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DEVELOPMENT OF A TRADING STRATEGY FOR RISK-AVERSE INVESTORS BASED ON VAR MODELS

Abstract

In this paper various topics related to programming, statistics and financial modelling were addressed with the main idea of establishing a trading strategy. As discussed in the paper, no research has been done on this topic. On the other hand, much research has been done on which model is better, which distribution or confidence level is more appropriate or provides better forecasting capabilities. No one has investigated whether these differences could lead to a development of trading strategy. The paper starts with a definition of the gap in literature and practice. Then the research methodology is outlined in detail. Formulas and parameters are defined and presented. The main conclusion of this paper is the importance of GARCH VaR and the possibility of creating trading strategies. As long as the difference between the GARCH VaR and the other two VaRs does not exceed 1.5%, there is no need to leave the market. Should this situation change, one should leave the market as long as these differences do not fall below 1.50%.

Key words: *Trading strategy, VaR, GARCH, financial crisis, mean-variance analysis*

JEL classification: *G11*

РАЗВОЈ СТРАТЕГИЈЕ ТРГОВАЊА ЗА ИНВЕСТИТОРЕ КОЈИ НИСУ СКЛОНИ РИЗИКУ

Апстракт

Овај рад обрађује различите теме везане за програмирање, статистику и финансијско моделовање са идејом да се успостави стратегија трговања. као што је наведено у раду, до сада није рађено истраживање на ову тему. С друге стране, урађена су многа истраживања на тему који је модел бољи, која дистрибуција или ниво поверења погоднији или који модел пружа боље могућности предвиђања. оно што није истражено, јесте да ли ове разлике могу довести до развоја стратегије трговања. Сам рад почиње дефиницијом јаза у литератури и пракси. затим се детаљно описује коришћена методологија

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истраживања. Формуле и параметри су јасно дефинисани и приказани. Главни закључак овог рада јесте значај гарцх вар-а као и на то да постоји могућност креирања стратегија трговања. Све док разлика између гарцх вар-а и друга два вар-а не прелази 1,5%, нема потребе да инвеститор напушта тржиште. Уколико се ова ситуација промени, требало би напустити тржиште све док ове разлике не би пале испод 1,50%.

Кључне речи: стратегија трговања, вар, гарцх, финансијска криза, анализа средње варијансе

Introduction

Historically, traders have tried to develop an optimal trading strategy that they can apply. One of the problems that they are confronted with is that a strategy that has worked well in the past does not mean that it will work in the future. Moreover, the main question that arises is whether it is profitable to apply any trading strategy or to take a hold-and-buy approach. This paper attempts to answer this question by developing a trading strategy using value at risk (VaR) models. On the one hand, some investors are risk-averse and unwilling to take additional exposure to achieve higher returns, while on the other hand, there are investors who are willing to take higher risks. The assessment of these two categories is therefore of paramount importance, irrespective of the type of investor.

The calculation of the risk and return depends on whether it is an asset class or a portfolio. The portfolio return can be calculated by multiplying the returns of the individual assets by their respective weights, while several different calculation methods could be used for portfolio risk. In this paper portfolio risk will be calculated using VaR method, more precisely three different VaR will be further discussed, namely historical VaR, delta-normal VaR and generalized autoregressive conditional heteroskedasticity (GARCH) VaR. The main purpose of using these methods is to observe whether the early signs of a possible crisis in the markets can be detected, or more precisely, when to leave the market and enter it. In addition to these metrics, one can also use liquidity ratios to assess risks in companies (Vesić, Rević, & Đekić, 2019) or Safety-First-Model (SFM) that was used to analyse the risk attitude (Oladipo Akanbi, Adekunle, Mukaila, & Isola, 2022). One underlying assumption is that the investor is risk-averse, so he should choose a specific exit point and use it as soon as the first signs are visible. To create such a strategy, the Sharpe ratio is used as an additional risk measure. Therefore, this paper focuses on developing the trading strategy for the risk-averse investor.

The portfolio will be consisting of four stock indices, whose weights will be assigned according to mean-variance analysis. As soon as the portfolio is created, the VaR is calculated using historical simulation, delta-normal approach and GARCH (1,1). The goal of these calculations is to determine the deviance in the VaR results obtained from GARCH and from the other two methods (historical simulation and delta-normal). Once the differences have been identified, specific points for market entry and exit are determined using the Sharpe ratio. The main assumption is that GARCH VaR results indicate volatility in the market earlier and that deviations of the results from delta-normal VaR and historical VaR signals extreme events in the market. Using this assumption with maximizing the Sharpe ratio should result in finding the exit point. As regards the time frame, the global picture of the financial world is covered for the period April 2007 to April 2020. This time frame has been chosen to cover the period of one economic cycle. During this period, the focus is on periods where the GARCH VaR is significantly higher than other VaRs to determine what percentage deviation indicates the beginning of periods of higher volatility. For these periods the Sharpe ratio is calculated, and the maximum Sharpe ratio is considered as the optimal point for market exit or entry. Although the main idea is to develop an investment strategy, the knowledge gap will be focused rather on VaR measures than on the trading strategy itself. The main problems encountered in developing a trading strategy are linked to the choice of the optimal time window, the level of trading costs and the timing of switching to a different strategy (Krause, 2009).

There has been little or no research done on the comparison between the results in terms of developing a trading strategy. In this paper, the author intends to do research by creating an optimal portfolio and applying these methods to determine if there is evidence that the market is going through a more volatile period and construct the trading strategy based on the results.

Problem Statement

VaR models are widely used in practice, and the question of which method is best suited to calculate VaR arises repeatedly. Depending on the method chosen, the VaR figure can vary considerably. There has been a lot of research on this topic, but rarely has anyone questioned whether these differences could bring something new into practice. This paper does not attempt to prove which method is better, but to use these differences as an advantage. The aim of this study is to investigate if these differences could help in developing a trading strategy for riskaverse investors.

The main assumption is that the GARCH model shows the earliest signs of higher volatility, followed by other methods. The difference between GARCH VaR on the one hand and deltanormal VaR and historical VaR on the other should indicate changes in the market. If this difference increases, extreme events could occur. Similarly, a decrease in the difference may mean that the extreme events have expired. The main objective is to find two points in time - an optimal exit and entry point. An optimal exit point would be the day on which a certain threshold would be exceeded, for which the Sharpe ratio would be calculated, and an entry point would be the day on which the values would fall below the defined threshold. By calculating both Sharpe ratios on the days with an average Sharpe ratio for this interval, one can decide which threshold would be the most suitable for risk-averse investors to develop a trading strategy. The Sharpe ratio is used to determine these optimal points by calculating it for the different thresholds and selecting the maximum one. A threshold value is an interval of differences.

Theoretical backgrounds of VaR methods

Value at Risk is a risk measure mainly used to measure the risk position of a bank or investment company. The early 1990s brought uncertainty to the financial market (Angelidis, Benos, & Degiannakis, 2004), which led to the development of different models for estimating market risk. This influenced the creation of VaR in 1995 by JP Morgan, who published a document entitled Risk Metrics (Morgan/Reuters, 1995). The document introduced what VaR is and how it can be calculated. Even before publishing the document, Group of Thirty suggested using VaR as a measure of market risk (Thirty, 1993). Moreover, some authors believe that the origins of VaR stem back to 1922, when capital requirements were first established on the New York Stock Exchange (Wang & Recht, 2012).

According to JP Morgan, VaR is a measure of loss with a given probability over a time horizon. The most important parameter in its formula is the standard deviation as a measure of dispersion. The standard deviation or its squared version variance can be calculated in many ways, e.g. historical volatility, EWMA, GARCH, etc. The VaR itself can be calculated using simulation models such as historical simulation or Monte Carlo simulation. Out of all these methods, the only method which is not being discussed in this paper is VaR calculated using Monte Carlo Simulation. The VaR methods can be classified into three categories: parametric methods - the delta-normal approach, non-parametric methods - historical simulation and Monte Carlo methods (Nabela , Maski, & Wahyudi, 2020).

In the literature there are different views available. For example, the historical simulation model has given better forecasting results than other methods used if the sample size is large enough and if the higher confidence level is included (Jackson, Perraudin, & Maude, 1998), (Kiohos & Dimopoulos, 2004). Furthermore, simulation methods were better than parametric methods when it comes to assessment of the VaR (De Raaji & Raunig, 1998). Nevertheless, drawback is that the historical volatility is too simple method of calculating volatility that is just using the standard deviation formula (Marra, 2015). With this background information, a delta-normal approach was developed including covariance matrix as an additional parameter for the calculation. It belongs to the group of parametric VaR methods, with the main assumption of the normally distributed returns (Kulali, 2016).

The Basel Committee on Banking Supervision published in 1996 a proposal 'Internal proposals recognizing the new quantitative risk estimation techniques used by the banking industry', in which volatility is measured as the standard deviation of the normal distribution for historical observations, using the equal or alternative weighting scheme. If the same weights are given, the delta-normal VaR can be calculated. Further, volatility is calculated as the standard deviation of the normal distribution for exponentially weighted historical observations with a decay factor (Morgan/Reuters, 1995). Many researchers have welcomed this metric (Korkmaz & Aydin, 2002). A statistical method that gives more weight to the more recent data is called EWMA, and in this model the weights decrease exponentially as one goes back in time (Hull, 2018). Whereas some authors suggest measuring and forecasting volatility using the adjusted mean absolute deviation, because this method has provided a better prediction than historical volatility or even GARCH (Ederington & Guan, 2006).

One can go even further and extend the data period to obtain more accurate results. There is a proposal to switch from daily to intraday data. This approach increases accuracy, especially in the GARCH estimate of volatility (Anderson & Bollerslev, 1998). However, when comparing EWMA with the GARCH method, the results have shown that GARCH produces a more thorough analysis than EWMA (Korkmaz & Kazim, 2022). This model has similarities to the model Bollerslev made in 1986, namely GARCH. On the other side, GARCH is an extension of the autoregressive conditional heteroskedasticity (ARCH) model introduced by Engle in 1982. He added a new parameter to the formula for measuring variance, namely the lagged weighted variance.

Engle published a paper demonstrating the usefulness of the ARCH and GARCH models for portfolio risk where he was highlighting their good forecasting capabilities (Engle, 2001). In this paper, Engle reviewed models that preceded the ARCH model, citing rolling standard deviation as a precursor. In this paper researchers have used the 12-month rolling standard deviation as a volatility estimate (Fama, 1976). The rolling standard deviation takes a fixed number of days and calculates the standard deviation. The standard deviation for the next day is calculated taking into account, for example, the last 30 days and thus each subsequent day. The disadvantage of this model is that all events are weighted equally. Another disadvantage of the rolling standard deviation is solved by the GARCH model by giving decreasing weights to events that never go to zero.

The GARCH model represents a more general class of processes that allow more flexible lag structures (Bollerslev, 1985). Bollerslev uses the empirical example of the inflation rate to prove that GARCH is more suitable than the ARCH model. Furthermore, Korkmaz and Aydin have shown in their paper that the GARCH model provides a more precise analysis than the EWMA model in the case of volatility of the ISE-30 index return and the stock return (Korkmaz & Kazim, 2022).

As mentioned above, the aim of this paper is to identify early signs of anomalies in the market and to choose an exit point by comparing different VaR results, which was not covered by literature so far. By calculating three different VaR and comparing its difference threshold with the maximisation of the Sharpe ratio will enable one to determine the signs for exiting and entering the market, which will be further discussed in the next chapters.

Methodology overview of the used metrics

This paper uses a diverse set of statistical methods, which will be described in this chapter. First, the data is imported into Python, followed by a chronological set of analyses.. When an optimal portfolio is created, methods such as historical VaR, delta-normal VaR and GARCH VaR will be conducted. Addressing the subject of VaR, the main intention is to calculate the loss on a portfolio with a given probability over a given period (Jorion, 2007). In this manner, the potential portfolio loss is calculated using three methods which are in more details explained below. There will be periods of time when the models are consistent and periods of time when they are not. If GARCH VaR does not deviate by a lot from other VaRs, it can be assumed that the market is normal. If GARCH VAR is higher than historical VaR and delta-normal VaR, one can assume that it can be a signal for extreme events. The main idea is to observe these signals and quantify them in order to create a trading strategy. Once quantified on the training data set, the strategy can be tested on the test data set. A divestment is proposed when signals of higher volatility are shown, which will be quantified, and the reinvestment is proposed when these signals disappear.

In this chapter the research methodology will be described in detail, with step-by-step instructions on how and what is calculated. By reading this chapter, one becomes familiar with all the formulas necessary to carry out this research. From the modern portfolio theory to three different types of VaR calculation. The data set used is explained in short sentences.

Value-at-risk is a statistical measure generally used to analyze market risk associated with financial assets or portfolios. It dates back to 1995, when JP Morgan published a RiskMetrics document, which explained VaR as a model. It was not defined under that name until 1995, but as a metric itself it was already in use (Kondapaneni, 2005). Following its introduction by JP Morgan, it became a widely used measure of exposure to market risk. It provides a simple and readily applicable quantitative measure for assessing the overall market risk one is exposed to. It is also used by many risk managers to estimate the potential loss of the portfolio over a period of time and at a certain confidence level.

There are two key elements to describe VaR (Carol, 2008):

1. Time horizon - the bigger the horizon, the greater the VaR. Once the daily VaR is calculated, it can be extended to more days by multiplying the square root of time. This is the case when the returns are independently and identically distributed (i.i.d) with a normal distribution (Jorion, 2007);

2. Confidence level - the higher the confidence level, the greater the VaR and the more scenarios are covered. The commonly used probabilities are those of 95% and 99%.

These elements can be described in one sentence: "We are X percent certain that we will not lose more than V dollars in time T" (Hull, 2018). VaR is therefore defined as an amount of money that can be lost over a period of time at a certain confidence level.

$$VaR = \mu + \sigma N^{-1}(X) \tag{1}$$

Where μ is a mean, σ is a standard deviation of the portfolio, $N^{-1}(X)$is the inverse cumulative normal distribution (Hull, 2018).

It can be said that if the VaR of the portfolio is one million per day with 95% certainty, there is only a 5% chance that the loss will be greater than one million. The disadvantage of VaR is expressed here, as it does not say anything about the amount of loss if this 5% occurs. There are many ways to calculate VaR, and three of them will be discussed in this paper and the following subchapters. The focus will be on historical simulation, delta-normal and GARCH VaR.

Sharpe Ratio

The Sharpe ratio is known in the literature as a risk-adjusted risk measure developed by William Sharpe. It is based on the same assumption as the MPT that risk corresponds to volatility, and as diversification increases, risk exposure under the MPT should decrease and the Sharpe ratio should be increasing. It calculates the excess return over a given risk free rate and can be calculated ex post or ex ante. The ex post calculation uses historical returns and standard deviation, whereas the ex ante calculation uses expected returns and projected risk (Sharpe, 1996). This paper uses the ex-post Sharpe ratio as calculated on the basis of historical data. Where R is the portfolio return, Rfr is the risk-free rate and σ is the portfolio standard deviation. Since the risk-free rate is riskless, its standard deviation is assumed to be zero and only the standard deviation of the portfolio is included in the calculation (Sharpe, 1994). The excess return would be the return above the risk-free interest rate, and therefore every investor has the goal of achieving a higher excess return. The higher the Sharpe ratio, the better the chosen portfolio. On the other hand, it can also be negative, which is caused by the negative return or the high risk-free interest rate, and it might not be rational to invest in a selected portfolio if the risk-free interest rate is higher than the portfolio return. Moreover, the negative risk-free rates in the 21st century have shown that they bear part of the risk and that they do not necessarily offer a safe return. So even if the Sharpe ratio is negative, this does not necessarily mean that one should rule out the possibility of investing in such a portfolio. Together with the VaR measure, the Sharpe ratio is used as a measure of risk to estimate the optimal time to exit and enter the market. One of the benefits that modern portfolio theory (MPT) has brought is the influence on traders to diversify their portfolios rather than concentrating on one asset class. Although it is based on many restrictive assumptions, it has allowed portfolio risk and return to be assessed. Some of the main assumptions are the normal distribution of returns and the rational behavior of investors (Rice, 2017).

Historical VaR

The historical VaR model assumes that all possible future fluctuations have occurred in the past and that the historically simulated distribution is identical to the distribution of returns over the future risk horizon (Carol, 2008). The model is developed shortly after the publication of RiskMetrics (Boudoukh, Richardson, & Whitelaw, 1998). It is renowned for being the most easy-to-follow method. This methodology calculates VaR in such a manner that all calculated returns are sorted once from positive to negative and the quantile is calculated on the loss side.

When creating possible scenarios, the following formula can be used (Mausser & Rosen, 1998):

$$\Delta vij = vi0 - vij \tag{2}$$

Where $vi0$ is the base scenario and vij is the value of one unit in future. With the use of this formula the value of the portfolio in the first scenario can be calculated. Comparing the ending or calculated value with the initial value of the portfolio, either a portfolio loss or a portfolio gain can be observed. The portfolio losses are sorted from the highest to the lowest losses. A quantile is then calculated, usually the first or fifth quantile, depending on whether one calculates 99% VaR or 95% VaR. One of the advantages of this model is its easy calculation and interpretation (Korkmaz & Aydin, 2002). Once all portfolio losses have been calculated, one only needs to sort them and calculate a quantile of them to determine the historical VaR for that day. If the VaR for one day has to be calculated for several days, this value should then be multiplied by the square root of the number of days for which one would like to obtain the VaR. The second advantage, mentioned above, is that this model does not make assumptions distribution (Carol, 2008), which is very important because returns are rarely normally distributed, which in some models are assumptions. The disadvantages start with the fact that all earlier observations are equally weighted and it may happen that not all earlier distributions have been captured because the data set is not large enough (Hull, 2018). Moreover, there are limitations inherent in the sample size, as the sample size should be as large as possible. The best option would be to use daily data and a span of many years to capture all past distributions. Many authors also mention the slow speed of adaptation to market situations labeling it as a sluggish model.

Delta Normal VaR

This method exists in the literature under various names such as variance-covariance VaR, delta-normal VaR or normal-linear VaR. It is grounded on modern portfolio theory (Hull, 2018). This method is based on the assumption that the returns are normally distributed and that their common distribution is normal, thus the covariance matrix is all that is needed to capture the interdependence between the returns (Carol, 2008). Volatility is calculated as the standard deviation of logarithmic returns. This approach uses the same assumptions as the portfolio theory (Wang & Recht, 2012). The most common method is to take daily closing prices and calculate the volatility of the returns, and then calculate the returns on an annual basis. It takes only a few steps to calculate volatility in this way.

Delta-normal VaR can be calculated as following.

$$X \sim N(\mu\sigma^2) \tag{3}$$

Where X is return that is normally distributed and i.i.d.

$$VaR_{\alpha} = \Phi^{-1}(1-\alpha)\sigma \tag{4}$$

Where α is the quantile return, Φ^{-1} is the inverse cumulative normal distribution function and σ is the standard deviation (Carol, 2008). The main advantage of this model is that it is easy to create and adapt (Marra, 2015). Its calculation is transparent because it is based on modern portfolio theory. However, by weighting all events equally, it reduces the impact of the recent past and makes it as important as an event that took place a long time ago. If this iss the case, then the VaR would be underestimated. Linked to this, the long-term volatility tends to over- or underestimate volatility and, in this context, meaning to over- or underestimates VaR (Marra, 2015).

GARCH (1,1) VaR

GARCH or Generalized Autoregressive Conditional Heteroskedasticity Model was introduced by Bollerslev in 1986. It is an extension of the ARCH process developed by Robert Engle in 1982, which allows the estimation of weighting parameters (Engle, 2001). This model allows past conditional variance to change over time (Bollerslev, 1985).

Key aspects of its definition are the following:

General: it is a generalized ARCH method in the sense that the squared volatility may depend on previous squared volatilities (McNeil, Frey, & Embrecht, 2005);

Autoregressive (AR): The variance of tomorrow is a regressive function of the variance of today - it regresses to itself (Heuermann, 2010);

Conditional (C): Tomorrow's variance is conditionally (dependent) on the most recent variance. The conditional variance varies over time as a function of past errors, while the unconditional variance remains constant (Bollerslev, 1985);

Heteroskedastic (H): Heteroskedasticity is the assumption that the expected value of error terms is not constant when squared and that they fluctuate over time. These observations do not tend to scatter randomly across the data, but rather to cluster (Engle R. F., 2001). Cluster formation is mainly influenced by the behavior of investors towards the new information (Marra, 2015). One of the reasons why GARCH is well suited for forecasts is the volatility clustering (Banulescu, Hansen, Huang, & Matei, 2015).

The GARCH regresses to the squared return (p) and the squared variance (q) of the last period and this (1,1) represents one lag back in time. The GARCH (1,1) is given by the following equations (Angelidis, Benos, & Degiannakis, 2004)

$$un = \sigma n \, Zn$$

$$Z_n \sim N(0,1)$$

$$\sigma_n^{\,2} = \omega + \alpha un2{-}1 + \beta \sigma t2{-}1 \qquad (5)$$

Where $\sigma_n^{\,2}$ is the variance that should be calculated. The ω , α, β are weights that should be estimated. The weights are (1- α -β, β, α). β can be interpreted as a decay rate and is similar to lambda in the EWMA model (Hull, 2018). Two conditions must be fulfilled: α >0; β >0; ω>0 and $\alpha + \beta$ <1 (Engle, 2001).

There are many advantages to using GARCH for volatility estimation, some of which are:

1. The parameters are not chosen subjectively, but are estimated from the sample data (Carol, 2008).

2. Share prices fluctuate more in times of crisis than in quieter times. GARCH models are therefore particularly suitable for modeling financial market time series (Heuermannn, 2010).

3. Captures long-term reversion and short-term volatility fluctuations (Marra, 2015).

The disadvantages are based on the complexity and difficulty of implementation. There are times when the GARCH is unstable, if the sum of the weights is higher than one, then it is not recommended to use it (Korkmaz & Aydin, 2002). Furthermore, there are more advanced GARCH methods such as TGARCH, EGARCH, but they failed to assess VaR when dealing with emerging markets (Smolovic, Bozovic, & Vujosevic, 2017).

Research results and Discussion

The three different VaRs are calculated and graphically displayed: historical VaR, delta-normal VaR and GARCH VaR. Each calculation is based on a rolling window of 300 days. The historical VaR shows values ranging from 0.40% to 1.40% portfolio loss for one day, with the highest values being shown at the end of 2008. The lines are constant, as the historical VaR changes whenever an extreme event occurs in the market. Similarly, the historical VaR changes when an old extreme event falls outside the observed time series.

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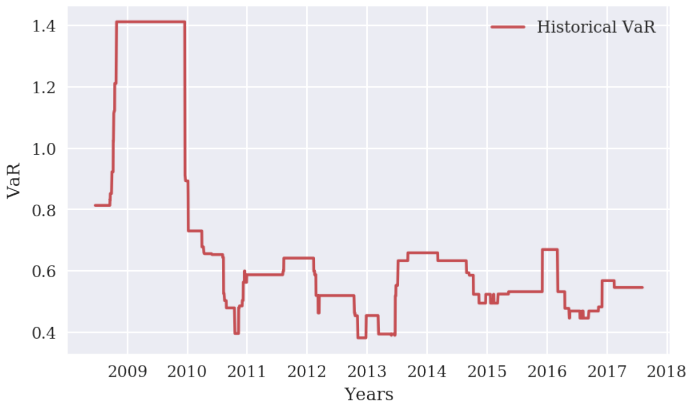
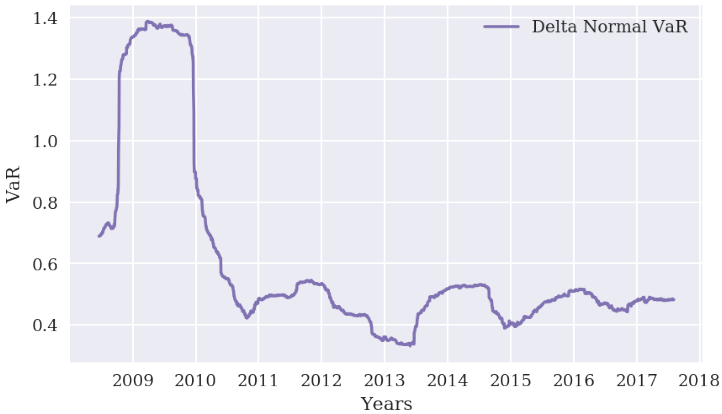
Figure 2: Historical VaR from 2007-2017



Source: Authors calculation based on data from investing.com

Delta-normal VaR shows more or less similar pattern as historical VaR, with the difference that the lines are not as strict and strong. This method is based on the assumption of the normal distribution, which was already neglected in the previous part. At the next step, the GARCH VaR is calculated.

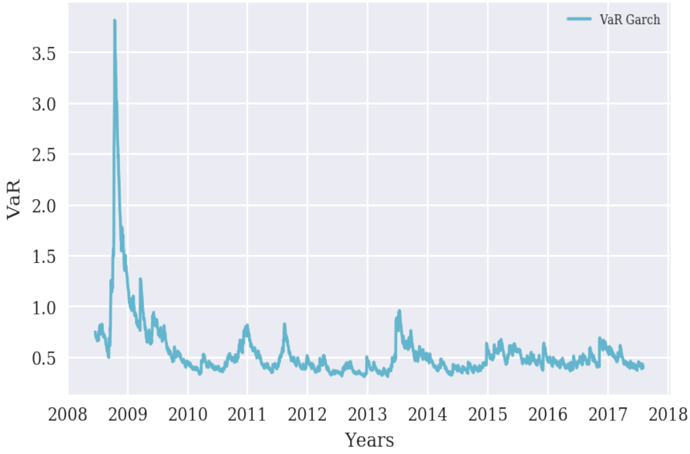
Figure 3: Delta Normal VaR from 2007-2017



Source: Authors calculation based on data from investing.com

As can be seen in the graph, the GARCH VaR shows different results compared to the previous two methods, while the VaR reaches values of 3.50%, which is more than double, compared to the other two VaRs.

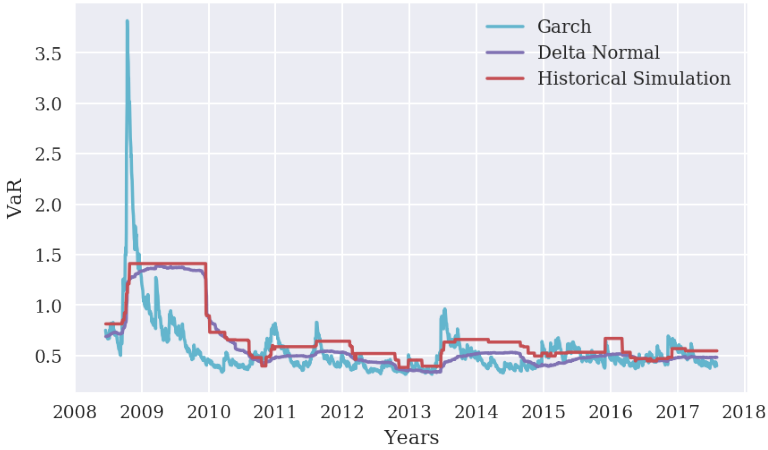
Figure 4: GARCH VaR from 2007-2017



Source: Authors calculation based on data from investing.com

The best way to spot the differences is to plot them all on the graph and then delve deeper into these differences.

Figure 1: Comparison between three VaRs



Source: Authors calculation based on data from investing.com

The following is used to create a trading strategy:

1. The differences are divided into six thresholds: a) higher than 2.50 %; b) higher than 2.00 %; c) higher than 1.50 %; d) higher than 1.00 %; e) higher than 0.50 %; f) higher than 0.00%
2. For each threshold, the Sharpe ratio at the beginning and end of the period is calculated.
3. The highest Sharpe ratio is taken as a measure of the best threshold.

4. Once the maximum Sharpe ratio is found for one of the thresholds, it is used as a market exit signal and tested on the test data set.

As the results that the paper has shown, GARCH VaR should produce different results than historical VaR and delta-normal VaR during periods of higher volatility. Furthermore, the results of the analysis have shown that the threshold that should be considered is the one with the difference of 1.50%. Therefore, an investor should leave the market when the differences exceed 1.50% and return to the market when they fall below 1.50%. Trading costs are excluded from this consideration. In this way, an investor should benefit from exiting the market before the higher volatility occurs and avoid large losses that could result from market instability. This could be especially advantageous for risk averse investors. Moreover, the difference between historical VaR and delta-normal VaR are minor.

A risk-averse investor would be therefore advised to perform the following steps:

1. To calculate GARCH
2. To calculate the historical VaR and/or delta-normal VaR
3. Monitor the difference between the VaRs and exit the market if the differences exceed 1.50% and return to the market if they fall below 1.50%.

The previous part gave a broad overview of the results, which are summarized here with recommendations for further actions. Defined problem descriptions were directly incorporated into the development of a trading strategy and the question was posed. The aim was to develop a trading strategy based on the differences in the results of VaRs using the GARCH VaR scale. What made this approach feasible is the reliability of GARCH VaR. It is shown that the GARCH VaR tracks the returns.

Several types of analysis were carried out when the research gap has been identified. The investor should first define his preferences in terms of risk/return position. Once this has been defined, he should think about which stocks he wants in his portfolio. The top-down approach could be useful here, or even investing in indices or etfs. It can lead to a reduction in the time needed to create a portfolio. For the selected stocks, one should take advantage of modern portfolio theory in order to assign weights to these stocks. Now, one can include risk measures. As the results of the paper indicate, GARCH VaR should produce contrasting results compared to the historical VaR and delta-normal VaR during periods of higher volatility. Furthermore, the results of the analysis have shown that the threshold, that should be considered, is the one with the difference of 1.50%. Therefore, an investor should leave the market when the differences exceed 1.50% and return to the market when they fall below 1.50%. Trading and transaction costs are excluded from this consideration. In this way, an investor should benefit from exiting the market before the higher volatility occurs and avoid large losses that could result from market instability. This could be especially advantageous for risk averse investors.

Moreover, the difference between historical VaR and delta-normal VaR are minor. A risk-averse investor would be therefore advised to perform the following steps:

1. To calculate GARCH;
2. To calculate the historical VaR and/or delta-normal VaR; and
3. Monitor the difference between the VaRs and exit the market if the differences exceed

1.50% and return to the market if they fall below 1.50%.

One should use a code that signals when this threshold is exceeded. Changing the weights also changes the VaR figure and one can adjust it according to one's preferences. Finally, the paper managed to answer the question:

1. It is possible to create a trading strategy with GARCH VaR.

Conclusion

This paper dealt with various issues related to programming, statistics and financial modelling, with the main idea being to implement a trading and investment strategy. After reading the various available literature, the gap was identified. As discussed in the chapter Problem Statement, no research has been done on this topic. On the other hand, much research has been done on which model is better, which distribution or confidence level is more appropriate or provides better forecasting capabilities. No one has investigated whether these differences could lead to a development of trading strategy. The paper starts with a definition of the gap in literature and practice. Then the research methodology is outlined in detail. Formulas, graphs, parameters are defined and presented, as well as the sources used, so that the reader has an entire and transparent overview available. The implementation in the software is briefly described, as the entire research methodology has already been described. Calculation results and analysis cover the major part of the master thesis and all results are described in the chapters that follow.

The main conclusion of this thesis is the importance and usefulness of GARCH VaR and the possibility of creating trading strategies. As long as the difference between the GARCH VaR and the historical VaR and delta-normal VaR does not exceed 1.50%, there is no need to leave the market. Should this situation change, one should leave the market as long as these differences do not fall below 1.50%.

Some of the additional research opportunities could go in the direction of extending the data set, as only a 13-year period is used here. It would be interesting to see whether the same solution would be chosen if the period of 20 years or more were used. Second, it would be interesting to compare different GARCH models, as they might give different results compared to the normal GARCH(1,1), but at the moment this is only an assumption. Third, the same analysis can be performed at the lower confidence level or using the maximum Sharpe ratio instead of the minimum volatility with different weights assigned to the shares. In addition, a strategy for risk-appetite investors can likewise be developed (Devarajan & Jayamohan, 2015).

As one can see, there is still a lot of potential for further research and improvement, and this paper has only considered parts of the impact features.

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