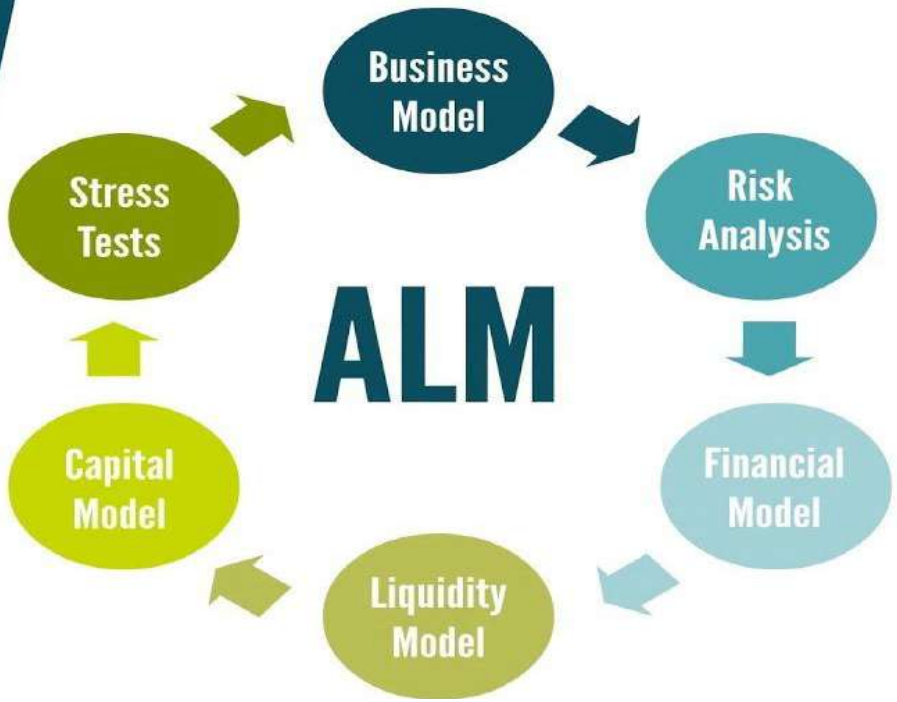

Introduction to ALM

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Value At Risk (VaR)

- Value at risk (VaR) is used to measure the risk of loss on a portfolio of financial assets, or an investment, over a specific period. Financial institutions use VaR to determine how much emergency cash they need to put aside to cover potential losses.
- It has sometimes been referred to as the “new science of risk management”. VaR is mainly used in risk management, financial control, financial reporting and computing regulatory capital.
- VaR helps investors determine what could happen in a worst-case scenario – it tells them how much they could potentially lose in a really bad month, week or even day.

- It is the probability that a portfolio will experience a mark-to-market loss that exceeds that of a specific predetermined threshold value.
- Essentially this means that value at risk is measured in three variables:
  - The amount of potential loss,
  - The probability of that loss, and
  - The timeframe.
- The most common parameters for VaR are 1%, 5%, and 10% probabilities and time periods of one day, two weeks, or a month. However, there are a variety of different combinations that investors use.

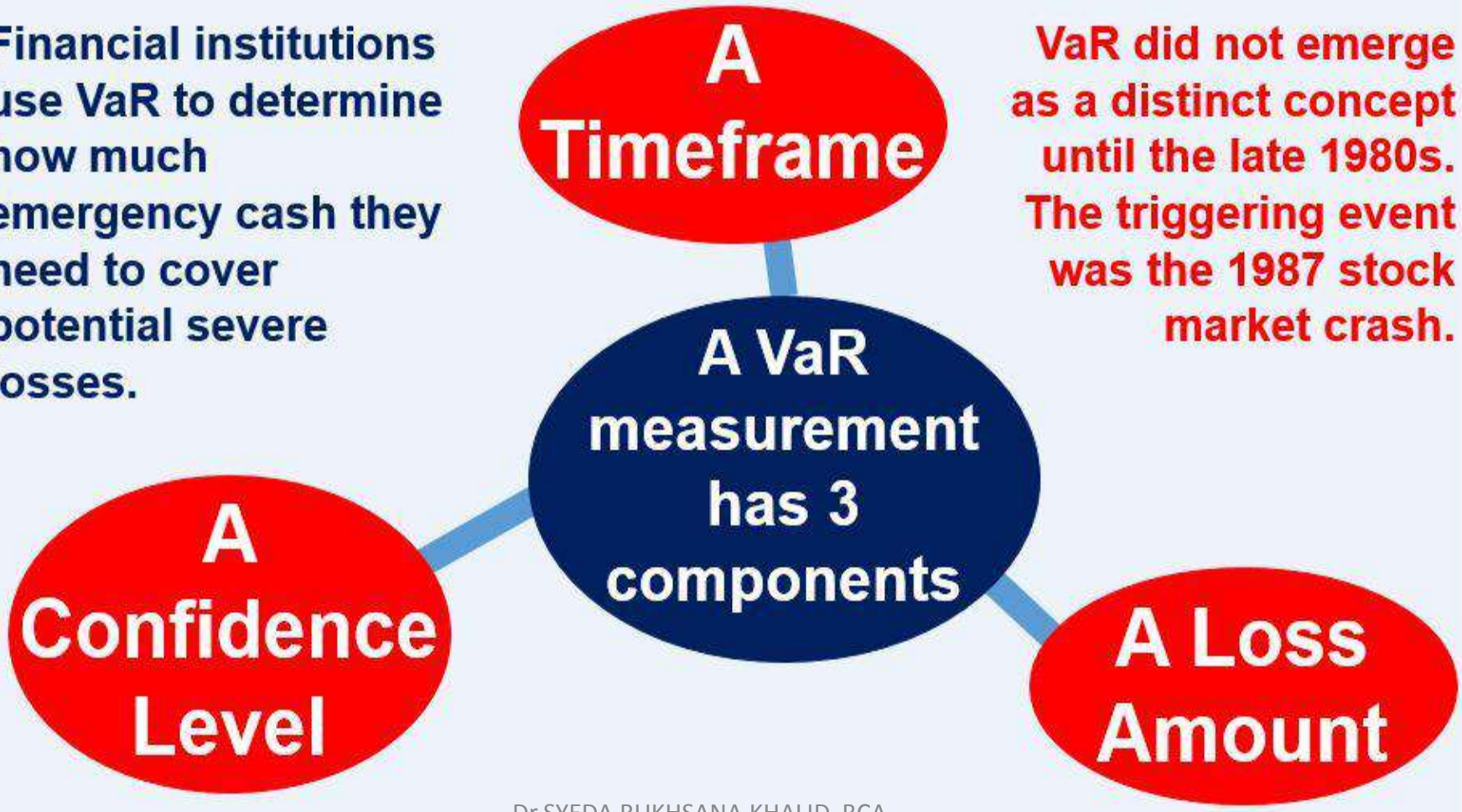
Example of value at risk (VaR)

- If a portfolio has a VaR of 10% on a certain day of $10 million USD, then this portfolio has a 0.10 probability that the portfolio will drop in value by $10 million. A loss of more than the VaR threshold is considered to be a "VaR break".

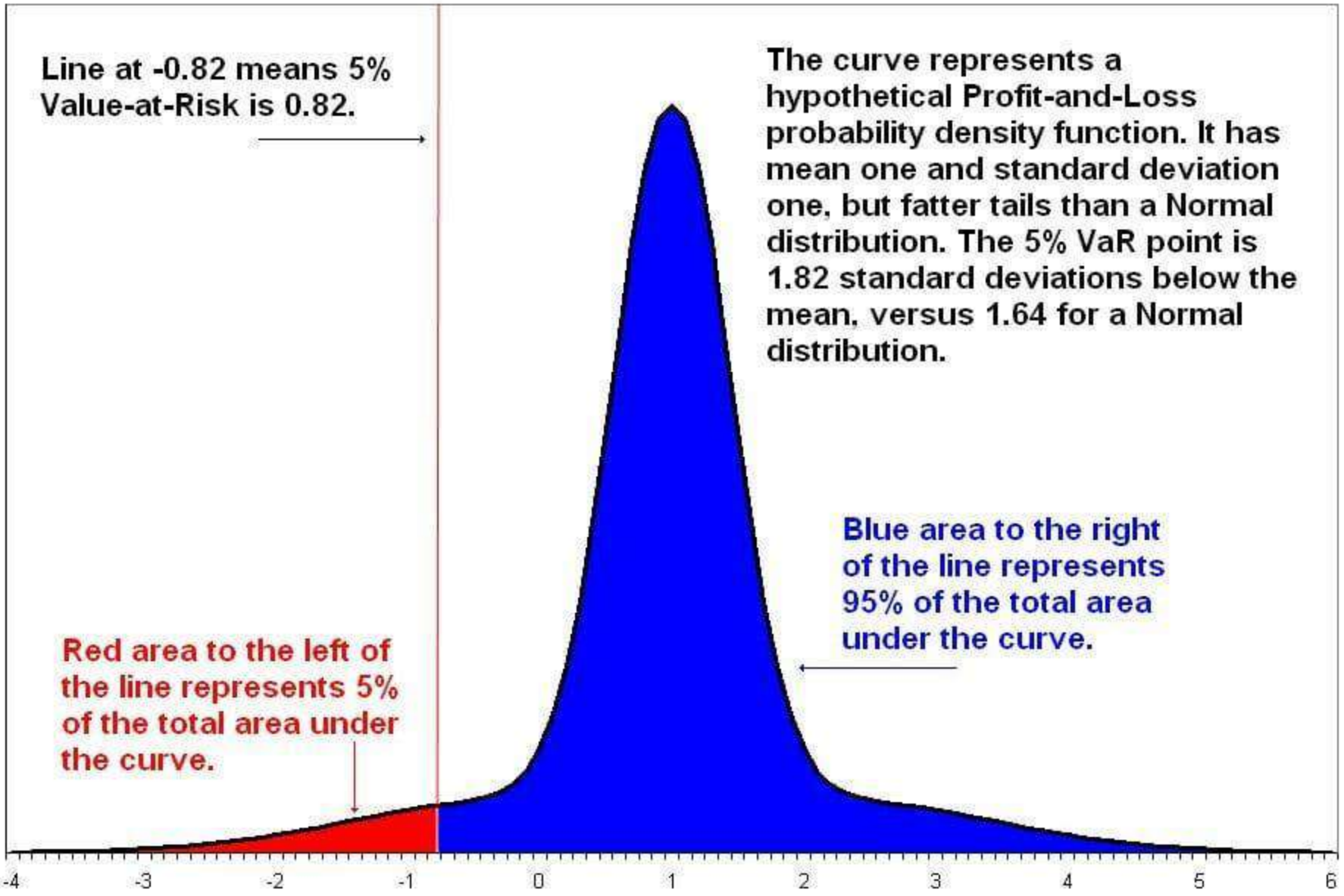
- In 1993, the Group of Thirty (G-30) endorsed VaR as a best practice for dealing with derivatives. Since then, VaR has revolutionized market risk measurement for institutions.
- Gradually, this concept has been extended to other risks such as credit risk, operational risk, and even integrated risk management.
- VaR is a method of assessing risk using standard statistical techniques. Formally, it is the maximum loss over a target horizon such that there is a low, predetermined probability that the actual loss will be larger.
- VaR has a scientific basis and provides users with a summary measure of market risk.
- For instance, a company might say that the daily VaR of its trading portfolio is INR 35 million at the 99% confidence level.
- In other words, there is only one chance in a hundred, under normal market conditions, that a loss greater than this amount will occur.

Value at Risk

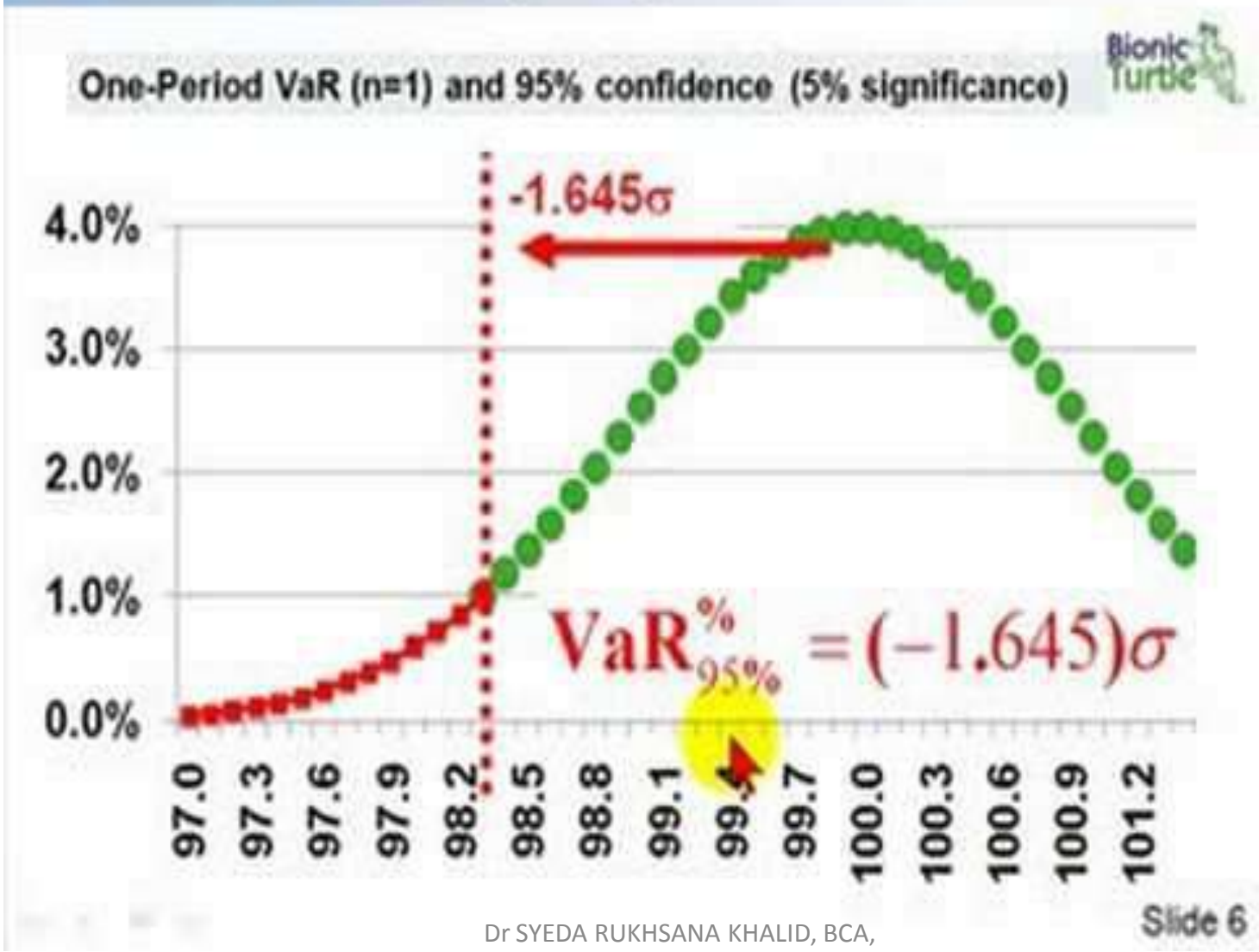
Financial institutions use VaR to determine how much emergency cash they need to cover potential severe losses.



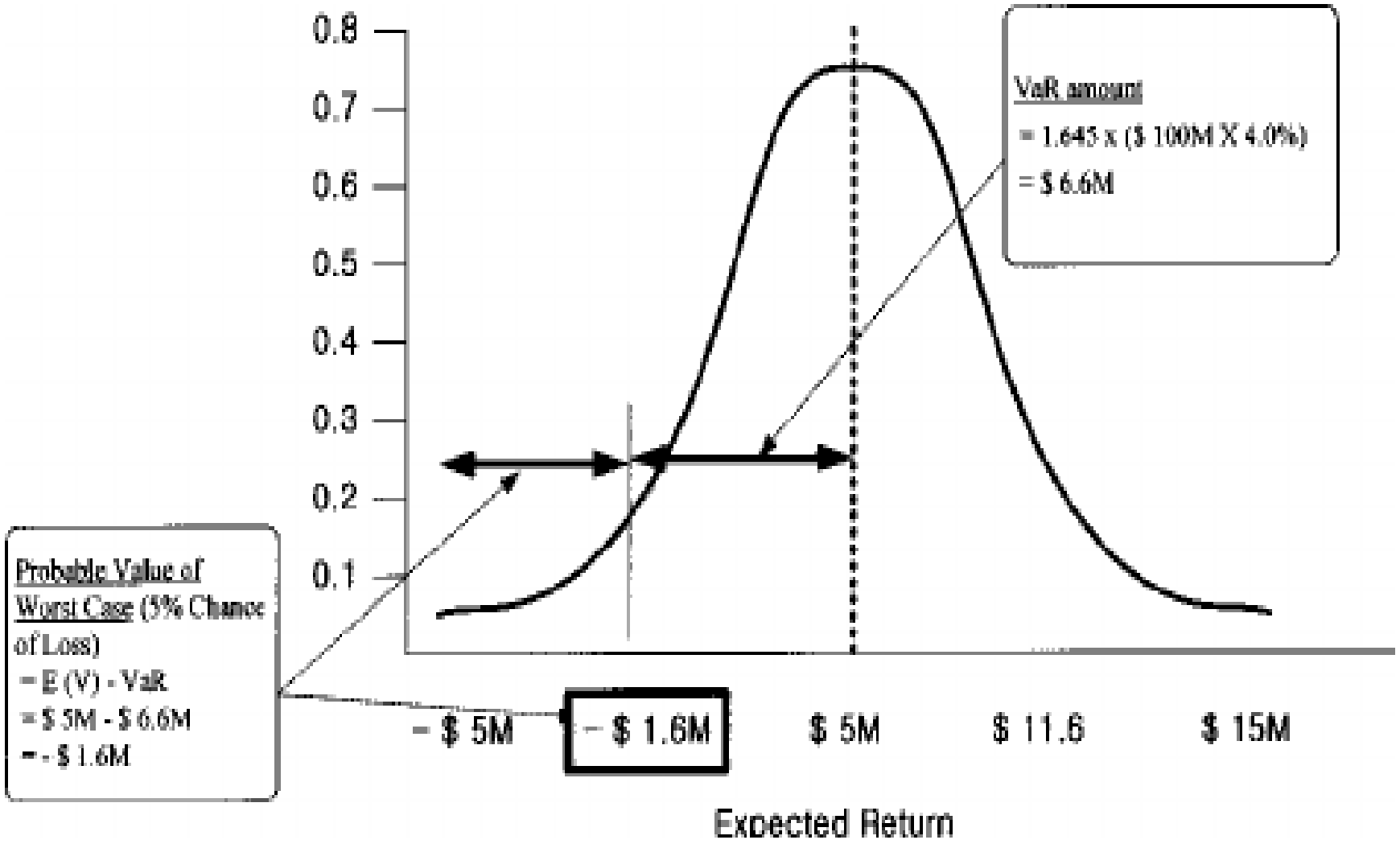
VaR did not emerge as a distinct concept until the late 1980s. The triggering event was the 1987 stock market crash.


Line at -0.82 means 5% Value-at-Risk is 0.82.
The curve represents a hypothetical Profit-and-Loss probability density function. It has mean one and standard deviation one, but fatter tails than a Normal distribution. The 5% VaR point is 1.82 standard deviations below the mean, versus 1.64 for a Normal distribution.
Blue area to the right of the line represents 95% of the total area under the curve.
Red area to the left of the line represents 5% of the total area under the curve.
-4
-3
-2
-1
0
1
2
3
4
5
6

% Value at Risk (VaR)



- ***VaR*** **=[Expected Weighted Return of the Portfolio− (*z*-score of the confidence interval× standard deviation of the portfolio)]× portfolio value**


0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
VaR amount
= 1.645 x ($ 100M X 4.0%)
= $ 6.6M
Probable Value of Worst Case (5% Chance of Loss)
= E (V) - VaR
= $ 5M - $ 6.6M
= - $ 1.6M
- $ 5M
- $ 1.6M
$ 5M
$ 11.6
$ 15M
Expected Return

Example of value at risk (VaR)

- If a portfolio has a VaR of 10% on a certain day of $10 million USD, then this portfolio has a 0.10 probability that the portfolio will drop in value by $10 million. A loss of more than the VaR threshold is considered to be a “VaR break”.

- This number summarizes the company's exposure to market risk as well as the probability of an adverse move.
- Shareholders and managers can then decide whether they feel comfortable with this level of risk
- If the answer is no, the process that led to the computation of VaR can be used to decide where to trim risk.
- VaR takes into account both portfolio diversification and leverage effects.
- Various methods are possible to compute Value At Risk.

- These methods basically differ in terms of:
- Distributional assumptions for the risk factors (e.g. normal versus other distributions)
- Linear vs. full valuation, where the former approximates the exposure to risk factors by a linear mode Some of the important methods for measuring VaR are:
- 1. Delta Method
- 2. Historical Simulation Method
- 3. Monte Carlo Method

1. Delta-Normal Method

- This method assumes that the individual asset returns are normally distributed.
- Since the portfolio return is a linear combination of asset returns, it is also normally distributed.
- The variance-covariance matrix and correlations for all risk factors are computed from historical data for a period of 3- 5 years.
- Once this is done, the portfolio risk is computed by using forecasts of volatility and correlations for each risk factor and the exposure to these risk factors.

2. Historical Simulation Method

- This method is similar to the Delta Normal method in that it also uses historical data of asset returns and the exposure to these risk factors.
- The difference is that this return does not represent an actual portfolio but rather reconstructs the history of a hypothetical portfolio using the current position.
- Both the methods would generate the same VaR if asset returns are all normally distributed.

3. Monte Carlo Method

In this method there are two steps:

- First, specifying a stochastic process for financial variables as well as process.
- Second, simulating fictitious price paths for all variables of interest.
- The portfolio is marked-to-market at each horizon considered, which can be one day or many months ahead.
- Each of these hypothetical returns is then used to compile a distribution of returns, from which a VaR figure can be measured.

Comparison of Methods

1. Delta-normal method This is the simplest method to implement. The drawback however, is that it assumes that all risk factors are normally distributed and that all assets are linear in risk.
2. Historical Simulation Method This is also relatively simple. The drawback to this is that only one sample path is used for simulation, which may not adequately represent future distributions.
3. Monte Carlo Method This is the most sophisticated method. It accommodates even non-normal distributions and non-linear assets, but requires work on computers and a good understanding of the underlying stochastic process.

Caveats in the use of Value At Risk

- It does not describe the worst loss; for example, in VaR calculation with 99% confidence, there is a one in hundred possibility that actual loss will exceed VaR estimates.
- It does not describe the distribution of losses.
- VaR itself is subject to some sampling variation; a different sample period or a period with a different length could lead to different VaR numbers.

Stress Testing

- Stress testing achieves a very different risk management objective as compared to VaR.
- Its purpose is to examine the impact of extreme events on the portfolio.
- This test thus deals with the ability of the business to survive extreme conditions & implement changes in strategy.
- It provides a deeper understanding of the risk & thereby prepares a ground for better protection.
- This can also be used to understand how new products will respond to extreme conditions.
- Thus, investment risks can be better assessed before the business becomes involved.
- Stress testing can be applied to test market risk & derivatives & also operational, credit & counterparty risk.

Some examples of extreme events are:

- The October 1987 crash of more than 20% in one day in the US Equities market followed by a contagion effect in other markets.
- The 1990 Nikkei crash
- The rise in US interest rates by about 250 basis points in 1994
- The Mexican Peso crises in 1994 & Latin America crises in 1995 - The East Asian crises in 1997
- The 1998 LTCM crises
- The Russian crises where the Russian Ruble fell by 29% in 1998
- The 1999 Brazil crises

- These events underscored the need to go beyond the normal events that VaR deals with. Risk management must envisage extreme events & factor the risks caused by them.
- Stress testing deals with these events.
- The results or features of these extreme events are as follows:
- Contagion effect - A crisis in one market gets passed on to other markets & normal correlations go haywire. All markets get highly correlated with each other & accentuate the risk.
- Speed of price shocks - Shock waves spread rapidly & normal assumptions made in derivative transactions do not hold any more.
- Liquidity issues - Liquidity dries up in most markets & exit from a position becomes very difficult.
- Concentration - Under normal circumstances, concentration allows market leadership. However in extreme conditions, it creates the risk of a near fatal loss.

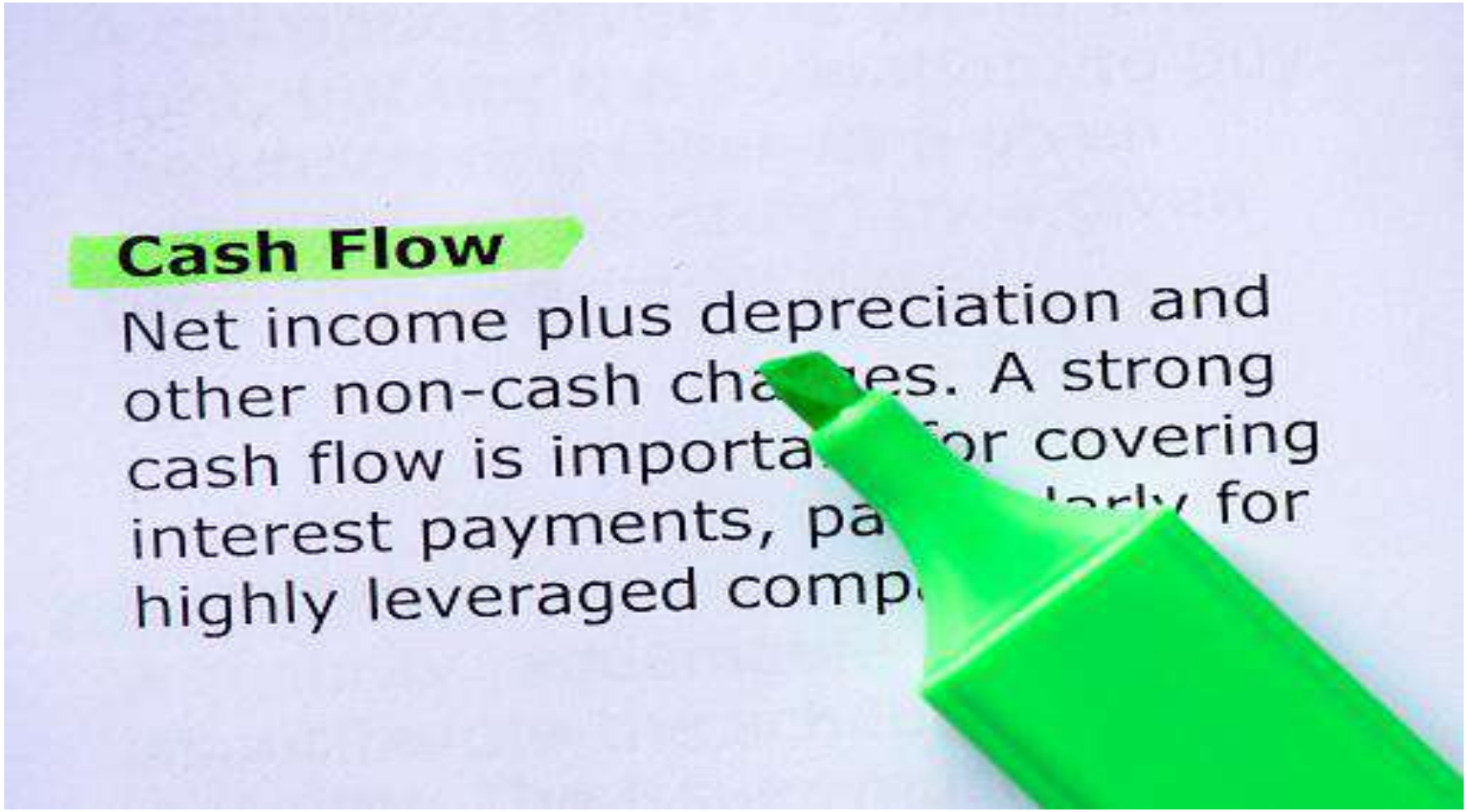
Stress tests are carried out with reference to some extreme events & can be categorized as follows:

- - Market Moves
  - o Parallel shifts in the yield curve
  - o Yield curve could twist o Basis (e.g. interest rate differential) changes
  - o Swap & other credit spreads o Currency devaluations
  - o Volatility changes & twists in the term structure of volatility
  - o Price shifts o Liquidity
  - o Credit tightening o Contagion effects
  - o Speed & duration of extreme market moves

- Modeling assumptions to be stress tested
  - o Yield curve interpolation & creation
  - o Pricing models, e.g. option pricing
  - o Models used for trading hedging strategies o Volatilities
  - o Correlations
- Product complexity
  - o Derivatives
  - o Mortgages
  - o Structured products with embedded multiple risks
  - o Products with a wide range of acceptable prices
  - o Difficulty in handling risks & asset types
  - o Emerging markets & difficult to handle markets
- Credit
  - o Name concentration
  - o Industry concentration
  - o Concentration across client segments
  - o Contingent credit exposures, particularly of derivatives

Approaches to stress testing

- **Historical event analysis:** Examines what happens if the extreme event occurs again
- **Scenario analysis:** Develops scenarios based on historical events and examine the Outcome for such scenarios
- **Institution specific scenario analysis:** Scenarios are developed based on the events relevant to the bank or institutional portfolio
- **Extreme standard deviation scenarios:** Examines what could happen if the returns vary by 5-, 6-, 10-standard deviations
- **Extreme incremental events and Tail risk:** Quantifies a set of progressively severe market moves or events and the loss that can ensure
- **Quantitative evaluation of tail events:** Examines whether there is any pattern in the tail events and uses the results in scenario analysis


Cash Flow
Net income plus depreciation and
other non-cash cha es. A strong
cash flow is importa or covering
interest payments, pa arly for
highly leveraged comp

Cash flow at risk (CFaR)

- It can be defined as the extent to which future cash flows may fall short of expectations as a consequence of changes in market variables.
- CFaR is an excellent corporate risk measure because it will improve the understanding of the risk dynamics of a business and how that risk profile can change due to price changes, entry of new products or geographies, acquisitions, or new projects coming into production.
- It generally focuses on the market risk that impacts the corporate's cash flows, ignoring things such as political, operational, environmental and legal risk.
- ***C-FaR is defined as an analytic method of measuring with high degree of probability the risk of cash flow shocks for non-financial firms by its producers.***
- This model helps firms by being a measure to evaluate the changes in their values.
- The model is proposed as a form of VaR for finding the overall risk against a firm's cash flow (Vural, 2004).

How useful is CFaR?

- The value of CFaR does not so much lie in the number itself, but more in the benefit from doing a deep-dive into all the risk factors and cash flow drivers, and the good information this provides to management. In addition:
- The portfolio dynamics will be much better understood.
- It is relatively easy to calculate and aggregates the portfolio risk into a single number.
- It can promote a more robust discussion on risk throughout the whole organization.
- It can act as a brake against excessive risk taking and can support consistency in decision-making.

- Unnecessary or costly hedging may be prevented given the existence of natural hedges, i.e., where the portfolio risk level is substantially less than the aggregate risk from individual risk factors.
- If market risk is managed at the portfolio level, then the business units can fully focus on their operational efficiencies (production, cost and safety).
- Different scenarios and assumptions can be modeled and stress tested—for example, consider how different CFaR scenarios can impact the FFO (funds from operations) to net debt ratio over a 12 month period. The company can use this information to ensure potential issues (e.g. pressure on credit rating) can be managed proactively.

- When setting CFaR limits, it must be linked to the impact on a ratio, debt capacity, financial flexibility, etc. It will typically be set with reference to a credit rating threshold (e.g., net gearing or FFO to net debt ratio over a 12- or 24-month period).
- A CFaR to cash flow ratio can be useful to show how the riskiness of the company is changing—recognizing however that if this ratio increases, but it is coupled with higher absolute cash flows, then a higher ratio (higher cash flow volatility) is acceptable.

The CFaR process

- The steps in the quantification process will typically be as follows:
- Map the exposures
- Overlay market-derived statistics
- Modeling
- Generate results
- Determine the impact on the business.
- The CFaR process is typically owned by the treasury function as the custodian of financial risks, but the accounting function and the other business units should also provide input. It can be further observed that:

- The calculation period can range from a quarter up to two years and even five years
- The market derived statistics should be stress tested to understand the impact of abnormal market conditions
- Back testing the results can provide valuable insights as to how ‘predictive’ (or not) the model is
- More weighting can be given to recent data if it is considered more relevant (exponential weighting).

Backtesting

- A technique used to compare the predicted losses from VaR with the actual losses realised at the end of the period of time.
- This identifies instances where VaR has been underestimated, meaning a portfolio has experienced a loss greater or than the original VaR estimate.
- The results of the Back Testing can be used to refine the models used for the VaR predictions, making them more accurate and reducing the risk of unexpected losses.

Key Points of Back Testing Value-at-Risk

1. The following minimum standards apply to calculating capital charge within a model measuring market risk;
2. Data sets should be updated at least once every 3 months
3. VaR must be calculated on a daily basis
4. 99th percentile, one-tailed confidence interval is to be used
5. A 10 day movement in prices should be used as the instant price shock
6. 1 year is classified as a minimum period for "historical" observations

- For example, if the confidence level used for calculating daily VaR is 99%, we expect an exception to occur once in every 100 days on average.
- In the backtesting process, we could statistically examine whether the frequency of exceptions over some specified time interval is in line with the selected confidence level.

Research to date has focused on VaR measures used by banks. Published backtesting methodologies mostly fall into three categories:

- **Coverage tests** – assess whether the frequency of exceedances is consistent with the quantile of loss a VaR measure is intended to reflect.
- **Distribution tests** – are goodness-of-fit tests applied to the overall loss distributions forecast by complete VaR measures.
- **Independence tests** – assess whether results appear to be independent from one period to the next.

- In this respect, an accurate VaR model needs to satisfy the so-called *Unconditional Coverage Property*.
- **Unconditional Coverage** – refers to the fact that the fraction of overshootings obtained should be in line with the confidence level of VaR.
- Failure of unconditional coverage means that the calculated VaR does not measure the risk accurately.

Unconditional Coverage

- Denoting the number of exceptions as **x** and the total number of observations as **T**:
- We may define the failure rate as x/T.
- In an ideal situation, this rate would reflect the selected confidence level.
- For instance, if a confidence level of 99 % is used, we have a null hypothesis that the frequency of tail losses is equal to p = (1-c) = 1-0.99 = 1%.
- Assuming that the model is accurate, the observed failure rate x/T should act as an unbiased measure of p, and thus converge to 1% as sample size is increased.

- Each trading outcome either produces a VaR violation exception or not. This sequence of 'successes and failures' is commonly known as Bernoulli trial.
- The number of exceptions, **x** ,follows a binomial probability distribution:

TABLE 8-1

Probability of Exceptions Experienced in 250 Days if the VaR Model is Correct

Exceptions	Probability	Cumulative Probability
0	8.1%	8.1%
1	20.5%	28.6%
2	25.7%	54.3%
3	21.5%	75.8%
4	13.4%	89.2%
5	6.7%	95.9%
6	2.7%	98.6%
7	1.0%	99.6%
8	0.3%	99.9%
9	0.1%	99.98%
10+	0.01%	99.99%

This table demonstrates that 10 or more exceptions are unlikely if the VaR model is correct.

- By utilizing this binomial distribution we can examine the accuracy of the VaR model.
- However, when conducting a statistical backtest that either accepts or rejects a null hypothesis (of the model being 'good'), there is a tradeoff between two types of errors.

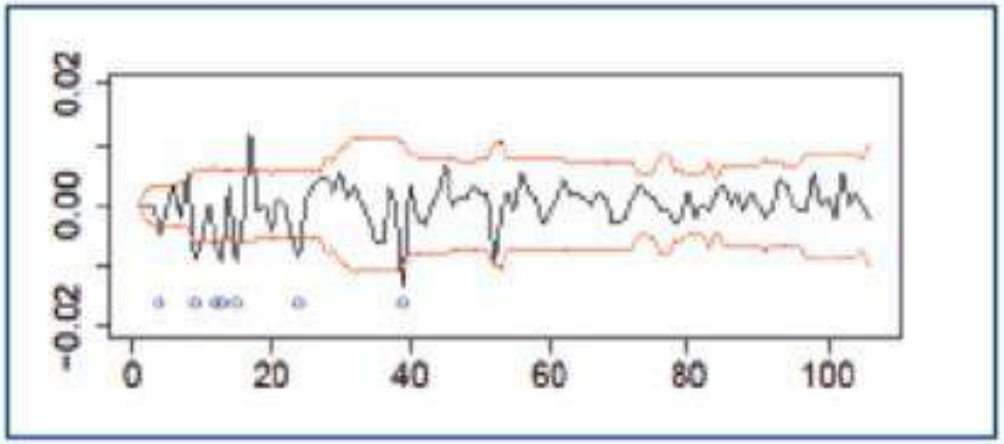
- **Type I errors** occur when we reject the model which is correct, while **Type II errors** occur when we fail to reject (that is incorrectly accept) the wrong model.
- It is clear that in risk management, it can be much more costly to incur in type II errors, and therefore we should impose a high threshold in order to accept the validity of any risk model.

Independence Property

- Besides unconditional coverage, VaR should satisfy the *independence property*.
- **Independence property** – refers to the clustering of overshootings.
- If the market conditions change, the VaR model should adapt quickly to the new situations.
- Therefore, observing an overshooting tomorrow should be independent of observing an overshooting today.
- Series of overshootings – means that the risk is underfunded for prolonged periods during episodes of increased risk.

Independence Property

- Graphical analysis allows a first glance at the results and assists in detecting problems visually.
- For example, the time chart below shows +/- VaR (red), the change of the value of the portfolio in percent (black), and the overshootings (blue).



Clearly, all of the overshootings appear in the first half of the period.

- This may be due to a failure of the independence property.

- The simplest backtest consist of counting the number of exceptions (losses larger than estimated VaR) for a given period and comparing to the expected number for the chosen confidence interval.
- A more rigorous way to perform the backtesting analysis is to *determine the accuracy of the model* predicting both the frequency and the size of expected losses.
- **Backtesting Expected Tail Loss (ETL)** or **Expected Tail Gain (ETG)** numbers can provide an indication of how well the model captures the size of the expected loss (gain) beyond VaR, and therefore can enhance the quality of the backtesting procedure.

Backtesting

- Statistical testing that consist of checking whether actual trading losses are in line with the VAR forecasts

In its simplest form, the backtesting procedure consists of calculating the number or percentage of times that the actual portfolio returns fall outside the VaR estimate, and comparing that number to the confidence level used.

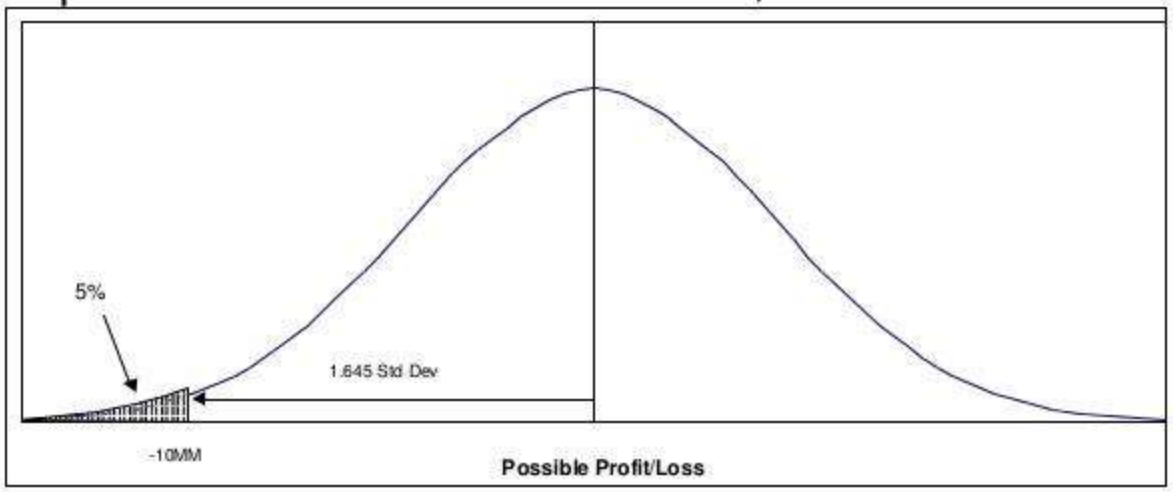
- The Basel back-testing framework consists in recording daily exception of the 99% VAR over the last year
- Even though capital requirements are based on 10 days VAR, back testing uses a daily interval, which entails more

- On average, one would expect 1% of 250 or 2.5 instances of exceptions over the last year
- Too many exceptions indicate that
  - either the model is understating VAR
  - the Bank is unlucky
  - How to decide ?
    - ✓ Statistical inference

- On average, the number should be about 2.5
  - Higher number could happen either because of Bad Luck or because of a wrong risk model
  - However, it is unlikely that this outcome is due solely to bad luck

Visualizing VAR : Example

- A 1-day VAR of $10mm using a probability of 5% means that there is a 5% chance that the portfolio could lose more than $10mm in the next



Value at Risk vs. Cash Flow at Risk

Disadvantages of Value at Risk for Non-Financial Companies

- VaR measures how much the value of financial assets/liabilities – receivables, payables, equities, commodities, bonds – changes due to adverse market movement.
- VaR does not cover changes in value of cash flows.
- Compared to financial companies, non-financial companies have substantially higher ratio of cash flows (sales/purchases) to assets. Non-financial companies are exposed comparatively higher to changes in value of their cash flows.
- The right risk measure for these companies is different – for example CFaR.

Non Insurance Methods of Risk Management


for pure risks only
(chance of loss but
no chance of gain)
Risk Management Techniques
Risk Avoidance
Loss Control
Risk Retention
Risk Financing
Risk Transfer
Speculative risk → chance of loss or gain (e.g., stock market)

There are four risk management techniques

1. Risk avoidance
2. Loss Control
3. Risk Retention
4. Risk Transfer

- These techniques work for pure risks (chance of loss but no chance of gain) but not speculative risks (chances of gain or loss, as with stock market).
- Insurance reduces uncertainty about non speculative financial losses.
- There are requirements for insurable risks.

Risk Avoidance

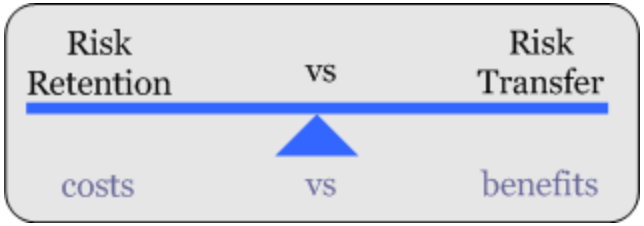
- Elimination of risk at any cost (e.g., drop a hazardous product)
- Most aggressive and effective … but not practical
  - eg, staying in bed all day to avoid risk of injury or death

Loss Control

- loss prevention: reduce frequency of loss
  - usually impossible or impractical
    - (e.g., to maintain income —> insurance or adopt a healthier lifestyle
- loss reduction: reduce the severity and financial impact
  - eg, upon disability —> physical rehabilitation, crosstrain a backup
- safety measures, pooling, segregating (e.g., key employees travel separately),
- diversifying (not imperiling group by one member's actions)

Risk Retention

- Finance some or all of the losses yourself
  - eg, health insurance has deductibles and waiting period
- eg, buy Long Term Disability but not Short Term Disability



Risk Transfer

- Non insurance
  - eg, relatives help out
- Insurance
  - formal arrangement between you and an insurer