Analysis of the Performance of VAR Models as a tool for Market Risk

Dr. Anirban Ghatak,  
Asst. Professor,  
Christ University Institute of Management, Bangalore  
anirban.ghatak@christuniversity.in

Introduction:

Risk management is an important aspect to determine profitability and sustainability in banking organizations. In present scenario, increasing trading activities and growing instability in global markets call for reliable risk measurement techniques. Value at Risk (VAR) is a widely used risk measure for specific portfolio of risky assets. Banking organizations employ Various VAR models to calculate expected risk with respect to interest rate changes, foreign exchange rates and commodity prices. But the question arises which is the best VAR model to measure risk for a portfolio. VAR is a technique that measures the market risk that a specific portfolio is subjected to. VAR estimates indicate the maximum amount of loss that a portfolio can suffer at certain confidence level. It is nothing but the maximum tolerable loss. The use of VAR models is growing in use, and it is very evident from the fact that Basel Committee on Banking Supervision rules regarding Capital Adequacy. VAR has become an integral part for risk management

At present regulators do not provide any specific VAR model to the banks and they are free to choose any model of risk estimate. But to make sure that supervised banks are giving a correct estimate, the banks have to undergo back testing of the VAR models. There are mainly four broad categories of VAR models available. These are- the Historical Simulation method, the Monte Carlo simulation method, modeling return distribution and methods under Extreme Value Theory (EVT). All these models use classical approach and deal with time series of returns. In this study, there are three models of VAR estimates which have been tested. Equally Weighted Moving Average, Exponentially Weighted Moving Average and Historical Simulation Approach. For EWMA 50days, 125days, 250days, 500days, 1250days. For ExWMA $\lambda=0.94, 0.97, 0.99$. Historical Simulation Approaches includes tests for the observation period.

Reviews of Literature:

Carol Alexander, José María Sarabia , (2011), in the research paper titled “Value- At-Risk Model Risk” provided a top- down approach to quantify VAR model risk through a statistical framework. The study focused on the risk assessments in the risk management models with emphasis on VAR model. The research observed a Maximum Entropy Distribution (MED), information available regarding the random Variable’s behavior. The study also designs an experiment in which a portfolio’s returns are simulated based on a data generation process. The study highlights the density of model risk at different probability levels of VAR. For different quartile probabilities, the regulatory capital which should be kept aside as an add-on cover is also specified.

Mo Chaudhury, (2011), in the paper titled “Extended Value at Risk (EVAR) Measure for Market Risk”, proposed an Extended Value at Risk (EVAR) measure for market risk that tries to include the new guidelines of BASEL committee, through a simple framework that includes the widely popular Normal distribution and implied volatility of options. The research uses the widely popular Normal Distribution and implied volatility of options. The study found that EVAR has been successfully proved to make an estimation of capital buffer to be kept by banks in turbulent times keeping in mind the recommendations made in Basel norms.
Sebastian Stange, Christoph Kaserery, (2010), in the study titled “Why and How to Integrate Liquidity Risk into a VAR-Framework”, aimed to clearly identify the situations, in which weighted spread can be validly employed in the risk management context. Secondly analyze the magnitude of liquidity impact at standard, larger-than-intraday horizons in a representative sample of stocks. Results are structurally similar when using expected shortfall instead of VAR risk measures. Results are also similar for portfolios of stocks, when portfolio diversification is accounted for.

Loriano Mancini, Fabio Trojani, (2010), in the paper titled “Robust Value at Risk Prediction” proposed a robust semi parametric bootstrap method to estimate predictive distributions of GARCH-type models. The study used the tools like GARCH modeling, Monte Carlo Simulation, Risk Metrics, CAViaR, and Historic Simulation. To conduct the study the researcher has simulated 2000 observations. Also four historical series of daily rate of returns: S&P 500 index from December 1988 to July 2003, Dollar-Yen exchange rate from January 1986 to January 2005, Microsoft share price from March 1986 to January 2005, and Boeing share prices from January 1980 to January 2005 have been used. The study found that robust method provides more accurate VAR forecasts than classical methods, often by a large extent, especially for several days’ ahead horizons and/or in presence of outlying observations. Robust estimation reduces tail estimation risk, providing more accurate and more stable VAR prediction intervals over time.

Research Methodology:

Statement of the problem

There are various models for VAR estimation. Banks and other institutions are free to choose any model as per their choice but it is subjected to the “back testing” test by the regulators. For this purpose it is necessary for the traders to select an appropriate model which gives a correct VAR estimate. This study focuses on evaluating performance of Various VAR models employed by institutions to verify their accuracy levels. The objective is to identify a superior VAR model to estimate market risk.

Objectives of the study

The present study has been undertaken with the following objectives:

- To gain better insight into the various models available for Value at Risk estimation.
- To study how closely the risk estimates produced by the VAR models actually coincide with the actual outcomes
- To Study the observation periods to determine the Variability over time in the risk estimates.
- To study the changes in risk over time and the performance of VAR model in reality.

Operational Definition:

Simple Moving Average

In order to analyze the time series SMA is calculated. Equal weight will be given to each day’s closing portfolio value. The formula will be:

\[
\text{variance} = \sigma^2_n = \frac{1}{m} \sum_{i=1}^{m} u^2_{n-i}
\]

Where, M= no. of days, \(u^2\) = Squared Periodic Return

Five sets of data will be analyzed which will include- 50, 125, 250, 500 and 1250 days.
Exponentially Weighted Moving Average
EWMA will help in giving greater emphasis on the more recent data in relation to the older data. The more recent observations in such a case get more weightage compared to the older ones. The portfolio standard deviation in such a case will be calculated as follows:

\[ \sigma^2_{n}(\text{ewma}) = \lambda \sigma^2_{n-1} + (1-\lambda)u^2_{n-1} \]

Where \( \lambda \) = smoothing parameter, that is the rate at which the weightage to a given observation is declining. The VAR in this manner will be calculated as- \( \lambda = 0.94, \lambda = 0.97, \lambda = 0.99 \)

Historical Simulation
In case of Historical Simulation, the historical data is used, which in this study ranges from Jan 2000 to Dec 2010. The last 10 years SENSEX values have been used to calculate the risk measure. Under this approach, the percentile method has been used, with 95 and 99 percentiles.

Types of Data
The data that has been used to estimate portfolio risk is the last 10 years SENSEX closing price, which ranges from Jan 2000 to Dec 2010. The data has been collected from CMIE Prowess database.

Hypothesis

\( H_0 \) : Portfolio does not have a significant impact on VAR.

Value at Risk Approaches:
The VAR approaches use the historical data to estimate the potential changes in a portfolio in the future. In such a case we make an assumption that the future will behave like the past. Also, the VAR measure can be applied when portfolio values are normally distributed.

The two important parameters of VAR are -

**The Time Horizon**
The choice of the time horizon depends upon the ultimate application of the measure. Banks need to calculate daily profit and loss on their portfolio hence they use one-day VAR. The investment portfolio held by a pension fund, a time horizon of one month is chosen. Thus we can say that the time horizon is determined as per the frequency of trading. However when market risk is being monitored, VAR is calculated over a one trading day time horizon.

\[ T\text{-day VAR}= 1 \text{ day VAR} * \sqrt{T} \]

**Confidence Level**
The confidence level is chosen keeping in mind the level of accuracy that is desired. A confidence level of greater than equal to 99% is chosen. In this study a comparison has been presented with different confidence level and their level of accuracy.

\[ \text{VAR} (X) = \sigma N^{\text{-1}*} (X) \]

Estimating Volatility from Historical Data
In order to estimate volatility periodic returns have been calculated for the indices spread over a 10 years period.

**Equally Weighted Moving Average Approach**
The equally weighted moving average method calculates a portfolio’s Variance and thus calculates its standard deviation. The first in order to analyze the simple moving average an equal weight has been allotted to each day.

The SENSEX closing values have been used from the year 2000 to 2010. The analysis showed that a 50 day risk measure is much more volatile as compared to a 250 day measure. Compared to any other set a 1250 day measure is much more stable. Here it is assumed that the daily returns of the indices are normally distributed. Out of the above 5 sets, the graph for 3 sets has been shown to show the stability
of the 1250 day measure. Thus longer the time measure of study, lesser is the volatility. The rest of the
data has been shown in the appendix. The rest of the data has been shown in the appendix.

Fig.1: VAR Approach Equally Weighted Moving Average

Exponentially Weighted Moving Average

Under exponential weighted moving average the emphasis given more to the recent data by assigning
it higher weights as compared to older observations. Hence, as compared to equally weighted moving
average, in case of exponential weighted average the weights allotted to the observations decline
exponentially. Thus more recent observations get more weight-age in the analysis.

The choice of lambda depends upon the weights that we want to allot to more recent data. This will
ensure that the Variance that will be derived will be a weighted bias towards more recent observation.
Using these 3 risk metrics the results are as follows:

Table1: VAR Approach Exponentially Weighted Moving Average

<table>
<thead>
<tr>
<th>Lambda</th>
<th>94%</th>
<th>97%</th>
<th>99%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sum</td>
<td>0.009682</td>
<td>0.010546</td>
<td>0.012746</td>
</tr>
<tr>
<td>Variance</td>
<td>0.010004</td>
<td>0.010729</td>
<td>0.012828</td>
</tr>
<tr>
<td>EWMA</td>
<td>0.031304</td>
<td>0.021357</td>
<td>0.016349</td>
</tr>
</tbody>
</table>

The analysis shows that the smaller the lambda that is the decay factor, the faster the decay of
influence in the observation data. When lambda is .94, there is a very high Variability as compared to
the lambda of .97 and .99. Also higher the lambda, the smaller is the effective observation period. This
can in a way increase the possibility of an error. Thus we can say that EWMA is more error prone
when lambda is higher.
Historical Simulation

Historical Simulation is another method to calculate VAR that involves using past data to predict the future. Under this method first of all a probability distribution of the daily profit/loss is defined. Then the percentiles are calculated as per the confidence level chosen. This suggests that when the data is normally distributed the corner 5% or 1% as the confidence level may be is our expected worst loss case. Thus the historical simulation method uses the percentiles of the observation period to calculate VAR.

Using this method VAR has been calculated, where observation period is the same, i.e., periodic return from SENSEX indices from year 2000 to 2010. The result is shown in Table 2:

<table>
<thead>
<tr>
<th></th>
<th>95% VAR</th>
<th>99% VAR</th>
</tr>
</thead>
<tbody>
<tr>
<td>95% VAR</td>
<td>-2.91%</td>
<td></td>
</tr>
<tr>
<td>99% VAR</td>
<td>-5.09%</td>
<td></td>
</tr>
</tbody>
</table>

Thus by using historical simulation we can predict that with 95% confidence level, the maximum loss that our returns can suffer is 2.91% of the value, also with 99% confidence level this value goes up to 5.09%. Thus we can say that higher the confidence level more conservative the prediction is.

Portfolio VAR Analysis

In order to understand VAR more clearly a hypothetical portfolios have been built on which the VAR has been calculated and the analysis on it has been presented. The data that has been used is the stock prices for the year 2011. Each portfolio contains different stocks and with the portfolio’s daily return the one-day VAR has been calculated at 99% confidence level.

The t hypothetical portfolio that has been constructed assumes one script each of the 10 stocks that have been chosen. An inclination has been given towards the IT stock. The stocks that have been chosen are:

TCS, GAIL, DLF, Bharti Airtel, NTPC, Infosys, HUL, ITC, Hero Motocorp, Wipro

The historical data for last one year has been collected for each script and daily periodic return was calculated for each day. Based on that standard deviation was calculated and finally the VAR at 99% confidence level, with the following formula:

\[
VAR (X) = \sigma N^{-1} (X), \text{ where}
\]

\[
\sigma = \text{standard deviation}
\]

\[
N^{-1} = \text{cumulative normal distribution}
\]

\[
X = \text{Confidence Level}
\]

Thus it can be clearly seen in the analysis below that VAR has predicted the worst loss limit correct nearly 85% of the time. Rest 15% of the prediction has been wrong. This result is present when VAR has been calculated at 99% confidence level over a one-day trading period.

During the observation period, VAR prediction went wrong mainly because of peculiar market movements and investors sentiments. Also VAR is a derivation based on the past data; therefore it can never be 100% accurate. The 15% of the time, when VAR predictions could not be met can be explained by way of temporary unexpected market volatility and peculiar investor’s behavior.

Hypothesis Testing

To analyze the data further and to understand the correlation between the correctness of VAR and the stocks chosen, the hypothesis test is conducted. The test that has been used is “PAIRED SAMPLE T-TEST”. If more than 5 stoks Sig. level will be more than .05 the researcher will accept the null hypothesis i.e. Portfolio does not have a significant impact on VAR, or else the alternative hypothesis will be accepted.
Table 3: Portfolio - Paired Sample T Test

<table>
<thead>
<tr>
<th>Pair</th>
<th>Stocks</th>
<th>N</th>
<th>( r^* )</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pair 1</td>
<td>VAR &amp; TCS</td>
<td>245</td>
<td>-0.275</td>
<td>0.000</td>
</tr>
<tr>
<td>Pair 2</td>
<td>VAR &amp; GAIL</td>
<td>245</td>
<td>-0.118</td>
<td>0.066</td>
</tr>
<tr>
<td>Pair 3</td>
<td>VAR &amp; DLF</td>
<td>245</td>
<td>-0.141</td>
<td>0.027</td>
</tr>
<tr>
<td>Pair 4</td>
<td>VAR &amp; Bharti Airtel</td>
<td>245</td>
<td>-0.125</td>
<td>0.051</td>
</tr>
<tr>
<td>Pair 5</td>
<td>VAR &amp; NTPC</td>
<td>245</td>
<td>-0.166</td>
<td>0.009</td>
</tr>
<tr>
<td>Pair 6</td>
<td>VAR &amp; Infosys</td>
<td>245</td>
<td>-0.099</td>
<td>0.121</td>
</tr>
<tr>
<td>Pair 7</td>
<td>VAR &amp; HUL</td>
<td>245</td>
<td>0.021</td>
<td>0.749</td>
</tr>
<tr>
<td>Pair 8</td>
<td>VAR &amp; ITC</td>
<td>245</td>
<td>-0.061</td>
<td>0.345</td>
</tr>
<tr>
<td>Pair 9</td>
<td>VAR &amp; HEROMOTO</td>
<td>245</td>
<td>0.020</td>
<td>0.758</td>
</tr>
<tr>
<td>Pair 10</td>
<td>VAR &amp; Wipro</td>
<td>245</td>
<td>-0.163</td>
<td>0.011</td>
</tr>
</tbody>
</table>

\* \( r \) means correlation

If the significance level is less than 0.05, the hypothesis will be rejected.

As except TCS, DLF, Wipro and NTPC all the other stocks Sig. level is more than 5%. So only these 3 stocks have a significant impact on VAR. So the Null hypothesis is accepted.

**Findings of the Study:**

In present scenario of increasing trading activities, it is imperative to have a reliable risk measure. The growing financial instability and volatility in the trading portfolio has called for the attention of the risk managers to concentrate on a sophisticated risk measure, which can most accurately predict the risk on a portfolio. The “VALUE-AT-RISK” models serve this purpose effectively and efficiently.

Following are the findings of my study-  
- All the approaches of VAR are effective risk management tools are able to cover the risk that they are intended to cover.
- The VAR risk measure is able to predict the risk estimate with accuracy in around 90% of the observations.
- With longer time period, VAR models are able to produce results that are less instable.
- In order to achieve the desired level of coverage in the observation period, Exponentially Weighted Moving Average proved to be a suitable approach.
- The time horizon and the confidence level chosen make a difference in the risk estimate produced by the VAR models. Therefore care needs to be taken while defining these two parameters.
- VAR is calculated for one day trading period for more liquid portfolios as compared to less traded ones.
- As compared to daily VAR, a ten day VAR is more appropriate-

Table 4: VAR Approaches Comparison

<table>
<thead>
<tr>
<th>For a one day VAR out of 245 observations VAR was wrong -</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>99% confidence level</td>
<td>21.63%</td>
<td></td>
</tr>
<tr>
<td>95% confidence level</td>
<td>15.92%</td>
<td></td>
</tr>
<tr>
<td>For a Ten Day VAR out of 238 observations VAR was wrong-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>99% confidence level</td>
<td>2.52%</td>
<td></td>
</tr>
<tr>
<td>95% confidence level</td>
<td>7.14%</td>
<td></td>
</tr>
</tbody>
</table>

- In case of a portfolio, out of 10 stocks in each portfolio there are only 4 stocks that actually have a significant impact on VAR.
• In every portfolio the most liquid stocks are the ones that significantly make an impact on VAR.
• In the portfolio TCS, DLF, NTPC, Wipro, stocks that drive the fluctuations in VAR.
• In case of Equally Weighted Moving Average the longer the observation period, the more stable and less volatile if the average.
• In case of Exponentially Weighted Moving Average higher the value of Lambda, the smaller is the effective observation period. The Variance tends to be higher with higher lambda, but the EWMA tends to fall. This can in a way increase the possibility of an error.

<table>
<thead>
<tr>
<th></th>
<th>94%</th>
<th>97%</th>
<th>99%</th>
</tr>
</thead>
<tbody>
<tr>
<td>LAMBDA</td>
<td>0.01%</td>
<td>0.01%</td>
<td>0.01%</td>
</tr>
<tr>
<td>SUM</td>
<td>0.01%</td>
<td>0.01%</td>
<td>0.01%</td>
</tr>
<tr>
<td>VARIANCE</td>
<td>0.03%</td>
<td>0.02%</td>
<td>0.02%</td>
</tr>
<tr>
<td>EWMA</td>
<td>0.01%</td>
<td>0.01%</td>
<td>0.01%</td>
</tr>
</tbody>
</table>

• Using Historical Simulation as a risk measurement tool produces higher risk estimate with higher confidence level. A higher confidence level is a more conservative measure and produces results that are more certain. In case of Historical Simulation VAR is the appropriate percentile of the historical database.

Conclusion

Risk management is an important aspect to determine profitability and sustainability in banking organizations. Right from the time when Markowitz’s theory on portfolio selection threw light on defining and measuring risk, to today, correct measurement and then management of risk contributes to an important area of study. In present scenario, increasing trading activities and growing instability in global markets call for reliable risk measurement techniques. At present regulators do not provide any specific VAR model to the banks and they are free to choose any model of risk estimate. But to make sure that supervised banks are giving a correct estimated, the banks have to undergo back testing of the VAR models. VAR should be greatly used by trading firms and other financial institutions as a part of investing and hedging decisions. VAR with a higher level of confidence level is more certain compared to one with a lower level. It is better to use a 10 day VAR as compared to daily VAR, because it takes into account the standard deviation of the last 10 days, and thus by using a longer historical data, the result is more accurate. It is also better to include more liquid stocks in the portfolio in order to better manage the VAR and thus the risk level that a portfolio is comfortable at.

References:


