes formulas for the prices of European Calls (C) and Puts (P) for non-dividend-paying stocks are given below. [6]

$$C = e^{-rt}[FN(d_1) - XN(d_2)]$$

$$P = e^{-rt}[XN(-d_2) - FN(-d_1)]$$

$$\text{Where} \quad d_1 = \frac{\ln\left(\frac{F}{X}\right) + \left(\frac{\sigma^2}{2}\right)t}{\sigma\sqrt{t}}$$

$$d_2 = \frac{ln(F/X) - (\sigma^2/2)t}{\sigma\sqrt{t}} = d_1 - \sigma\sqrt{t}$$

C : call option price

P : put option price

S : spot price of underlying asset

X : strike price of option

r : risk-free interest rate

T : time to expiration of the option content

σ : volatility of the underlying asset

N(x) : the cumulative probability function for a standardized normal variable. It represents the probability that a variable with a standard normal distribution Φ (0,1) will be less than x.

Option Pricing Model: Black Model

The Black formulas for the prices of European Calls (C) and Puts (P) are given below.

$$C = e^{-rt}[FN(d_1) - XN(d_2)]$$

$$P = e^{-rt}[XN(-d_2) - FN(-d_1)]$$

$$\text{Where} \quad d_1 = \frac{ln(F/X) + (\sigma^2/2)t}{\sigma\sqrt{t}}$$

$$d_2 = \frac{ln(F/X) - (\sigma^2/2)t}{\sigma\sqrt{t}} = d_1 - \sigma\sqrt{t}$$

In the formula F is the future price of the underlying asset and other input parameters are similar to the inputs used in the Black-Scholes model. [6]

Option Pricing Model: Monte-Carlo Simulation

The first formula is used to calculate the rate of change of underlying asset price in a period of time. [3][19]

$$\frac{ds}{s} = \mu dt + \sigma dw$$

$\frac{ds}{s}$: rate of return function of the changing asset price in a period of time

μ : average rate of change of the asset price in a period of time

dt : time period of the changing asset price in a period of time

σ : standard deviation of the asset price in a period of time

dw : Wiener process (Wt+1 – Wt is a random variable from the normal distribution N(0, 1)

Then use the second formula to calculate the asset price in the next period.

$$S(t_{i+1}) = S(t_i) \times (1 + \frac{ds}{s})$$

$S(t_{i+1})$: asset price on the initial date

$S(t_i)$: asset price in the next period using Geometric Brownian Motion(GBM)

Repeat the first two steps for n-1 times until getting the simulation of underlying asset prices from the initial date to the expiration date of the option. Then use the third formula and asset price on the expiration date to calculate the payoff from exercise or not exercise the contract.

$$payoff_{call,EU} = max(S_T - X, 0)$$
$$payoff_{put,EU} = max(X - S_T, 0)$$

S_T : underlying asset price on the expiration date

X: strike price

payoff: the return of the option contract

Repeat calculates the payoff for n times and then averages them in order to get the most efficient value. Lastly, calculate back to get the fair value of the option using the average payoff, risk-free interest rate, and time to expiration.

$$V = payoff \times e^{-r(T-t)}$$

r : risk-free interest rate

T : expiration date

t : current date

Numerical Method: Newton-Raphson Method

The formula is the following [17]:

$$\sigma_{i+1} = \sigma_i - \frac{C(\sigma_i) - C_m}{\frac{\delta_C}{\delta_{\sigma i}}}$$

σ_i : the initial guess for the implied volatility if (i=0)

$C(\sigma_i)$: the option price derived from the initial guess.

C_m : the market price of the option

$\frac{\delta_C}{\delta_{\sigma i}}$: obviously the Vega in terms of the initial guess

Numerical Method: Secant Method

The formula is the following [17]:

$$\sigma_n = \sigma_{n-i} + \frac{[C_m - C(\sigma_{n-1})](\sigma_{n-1} - \sigma_{n-2})}{C(\sigma_{n-1}) - C(\sigma_{n-2})}$$

C_m : the market price

σ_n : the result for each iteration

$C(\sigma_n)$: the theoretical price for each result

Numerical Method: Bisection Method

To calculate the implied volatility using the Bisection method conceptually starts by passing the value of selected upper and lower bounds of the volatility through the following equation and finding the root.

$$f(v) = BlackScholesCall(S, X, T, r, d, v) - Market\ Price$$

Then, $f(\sigma_L)$ and $f(\sigma_U)$ should be opposite in sign, so it can be implied that the root or the desired implied volatility lies between σ_L and σ_U . This method is to repeat the process of finding volatility that lies halfway between σ_L and σ_U, named σ_{Mid} , to get the new bounds of lower and upper volatility by considering the determined criteria until $f(\sigma_{Mid}) = 0$ *and the desired* implied volatility would be the final σ_{Mid} [17].

Consequently, in the subsequent stage of comprehensive model testing, nine combinations of option pricing models and numerical methods need to be addressed to eventually find the best combination for calculating implied volatility. These tasks are outlined below.

1. Black-Scholes model with Newton-Raphson method
2. Black-Scholes model with Secant method
3. Black-Scholes model with Bisection method
4. Black model with Newton-Raphson method
5. Black model with Secant method
6. Black model with Bisection method
7. Monte-Carlo simulation with Newton-Raphson method
8. Monte-Carlo simulation with Secant method
9. Monte-Carlo simulation with Bisection method

TVIX Calculation

Based on the earlier study, it is suggested that when calculating the VIX for trading options in Thailand, specifically represented by TVIX, it is preferable to employ the methodology of VXO. The study reveals that VXO aligns more accurately with the prevailing conditions of the Thai option market, where at-the-money options experience greater trading activity throughout their duration.

The models take into account variables which are the collected settlement price of SET50 index options, spot price of SET50 index, risk-free interest rate and last trading day of options to derive the required implied volatility of options to construct TVIX based on the VXO formula. The construction of TVIX is done by applying VXO formula from the research paper, "A Tale of Two Indices" by Peter Carr and Liuren Wu (2006). Then, the results obtained will be used for further analysis. [2]

This paper has significantly contributed to our understanding of the steps to calculate TVIX. Next, the detailed explanation of the calculation steps will be presented below.

1. Inspect the spot price of SET50 index at the specified period of time.
2. Find the 2 nearest maturities of that specified period of time then assign the first and the second nearest maturities as T1 and T2, respectively.
   Note that if the time to the nearest maturity is less than eight calendar days, the next two nearest maturities are used instead.

Repeat the steps 3. to 8. twice for maturity T1 and T2

3. Select 4 near-the-money options which are two call options and two put options of the two strike prices that straddle the spot level.
4. Calculate the IV for each option.
5. Average the two implied volatilities of the call options and put options that have the same strike price.
6. Linearly interpolation the average implied volatility between two strike prices, and assign the result as ATMV(t, T_i)
7. Calculate NT using the formula below.

$$NT = NC - \{2 \times int(\frac{NC}{7})\}$$

   NC : number of actual days of the time to reach maturity

   NT : number of trading days between time t and the option expiry date T

8. Calculate TV(t, T_i) using the formula below

$$TV(t, T_i) = ATMV(t, T_i)\frac{\sqrt{NC}}{\sqrt{NT}}$$

TV(t, T_i) : trading-day volatility

9. Calculate TVIX from the VXO formula below.

$$VXO_t = TV(t, T_1)\frac{NT_2-22}{NT_2-NT_1} + TV(t, T_2)\frac{22-NT_1}{NT_2-NT_1}$$

VXO: interpolated trading-day volatility at 22 trading days based on the two trading-day volatilities at the two nearest maturities (TV (t,T_1) and TV (t,T_2)

3.3.3 Model Testing

Following the identification of the nine combinations of option pricing models and numerical methods, the subsequent step involves comprehensive testing using a Python program. This program will be specifically developed to calculate the implied volatility by employing the selected combinations and analyzing various sample data.

During the testing phase, the program will execute the pricing models and numerical methods for each combination. It will take into account essential input parameters, such as option prices, strike prices, risk-free interest rates, and time to maturity. Utilizing the chosen pricing model and numerical method, the program will calculate the implied volatility. Subsequently, a comparison will be conducted between the calculated implied volatilities and the observed volatilities derived from the sample data. This comparative analysis will enable the evaluation of any biases or errors associated with each combination.

By subjecting the combinations to this rigorous testing process, the program will provide valuable insights into their performance and accuracy. The ultimate goal is to determine the most reliable and precise pricing models and numerical methods for estimating the implied volatility required for TVIX calculations.

Finally, this study utilizes the implied volatility in the VXO formula to execute the model and evaluate the performance of two combinations: the Black-Scholes model with the Newton-Raphson method and the Black-Scholes model with the Bisection method.

3.3.4 Model Evaluation

To acquire the best final model, assess the performance of the model by evaluate descriptive statistics such as mean, standard deviation, kurtosis, and skewness. Moreover, compare the performance of the methods in predicting an outcome variable using a hypothesis test to evaluate whether there was a significant difference in performance between the two methods.

A t-test was conducted using the difference in means approach, assuming that the variances of the methods were unknown. The t-test focused on examining the prediction errors generated by each method, specifically counting the number of cases where the predicted outcome equaled 0.

The dataset used for the analysis consisted of 2,340 observations. A significance level (α) of 0.05 was chosen for the test, indicating the threshold for determining statistical significance. By conducting this hypothesis test, we aimed to assess whether one method outperformed the other in predicting the outcome variable.

Applying the seven-step procedure gives the following:

1. **Parameter of interest:** The parameters of interest are the mean arsenic concentrations for the two geographic regions, say, M1 and M2, and we are interested in determining whether $\mu_1 - \mu_2 = 0$.
2. **Null hypothesis:** H_0: $\mu_1 - \mu_2 = 0$ or H_0: $\mu_1 = \mu_2$.
3. **Alternative hypothesis:** H_1: $\mu_1 \neq \mu_2$.
4. **Test statistic:** The test statistic is

$$t - value = \frac{\bar{x}_1 - \bar{x}_2 - 0}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

$\bar{x}$: weighted average error

s^2 : variance

n : number of options

5. **Find the t-table:** use the degrees of freedom (v) as

$$v = \frac{\left(\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}\right)^2}{\frac{\left(\frac{s_1^2}{n_1}\right)^2}{n_1 - 1} + \frac{\left(\frac{s_2^2}{n_2}\right)^2}{n_2 - 1}}$$

Note that if v is not an integer, round down to the nearest integer.

6. **Conclusions:** Reject H_0: $\mu_1 = \mu_2$ if t-table > t-value. Otherwise, not reject H_0.

Overall, the research methodology applied in this study has the major purpose to explore a comprehensive and accurate measurement of market volatility in Thailand and finalized it as the volatility index of the market for option trading. Giving the additional explanatory, this study attempts to develop TVIX by gathering data from the reliable source and utilizing it through the quantitative approach. Thus, Thailand's VIX will be able to serve the market participants, option traders, investors, and policymakers as a tool to assess and analyze the market sentiment and risk.

Chapter 4

Results and Discussion

This chapter discusses the result of each stage of the study, beginning with a comparison of the accuracy of the numerical methods, followed by a comparison of the options pricing model, a hypothesis test between two semi-final methods, and the TVIX results. Additionally, the discussion section also provides a further analysis of the results.

4.1 Result Comparison of Numerical Methods for Implied Volatility

There is no ideal, error-free, and rapid method to extract implied volatility from market prices. Despite its limitations, the Newton–Raphson method is the dominant technique in this field. With strong beginning predictions, the Newton–Raphson formula may be a very clever strategy that yields accurate outcomes, especially for near–the–money options with high efficiency. The Bisection method is not seen as interesting, yet it produces greater confidence intervals. Moreover, the Secant method is as quick as the Newton–Raphson method, but it is extremely difficult to apply.

Table 4.1: Numerical Methods Comparison [17]

	Newton-Raphson	**Secant**	**Bisection**
Efficiency	4	4	3
Accuracy	4	4	4.5
Difficulty	4	2	4.5
Total	12	10	12

The above table lists (Table 4.1) and ranks all models and attributes to summarize the current research. Higher scores are preferable. Even "Difficulty" is measured, so a higher score suggests it's simpler to accomplish.

Newton–Raphson and Bisection method score highest. In fact, they aren't always suggested. When dealing with a big collection of possibilities, the Newton–Raphson technique is better than the Bisection method. [17]

According to “On some Numerical Methods for Implied Volatility Calculation" thesis by Miss Rosmoh Nisani which demonstrates implied volatility calculation for SET50 index options from October 1st, 2014, to March 31st, 2015, separating the time period into 6 periods before the expiration, it used three numerical methods including Newton-Raphson, Secant, and Bisection method, and each method has a different process in calculation and limitations.

The results can be summarized in that all three methods have the value of standard deviation lying between the range of [0,0.0125]. If considering the result performance, Newton’s method converges to a solution fastest, but the calculation must know the derivative of the option which is very complicated. While the secant method converges slowly and if the initial guess is not suitable, it may not converge to an exact solution. Another method is the bisection method which converges to a solution very slowly but always converges. [11]

4.2 Result Comparison of Option Pricing Models

According to the previous results of study from model testing, it has been found that, although Monte-Carlo simulation is a powerful tool for option pricing, it actually has some limitations and drawbacks. This study has experienced a long-time convergence of the result value with some significant errors of the calculated price which the randomly picked samples of the input data for calculation are considered as the cause of this kind of error. Then, it results in the final value of IV is not stable such that every time the code is executed, the output has been changed, thus it theoretically conducts the open-form solution.

The Black model was developed by Fischer Black in 1976 and sometimes called Black-76. It is an extension of the Black-Scholes model that incorporates the effects of interest rates and dividends, and it is useful for pricing options on futures contracts. It is also used to value options on commodities, such as oil, natural gas, and metals. While the case of this project is the study of pricing options on option contracts which the underlying asset is the market index, SET50 index. Besides, there is a limitation for data research that the team cannot find the futures data which is necessary for IV calculation using Black model. Moreover, it is obvious that using SET50 data would be more relevant to options than futures data. Therefore, to price the options on a market index, the Black-Scholes model would be the appropriate choice to do option pricing for further creating volatility index rather than the Black model.

4.3 Hypothesis test

The objective of this hypothesis test was to compare the performance of the Newton-Raphson method and the Bisection method in predicting the outcome variable. The null hypothesis (H0) stated that there is no significant difference in performance between the two numerical methods, while the alternative hypothesis (H1) proposed that one method outperforms the other.

To compare the models using hypothesis test on the difference in means with unknown variances, a t-test was conducted on the prediction of errors, which counts the number of results from each method that equal to 0 using a significance level (α) of 0.05 and the test was performed on the sample contract of 2,340 observations.

Table 4.2: Hypothesis Test

Research Hypothesis	t-value	t-table	Hypothesis Testing Result
H0: $\mu 1 - \mu 2 = 0$ H1: $\mu 1 - \mu 2 \neq 0$	3.1449	2.2410	Reject H0

The test statistic value was calculated as t-value = 3.1449 and t-table = 2.241. Based on the obtained t-value, which is higher than the t-table, the null hypothesis is rejected. This provides strong evidence to support the alternative hypothesis, indicating that there is a statistically significant difference in performance between the Bisection method and Newton-Raphson method. Further analysis of the results revealed that Newton-Raphson method had a lower error (Weighted Average Error = 9.9831, SD = 19.2518, Variance = 370.6307) compared to Bisection method (Weighted Average Error = 11.8679, SD = 21.6766, Variance = 469.8755).

In conclusion, the hypothesis testing results indicate that Newton-Raphson method performs significantly better than Bisection method. Moreover, the Newton-Raphson method consumes less time in executing the method than the Bisection method. The run time of Newton-Raphson and Bisection methods in calculating one IV are 8.1616 milliseconds and 12.6332 milliseconds, respectively. Therefore, the Newton-Raphson method is recommended as the preferred choice for calculating the IV for the model.

4.4 TVIX Results

Table 4.3: TVIX Results (2014 - 2023)

Date	TVIX
06-05-14	12.39946
07-05-14	12.73467
08-05-14	15.01532
09-05-14	14.33686
12-05-14	13.87678
…	…
14-02-23	9.461838
15-02-23	9.456168
16-02-23	8.967378
17-02-23	9.386748
20-02-23	10.15693

According to Table 4.3, it presents the results of calculated Thailand's VIX (TVIX) by using the Black-Scholes model for option pricing, Newton-Raphson method for implied volatility calculation, and VXO formula for transforming implied volatility to TVIX. This table provides a comprehensive summary of the TVIX value using call and put datasets with all strike prices of SET50 index options from May 6th, 2014, to February 2nd, 2023, meaning that the sample size for testing the model is 2143 samples.

Table 4.4: Descriptive Statistics of TVIX Result during 2014 to 2022

	2014 - 2022 (Total Observations)	**2014 - 2019 (Before COVID-19)**
Mean	16.82754	14.89940912
Standard Error	0.209367	0.13728486
Standard Deviation	9.692144	5.105446561
Sample Variance	93.93766	26.06558459
Kurtosis	25.90602	0.135741343
Skewness	4.270645	0.451661283
Minimum	0	4.214418031
Maximum	99.43065	32.1379928
Count	2143	1383

The above table showing the result of descriptive statistics is considered to be an efficient tool for studying deeper into the result of TVIX during the determined dates. According to the results of the total observation between 2014 to 2022, the sample size is 2,143 and after the model was tested, the mean of these results is approximately 16.8275 with the standard deviation and the sample variance are 9.692144 and 93.93766 respectively.

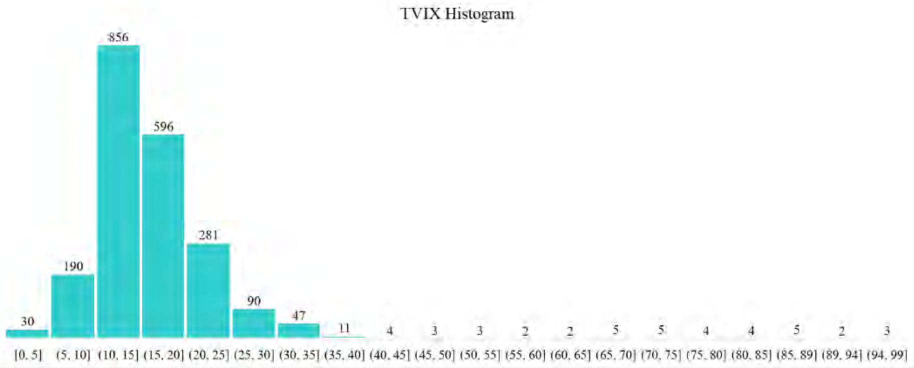

Figure 4.1: Histogram of TVIX Result (2014 - 2023)

The graphical representation of TVIX value distribution, as shown in Figure 4.1, can demonstrate the value of TVIX that varies between the range of 0 to 99.4307 which is divided into intervals of 5. It could be seen that the majority of the TVIX value, 856 tested samples, is bunched up in the range of 10 to 15, followed by the second cluster of value, 596 samples, which lies within the range of 15 to 20. Considering the overall of the above histogram, it suggests that there is a cluster of values that are relatively close together in this range, while the values outside of this range are less frequent.

Additionally, to that, the histogram has a positive skewness of 4.2706, with a tail that extends to the right of the majority of the data with more values concentrated on the left. Apart from this, this result also has Leptokurtic indicating a positive excess kurtosis which is equal to 25.9060. Since the data distribution is considered to be positive skewness and Leptokurtic kurtosis, this could be expected of some outliers or extreme values in the results data and affects the shape of the distribution, and it is generally considered to be risky in the eyes of investors.

In fact, the sample range used for model testing covers the first wave of the COVID-19 crisis in Thailand that had begun since the end of February in 2020 and the results began to fluctuate significantly with the peak TVIX value of 99.43065 on March 23, 2020. Since, the pandemic is expected to be the main factor that affects the results to be various and unreliable. Moreover, Table 4.4 also reveals descriptive statistical data of TVIX results before the COVID-19 crisis representing the attempt to prove the effect of the pandemic on TVIX value and the statistical results. The sample range is between around 2014 to 2019 which consists of 1,383 samples, then the TVIX values shift from the range [0,100], to the smaller range [0,40]. The mean is reduced to 14.8994 together with the standard deviation and the sample variance which are 0.1373 and 5.1054 respectively. Besides, the data distribution is positively skewed, with 0.4517 of skewness indicating that the distribution is approximately symmetric since it is near zero. Also, the kurtosis is 0.1357 which is mesokurtic referring to an excess kurtosis close to zero. This means that the TVIX value before the crisis is likely to follow a normal distribution.

Comparing the descriptive statistics of the result before the COVID-19 crisis and the total observations, it is obvious that every factor representing errors and uncertainties of the period before the crisis are all lower such as the standard deviation and standard error. Also, the kurtosis, and skewness that are very close to zero leading to answer the question about the outliers TVIX value which is considered to be probably small for this case. Besides, the less skewed the data, the more accurate this TVIX model is. [5] Furthermore, the range of the majority is more reasonable and reliable than the data of whole samples.

To summarize, during the normal condition of the market, the model of this study can be used to calculate the value of TVIX which, according to the study, mostly falls in the reasonable range with possibly small numbers and value of outliers. Even though, it is the crisis condition of the market, or some outbreak movements probably occur, which obviously influences the descriptive statistics of the results especially the factors that represent errors and fluctuations, similarly to the case of COVID-19 crisis in this study, this model can still finalize and come out with the value of TVIX that is corresponding to the market condition.

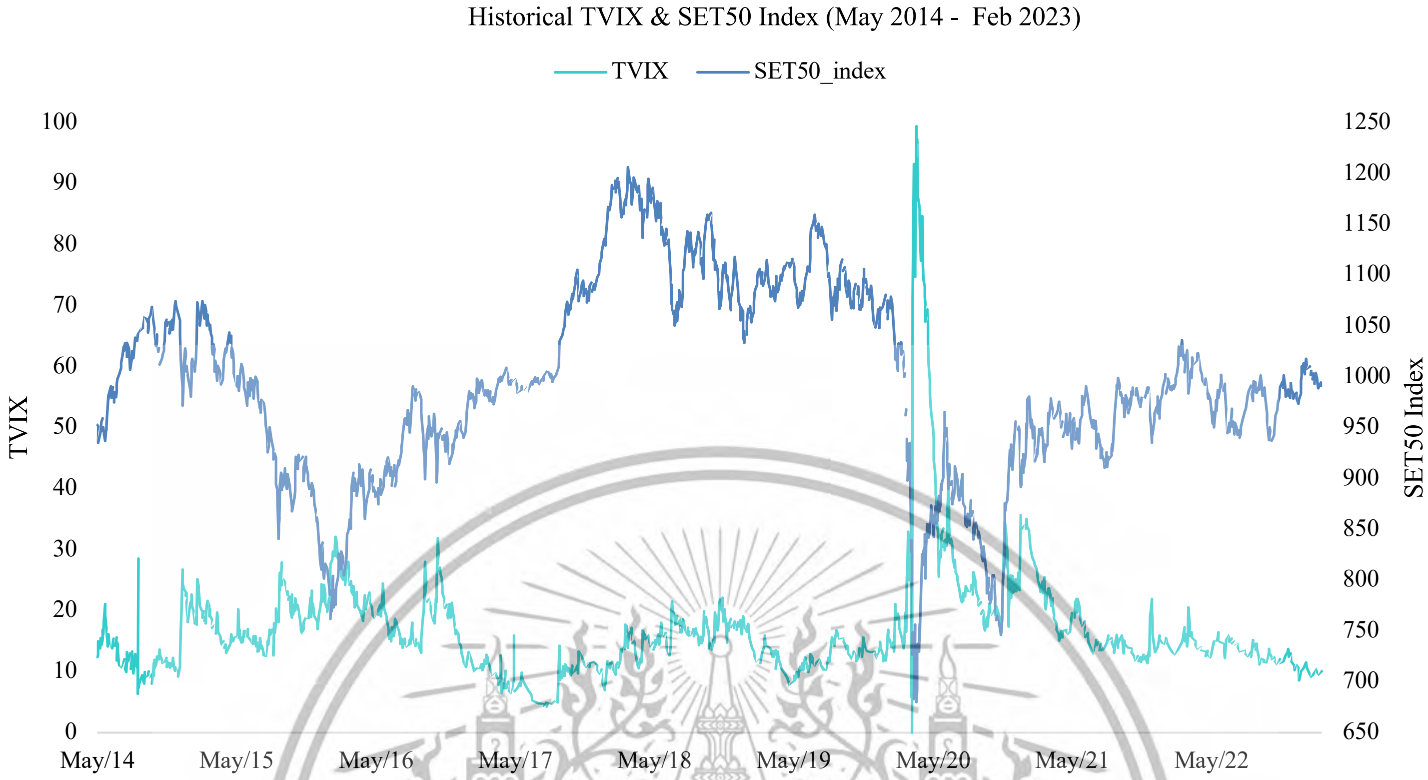

Figure 4.2: TVIX and SET50 Index Result (2014 - 2023)

Table 4.5: Correlation Matrix between TVIX and SET50 Index

	TVIX	SET 50 Index
TVIX	1	-0.5244
SET 50 Index	-0.5244	1

Our team compares the SET50 index to the TVIX result to see whether there is any tendency for them to move in the opposite direction by using the concept of relationship between VIX and S&P 500 index. According to the fact that the VIX is widely known as the "Fear Index" and used as a gauge of market volatility or investor sentiment in the stock market since it tends to increase when there is uncertainty, fear, or perceived risk. Investors typically become more risk-averse when they anticipate or experience market downturns or economic instability. The increase in risk aversion is often accompanied by an increase in the demand for hedge instruments and a desire to secure investments. Consequently, the demand for options, which the VIX is based on, rises and driving up the VIX value. In such situations, it is common to observe a decrease in the S&P 500 as investors sell stocks and shift to safer assets. Therefore, it can be concluded that there is a negative relationship between VIX and the S&P 500 index since VIX tends to rise while the market is falling and vice versa.

Chapter 5
Conclusion and Recommendation

Based on our analysis and research of various models and methods, our team has successfully developed a final model that effectively calculates intraday TVIX in accordance with our objectives. The model combines the Black-Scholes model with the Newton-Raphson method, the VXO formula, and other factors to accurately estimate the TVIX value which measures market volatility and tends to rise when investors expect more uncertainty or fear in the market. On the other hand, the SET50 index represents the overall performance of the stock market and tends to rise when investors are optimistic and confident. The results tend to move in the opposite direction of the SET50 index which indicates that the calculated TVIX value can reflect the investors' feelings of uncertainty or fear about the future direction of the market. Therefore, this final TVIV model can be executed as the tool for calculating the intraday TVIX and collecting the historical data of TVIX.

Our research study faced several obstacles that required careful consideration and adaptation. For instance, the lack of research studies focusing on this topic within Thailand becomes a notable challenge for this thesis. Besides, when researching and implementing research studies of other countries, it is necessary to carefully consider due to differences in market conditions between countries as well. Moreover, there are some errors during the coding process posed challenges to our study. However, through diligent efforts and adaptability, our team was able to overcome these obstacles and derive valuable insights from the research. Eventually, the TVIX serves as a powerful tool in our analysis and understanding of market dynamics and provides insightful information on market volatility that is beneficial for risk management, investment strategies, and decision-making processes.

For the further development of this study, this model can potentially be used with real-time data to calculate TVIX at higher frequency levels. Besides, it should be regularly adjusted and updated to maintain the model's efficiency in reflecting market sentiment since the market always changes over time. Moreover, it may add more various variables in the TVIX calculation, such as inflation, GDP, and some factors which can reflect situations of the world economy, to produce a more accurate estimate of market volatility.

This study would contribute the developed TVIX model that will enhance the efficiency of Thailand's options market and offer Thai traders a deeper comprehension of the market dynamics. The anticipated outcome is not only to provide theoretical insights but also to apply the model in practical market situations. This practical application would be advantageous to investors as it would enable them to make informed decisions, effectively manage risks, optimize investment strategies, and navigate volatile market conditions with confidence. Ultimately, the developed TVIX model holds the potential to create a more favorable trading environment and empower market participants in Thailand.

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Appendix A

Python Code for TVIX Calculation

Import Libraries

```
from math import *
import math
import pandas as pd
from datetime import datetime
from datetime import time
import csv
import numpy as np
import random
from scipy.stats import norm
import calendar
import matplotlib.pyplot as plt
import seaborn as sns
```

Import Dataset

```
# Import options price data from 2014 to 2023
options_raw = pd.read_csv('/path/to/SettlementPrice_2014-2023.csv',parse_dates=[0],
dayfirst=True)
options = pd.DataFrame(options_raw)
options

# Create pivot table of options price data
options_data = pd.pivot_table(options, values='SettlementPrice',
index=['BusinessDate'], columns=['SeriesName'])
options_column = options_data.columns.values
options_data

# Import SET50 index price data
set50_data =pd.read_csv('/path/to/SET50Index_2014-2023.csv', parse_dates=[0],
dayfirst=True)
set50_data['Date'] = pd.to_datetime(set50_data['Date'])
set50_data['Date'] = set50_data['Date'].dt.strftime('%Y-%m-%d')
set50_spot = pd.pivot_table(set50_data, values='Price', index=['Date'])
set50_spot

# Import T-bill 3 months index price data
tbill_3m_data = pd.read_csv('/path/to/GovBondYield_2014-2023.csv',
parse_dates=[0], dayfirst=True)
```

```
tbill_3m = pd.pivot_table(tbill_3m_data, values='T-BILL3M', index=['Date'])
tbill_3m

# Import last trading day data of options
last_trading_day_data = pd.read_csv('/path/to/LastTradingDay_2014-2023.csv',
parse_dates=[0], dayfirst=True)
last_trading_day_data

# Import date of data
date_for_cal_TVIX = pd.read_csv('/path/to/DateForTVIX_2014-2023.csv',
parse_dates=[0], dayfirst=True)
date_for_cal_TVIX
```

Introduce Variables

```
r = 0
e = 0
option_month_num_dict = {1:"F", 2:"G", 3:"H", 4:"J", 5:"K", 6:"M", 7:"N", 8:"Q",
9:"U", 10:"V", 11:"X", 12:"Z" }
```

Time to Expiration Calculation

```
def time_to_exp(current_day, day_last):
    current_day = datetime.strptime(current_day, '%Y-%m-%d')
    Ttm = day_last-current_day
    Ttm = Ttm.days
    return Ttm/365
```

Option Pricing Model: Black-Scholes Model

```
N_prime = norm.pdf
N = norm.cdf
def black_scholes_call(S, K, T, r, sigma):
    '''
    :param S: Asset price
    :param K: Strike price
    :param T: Time to maturity
    :param r: risk-free rate (treasury bills)
    :param sigma: volatility
    :return: call price
    '''
    d1 = ((np.log(S / K) + (r + (sigma ** 2)/2 ) * T) / (sigma * np.sqrt(T)))
    d2 = d1 - (sigma * np.sqrt(T))
```

```
    call = (S * N(d1)) -  (N(d2)* K * np.exp(-r * T))
    return call

def black_scholes_put(S, K, T, r, sigma):
    '''
    :param S: Asset price
    :param K: Strike price
    :param T: Time to maturity
    :param r: risk-free rate (treasury bills)
    :param sigma: volatility
    :return: call price
    '''
    d1 = ((np.log(S / K) + (r + (sigma ** 2)/2 ) * T) / (sigma * np.sqrt(T)))
    d2 = d1 - (sigma * np.sqrt(T))
    put = (N(-d2)* K * np.exp(-r * T)) - (S * N(-d1))
    return put

### Numerical Method: Newton-Raphson Method

def vega(S, K, T, r, sigma):
    '''
    :param S: Asset price
    :param K: Strike price
    :param T: Time to Maturity
    :param r: risk-free rate (treasury bills)
    :param sigma: volatility
    :return: partial derivative w.r.t volatility
    '''
    d1 = ((np.log(S / K) + (r + (sigma ** 2)/2 ) * T) / (sigma * np.sqrt(T)))
    vega = S * N_prime(d1) * np.sqrt(T)
    return vega

def newton(C, S, K, T, r, guess, series_name, tol=0.0001, max_iterations=100):
    '''
    :param C: Observed call price
    :param S: Asset price
    :param K: Strike Price
    :param T: Time to Maturity
    :param r: riskfree rate
    :param tol: error tolerance in result
    :param max_iterations: max iterations to update vol
    :return: implied volatility in percent
    '''
```

```
    sigma = guess
    if (series_name[6] == 'C'):
        for i in range(max_iterations):
            diff = black_scholes_call(S, K, T, r, sigma) - C
            if abs(diff) < tol:
                break
            sigma = sigma - (diff / vega(S, K, T, r, sigma))

    elif (series_name[6] == 'P'):
        for i in range(max_iterations):
                diff = black_scholes_put(S, K, T, r, sigma) - C
                if abs(diff) < tol:
                    break
                sigma = sigma - diff / vega(S, K, T, r, sigma)
    return sigma

### IV Calculation

def find_strike_range(target):
    strike_set = [0, 25, 50, 75, 100, 125, 150, 175, 200, 225, 250, 275, 300, 325, 350,
375, 400, 425, 450, 475, 500, 525, 550, 575, 600, 625, 650, 675, 700, 725, 750, 775,
800, 825, 850, 875, 900, 925, 950, 975, 1000, 1025, 1050, 1075, 1100, 1125, 1150,
1175, 1200, 1225, 1250, 1275, 1300, 1325, 1350, 1375, 1400, 1425, 1450, 1475,
1500]
    strike_range = []
    less_than_index = 0
    greater_than_index = 0
    for i in range(len(strike_set)):
        if strike_set[i] < target:
            less_than_index = i
        elif strike_set[i] > target:
            greater_than_index = i
            break
    strike_range.extend([strike_set[less_than_index],strike_set[greater_than_index]])
    return strike_range

def find_nearest_maturity(target_day, month_num,year):
    for t in range (len(last_trading_day_data)):
        t1_month_num = month_num
        t1 = calendar.month_name[t1_month_num]

        if ((last_trading_day_data['Contract_month'][t] == t1) and
(last_trading_day_data['Series'][t][4:6] == year)):
```

```
            last_td_t1 = last_trading_day_data['Last_trading_day'][t]
            last_td_t2 = last_trading_day_data['Last_trading_day'][t+1]
            last_td_t1 = datetime.strptime(last_td_t1, '%Y-%m-%d')
            last_td_t2 = datetime.strptime(last_td_t2, '%Y-%m-%d')
            current_date = datetime.strptime(str(target_day), '%Y-%m-%d')

            if ((last_td_t1 - current_date).days <= 8):
                last_td_t1 = last_trading_day_data['Last_trading_day'][t+1]
                last_td_t2 = last_trading_day_data['Last_trading_day'][t+2]
                last_td_t1 = datetime.strptime(last_td_t1, '%Y-%m-%d')
                last_td_t2 = datetime.strptime(last_td_t2, '%Y-%m-%d')
        t1_month_num += 1
    return (last_td_t1,last_td_t2)

def cal_IV_daily(current_day, option_set, S50_spot, nearest_maturity):
    result_IV = {'Date': [], 'SeriesName': [], 'IV': []}
    for q in range (len(tbill_3m)):
        p = q
        tbill_i = tbill_3m.index[p].strftime('%Y-%m-%d')
        if (current_day) == (tbill_i):
            for i in range (len(option_set)):
                market_price = options_data.loc[current_day, option_set[i]]
                strike_price = int(option_set[i][7:])
                if (i < (len(option_set) /2)):
                    expiry = time_to_exp(current_day,nearest_maturity[0])
                elif (i >= (len(option_set) /2)):
                    expiry = time_to_exp(current_day,nearest_maturity[1])
                rf_rate = (tbill_3m['T-BILL3M'][p])/100.00
                guess = 0.8
                iv =
newton(market_price,S50_spot,strike_price,expiry,rf_rate,guess,option_set[i])
                if math.isnan(iv):
                    result_IV["Date"].append(current_day)
                    result_IV["SeriesName"].append(option_set[i])
                    result_IV["IV"].append(0)
                else:
                    result_IV["Date"].append(current_day)
                    result_IV["SeriesName"].append(option_set[i])
                    result_IV["IV"].append(iv*100)
            break

    return result_IV
```

```
def average_IV(IV_for_tvix):
    average_IV = {'Strike': [], 'Month': [], 'Average_IV': []}
    IV_call = {'Strike': [], 'Month': [], 'IV': []}
    IV_put = {'Strike': [], 'Month': [], 'IV': []}

    for k in range(len(IV_for_tvix['SeriesName'])):
        if (IV_for_tvix['SeriesName'][k][6] == 'C'):
            IV_call["Strike"].append(IV_for_tvix['SeriesName'][k][7:])
            IV_call["Month"].append(IV_for_tvix['SeriesName'][k][3:6])
            IV_call['IV'].append(IV_for_tvix['IV'][k])
        elif (IV_for_tvix['SeriesName'][k][6] == 'P'):
            IV_put["Strike"].append(IV_for_tvix['SeriesName'][k][7:])
            IV_put["Month"].append(IV_for_tvix['SeriesName'][k][3:6])
            IV_put['IV'].append(IV_for_tvix['IV'][k])

    for i in range (len(IV_call['IV'])):
        for j in range (len(IV_put['IV'])):
            if ((IV_call['Strike'][i] == IV_put['Strike'][j]) & (IV_call['Month'][i] ==
IV_put['Month'][j])):
                avg = (IV_call['IV'][i] + IV_put['IV'][j]) / 2.00
                average_IV["Strike"].append(IV_call['Strike'][i])
                average_IV["Month"].append(IV_call['Month'][i])
                average_IV["Average_IV"].append(avg)
    return average_IV
```

TVIX Calculation

```
def linearly_inter(avg_iv, strike_range, S50_spot, T):
    x1 = strike_range[0]
    x2 = strike_range[1]
    if T == 1:
        y1 = avg_iv['Average_IV'][0]
        y2 = avg_iv['Average_IV'][1]
    if T == 2:
        y1 = avg_iv['Average_IV'][2]
        y2 = avg_iv['Average_IV'][3]
    y = y1 + (S50_spot - x1) * (y2 - y1) / (x2 - x1)
    return y

def cal_TVIX (avg_iv, strike_range, S50_spot, target_day, nearest_maturity):
    ATMV_t1 = linearly_inter(avg_iv,strike_range,S50_spot,1)
    ATMV_t2 = linearly_inter(avg_iv,strike_range,S50_spot,2)
    NC1 = math.floor(time_to_exp(target_day,nearest_maturity[0]) * 365)
```

```
    NC2 = math.floor(time_to_exp(target_day,nearest_maturity[1]) * 365)

    NT1 = NC1 - (2 * int(NC1 / 7))
    NT2 = NC2 - (2 * int(NC2 / 7))

    TV1 = ATMV_t1 * sqrt(NC1) / sqrt(NT1)
    TV2 = ATMV_t2 * sqrt(NC2) / sqrt(NT2)

    TVIX = (TV1 * ((NT2 - 22)/(NT2 - NT1))) + (TV2 * ((22 - NT1)/(NT2 - NT1)))
    return TVIX

want = []
for i in range (len(date_for_cal_TVIX)):
    x = date_for_cal_TVIX['Date'][i].strftime('%Y-%m-%d')
    want.append(str(x))

want_tvix_date = want
TVIX_result = {'Date': [], 'TVIX': [], 'SET_50_index': []}

for d in range (len(want_tvix_date)):
    target_day = want_tvix_date[d]
    S50_spot = set50_spot.loc[want_tvix_date[d], 'Price']
    month_num = int(want_tvix_date[d][5:7])
    year = want_tvix_date[d][2:4]
    option_for_tvix = []
    nearest_maturity = find_nearest_maturity(target_day,month_num,year)
    strike_range = find_strike_range(S50_spot)
    Ti = []
    for i in range(2): # 2 because t1 and t2
        ti = nearest_maturity[i]
        Ti.append(option_month_num_dict[ti.month])
        for j in range(len(strike_range)):
            name_call = "S50" + option_month_num_dict[ti.month] + ti.strftime("%y")
+ "C" + str(strike_range[j])
            name_put = "S50" + option_month_num_dict[ti.month] + ti.strftime("%y")
+ "P" + str(strike_range[j])
            option_for_tvix.extend([name_call, name_put])
    IV_for_tvix = cal_IV_daily(target_day,option_for_tvix,S50_spot,nearest_maturity)
    avg_iv = average_IV(IV_for_tvix)
    TVIX = cal_TVIX(avg_iv,strike_range,S50_spot,target_day,nearest_maturity)
    TVIX_result["Date"].append(target_day)
    TVIX_result["TVIX"].append(TVIX)
    TVIX_result["SET_50_index"].append(S50_spot)
```

TVIX Result

```
# Show a table of date, TVIX result and SET50 index price
result_table = pd.DataFrame(TVIX_result)
result_table
with pd.option_context('display.max_rows', None,
                    'display.max_columns', None,
                    'display.precision', 3,
                    ):
   print(result_table)

# Plot a graph between TVIX result and SET50 index price
fig, ax1 = plt.subplots()
ax1.plot(result_table['Date'], result_table['TVIX'], 'b-')
ax1.set_xlabel('Date')
ax1.set_ylabel('TVIX', color='b')

ax2 = ax1.twinx()
ax2.plot(result_table['Date'], result_table['SET_50_index'], 'r-')
ax2.set_ylabel('SET_50_index', color='r')
plt.show()

# Export the result table to csv
result_table.to_csv('BS_Newton_TVIX_Result.csv', header=True, index=True,
encoding='utf-8')
```

Appendix B

TVIX Results

Date	TVIX
06-05-14	12.3995
07-05-14	12.7347
08-05-14	15.0153
09-05-14	14.3369
12-05-14	13.8768
14-05-14	15.4954
15-05-14	15.5396
16-05-14	14.3361
19-05-14	15.1698
20-05-14	16.8654
21-05-14	16.1163
22-05-14	16.3170
23-05-14	18.4473
26-05-14	21.0633
27-05-14	19.2334
28-05-14	17.9888
29-05-14	17.8125
30-05-14	17.1035
02-06-14	14.1487
03-06-14	15.3868
04-06-14	16.1854
05-06-14	15.2005
06-06-14	14.7316
09-06-14	15.3715
10-06-14	14.8432
11-06-14	15.0290
12-06-14	15.3355
13-06-14	13.8219
16-06-14	14.1279
17-06-14	15.4214
18-06-14	15.4789
19-06-14	15.5082
20-06-14	14.2335
23-06-14	14.9192
24-06-14	14.9770
25-06-14	15.6143
26-06-14	11.8095
27-06-14	14.7389
30-06-14	11.6792
02-07-14	11.3400
03-07-14	10.9445
04-07-14	11.2280
07-07-14	11.0059
08-07-14	11.0084
09-07-14	10.9028
10-07-14	10.7175
14-07-14	10.8328
15-07-14	12.0039
16-07-14	12.1978

Date	TVIX
17-07-14	10.4179
18-07-14	10.0151
21-07-14	9.8913
22-07-14	12.3578
23-07-14	13.2171
24-07-14	12.6066
25-07-14	11.6994
28-07-14	11.7018
29-07-14	12.1379
30-07-14	11.7650
31-07-14	12.9526
01-08-14	10.4865
04-08-14	12.3797
05-08-14	13.2521
06-08-14	12.9076
07-08-14	11.8392
08-08-14	9.7799
13-08-14	12.9131
14-08-14	12.5824
15-08-14	11.0868
18-08-14	11.0576
19-08-14	10.4920
20-08-14	6.3794
21-08-14	28.5396
22-08-14	7.3282
25-08-14	8.4128
26-08-14	8.1430
27-08-14	8.7195
28-08-14	8.9385
29-08-14	8.4742
01-09-14	9.4552
02-09-14	8.6865
03-09-14	8.6295
04-09-14	8.4668
05-09-14	8.0644
08-09-14	9.8972
09-09-14	9.6790
10-09-14	8.9231
11-09-14	9.3069
12-09-14	8.4701
15-09-14	9.3991
16-09-14	9.5883
17-09-14	9.4746
18-09-14	10.0306
19-09-14	10.4300
22-09-14	10.0756
23-09-14	8.8642
24-09-14	8.5912
25-09-14	9.5072

Date	TVIX
26-09-14	8.0156
29-09-14	9.9289
30-09-14	11.4556
01-10-14	9.3593
02-10-14	11.9061
03-10-14	10.5549
06-10-14	10.7234
07-10-14	11.0124
08-10-14	11.3398
09-10-14	12.4225
10-10-14	11.8586
13-10-14	12.5983
14-10-14	12.7181
15-10-14	11.9958
16-10-14	13.5848
17-10-14	12.6638
20-10-14	12.2970
21-10-14	12.8530
22-10-14	11.8044
24-10-14	11.1797
27-10-14	11.1565
28-10-14	11.1492
29-10-14	10.9774
30-10-14	10.7361
31-10-14	11.6922
03-11-14	12.2065
04-11-14	10.7933
05-11-14	11.7777
06-11-14	10.9296
07-11-14	10.8553
10-11-14	11.4573
11-11-14	10.6946
12-11-14	11.1485
13-11-14	10.5040
14-11-14	10.7328
17-11-14	11.4305
18-11-14	10.8629
19-11-14	10.9585
20-11-14	12.2338
21-11-14	11.1439
24-11-14	11.1957
25-11-14	10.1393
26-11-14	10.7398
27-11-14	10.5515
28-11-14	11.0060
01-12-14	11.0332
02-12-14	10.7000
03-12-14	9.8474
04-12-14	9.1968

Date	TVIX
08-12-14	10.8994
09-12-14	12.1149
11-12-14	16.4230
12-12-14	19.0947
15-12-14	26.7041
16-12-14	24.5781
17-12-14	24.2247
18-12-14	24.4005
19-12-14	23.5984
22-12-14	23.6350
23-12-14	23.0624
24-12-14	22.4125
25-12-14	22.9378
26-12-14	21.5098
29-12-14	18.1270
30-12-14	17.6902
05-01-15	21.1824
06-01-15	20.7258
07-01-15	21.7707
08-01-15	22.6131
09-01-15	20.6218
12-01-15	20.6225
13-01-15	20.0142
14-01-15	19.9498
15-01-15	19.5560
16-01-15	17.9204
19-01-15	18.9641
20-01-15	18.4843
21-01-15	17.6850
22-01-15	19.9482
23-01-15	25.1602
26-01-15	24.1088
27-01-15	23.3292
28-01-15	22.5868
29-01-15	22.1583
30-01-15	20.7413
02-02-15	20.6376
03-02-15	21.1181
04-02-15	20.5714
05-02-15	19.7940
06-02-15	18.8582
09-02-15	19.9259
10-02-15	20.0324
11-02-15	18.3723
12-02-15	18.9656
13-02-15	17.9618
16-02-15	19.8736
17-02-15	21.0605
18-02-15	21.5533

Date	TVIX
19-02-15	21.3211
20-02-15	21.8849
23-02-15	20.7498
24-02-15	19.0683
25-02-15	20.2811
26-02-15	19.1566
27-02-15	19.5123
02-03-15	18.5816
03-03-15	17.1759
05-03-15	17.3520
06-03-15	17.8620
09-03-15	18.1836
10-03-15	18.2354
11-03-15	17.3687
12-03-15	17.4068
13-03-15	16.2339
16-03-15	19.7537
17-03-15	18.3159
18-03-15	18.2598
19-03-15	16.3533
20-03-15	16.2117
23-03-15	16.2672
24-03-15	15.8114
25-03-15	15.3579
26-03-15	14.9190
27-03-15	14.5595
30-03-15	14.2698
31-03-15	14.0382
01-04-15	14.9387
02-04-15	15.0024
03-04-15	13.9312
07-04-15	14.4382
08-04-15	13.7546
09-04-15	13.1455
10-04-15	12.6670
16-04-15	14.1460
17-04-15	14.3614
20-04-15	14.6905
21-04-15	14.2866
22-04-15	16.0960
23-04-15	15.5557
24-04-15	15.0543
27-04-15	14.9463
28-04-15	15.5163
29-04-15	15.6071
30-04-15	15.2122

Date	TVIX
06-05-15	15.1131
07-05-15	15.9820
08-05-15	15.4605
11-05-15	20.2151
12-05-15	17.0751
13-05-15	15.7280
14-05-15	16.9236
15-05-15	15.3836
18-05-15	14.8105
19-05-15	14.9814
20-05-15	15.5754
21-05-15	16.0651
22-05-15	14.8505
25-05-15	16.6936
26-05-15	15.7063
27-05-15	16.7098
28-05-15	16.4151
29-05-15	16.8599
02-06-15	15.7757
03-06-15	15.6513
04-06-15	17.0288
05-06-15	15.7375
08-06-15	15.9100
09-06-15	15.4699
10-06-15	15.2806
11-06-15	15.2441
12-06-15	14.9267
15-06-15	15.2790
16-06-15	14.8397
17-06-15	15.3464
18-06-15	14.5605
19-06-15	15.8401
22-06-15	15.5178
23-06-15	15.0771
24-06-15	15.7719
25-06-15	14.6204
26-06-15	14.1381
29-06-15	14.7715
30-06-15	13.3198
02-07-15	14.2325
03-07-15	13.4337
06-07-15	14.6002
07-07-15	15.5477
08-07-15	14.7682
09-07-15	13.7854
10-07-15	14.3393

Date	TVIX
13-07-15	13.8089
14-07-15	13.6818
15-07-15	13.3468
16-07-15	12.5182
17-07-15	12.1648
20-07-15	12.5086
21-07-15	12.7773
22-07-15	12.4471
23-07-15	12.4518
24-07-15	12.5206
27-07-15	14.9319
28-07-15	14.4208
29-07-15	14.6104
31-07-15	16.8360
03-08-15	16.0858
04-08-15	16.4634
05-08-15	15.9980
06-08-15	15.9781
07-08-15	16.8443
10-08-15	14.0501
11-08-15	12.7143
13-08-15	17.9191
14-08-15	16.3586
17-08-15	18.0325
18-08-15	20.3298
19-08-15	18.6485
20-08-15	19.7119
21-08-15	19.5627
24-08-15	18.1093
25-08-15	21.7064
26-08-15	23.6498
27-08-15	26.2542
28-08-15	23.4004
31-08-15	25.4077
01-09-15	27.9236
02-09-15	24.2225
03-09-15	25.2703
04-09-15	25.5355
07-09-15	25.6757
08-09-15	25.1136
09-09-15	24.8027
10-09-15	24.9509
11-09-15	24.6093
14-09-15	24.8149
15-09-15	24.6348
16-09-15	22.5868

Date	TVIX
17-09-15	23.1811
18-09-15	21.8224
21-09-15	22.3098
22-09-15	22.4445
23-09-15	21.9975
24-09-15	21.3608
25-09-15	19.7527
28-09-15	18.8319
29-09-15	22.7027
30-09-15	22.3347
01-10-15	19.4277
02-10-15	20.8640
05-10-15	19.9392
06-10-15	19.5457
07-10-15	22.0246
08-10-15	21.3837
09-10-15	21.1749
12-10-15	20.6493
13-10-15	20.1670
14-10-15	20.8159
15-10-15	20.8532
16-10-15	19.5442
19-10-15	18.9491
20-10-15	19.3555
21-10-15	17.2547
22-10-15	16.7102
26-10-15	16.4879
27-10-15	16.1071
28-10-15	16.8783
29-10-15	18.0120
30-10-15	17.7894
02-11-15	18.7862
03-11-15	18.7609
04-11-15	18.5317
05-11-15	18.6236
06-11-15	18.8249
09-11-15	18.6992
10-11-15	18.8923
11-11-15	18.7161
12-11-15	18.4200
13-11-15	19.1572
16-11-15	22.1389
17-11-15	18.9499
18-11-15	18.5967
19-11-15	23.2844
20-11-15	21.5177

Date	TVIX
23-11-15	20.8660
24-11-15	20.4529
25-11-15	19.8879
26-11-15	19.1227
27-11-15	19.1036
30-11-15	19.4185
01-12-15	19.3760
02-12-15	18.3476
03-12-15	18.4847
04-12-15	17.0271
08-12-15	19.2564
09-12-15	19.6613
11-12-15	20.4108
14-12-15	22.1173
15-12-15	24.3148
16-12-15	22.6067
17-12-15	21.4952
18-12-15	23.1627
21-12-15	24.1997
22-12-15	23.4393
23-12-15	23.2988
24-12-15	22.8634
25-12-15	21.1902
28-12-15	20.8716
29-12-15	20.3676
30-12-15	19.7960
04-01-16	21.9920
05-01-16	21.9764
06-01-16	21.4975
07-01-16	27.5980
08-01-16	27.4850
11-01-16	27.2955
12-01-16	28.3772
13-01-16	29.7113
14-01-16	30.1352
15-01-16	29.9105
18-01-16	28.9194
19-01-16	30.4590
20-01-16	32.1380
21-01-16	30.3573
22-01-16	31.8170
25-01-16	29.7341
26-01-16	28.7871
27-01-16	28.3702
28-01-16	28.2681
29-01-16	28.3636

Date	TVIX
01-02-16	26.9301
02-02-16	27.4858
03-02-16	26.9826
04-02-16	26.3827
05-02-16	25.6421
08-02-16	25.2310
09-02-16	25.0752
10-02-16	24.7759
11-02-16	25.9245
12-02-16	25.6524
15-02-16	24.2724
16-02-16	25.3468
17-02-16	25.5464
18-02-16	29.5641
19-02-16	27.1038
23-02-16	28.0367
24-02-16	26.8292
25-02-16	26.0206
26-02-16	24.1972
29-02-16	24.8088
01-03-16	24.7811
02-03-16	24.0300
03-03-16	23.0413
04-03-16	22.8643
07-03-16	22.5419
08-03-16	23.9890
09-03-16	22.0974
10-03-16	22.1798
11-03-16	20.5554
14-03-16	21.4915
15-03-16	23.0731
16-03-16	23.2957
17-03-16	22.6372
18-03-16	20.8978
21-03-16	21.0389
22-03-16	20.6726
23-03-16	20.9721
24-03-16	20.6230
25-03-16	19.8546
28-03-16	19.6163
29-03-16	19.0462
30-03-16	19.9461
31-03-16	19.4448
01-04-16	18.3124
04-04-16	18.1691
05-04-16	21.6012

Date	TVIX
07-04-16	22.5481
08-04-16	20.2163
11-04-16	21.4388
12-04-16	21.6049
18-04-16	21.5494
19-04-16	22.9744
20-04-16	21.3275
21-04-16	21.1364
22-04-16	21.0284
25-04-16	20.5001
26-04-16	19.2625
27-04-16	18.8232
28-04-16	19.1874
29-04-16	18.8559
03-05-16	18.6321
04-05-16	18.2474
09-05-16	19.8852
10-05-16	20.2010
11-05-16	19.2689
12-05-16	20.2699
13-05-16	19.9682
16-05-16	20.9450
17-05-16	19.9935
18-05-16	20.4014
19-05-16	19.0941
23-05-16	23.8404
24-05-16	24.3980
25-05-16	22.6743
26-05-16	22.1227
27-05-16	20.3142
30-05-16	20.3589
31-05-16	20.2397
01-06-16	20.0365
02-06-16	18.9656
03-06-16	18.3921
06-06-16	17.6353
07-06-16	16.8158
08-06-16	16.0845
09-06-16	15.3530
10-06-16	15.3999
13-06-16	16.3766
14-06-16	15.8197
15-06-16	14.9697
16-06-16	17.2759
17-06-16	16.2461
20-06-16	17.0697

Date	TVIX
21-06-16	15.7836
22-06-16	15.5794
23-06-16	16.2989
24-06-16	18.6121
27-06-16	18.4494
28-06-16	18.4028
29-06-16	17.9845
30-06-16	17.4820
04-07-16	17.1629
05-07-16	16.7977
06-07-16	16.4807
07-07-16	15.7324
08-07-16	14.5845
11-07-16	15.3977
12-07-16	15.1754
13-07-16	14.7078
14-07-16	14.8848
15-07-16	13.9264
20-07-16	15.4111
21-07-16	14.9003
22-07-16	14.7714
25-07-16	14.5424
26-07-16	14.5573
27-07-16	13.8921
28-07-16	14.0526
29-07-16	13.8262
01-08-16	14.4423
02-08-16	15.1932
03-08-16	14.5587
04-08-16	14.3061
05-08-16	14.6156
08-08-16	18.0809
09-08-16	16.6952
10-08-16	15.6223
11-08-16	15.3406
15-08-16	15.2031
16-08-16	15.7672
17-08-16	14.2397
18-08-16	15.3271
19-08-16	14.4697
22-08-16	14.8424
23-08-16	15.0030
24-08-16	14.9732
25-08-16	14.6282
26-08-16	14.2216
29-08-16	13.9606

Date	TVIX
30-08-16	14.5132
31-08-16	13.9814
01-09-16	13.0905
02-09-16	15.3079
05-09-16	18.1497
06-09-16	18.3780
07-09-16	17.8975
08-09-16	20.1453
09-09-16	24.4344
12-09-16	27.9606
13-09-16	25.3278
14-09-16	24.7514
15-09-16	24.3516
16-09-16	21.5460
19-09-16	21.2635
20-09-16	22.0918
21-09-16	21.7205
22-09-16	22.0145
23-09-16	21.9132
26-09-16	20.5959
27-09-16	20.0324
28-09-16	19.7220
29-09-16	19.5901
30-09-16	19.8107
03-10-16	18.3477
04-10-16	19.2064
05-10-16	18.4381
06-10-16	17.9079
07-10-16	17.7302
10-10-16	22.0261
11-10-16	21.4381
12-10-16	24.3441
13-10-16	24.2708
14-10-16	31.9201
17-10-16	29.0732
18-10-16	29.2100
19-10-16	26.5602
20-10-16	27.0994
21-10-16	26.0781
25-10-16	25.2632
26-10-16	24.0079
27-10-16	23.1478
28-10-16	22.5775
31-10-16	22.3206
01-11-16	21.9973
02-11-16	20.4898

Date	TVIX
03-11-16	20.2976
04-11-16	20.0824
07-11-16	20.9940
08-11-16	20.6786
09-11-16	19.4266
10-11-16	18.7956
11-11-16	19.3496
14-11-16	21.0418
15-11-16	20.8948
16-11-16	19.6180
17-11-16	19.7437
18-11-16	18.8812
21-11-16	21.2451
22-11-16	21.3637
23-11-16	19.9072
24-11-16	19.7138
25-11-16	18.8701
28-11-16	17.6709
29-11-16	17.9024
30-11-16	16.1123
01-12-16	16.8620
02-12-16	16.7211
06-12-16	16.7367
07-12-16	16.2544
08-12-16	15.9669
09-12-16	14.7768
13-12-16	15.2051
14-12-16	14.8737
15-12-16	14.2025
16-12-16	12.9612
19-12-16	13.0720
20-12-16	12.3823
21-12-16	11.6620
22-12-16	11.3975
23-12-16	11.3973
26-12-16	11.5492
27-12-16	10.7551
28-12-16	10.4671
29-12-16	11.4424
30-12-16	11.1517
04-01-17	13.2354
05-01-17	13.0637
06-01-17	12.7793
09-01-17	12.7936
10-01-17	12.0601
11-01-17	11.7547

Date	TVIX
12-01-17	11.5010
13-01-17	11.3064
16-01-17	11.3270
17-01-17	10.4589
18-01-17	10.2234
19-01-17	9.8147
20-01-17	9.9353
23-01-17	9.6521
24-01-17	9.5966
25-01-17	9.9549
26-01-17	10.5500
27-01-17	10.3467
30-01-17	10.4403
31-01-17	10.9201
01-02-17	10.7037
02-02-17	10.6215
03-02-17	11.0235
06-02-17	11.1906
07-02-17	10.2327
08-02-17	10.4989
09-02-17	11.2478
10-02-17	10.2295
14-02-17	11.4501
15-02-17	11.9508
16-02-17	11.7790
17-02-17	11.2853
20-02-17	12.8086
21-02-17	12.7618
22-02-17	12.2653
23-02-17	11.6733
24-02-17	11.3628
27-02-17	10.9090
28-02-17	10.5968
01-03-17	10.4073
02-03-17	10.5065
03-03-17	10.1551
06-03-17	10.3534
07-03-17	10.3957
08-03-17	9.2702
09-03-17	9.4201
10-03-17	9.0354
13-03-17	9.5267
14-03-17	9.9378
15-03-17	9.8754
16-03-17	10.1811
17-03-17	9.4236

Date	TVIX
20-03-17	9.1982
21-03-17	9.2339
22-03-17	8.8128
23-03-17	7.8755
24-03-17	8.2910
27-03-17	7.9572
28-03-17	8.5768
29-03-17	12.6851
30-03-17	8.3578
31-03-17	6.4573
03-04-17	8.1136
04-04-17	7.9423
05-04-17	7.6846
07-04-17	7.3691
10-04-17	7.2603
11-04-17	10.2042
12-04-17	7.2652
17-04-17	8.3174
18-04-17	7.9800
19-04-17	6.8019
20-04-17	6.7514
21-04-17	6.9562
24-04-17	6.6609
25-04-17	6.6174
26-04-17	6.6025
27-04-17	6.3334
28-04-17	6.1798
02-05-17	8.6419
03-05-17	15.9691
04-05-17	6.7736
05-05-17	6.5893
08-05-17	6.8116
09-05-17	6.8374
11-05-17	6.6185
12-05-17	7.4458
15-05-17	7.7662
16-05-17	7.8411
17-05-17	7.6976
18-05-17	8.1586
19-05-17	7.6820
22-05-17	9.8617
23-05-17	9.2054
24-05-17	9.3553
25-05-17	9.0133
26-05-17	8.5891
29-05-17	8.8483

Date	TVIX
30-05-17	8.2464
31-05-17	8.5255
01-06-17	8.2235
02-06-17	7.7371
05-06-17	7.5425
06-06-17	7.5172
07-06-17	7.3002
08-06-17	6.9517
09-06-17	6.8492
12-06-17	6.5392
13-06-17	6.9842
14-06-17	6.9206
15-06-17	6.7276
16-06-17	6.2383
19-06-17	6.3249
20-06-17	6.1992
21-06-17	5.2495
22-06-17	5.3244
23-06-17	5.3192
26-06-17	5.0856
27-06-17	5.0432
28-06-17	5.0082
29-06-17	4.9035
30-06-17	4.7891
03-07-17	5.1160
04-07-17	5.1403
05-07-17	5.0088
06-07-17	4.9124
07-07-17	4.7681
11-07-17	4.5360
12-07-17	4.9656
13-07-17	5.0364
14-07-17	4.9203
17-07-17	4.7544
18-07-17	4.6945
19-07-17	4.9453
20-07-17	4.3485
21-07-17	4.2144
24-07-17	4.4776
25-07-17	4.9229
26-07-17	4.6521
27-07-17	4.2738
31-07-17	4.9162
01-08-17	4.8195
02-08-17	4.6550
03-08-17	4.5920

Date	TVIX
04-08-17	4.5016
07-08-17	4.5901
08-08-17	4.7091
09-08-17	4.8241
10-08-17	4.5137
11-08-17	4.8188
15-08-17	5.1079
16-08-17	5.1647
17-08-17	4.9496
18-08-17	4.8618
21-08-17	5.2677
22-08-17	5.4300
23-08-17	5.1225
24-08-17	4.9110
25-08-17	5.3596
28-08-17	5.3525
29-08-17	14.2183
30-08-17	11.7558
31-08-17	10.0047
01-09-17	8.6909
04-09-17	9.6055
05-09-17	9.3535
06-09-17	8.9561
07-09-17	9.0117
08-09-17	10.9353
11-09-17	10.6394
12-09-17	9.2727
13-09-17	9.1926
14-09-17	11.1998
15-09-17	10.7914
18-09-17	11.5910
19-09-17	10.5652
20-09-17	10.2573
21-09-17	10.0499
22-09-17	10.6067
25-09-17	10.7956
26-09-17	9.9848
27-09-17	9.7527
28-09-17	9.6383
29-09-17	9.4488
02-10-17	10.9790
03-10-17	10.1831
04-10-17	10.0397
05-10-17	9.7011
06-10-17	9.6277
09-10-17	9.4962

Date	TVIX
10-10-17	10.2384
11-10-17	10.1381
12-10-17	9.8123
16-10-17	10.9855
17-10-17	10.2506
18-10-17	9.7417
19-10-17	13.3462
20-10-17	13.1659
24-10-17	13.6614
25-10-17	13.1844
27-10-17	12.4448
30-10-17	11.8561
31-10-17	11.6333
01-11-17	11.5566
02-11-17	11.5070
03-11-17	11.1578
06-11-17	11.4319
07-11-17	11.1318
08-11-17	10.8990
09-11-17	10.6544
10-11-17	10.9206
13-11-17	10.6941
14-11-17	11.2717
15-11-17	11.4782
16-11-17	10.8123
17-11-17	11.2688
20-11-17	11.4270
21-11-17	11.3613
22-11-17	11.2436
23-11-17	11.5113
24-11-17	10.9027
27-11-17	11.5767
28-11-17	11.5033
29-11-17	11.5801
30-11-17	11.8235
01-12-17	11.2660
04-12-17	11.7132
06-12-17	11.0749
07-12-17	10.2099
08-12-17	9.9109
12-12-17	10.0504
13-12-17	9.8386
14-12-17	9.9925
15-12-17	9.4956
18-12-17	10.3163
19-12-17	10.3279

Date	TVIX
20-12-17	8.2533
21-12-17	8.0319
22-12-17	7.9867
25-12-17	8.3846
26-12-17	6.9998
27-12-17	7.5843
28-12-17	8.0481
29-12-17	8.1638
03-01-18	11.7082
04-01-18	12.1791
05-01-18	11.8512
08-01-18	10.6870
09-01-18	11.4400
10-01-18	10.5721
11-01-18	10.5103
12-01-18	10.4930
15-01-18	11.5851
16-01-18	11.2533
17-01-18	10.3779
18-01-18	10.5483
19-01-18	10.1937
22-01-18	10.0828
23-01-18	10.2032
24-01-18	9.4915
25-01-18	10.9354
26-01-18	11.1135
29-01-18	11.1241
30-01-18	11.4674
31-01-18	10.6374
01-02-18	10.5772
02-02-18	10.4524
05-02-18	11.6932
06-02-18	13.6310
07-02-18	12.7839
08-02-18	12.8695
09-02-18	13.3039
12-02-18	14.2714
13-02-18	14.4059
14-02-18	14.1931
15-02-18	14.5953
16-02-18	13.7197
19-02-18	17.7439
20-02-18	17.5043
21-02-18	16.5888
22-02-18	17.5206
23-02-18	15.3698

Date	TVIX
26-02-18	13.9319
27-02-18	16.1249
28-02-18	16.1065
02-03-18	17.0187
05-03-18	16.7835
06-03-18	16.3607
07-03-18	17.2214
08-03-18	16.5776
09-03-18	14.6552
12-03-18	15.2502
13-03-18	15.1213
14-03-18	15.3362
15-03-18	14.5871
16-03-18	13.6435
19-03-18	13.7514
20-03-18	13.4906
21-03-18	11.7244
22-03-18	11.4180
23-03-18	11.0766
26-03-18	10.6252
27-03-18	10.3169
28-03-18	10.8946
29-03-18	12.0289
30-03-18	12.1272
02-04-18	11.4919
03-04-18	11.9446
04-04-18	15.2068
05-04-18	16.7247
09-04-18	16.5987
10-04-18	16.3014
11-04-18	15.8650
12-04-18	15.2734
17-04-18	15.1011
18-04-18	15.6382
19-04-18	16.2693
20-04-18	15.7522
23-04-18	16.0042
24-04-18	15.4617
25-04-18	15.3228
26-04-18	13.9665
27-04-18	14.0903
30-04-18	14.2487
02-05-18	14.7542
03-05-18	13.5929
04-05-18	13.8084
07-05-18	14.1453

Date	TVIX
08-05-18	15.1551
09-05-18	15.1546
10-05-18	14.4899
11-05-18	15.1104
14-05-18	15.1494
15-05-18	15.0700
16-05-18	16.1472
17-05-18	15.1112
18-05-18	14.4640
21-05-18	14.5213
22-05-18	16.3806
23-05-18	16.0731
24-05-18	17.9984
25-05-18	16.7567
28-05-18	16.8481
30-05-18	17.0934
31-05-18	16.8155
01-06-18	15.6792
04-06-18	16.3014
05-06-18	16.0301
06-06-18	14.9344
07-06-18	14.6766
08-06-18	13.6371
11-06-18	14.0616
12-06-18	13.4566
13-06-18	13.4234
14-06-18	13.3174
15-06-18	12.6561
18-06-18	14.1520
19-06-18	19.8408
20-06-18	19.6277
21-06-18	21.5420
22-06-18	20.0431
25-06-18	20.1279
26-06-18	19.5744
27-06-18	19.1320
28-06-18	19.1770
29-06-18	17.7285
02-07-18	17.7996
03-07-18	17.9730
04-07-18	17.5420
05-07-18	19.0607
06-07-18	17.9434
09-07-18	17.9224
10-07-18	18.7824
11-07-18	18.5016

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13-07-18	16.4563
16-07-18	16.9379
17-07-18	16.4851
18-07-18	16.7757
19-07-18	16.5666
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23-07-18	17.7629
24-07-18	16.9598
25-07-18	17.3972
26-07-18	17.2871
31-07-18	16.0980
01-08-18	16.0156
02-08-18	17.2327
03-08-18	15.9521
06-08-18	16.5405
07-08-18	17.0032
08-08-18	16.5331
09-08-18	16.1485
10-08-18	15.8439
14-08-18	16.3417
15-08-18	17.0245
16-08-18	17.1201
17-08-18	15.7833
20-08-18	16.3493
21-08-18	16.3199
22-08-18	17.1063
23-08-18	16.7635
24-08-18	16.4345
27-08-18	16.0882
28-08-18	15.8495
29-08-18	15.7605
30-08-18	15.7352
31-08-18	14.3979
03-09-18	14.7908
04-09-18	14.4477
05-09-18	15.6896
06-09-18	15.4492
07-09-18	14.6467
10-09-18	15.2101
11-09-18	16.0523
12-09-18	15.8707
13-09-18	19.9095
14-09-18	18.2813
17-09-18	18.5136
18-09-18	19.0261

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24-09-18	16.6427
25-09-18	16.7305
26-09-18	15.4946
27-09-18	13.8607
28-09-18	14.6705
01-10-18	14.4417
02-10-18	14.7025
03-10-18	13.6610
04-10-18	13.8684
05-10-18	13.7489
08-10-18	15.2557
09-10-18	14.7885
10-10-18	15.7727
11-10-18	19.7439
12-10-18	19.4022
16-10-18	19.2490
17-10-18	17.9335
18-10-18	16.7893
19-10-18	17.4338
22-10-18	17.3246
24-10-18	21.2604
25-10-18	21.7739
26-10-18	21.3439
29-10-18	20.6988
30-10-18	19.9654
31-10-18	22.0969
01-11-18	21.4059
02-11-18	18.2397
05-11-18	20.2307
06-11-18	19.7047
07-11-18	19.2568
08-11-18	18.8820
09-11-18	17.9964
12-11-18	14.8018
13-11-18	17.9269
14-11-18	17.9286
15-11-18	18.0272
16-11-18	16.6578
19-11-18	18.1178
20-11-18	18.2522
21-11-18	18.0475
22-11-18	18.6204
23-11-18	17.2552

Date	TVIX	Date	TVIX	Date	TVIX	Date	TVIX
26-11-18	17.9716	04-02-19	12.2877	11-04-19	10.0737	24-06-19	12.5541
27-11-18	18.0900	05-02-19	12.1602	12-04-19	9.6870	25-06-19	12.2815
28-11-18	17.6431	06-02-19	12.1055	17-04-19	9.7607	26-06-19	11.3986
29-11-18	17.8547	07-02-19	11.4655	18-04-19	9.4634	27-06-19	11.4708
30-11-18	17.2224	08-02-19	11.2414	19-04-19	8.9857	28-06-19	11.1713
03-12-18	18.2850	11-02-19	12.7158	22-04-19	8.6263	01-07-19	11.5929
04-12-18	18.4587	12-02-19	12.6949	23-04-19	8.4190	02-07-19	11.6865
06-12-18	18.4805	13-02-19	13.2459	24-04-19	8.1022	03-07-19	10.8578
07-12-18	16.8794	14-02-19	12.8573	25-04-19	7.9783	04-07-19	11.3991
11-12-18	18.0953	15-02-19	13.2375	26-04-19	7.6312	05-07-19	11.1837
12-12-18	17.8369	18-02-19	14.0454	29-04-19	7.7648	08-07-19	11.0416
13-12-18	18.1330	20-02-19	15.9642	30-04-19	7.9179	09-07-19	11.4173
14-12-18	17.3819	21-02-19	15.9826	02-05-19	8.0215	10-07-19	12.1674
17-12-18	18.4521	22-02-19	14.2852	03-05-19	7.2853	11-07-19	11.8188
18-12-18	18.1137	25-02-19	14.0753	07-05-19	8.6066	12-07-19	11.7525
19-12-18	17.7656	26-02-19	14.4291	08-05-19	9.3190	15-07-19	11.5472
20-12-18	16.6432	27-02-19	13.8587	09-05-19	9.5127	17-07-19	10.9861
21-12-18	16.1025	28-02-19	14.3947	10-05-19	8.5257	18-07-19	10.7615
24-12-18	15.8461	01-03-19	14.5859	13-05-19	9.2921	19-07-19	10.6400
25-12-18	19.1139	04-03-19	13.9211	14-05-19	9.5275	22-07-19	10.9784
26-12-18	18.5050	05-03-19	13.5159	15-05-19	9.8901	23-07-19	10.5622
27-12-18	17.4933	06-03-19	14.0716	16-05-19	10.2406	24-07-19	10.2549
28-12-18	17.7386	07-03-19	13.9286	17-05-19	9.0884	25-07-19	10.0032
02-01-19	17.6710	08-03-19	13.1593	21-05-19	10.2954	26-07-19	10.3436
03-01-19	16.5079	11-03-19	13.0911	22-05-19	10.6852	30-07-19	10.4318
04-01-19	17.0330	12-03-19	12.4225	23-05-19	10.7898	31-07-19	10.3068
07-01-19	17.7780	13-03-19	13.4242	24-05-19	10.2997	01-08-19	10.3423
08-01-19	17.2478	14-03-19	13.1271	27-05-19	10.2165	02-08-19	10.7968
09-01-19	16.8008	15-03-19	12.4475	28-05-19	10.6454	05-08-19	12.2660
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11-01-19	15.2622	19-03-19	13.5146	30-05-19	11.0881	07-08-19	11.7454
14-01-19	15.9180	20-03-19	10.5048	31-05-19	10.2214	08-08-19	11.7169
15-01-19	15.6219	21-03-19	10.4616	04-06-19	11.7943	09-08-19	11.8487
16-01-19	15.2075	22-03-19	11.4510	05-06-19	12.4066	13-08-19	14.7787
17-01-19	13.9236	25-03-19	13.3303	06-06-19	11.7652	14-08-19	14.7606
18-01-19	13.6806	26-03-19	12.5324	07-06-19	11.3552	15-08-19	15.5821
21-01-19	13.5691	27-03-19	12.2341	10-06-19	11.0298	16-08-19	15.2059
22-01-19	13.3004	28-03-19	11.9267	11-06-19	10.9428	19-08-19	15.3504
23-01-19	13.7472	29-03-19	11.6373	12-06-19	10.4835	20-08-19	14.8304
24-01-19	12.4418	01-04-19	11.5686	13-06-19	9.9932	21-08-19	14.2614
25-01-19	12.2819	02-04-19	10.9870	14-06-19	9.5764	22-08-19	14.9850
28-01-19	12.5317	03-04-19	10.6761	17-06-19	10.2731	23-08-19	15.1789
29-01-19	12.3208	04-04-19	10.4508	18-06-19	11.5276	26-08-19	16.8136
30-01-19	12.4050	05-04-19	10.1455	19-06-19	12.8747	27-08-19	16.7155
31-01-19	11.5655	09-04-19	10.4396	20-06-19	13.0833	28-08-19	16.9511
01-02-19	11.7086	10-04-19	10.2378	21-06-19	12.7845	29-08-19	16.6237

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09-09-19	15.3834
10-09-19	15.2048
11-09-19	15.1137
12-09-19	15.6077
13-09-19	15.0306
16-09-19	14.6435
17-09-19	14.5290
18-09-19	14.3972
19-09-19	13.9773
20-09-19	13.7134
23-09-19	14.2019
24-09-19	14.0392
25-09-19	13.7179
26-09-19	13.0070
27-09-19	12.9802
30-09-19	12.8675
01-10-19	13.3194
02-10-19	13.4504
03-10-19	12.4665
04-10-19	12.1301
07-10-19	12.2924
08-10-19	11.9372
09-10-19	11.8231
10-10-19	11.6454
11-10-19	13.3414
15-10-19	13.2745
16-10-19	13.1444
17-10-19	12.2737
18-10-19	11.7189
21-10-19	12.1413
22-10-19	12.2916
24-10-19	12.3036
25-10-19	13.8666
28-10-19	13.6311
29-10-19	13.3592
30-10-19	13.6230
31-10-19	13.3266
01-11-19	12.5120
04-11-19	15.6306
05-11-19	15.2457

Date	TVIX
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08-11-19	14.3076
11-11-19	14.4327
12-11-19	14.2419
13-11-19	14.1524
14-11-19	14.0840
15-11-19	13.2734
18-11-19	13.3184
19-11-19	13.1074
20-11-19	13.4250
21-11-19	13.2839
22-11-19	13.7318
25-11-19	13.1814
26-11-19	13.3437
27-11-19	13.0876
28-11-19	13.1201
29-11-19	13.0117
02-12-19	13.2499
03-12-19	13.3686
04-12-19	13.0037
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13-12-19	12.2577
16-12-19	13.5341
17-12-19	13.1644
18-12-19	14.0959
19-12-19	14.8326
20-12-19	13.8576
23-12-19	13.5828
24-12-19	13.3119
25-12-19	13.0008
26-12-19	12.6686
27-12-19	11.7581
30-12-19	11.5537
02-01-20	12.7871
03-01-20	11.8524
06-01-20	13.6909
07-01-20	14.1887
08-01-20	16.0735
09-01-20	16.8608
10-01-20	15.5706
13-01-20	15.4300
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17-01-20	14.0532
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21-01-20	14.7948
22-01-20	14.7863
23-01-20	14.2309
24-01-20	13.3104
27-01-20	21.1271
28-01-20	20.5489
29-01-20	20.2487
30-01-20	19.4835
31-01-20	18.5044
03-02-20	18.6692
04-02-20	19.5095
05-02-20	19.0593
06-02-20	18.3489
07-02-20	17.1402
11-02-20	17.0231
12-02-20	16.9250
13-02-20	16.7481
14-02-20	15.6659
17-02-20	15.4186
18-02-20	15.4762
19-02-20	13.8084
20-02-20	14.7285
21-02-20	14.3061
24-02-20	19.7506
25-02-20	16.5644
26-02-20	25.5433
27-02-20	23.9090
28-02-20	28.1827
02-03-20	32.9822
03-03-20	27.4121
04-03-20	25.9122
05-03-20	24.9577
06-03-20	27.8223
09-03-20	5.8728
10-03-20	47.3202
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18-03-20	81.8824
19-03-20	74.7348

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26-03-20	90.2883
27-03-20	88.0084
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31-03-20	85.9205
01-04-20	84.1501
02-04-20	79.8389
03-04-20	77.3978
07-04-20	84.7331
08-04-20	82.5921
09-04-20	76.7124
10-04-20	74.2736
13-04-20	73.1325
14-04-20	71.4874
15-04-20	70.2094
16-04-20	67.4196
17-04-20	66.9441
20-04-20	67.1629
21-04-20	69.3971
22-04-20	66.8155
23-04-20	64.2112
24-04-20	60.3099
27-04-20	57.7290
28-04-20	55.6474
29-04-20	53.7215
30-04-20	52.4765
05-05-20	49.8736
07-05-20	48.2318
08-05-20	44.6967
11-05-20	42.8447
12-05-20	40.5867
13-05-20	39.2750
14-05-20	37.8739
15-05-20	34.6516
18-05-20	33.4923
19-05-20	32.4905
20-05-20	25.6349
21-05-20	26.9986
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25-05-20	29.9700
26-05-20	28.7831
27-05-20	29.1046
28-05-20	32.4217

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08-06-20	31.6617
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11-06-20	31.7196
12-06-20	35.6070
15-06-20	40.0540
16-06-20	36.3419
17-06-20	33.9105
18-06-20	32.5713
19-06-20	31.1577
22-06-20	31.8406
23-06-20	30.9746
24-06-20	31.4939
25-06-20	30.6826
26-06-20	28.4786
29-06-20	28.0308
30-06-20	27.4327
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02-07-20	28.3214
03-07-20	26.3225
07-07-20	26.0161
08-07-20	25.7401
09-07-20	25.1052
10-07-20	24.4942
13-07-20	24.2040
14-07-20	23.5292
15-07-20	23.5293
16-07-20	23.0993
17-07-20	22.0754
20-07-20	21.3857
21-07-20	22.1868
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23-07-20	21.6340
24-07-20	22.8211
29-07-20	22.3106
30-07-20	24.0130
31-07-20	23.9912
03-08-20	23.7040
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05-08-20	23.1956
06-08-20	23.0758

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14-08-20	24.2285
17-08-20	24.1552
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21-08-20	26.4113
24-08-20	25.9700
25-08-20	24.9935
26-08-20	23.3466
27-08-20	23.0593
28-08-20	22.8604
31-08-20	22.5624
01-09-20	21.9604
02-09-20	20.8333
03-09-20	20.7337
08-09-20	21.3620
09-09-20	19.4620
10-09-20	19.2647
11-09-20	19.6697
14-09-20	19.9865
15-09-20	19.0332
16-09-20	17.6451
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21-09-20	16.8844
22-09-20	16.8767
23-09-20	16.8719
24-09-20	18.8527
25-09-20	17.4341
28-09-20	19.7923
29-09-20	19.5561
30-09-20	21.2286
01-10-20	20.7847
02-10-20	20.2723
05-10-20	20.3314
06-10-20	19.9597
07-10-20	20.2553
08-10-20	20.3049
09-10-20	19.1940
12-10-20	19.0598
14-10-20	19.4453
15-10-20	20.3312

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21-10-20	20.3406
22-10-20	19.9403
26-10-20	19.1516
27-10-20	18.7410
28-10-20	18.4178
29-10-20	18.2716
30-10-20	18.1735
02-11-20	17.4852
03-11-20	18.5616
04-11-20	18.0947
05-11-20	23.8072
06-11-20	23.7415
09-11-20	24.0912
10-11-20	34.6731
11-11-20	34.8015
12-11-20	33.8617
13-11-20	32.8572
16-11-20	29.5626
17-11-20	27.2332
18-11-20	26.6667
19-11-20	17.3637
20-11-20	19.7453
23-11-20	23.7884
24-11-20	25.8070
25-11-20	23.6074
26-11-20	22.1616
27-11-20	21.8525
30-11-20	25.6946
01-12-20	24.4174
02-12-20	22.9609
03-12-20	24.5206
04-12-20	23.1811
08-12-20	25.2032
09-12-20	23.1545
14-12-20	25.2120
15-12-20	26.2227
16-12-20	24.0057
17-12-20	24.5624
18-12-20	23.3469
21-12-20	35.6432
22-12-20	35.5178
23-12-20	35.2604
24-12-20	35.4643

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25-12-20	33.4282
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29-12-20	34.0682
30-12-20	33.9527
04-01-21	33.4493
05-01-21	35.0775
06-01-21	34.9960
07-01-21	34.6816
08-01-21	33.8052
11-01-21	33.7644
12-01-21	33.1545
13-01-21	32.6611
14-01-21	31.7534
15-01-21	30.4707
18-01-21	30.6953
19-01-21	30.4344
20-01-21	30.4097
21-01-21	28.7300
22-01-21	28.4490
25-01-21	28.0199
26-01-21	27.6812
27-01-21	27.8093
28-01-21	27.5248
29-01-21	27.1209
01-02-21	27.4159
02-02-21	26.8299
03-02-21	26.4558
04-02-21	24.8091
05-02-21	24.7887
08-02-21	25.3131
09-02-21	24.3206
10-02-21	23.6954
11-02-21	23.0511
15-02-21	23.6046
16-02-21	24.7339
17-02-21	24.2686
18-02-21	22.9015
19-02-21	23.1205
22-02-21	25.4760
23-02-21	22.2276
24-02-21	21.2229
25-02-21	20.2401
01-03-21	22.3479
02-03-21	22.6140
03-03-21	23.5878
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15-03-21	22.0506
16-03-21	20.9769
17-03-21	20.0581
18-03-21	19.3483
19-03-21	18.6504
22-03-21	18.9301
23-03-21	18.5600
24-03-21	18.2571
25-03-21	17.9010
26-03-21	16.8025
29-03-21	16.8012
30-03-21	16.6065
31-03-21	16.2908
01-04-21	16.0897
02-04-21	15.0961
05-04-21	15.8314
07-04-21	16.7145
08-04-21	16.4409
09-04-21	15.6513
12-04-21	16.6663
16-04-21	16.2800
19-04-21	16.9533
20-04-21	16.7271
21-04-21	16.7258
22-04-21	16.7955
23-04-21	17.0452
26-04-21	16.0507
27-04-21	15.7456
28-04-21	16.2090
29-04-21	16.5010
30-04-21	16.5555
05-05-21	19.6575
06-05-21	20.0104
07-05-21	19.8934
10-05-21	19.2225
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14-05-21	21.4751
17-05-21	21.8785

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24-05-21	22.1806
25-05-21	20.5784
27-05-21	18.5458
28-05-21	18.2353
31-05-21	18.3130
01-06-21	18.7085
02-06-21	17.2848
04-06-21	17.5674
07-06-21	18.2671
08-06-21	17.0424
09-06-21	15.7368
10-06-21	15.4000
11-06-21	15.9220
14-06-21	15.7237
15-06-21	16.3155
16-06-21	15.6817
17-06-21	15.4900
18-06-21	14.7932
21-06-21	15.0339
22-06-21	14.8720
23-06-21	14.5282
24-06-21	14.3279
25-06-21	13.3945
28-06-21	13.4472
29-06-21	13.5632
30-06-21	13.3631
01-07-21	13.1928
02-07-21	12.8181
05-07-21	12.9078
06-07-21	12.7587
07-07-21	13.0619
08-07-21	15.2273
09-07-21	14.3804
12-07-21	14.3845
13-07-21	14.8888
14-07-21	14.7037
15-07-21	14.4825
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19-07-21	14.5842
20-07-21	14.6617
21-07-21	13.4926
22-07-21	14.0066

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03-08-21	13.7547
04-08-21	13.8085
05-08-21	14.8608
06-08-21	15.0592
09-08-21	15.9318
10-08-21	14.9597
11-08-21	14.9264
13-08-21	14.9860
16-08-21	15.4894
17-08-21	14.8698
18-08-21	14.9945
19-08-21	14.8012
20-08-21	14.4705
23-08-21	13.7710
24-08-21	13.1105
25-08-21	13.4007
26-08-21	12.9116
27-08-21	14.8647
30-08-21	16.0122
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01-09-21	15.2787
02-09-21	13.9555
03-09-21	14.6031
06-09-21	14.9267
07-09-21	15.3516
08-09-21	14.9729
09-09-21	15.6392
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13-09-21	15.9124
14-09-21	15.6390
15-09-21	15.2245
16-09-21	13.7063
17-09-21	12.9960
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22-09-21	14.2140
23-09-21	14.8790
27-09-21	14.3818
28-09-21	14.1408
29-09-21	13.9264
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06-10-21	13.7857
07-10-21	13.9845
08-10-21	13.2496
11-10-21	13.4095
12-10-21	13.3561
14-10-21	13.3173
15-10-21	12.5897
18-10-21	12.8100
19-10-21	12.7999
20-10-21	11.6117
21-10-21	11.9247
25-10-21	12.5159
26-10-21	11.7214
27-10-21	11.9526
28-10-21	11.9856
29-10-21	11.9550
01-11-21	12.4029
02-11-21	11.6582
03-11-21	11.7711
04-11-21	12.0023
05-11-21	12.2542
08-11-21	12.7569
09-11-21	12.0214
10-11-21	12.0521
11-11-21	11.8616
12-11-21	11.8922
15-11-21	12.5757
16-11-21	11.9128
17-11-21	12.0577
18-11-21	11.4160
19-11-21	11.7365
22-11-21	13.3415
23-11-21	12.9543
24-11-21	12.5826
25-11-21	12.4043
26-11-21	18.9571
29-11-21	20.5941
30-11-21	21.9466
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02-12-21	18.0871
03-12-21	16.1300
07-12-21	13.8710
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16-12-21	13.8507
17-12-21	14.5353
20-12-21	15.9547
21-12-21	15.3409
22-12-21	15.2366
23-12-21	15.5072
24-12-21	15.3826
27-12-21	14.7290
28-12-21	14.7724
29-12-21	14.7586
30-12-21	14.6764
04-01-22	14.5699
05-01-22	14.4142
06-01-22	15.5047
07-01-22	15.3898
10-01-22	14.6859
11-01-22	14.6695
12-01-22	14.7224
13-01-22	14.6404
14-01-22	14.5530
17-01-22	13.8413
18-01-22	14.0548
19-01-22	13.9706
20-01-22	13.8299
21-01-22	13.7095
24-01-22	13.1538
25-01-22	13.0864
26-01-22	13.2341
27-01-22	13.2572
28-01-22	13.2202
31-01-22	12.8208
01-02-22	13.1447
02-02-22	12.9904
03-02-22	12.7533
04-02-22	12.8484
07-02-22	12.5438
08-02-22	12.5901
09-02-22	13.8569
10-02-22	13.5630
11-02-22	13.4968
14-02-22	13.6281
15-02-22	13.6793

Date	TVIX
17-02-22	14.8969
18-02-22	14.6647
21-02-22	15.7092
22-02-22	16.6563
23-02-22	15.2375
24-02-22	17.2512
25-02-22	14.9327
28-02-22	16.1057
01-03-22	15.4506
02-03-22	15.4043
03-03-22	14.1483
04-03-22	15.5863
07-03-22	20.5893
08-03-22	19.1568
09-03-22	17.7784
10-03-22	16.3897
11-03-22	15.8206
14-03-22	16.4391
15-03-22	16.8564
16-03-22	16.3328
17-03-22	15.4669
18-03-22	15.4904
21-03-22	15.6443
22-03-22	15.3270
23-03-22	15.2284
24-03-22	15.1035
25-03-22	14.3648
28-03-22	14.4123
29-03-22	14.3648
30-03-22	14.3610
31-03-22	14.2504
01-04-22	13.5915
04-04-22	13.7293
05-04-22	13.4149
07-04-22	14.2742
08-04-22	13.4520
11-04-22	13.6552
12-04-22	13.5090
18-04-22	13.4108
19-04-22	13.0149
20-04-22	12.6167
21-04-22	12.8475
22-04-22	12.6933
25-04-22	13.4141
26-04-22	12.6359
27-04-22	12.5818

Date	TVIX
28-04-22	12.6204
29-04-22	12.5615
03-05-22	12.2482
05-05-22	12.3001
06-05-22	12.8477
09-05-22	14.0376
10-05-22	13.5984
11-05-22	13.8615
12-05-22	15.0090
13-05-22	14.6967
17-05-22	14.9956
18-05-22	14.7161
19-05-22	15.4180
20-05-22	15.0467
23-05-22	15.6934
24-05-22	16.4538
25-05-22	16.4575
26-05-22	14.8698
27-05-22	14.6430
30-05-22	15.3125
31-05-22	15.1948
01-06-22	15.2881
02-06-22	14.7735
06-06-22	14.6544
07-06-22	14.3565
08-06-22	13.2705
09-06-22	12.2253
10-06-22	12.3771
13-06-22	15.1683
14-06-22	14.7980
15-06-22	14.7753
16-06-22	16.1747
17-06-22	16.2138
20-06-22	15.8752
21-06-22	15.3952
22-06-22	14.9104
23-06-22	14.7677
24-06-22	14.8627
27-06-22	15.1490
28-06-22	15.3892
29-06-22	14.6262
30-06-22	15.0201
01-07-22	14.9801
04-07-22	15.1462
05-07-22	15.2548
06-07-22	14.2571

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11-07-22	14.6157
12-07-22	14.7464
14-07-22	14.0148
15-07-22	13.8324
18-07-22	14.3112
19-07-22	14.1778
20-07-22	13.2181
21-07-22	13.3471
22-07-22	13.3809
25-07-22	13.4970
26-07-22	13.3907
27-07-22	12.8032
01-08-22	13.6323
02-08-22	13.6282
03-08-22	12.8332
04-08-22	12.8136
05-08-22	12.7556
08-08-22	13.2801
09-08-22	13.1850
10-08-22	12.5907
11-08-22	12.4313
15-08-22	12.8566
16-08-22	13.0693
17-08-22	12.4367
18-08-22	12.7734
19-08-22	12.8071
22-08-22	15.1472
23-08-22	14.4366
24-08-22	14.2552
25-08-22	14.1970
26-08-22	13.7758
29-08-22	14.5210
30-08-22	13.5864
31-08-22	13.6872
01-09-22	14.5876
02-09-22	13.8709
05-09-22	13.6341
06-09-22	12.4483
07-09-22	12.3215
08-09-22	12.5558
09-09-22	11.1536
12-09-22	12.1706
13-09-22	11.6837
14-09-22	11.8778

Date	TVIX
15-09-22	12.3120
16-09-22	12.6003
19-09-22	12.5719
20-09-22	12.0456
21-09-22	11.3761
22-09-22	11.3613
23-09-22	11.5911
26-09-22	11.3110
27-09-22	11.2141
28-09-22	11.4852
29-09-22	11.6631
30-09-22	11.5401
03-10-22	13.2068
04-10-22	13.7461
05-10-22	13.2690
06-10-22	13.0137
07-10-22	12.8342
10-10-22	12.4432
11-10-22	12.2512
12-10-22	11.8639
17-10-22	11.5806
18-10-22	12.3696
19-10-22	11.8253
20-10-22	11.9287
21-10-22	11.6529
25-10-22	11.9996
26-10-22	11.0651
27-10-22	11.4516
28-10-22	11.2304
31-10-22	11.3112
01-11-22	12.0544
02-11-22	11.2212
03-11-22	11.1048
04-11-22	10.9054
07-11-22	11.2871
08-11-22	11.5157
09-11-22	11.0192
10-11-22	11.0662
11-11-22	11.7072
14-11-22	12.4607
15-11-22	12.2848
16-11-22	12.2098
17-11-22	12.3847
18-11-22	12.1469
21-11-22	13.2482
22-11-22	13.6078

Date	TVIX
23-11-22	13.7238
24-11-22	13.1478
25-11-22	12.4827
28-11-22	12.7622
29-11-22	13.0251
30-11-22	13.2900
01-12-22	12.8837
02-12-22	11.6207
06-12-22	11.8659
07-12-22	11.5631
08-12-22	11.0637
09-12-22	10.2347
13-12-22	11.1635
14-12-22	11.2107
15-12-22	11.2158
16-12-22	10.8684
19-12-22	10.7663
20-12-22	10.6633
21-12-22	8.5889
22-12-22	8.7219
23-12-22	8.4909
26-12-22	8.7145
27-12-22	10.0992
28-12-22	9.7997
29-12-22	10.4878
30-12-22	10.5092
03-01-23	10.5513
04-01-23	10.4092
05-01-23	10.7013
06-01-23	10.7223
09-01-23	11.5570
10-01-23	10.7209
11-01-23	10.7196
12-01-23	10.4760
13-01-23	10.5037
16-01-23	10.4471
17-01-23	9.6924
18-01-23	9.6685
19-01-23	9.4314
20-01-23	9.9604
23-01-23	9.8675
24-01-23	9.0248
25-01-23	8.8771
26-01-23	9.3396
27-01-23	9.5551
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06-02-23	10.6626
07-02-23	9.9033
08-02-23	10.0209
09-02-23	9.8720
10-02-23	9.7547
13-02-23	9.6671
14-02-23	9.4618
15-02-23	9.4562
16-02-23	8.9674
17-02-23	9.3867
20-02-23	10.1569