The Impact of Exponentially Weighted Moving Average Value at Risk in Indian stock market

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Abstract:
Value at Risk is a measure to estimate the potential devaluation in the asset at the given confidence level and for the time horizon. This measure enables organizations to estimate the market risk of their investments due to such devaluation and safeguard themselves against probable occurring due to fluctuations in stock market. The importance of the value at risk cannot be overemphasized particularly in light of crisis like sub-prime crisis in U.S market in 2008, leading to collapse of many leading global financial institutions. In fact the first pillar of Basel II norms addresses the risk element. Under Basel Accord various models were recommended for measuring risk and out of which the most important one was Value At Risk. There are various methods to estimate this measure which are based on quite different underlinning assumptions like distribution of information, expected behavior of the data and the importance of each data point on time scale. Popular models are Covariance Approach, Historical Simulations, Monte Carlo Simulations, Extreme Value theory, GARCH based EWMA approach etc.

This paper verifies the efficacy of the Exponential Weighted Moving Average based Value At Risk on the 430 BSE S&P companies for observation period of 328 trading days from 1st April 2012 till 22nd July 2013. The decay factor used in the analysis is 0.94, 0.97 and 0.99. The same analysis is done on the portfolio of stocks. Five sets portfolios are analysed each containing ten companies stocks in equal proportion for this purpose.

Keywords: Generalized autoregressive conditional heteroskedasticity (GARCH), Exponential Weighted Moving Average (EWMA), Value at Risk(VaR), Covariance Approach, Historical simulations, Back-testing.

Introduction:

Value at Risk is a measure to estimate the potential devaluation in the asset at the given confidence level and for the time horizon. This measure enables organizations to estimate the market risk of their investments due to such devaluation and safeguard themselves against probable occurring due to fluctuations in stock market. The importance of the value at risk cannot be overemphasized particularly in light of crisis like sub-prime crisis in U.S market in 2008, leading to collapse of many leading global financial institutions. In fact the first pillar of Basel II norms addresses the risk element. Under Basel Accord various models were recommended for measuring risk and out of which the most important one was Value At Risk. There are various methods to estimate this measure which are based on quite different underlinning assumptions like distribution of information, expected behavior of the data and the importance of each data point on time scale. Popular models are Covariance Approach, Historical Simulations, Monte Carlo Simulations, Extreme Value theory, GARCH based EWMA approach etc. The special feature of the EWMA method is that weights assigned to everyday data is decremented as the data becomes dated which means higher importance is given to the data which is recent and lesser to the older data set in the estimation model. Due to this the daily variation in the estimate changes at the much higher rate than Simple moving average models. This approach is
beneficial for the investment in the assets for short term and can be applied in multiple sectors in the realm of finance and need not be restricted to Banking Arena.

This paper verifies the efficacy of the Exponential Weighted Moving Average based Value At Risk on the 430 BSE S&P companies for observation period of 328 trading days from 1st April 2012 till 22nd July 2013. The decay factor used in the analysis is 0.94, 0.97 and 0.99. The same analysis is done on the portfolio of stocks. 5Five sets portfolios are analysed each containing ten companies stocks in equal proportion for this purpose.

Keywords: Generalized autoregressive conditional heteroskedasticity (GARCH), Exponential Weighted Moving Average (EWMA), Value at Risk(VaR), Covariance Approach, Historical simulations, Back-testing.

Review of Literature:
Hao Li, Xiao Fan, Yu Li, Yue Zhou, Ze Jin and Zhao Liu, (2012) in the paper titled “Approaches to VaR” compared various models like historical simulation, GARCH with their variants on the 41 stocks, correlated options portfolio. The detailed testing of each model was carried out by analysing results with different data set. Apart from this each model was tested for conditional coverage and unconditional coverage wherein Conditional VAR was also estimated to find out the estimated average loss in the exceptions in each model.

Anirban Ghatak, (2013), in his research paper “Analysis of performances of VaR models as a tool for Market Risk” examined the EWMA Value at Risk on the 10 Indian companies stock and their portfolio using different decay factor wherein impact of single stock on the portfolio was examined. The results proved that the liquid stocks had higher impact on the portfolio VaR. The analysis was carried out at different confidence level and different time horizon period.

Dai Bo, (2001), in the study titled “Value at Risk” explained the concepts of risk management using Marginal VaR, Incremental VaR, Component VaR using different mathematical formula and statistical tools to create appropriate risk management mechanism. Apart from this the concepts of simple moving averages and GARCH process have been briefly explained.

Suresh A.S, Shagun Mittal, (2013), in the paper titled “Back-testing Value at Risk models on Indian stock markets using Covariance and Historical Simulation approach,” Back-tested the covariance approach and historical simulation approach for both portfolio and 431 single scrips and observed that both these model performed well in the Indian stock market as predictive models. For predicting risk.

Problem statement: There are various methods of calculating VaR and it is difficult to decipher as to which model is appropriate in the Indian context and hence this study focuses on the back-testing of Exponentially weighted moving average Value at Risk model on 431 S&P BSE companies share prices and verify it to get insights into robustness and accuracy of various models applying appropriate decay factor to the EWMA VaR model which generates lowest exceptions for the estimations in the observation period so that the same can be used in conjunction with other models to get a long term and short term risk management perspective.

Objectives of the Study:
- To understand the working of EWMA Value at Risk model as the risk metric in the stocks as the assets.
- To validate the accuracy of model in Indian stock markets context.
- To find the optimal decay factor value suitable for the given study at different confidence level.
- To Understand frame work for a predictive model for managing short term risk.

Data collection:
Historical share prices(daily closing) of the 431 BSE S&P companies was obtained from Prowess database for the period of 7 years (from 1st April 2006 to 22th July 2013). Out of this the period from 1st April 2012 to 22th July 2013 is used as observation period for the back-testing of model.
Sample size and techniques:

431 companies listed under (Annexure 1) BSE 500 S&P are used as the sample for the testing the EWMA Value at Risk models. In order to test this model on the portfolio of stocks, 5 portfolios each containing 10 companies at the equal proportion in portfolio are used. The analysis is carried out at 95% and 99% confidence level and at the decay factor of 0.94, .97 and 0.99.

**Exponential weighted moving average:** As opposed to simple moving average EWMA assigns higher weights to the recent data and less importance to dated ones. In order to achieve this EWMA employs decay factor weight each day's percentage price change. The assumption of normality is not taken in this model. The equation for deriving volatility using EWMA is

$$\sigma = \sqrt{\sum_{t=n}^{t=1} (1 - \lambda) \sum_{t=1}^{t=1} (\lambda^t \cdot (X(t) - \mu)^2)}$$

Here

- $\sigma$ = standard deviation of daily returns on the asset
- $\lambda$ = decay factor in the EWMA model.
- $X(t)$ = daily return on the stock at the given day t.
- $\mu$ = mean of the daily returns of stock under consideration. For the simplicity of the equation the mean of the daily return is assumed to be negligible.

**EWMA VaR:** The Value at Risk is derived from the EWMA standard deviation by using the following formula.

$$\text{VAR(1 day)} = \text{standard normal deviation(at given confidence level)} \times \sigma$$

Standard normal deviation is derived at the confidence level using normal distribution function. For 99% confidence level the value remains 2.32(approx.) and for the 95% confidence level the value remains 1.65(approx).

**Back-testing:**

Back-testing is the process of checking the accuracy of the model. Here the backtesting is used to compare the daily estimated VaR with the actual daily returns. The period of 313 trading is used as back-testing observation days. If the actual returns on the given asset is lower than the estimated model then that observation day is called a exception day for that asset.

**Exception test:**

Basel committee have suggested the exception limit for accepting the model at the given confidence level. The number of acceptable band of exception are governed by the formula as follows.

$$\text{Number of exceptions} \leq \alpha \times \sqrt{(tc) \ast (1 - c)} + t(1 - c)$$

Where $\alpha$ represents number of z value at given confidence level, t total number of observations and c is confidence level.

In order to test for the accuracy of the model test was done using Bernoulli equations. This means that at 99% confidence level the model works if the exception generated in asset is 8 or less and at 95% confidence level the exception limit being 23.

**Hypothesis:**

At 95% confidence level : (also generated at 95% confidence level)

1. H0: The model is acceptable at 95% confidence level for single scrips.
   H1: the model is not acceptable at 95% confidence level for single scrips.
2. HO: The model is acceptable at 95% confidence level for portfolio of scrips.
   H1. The model is not acceptable at 95% confidence level for portfolio of scrips.

At 99% confidence level : (also generated at 99% confidence level)

3. H0: The model is acceptable at 99% confidence level for single scrips.
   H1: the model is not acceptable at 99% confidence level for single scrips.
4. HO: The model is acceptable at 99% confidence level for portfolio of scrips.
   H1. The model is not acceptable at 99% confidence level for portfolio of scrips.

The same hypothesis is tested using different decay factor values.
Observations:

For single scrips:

<table>
<thead>
<tr>
<th>number of companies stock beyond exception limit (out of 431)</th>
<th>confidence level</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>95%</td>
</tr>
<tr>
<td></td>
<td>99%</td>
</tr>
<tr>
<td>decay factor</td>
<td></td>
</tr>
<tr>
<td>0.99</td>
<td>3</td>
</tr>
<tr>
<td>0.98</td>
<td>2</td>
</tr>
<tr>
<td>0.97</td>
<td>4</td>
</tr>
<tr>
<td>0.94</td>
<td>7</td>
</tr>
</tbody>
</table>

Fig 1. Analysis of single scrips

It was observed that the number of companies which did not have the number of exceptions within the limit prescribed by the Basel norms was minimal at decay factor of 0.98. As more and more the decay factor was deviated from this value the number of companies crossing this limit increased. In the above table the highest number companies beyond exception limit was observed a decay factor 0.94. The scrips which did not follow the model(exceptions beyond limits at given confidence level) at 95% confidence level and decay factor of 0.98 are Chennai Petroleum Corporation Ltd. with exceptions of 24 and B E M L Ltd. with exceptions of 25. Similarly at the 99% confidence level (decay factor 0.98) the companies which did not follow the limits prescribed are as follows.

<table>
<thead>
<tr>
<th>companies</th>
<th>number of exceptions</th>
<th>companies</th>
<th>number of exceptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chennai Petroleum Corpn. Ltd.</td>
<td>10</td>
<td>Monnet Ispat &amp; Energy Ltd.</td>
<td>10</td>
</tr>
<tr>
<td>Educomp Solutions Ltd.</td>
<td>10</td>
<td>Opto Circuits (India) Ltd.</td>
<td>11</td>
</tr>
<tr>
<td>Gujarat Gas Co. Ltd.</td>
<td>10</td>
<td>Petronet L N G Ltd.</td>
<td>9</td>
</tr>
<tr>
<td>Hindustan Oil Exploration Co. Ltd.</td>
<td>10</td>
<td>Ranbaxy Laboratories Ltd.</td>
<td>10</td>
</tr>
<tr>
<td>Maharashtra Seamless Ltd.</td>
<td>10</td>
<td>S Kumars Nationwide Ltd.</td>
<td>10</td>
</tr>
</tbody>
</table>

Fig 2. The companies not following exception limits at 99% confidence level. As the number of exceptions overall for companies fall within prescribed limits, null hypothesis-1 and null hypothesis-3 stand true.

For portfolios of scrips:

Portfolio 1:

Portfolio 1 consists of the following companies: 3M India Ltd, A B B India Ltd. K E C International Ltd, Adani Enterprises Ltd, Ranbaxy Laboratories Ltd, Wockhardt Ltd. Tata Power Co. Ltd, Steel Authority Of India Ltd, Mahindra & Mahindra Financial Services Ltd, Infosys Ltd.

portfolio 1. EWMA VaR (decay factor =0.94)
Portfolio 2:
Portfolio 2 consists of following companies: A C C Ltd, Bata India Ltd, Nestle India Ltd, Essar Oil Ltd, Reliance Infrastructure Ltd, Wipro Ltd, T V S Motor Co. Ltd, N T P C Ltd, Jindal Stainless Ltd, M R F Ltd.

<table>
<thead>
<tr>
<th>number of exceptions (out of 328 observation days portfolio 1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>decay factor</td>
</tr>
<tr>
<td>0.99</td>
</tr>
<tr>
<td>0.98</td>
</tr>
<tr>
<td>0.97</td>
</tr>
<tr>
<td>0.94</td>
</tr>
</tbody>
</table>

Portfolio 2: EWMA VaR (decay factor =0.94)

Portfolio 3:
Portfolio 3 consists of the following companies: Aditya Birla Nuvo Ltd, Bosch Ltd, Oracle Financial Services Software Ltd, G A I L (India) Ltd, State Bank Of India, Zee Entertainment Enterprises Ltd, Tata Motors Ltd, Prism Cement Ltd, K P I T Cummins Infosystems Ltd, Pidilite Industries Ltd.

<table>
<thead>
<tr>
<th>number of exceptions (out of 328 observations days portfolio 2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>decay factor</td>
</tr>
<tr>
<td>0.99</td>
</tr>
<tr>
<td>0.98</td>
</tr>
<tr>
<td>0.97</td>
</tr>
<tr>
<td>0.94</td>
</tr>
</tbody>
</table>

Portfolio 3: EWMA VaR (decay factor =0.94)
number of exceptions (out of 328 observation days portfolio 3)

<table>
<thead>
<tr>
<th>decay factor</th>
<th>99% confidence</th>
<th>95% confidence level</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.99</td>
<td>2</td>
<td>13</td>
</tr>
<tr>
<td>0.98</td>
<td>2</td>
<td>17</td>
</tr>
<tr>
<td>0.97</td>
<td>2</td>
<td>18</td>
</tr>
<tr>
<td>0.94</td>
<td>2</td>
<td>17</td>
</tr>
</tbody>
</table>

**Portfolio 4:**

Portfolio 4 consist of the following companies: Ambuja Cements Ltd, Britannia Industries Ltd, Pfizer Ltd, Gillette India Ltd, Syndicate Bank, Whirlpool Of India Ltd, Titan Industries Ltd, Reliance Capital Ltd, Kotak Mahindra Bank Ltd, Siemens Ltd.

**portfolio 4. EWMA VaR (decay factor = 0.94)**

![Portfolio 4 EWMA VaR Chart](chart4.png)

number of exceptions (portfolio 4)

<table>
<thead>
<tr>
<th>decay factor</th>
<th>99% confidence</th>
<th>95% confidence level</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.99</td>
<td>0</td>
<td>17</td>
</tr>
<tr>
<td>0.98</td>
<td>1</td>
<td>19</td>
</tr>
<tr>
<td>0.97</td>
<td>2</td>
<td>21</td>
</tr>
<tr>
<td>0.94</td>
<td>3</td>
<td>20</td>
</tr>
</tbody>
</table>

**Portfolio 5:**

Portfolio 5 consists of the following companies: Apollo Hospitals Enterprise Ltd, Dabur India Ltd, Raymond Ltd, Glaxosmithkline Pharmaceuticals Ltd, United Breweries Ltd, Yes Bank Ltd, Videocon Industries Ltd, H D F C Bank Ltd, Larsen & Toubro Ltd, Sterlite Industries (India) Ltd.

**portfolio 5. EWMA VaR (decay factor = 0.94)**

![Portfolio 5 EWMA VaR Chart](chart5.png)
<table>
<thead>
<tr>
<th>decay factor</th>
<th>99% confidence</th>
<th>95% confidence level</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.99</td>
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<tr>
<td>0.97</td>
<td>0.97</td>
<td>0.97</td>
</tr>
<tr>
<td>0.94</td>
<td>0.94</td>
<td>0.94</td>
</tr>
</tbody>
</table>

As it was observed in the above 5 portfolios the number of exceptions at 95% and 99% confidence level were with the limits the 2nd and 4th null hypothesis cannot be rejected.

Findings:

- EWMA VaR model is dynamic in nature due to which it fluctuates more as compared to historical simulation and covariance approach.
- As observed in the single scrips the best suited decay factor for the EWMA VaR model is 0.98. It was observed that as the decay factor varies away from 0.98 the number of companies which do not follow exception (not number of exceptions) limit increases. Most of the companies which did not follow this model were energy industry related.
- In the portfolio analysis the number of exceptions was least at the decay factor of 0.99 at both the confidence level. Impact of portfolio selection was observed in the EWMA model. The exceptions in portfolio 1 had close exceptions at both confidence level, whereas portfolio 5 had very low and high number of exceptions at both the confidence level.
- It was observed that the exceptions observed although were higher than historical simulations and covariance approach, the conditional (consecutive) exceptions were not observed. This enables this model to be more suited for adaptation to the current market scenario. Furthermore model works better for companies that showed periodic fluctuations.

Conclusions:

It can be concluded that EWMA VaR model can be significantly used as predictive Risk Model across financial sectors as observed in the sample of 431 single scrips and 5 portfolios. As this model helps in optimally quantifying the risk in the investments for short time horizons, it is robust when applied to daily investments objectives rather than long term investments. The dynamic nature of the model helps in increasing the revenue, if trade-off with risk associated is assessed. Hence if any firm is concentrating on the short term or long term basis it can achieve it by varying the decay factor accordingly. As compared to historical simulations and covariance approach EWMA enables proximation towards the threshold and therefore optimizes the risk rather than minimizing it which can be beneficial according to the objectives of the firm. The firms in order to use these models have to decide on the variables like decay factor, confidence level and portfolio to be assessed depending on the objectives of the firm. This model works as a better predictive model during the crisis period as it relies more on recent data and aptly suits investment bankers, treasury departments of the firms, stock trading in the firm. Etc.

Suggestions:

Internal risk rating departments should use this model depending on the market scenario, organization that focuses on the conditional risk measures can use this model at efficiently with attendant benefits. However the problem observed with this model is that it does not account for very high infrequent fluctuations in the assets value. The risk assessment in the investments with such models needs to be done at more frequent intervals. Hence it is recommended to use alternative models along in conjunction with this model for example historical simulations.
and covariance which can act as complementary models and add value to the firms risk assessment and management.

**Limitations and future scope:**

- Predictive model is based on past data and yet to be tested in real time situations.
- Works well in short term and hence a combination of long term model is also required to ensure the robustness of decision making.
- Similar analysis can be done for other industries/non banking sector

**References:**