Forecasting implied volatility: Special topics of finance.

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1 Abstract

The objective of this study is to examine the research that has been conducted on implied volatility and the factors that could possibly affect it. The additional aim of this study is to carry out an implied volatility forecast. The chosen asset class is the stock market, thus we took data for the VIX index as well as the S&P500 index and USD/EUR exchange rate (June 2021-June2023) so as to structure three AR models with three steps ahead forecasting period. Having the AR models combined with our dataset we were able to conduct forecast for the VIX prices. We found out that adding both stock perfrormance and macroeconomics informations in the AR model results better predicitve ability, thus, as the literature suggests, these variables has a robust relationship with implied volatility.

2 Introduction

This study aims to review implied volatility in relation to factors that are likely to determine it as well as to predict the implied volatility of an asset class using an AR model. The chosen asset class is the stock market, thus we are using the VIX implied volatility index, the S&P500 performance and the exchange rate of USD/EUR. These two variables have been chosen in order to forecast the VIX index. The rational of stock performance and exchange rate on implied volatility have been examined by the economic literature and will be reported in detail in the next segment.

Forecasting implied stock volatility is essential. It assists in risk management by enabling investors to evaluate potential hazards related to a stock or portfolio, enabling efficient capital allocation and successful hedging techniques. Precise predictions of implied volatility support a variety of trading methods, such as volatility trading and options spread strategies, improving profitability and risk management. Incorporating implied volatility into asset allocation models helps optimize portfolios by assuring effective capital allocation, Chris Brooks and Gita Persand (2002).

Having these variables chosen we gathered weekly data for the S&P500 performance, USD/EUR exchange rate and VIX index during the period of June 2021 through June 2023 and used three AR models with three steps ahead. The in-sample period is up until 2022 and the values from 2023 were used as the out of sample forecasting period. Since the factors improved the model's ability to forecast the future VIX prices, the economic literature confirms these interactions. The resultant inaccuracy of the three steps ahead predictions was reduced by the AR model with the independent variables of S&P500 and the USD/EUR. The predicted values were closer to the VIX index's actual prices than the model, which did not take such performance and macroeconomic data into account.

The next segment-Review(3)- is addressing the literature findings on implied volatility and what factor could possibly affect it. Furthermore, information about the data are described in the corresponding segment-Data(4). Moreover, Empirical models(5) chapter presents the AR models which used in order to forecast VIX prices, in chapter number six the results of each model have been discussed. Everything stated in this study has been concluded briefly in the Conclusions (7) segment and lastly there are the References (8) which had a vital role for this study.

3 Review

Financial literature has been interested in the influence of exchange rates on stock markets and their connection to implied volatility. Exchange rate fluctuations can impact stock markets directly and indirectly. Companies involved in international trade, notably importers and exporters, may be impacted by a major depreciation of a nation's currency. Exporters can gain from a lower native currency by raising the competitiveness of their goods on international markets, which could increase the value of their stock. In contrast, importers might have higher expenses as a result of currency depreciation, which would hurt their profitability and possibly result in lower stock prices. likewise changes in the exchange rate can affect implied volatility, which reflects market expectations for future stock market volatility, Gopinath, Boz, Casas, Díez, Gourinchas and Plagborg-Møller (2020).

Busch, Christensenb and Nielsenc (2011) have established insights on predicting future realized volatility using a range of indicators, including implied volatility derived from option pricing, in the foreign currency, stock, and bond markets. Their results show that implied volatility outperforms past continuous and jump components in terms of providing more information about future volatility in all three markets. The importance of implied volatility in anticipating future realized volatility components across all three markets is further supported by out-of-sample forecasting tests. However, macroeconomic aspects also posses a vital variable for implied volatility. The euro, British pound, and Swiss franc are the three major European currencies that are examined in the study of Nikkinen, Sahlström, Vähämaa in relation to the US dollar. In their work, the analysis of volatility expectations obtained from currency options is the main topic. According to the research, there are significant correlations between market estimates of future exchange rate volatility among the major European currencies. The implied volatility of the euro is also found to have a considerable influence on the volatility expectations of the British pound and the Swiss franc. The implied volatility of one currency may affect market perception and expectations of the volatilities of other associated currencies.

As far as we can comprehend , implied volatility has a significant place in the literature of economics since it addresses a complex issue with links to more broad fields of economic study like finance and macroeconomics. In the following paragraphs the conducted work of researchers has been presented with various implementations.

Stock market performance and Implied Volatility

Understanding the relationship between stock returns and implied volatility is crucial for investors, traders, and financial analysts.While implied volatility shows the market's expectation of future price variations, stock returns represent the profitability or loss experienced by holding a specific stock over time. These two parameters' interaction offers important insights into market dynamics and risk management. Investors are able to analyze market sentiment and predict future market swings by examining the correlation between stock returns and implied volatility. High implied volatility frequently signals increased market turbulence and the possibility of significant price fluctuations. Investors can use this information to manage portfolio risk, decide whether to buy or sell stocks, and alter their investing strategies as necessary.

The correlation between implied volatility and stock market returns has been the subject of numerous research. According to evidence, the VIX index and stock market returns are correlated. There is a positive impact between stock fluctuation and implied volatility. High levels of stock market's fluctuations are frequently accompanied by higher concerns and uncertainty, French, Schwert, and Stambaugh (1987).

Using a regime-switching paradigm, Giot and Laurent (2004) also examined the dynamics of the relationship between volatility and stocks. They discovered evidence of asymmetry, showing that market volatility is increased more noticeably by negative stock market returns than by positive ones. This implies that market declines are accompanied by greater concern among investors and increased volatility.

David Blitz and Pim Vliet (2007) examined an interesting implementation between stocks and implied volatility. Empirical data from their study suggested that stocks with low volatility typically produce superior risk-adjusted returns. Global portfolios with low volatility beat those with high volatility from 1986 to 2006 by an annual alpha spread of 12%. This volatility effect was noted both globally and in certain markets, including those in the US, Europe, and Japan. These results suggested that investors might be paying too much for riskier stocks.In order to benefit from the volatility impact, the authors advise incorporating low-risk stocks as a separate asset class during the strategic asset allocation stage of investors' decision-making.

Macroeconomic factors and Implied Volatility

For a number of reasons, it is essential to comprehend how implied volatility and macroeconomics interact. First off, macroeconomic factors have a significant impact on how the market behaves and how investors feel. The general economic outlook and market expectations can be significantly impacted by changes in variables including interest rates, inflation, GDP growth, and monetary policy. On the other hand, implied volatility reflects market participants' predictions of upcoming price changes in financial instruments. Investors and analysts can learn a great deal about the possible hazards and possibilities in the market by researching the relationship between macroeconomics and implied volatility. Investors may choose trading methods, risk management, and portfolio allocation with greater confidence if they have a solid understanding of this relationship.

Additionally, macroeconomic factors have a substantial impact on the VIX index. Economic growth and implied volatility were found to be negatively correlated by Bollerslev, Engle, and Wooldridge in 1988. This finding suggests that when the economy is doing well, there is typically less market uncertainty. They contended that lower market volatility results from increased investor confidence during times of economic expansion. On the other hand, economic downturns could worsen market anxiety and raise the VIX index values.

It has also been observed that implied volatility is affected by interest rates and inflation. Shifts in interest rates can impact market volatility, which therefore affects the VIX index. Additionally, macroeconomic factors such as inflation can affect market volatility, Leduc and Liu (2012). The VIX index and inflation have a positive association, indicating that greater inflation levels may increase concerns.

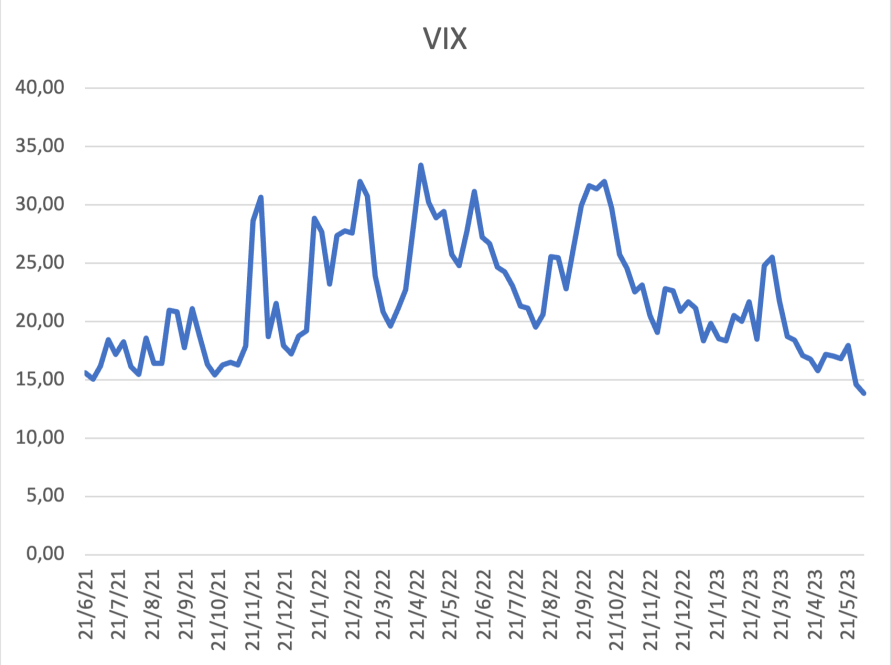
In order to conclude everything stated in this section, sharp currency fluctuations can raise risk and uncertainty, which can alter investors' expectations and perceptions of risk, increasing implied volatility. The stock market's volatility can be impacted by changes in exchange rates since they can shift investor sentiment and risk aversion. In order to effectively assess and manage risk, investors, policymakers, and other market participants must grasp the relationship between exchange rates and implied volatility in stock markets.

4 Data

The "fear gauge," frequently referred to as the VIX index, is a well-known indicator of market volatility of the S&P500 index. For investors, risk managers, and regulators, understanding the variables that affect the VIX index's movements is essential Robert E Whaley (2009). When the VIX is high, it signals that investors expect big swings in stock values, signaling more market anxiety or uncertainty. A low VIX, on the other hand, denotes lower anticipated volatility and perhaps a more stable market situation. The VIX index is a popular instrument for risk management, hedging methods, and market sentiment analysis among traders, investors, and analysts.

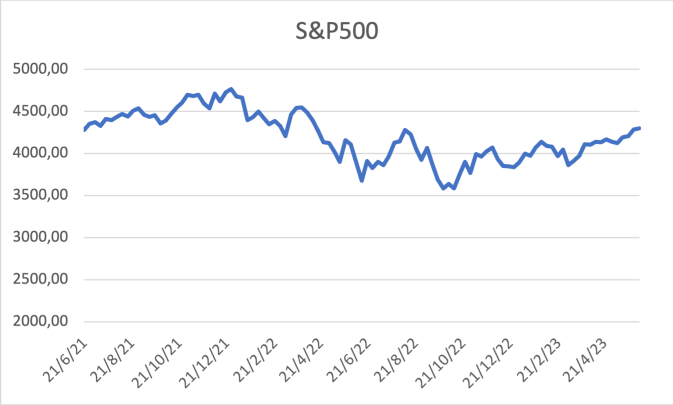
The VIX index has reached high levels throughout the COVID-19 era, signaling increased market volatility and uncertainty. The global pandemic caused unheard-of disruptions to financial markets, investor sentiment, and economies. Investors were concerned about the potential implications on corporate earnings, supply chains, and overall market stability. The high VIX levels during the time of COVID served as a reminder of the substantial market dangers and the necessity of efficient risk management plans during situations of emergency.

Graph 1: The Vix index (6/21 -6/23)



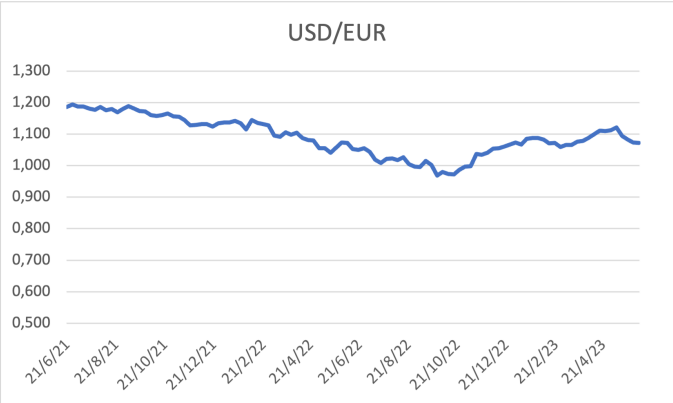
The performance of the S&P 500, a widely followed stock market index, is seen in the table below. The S&P 500 measures the performance of 500 large-cap U.S. corporations operating in a range of industries and is frequently used as an indicator for the state and direction of the stock market.

Graph 2: S&P500 index (6/21 -6/23)



The USD/EUR exchange rate, which shows how much one US dollar is worth in terms of euros is a key metric for international trade, investment, and the world's financial markets is the exchange rate between the US dollar and the euro. Changes in the exchange rate can have an effect on a number of things, including cross-border investments, currency conversions, and the competitiveness of import-export markets.

Graph 3: Exchange rate US/EUR (6/21 -6/23)



5 Empirical model

AR model for VIX

As it is commonly used in forecasting for its effetivness of use according to Pilbeam and Langeland (2015), we are using three AR(1) models with three steps ahead in order to predict the implied volatility for the out of sample period and then examine the distance between the actual values of the VIX index and the predicted ones.

$$V_t = a + b_1 V_{t-1} + e_t \tag{1}$$

where V_t is the VIX index (dependent variable) in t time, a is the model's constant term, b_1 is the coefficient of the independent variable V_{t-1} which is the lag of the VIX index in $t-1$ time and lastly, the error term e_t in time t which contains information that have not been included in the model.

AR model for VIX with S&P500

$$V_t = a + b_1 V_{t-1} + b_2 S_{t-1} + e_t \tag{2}$$

where V_t is the VIX index (dependent variable) in t time, a is the model's constant term, b_1 is the coefficient of the independent variable V_{t-1} which is the lag of the VIX index in $t-1$ time, b_2 is the coefficient of the second independent variable S_{t-1} which is the lagged stock price of the $S\&P500index$ in time $t-1$ and lastly, the error term e_t in time t which contains information that have not been included in the model.

AR model for VIX with S&P500 and USD/EUR

$$V_t = a + b_1 V_{t-1} + b_2 S_{t-1} + b_3 E_{t-1} + e_t \tag{3}$$

where V_t is the VIX index (dependent variable) in t time, a is the model's constant term, b_1 is the coefficient of the independent variable V_{t-1} which is the lag of the VIX index in $t-1$ time, b_2 is the coefficient of the second independent variable S_{t-1} which is the lagged stock price of the $S\&P500index$ in time $t-1$, b_3 is the coefficient of the third independent variable E_{t-1} which is the lagged exchange rate of US/EUR in time $t-1$ and lastly, the error term e_t in time t which contains information that have not been included in the model.

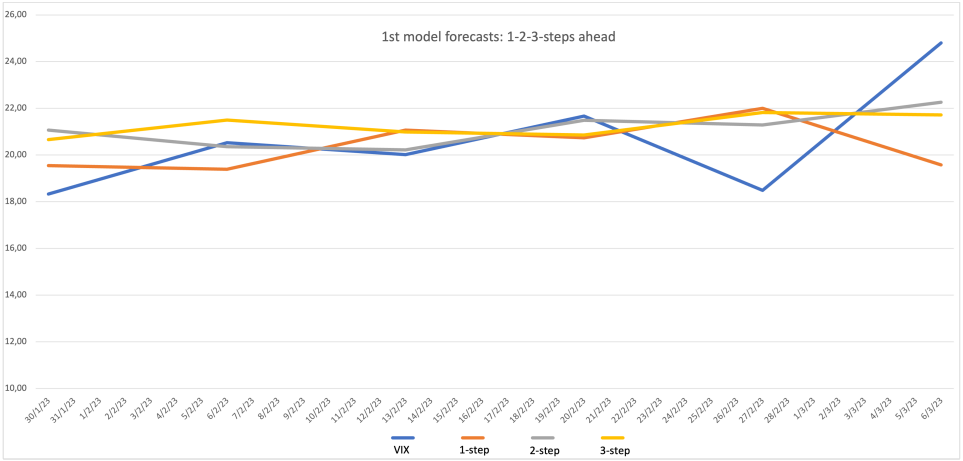
6 Results

AR model for VIX

Having the AR three steps ahead models we were able to predict future VIX prices, as expected the predictions carry a relative risk. We found out that the first model, which only used the lag of the VIX index, has predicted with an average deviation of 1.84 on the predicted VIX index prices. Graph 4 depicts the curves of the VIX index prices and the curves of each step ahead predictions respectively

As shown, the forecasts tend to follow the trend of actual values, however there are some errors. The most consistent line seems to be that of the 2-steps-ahead prediction as it has the smallest deviations from the actual values, 1.44 VIX index prices.

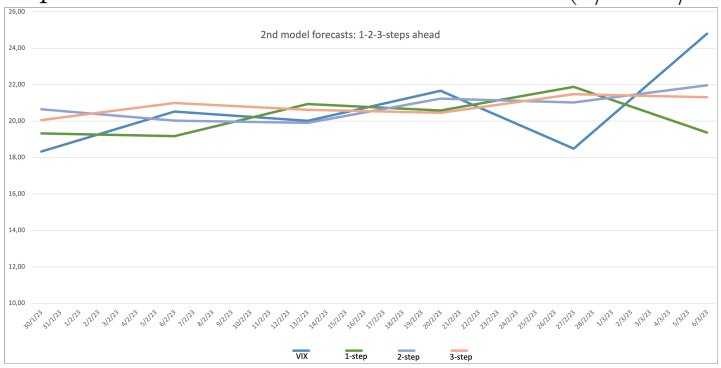
Graph 4: Forecast with VIX lag (1/23 -3/23)



AR model for VIX with S&P500

The second AR model, which additionaly includes the S&P500 index has on average an error of 1.80 VIX index prices. It seems that this model gives us predictions with lesser risk than the first model. Having these predictions we come to understand that the economic literature confirms these results, since the stock market performance information helps the model to predict with lesser risk.

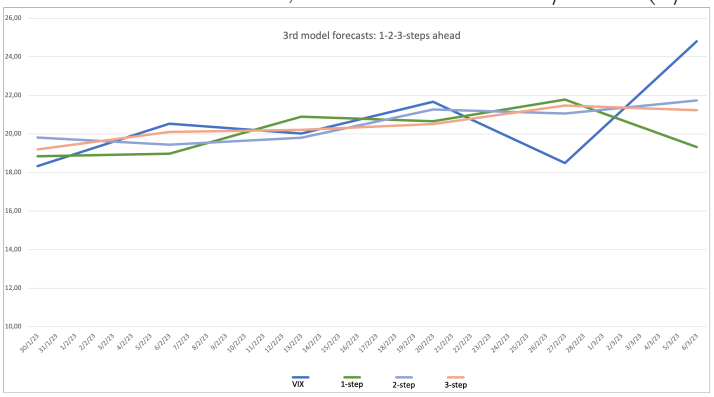
Graph 5: Forecast with VIX and S&P500 (1/23 -3/23)



AR model for VIX with S&P500 and USD/EUR

Having a macroeconomic factor included in the AR model we are able to make more robust predictions with lower forecasting errror, on average 1.71 VIX index prices. As initialy expected macroeconomic factors contritube in forecasting implied volatility, currency fluctuations can alter investors' expectations and perceptions of risk by increasing risk and uncertainty thus it is vital insight for the model.

Graph 6: Forecast with VIX, S&P500 and USD/EUR (1/23 -3/23)



7 Conclusions

As seen, the economic literature has addressed the influences on implied volatility in great detail, including stock performance and macroeconomic issues. Exploring the factors that affect implied volatility offers insightful information about market behavior and investor sentiment. The economic literature explores a range of variables, such as stock performance and macroeconomic concerns, that influence implied volatility.

Having examined the literature of implied volatility and the related variables, we were able to unsterstand the dynamics between this complicated relationship. By investigating the relationship between implied volatility and macroeconomic problems offers insightful information about the overall economy. Implied volatility changes can indicate changes in what the market anticipates will happen in terms of future inflation, economic growth, or monetary policy. Economists and decision-makers can better comprehend the transmission mechanisms between financial markets and the real economy by looking at these linkages.

With data for the VIX index as well as the S&P500 and USD/EUR exchange rate from Yahhoo finance for the period of June 2021 through June 2023, we structured an AR(1) model with three specifications for each of the variables in order to conduct a three steps ahead forecast for the future VIX prices. The test-set of the model was up until 2022 and the predictions took place for the 2023 prices.

More specifically, the topic of the paper—the influence of the S&P500 and the USD/EUR exchange rate on implied volatility—confirms previous research because the addition of the variables increased the model's predictive ability. The AR models with the independent variables of S&P500 and the USD/EUR reduced the resulting error of the three steps ahead predictions. The forecasted values were closer to the actuall prices of the VIX index, rather than the model which did not include such information about performance and macroeconomics.

Given the arose errors of the forecast, there is a substantial margin for improvements. The structured models possibly require more specialized information in order to minimize the risk of forecast error. More expertise and thorough examination would offer more integrated results on this matter.

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