Market Risk Measurement Methods

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CQF

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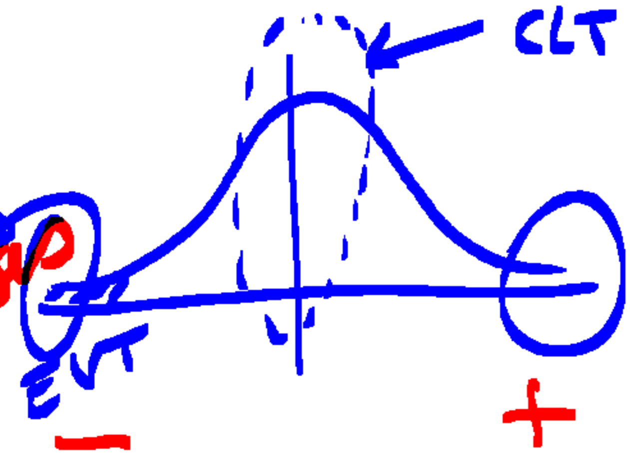
Losses



Basel 2.5/3

The Word Risk

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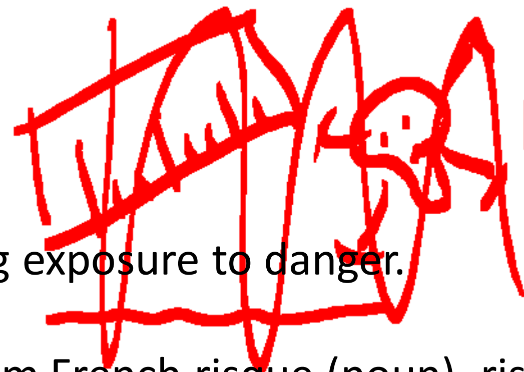


return

Markowitz

risk

risk, *noun*, situation involving exposure to danger.

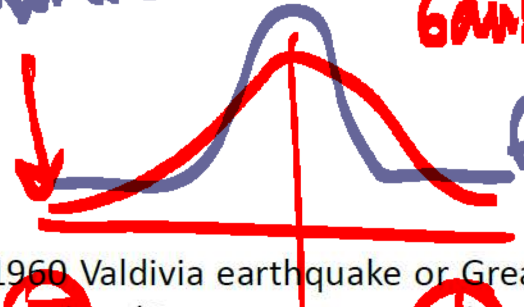
Origin: Mid 17th century: from French risque (noun), risquer (verb), from Italian risco 'danger' and rischiare 'run into danger'.

Oxford English Dictionary

risk management is the identification, assessment, and prioritization of risks followed by coordinated and economical application of resources to minimize, monitor, and control the probability and/or impact of unfortunate events or to maximize the realization of opportunities.

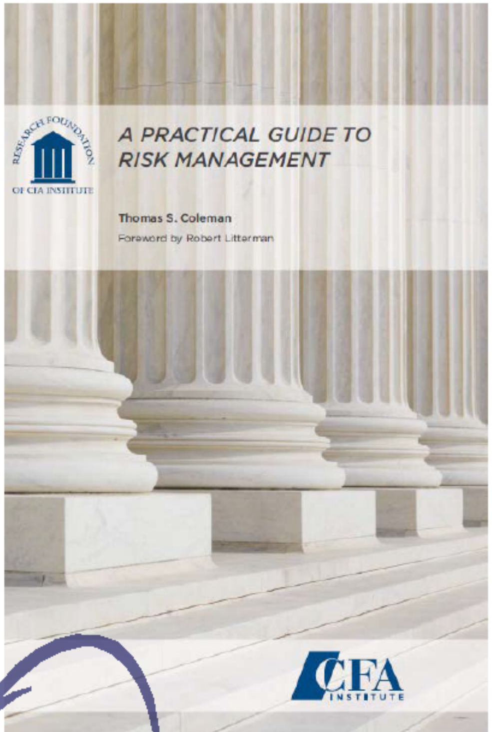
Hubbard, Douglas (2009). *The Failure of Risk Management: Why It's Broken and How to Fix It*. John Wiley & Sons.

leptokurtic Gaussian fat



The 1960 Valdivia earthquake or Great Chilean earthquake (Gran terremoto de Chile) of Sunday, 22 May 1960 was **the most powerful earthquake ever recorded**, rating a 9.5 on the moment magnitude scale.

It occurred in the afternoon (19:11 GMT, 15:11 local time), and lasted approximately 10 minutes. **The resulting tsunami** affected southern Chile, Hawaii, Japan, the Philippines, eastern New Zealand, southeast Australia, and the Aleutian Islands.



Coleman, Tom, A Practical Guide to Risk Management (July 27, 2011). CFA Institute Research Foundation M2011-2.
Available at SSRN:
http://ssrn.com/abstract=2586032

Risk measurement has three goals:

1
- **Uncovering “known” risks** faced by the portfolio or the firm. By “known” risks, I mean risks that can be identified and understood with study and analysis because these or similar risks have been experienced in the past by this particular firm or others. Such risks often are not obvious or immedi-ately apparent, possibly because of the size or diversity of a portfolio, but these risks can be uncovered with diligence.

Silos

2
- **Making the known risks easy to see**, understand, and compare—in other words, the effective, simple, and transparent display and reporting of risk. Value at risk, or VaR, is a popular tool in this arena, but there are other, complementary, techniques and tools.

viel

3
- **Trying to understand and uncover the “unknown”** or unanticipated risks—those that may not be easy to understand or anticipate, for example, because the organization or industry has not experienced them before.

Risk representation*

Overall P&L Distribution

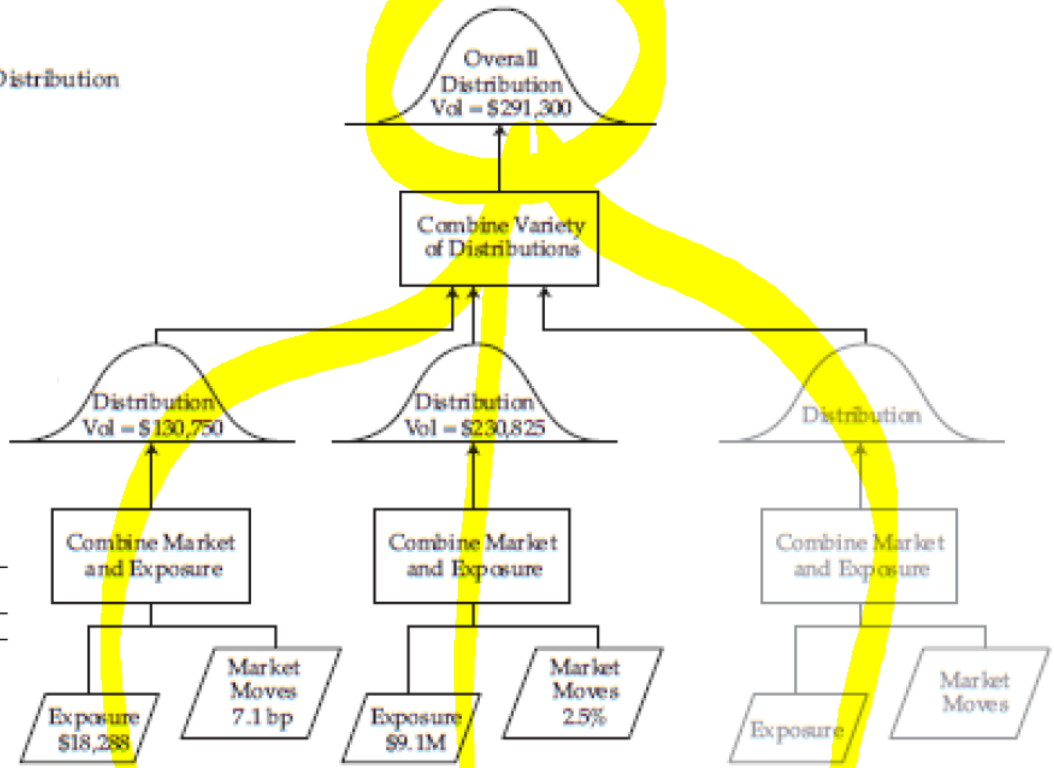


Table 1.3. Portfolio Sensitivity to One Standard Deviation Moves in Specific Market Risk Factors

Yield Curve (yield down)		Equity (index up)	
10-year par yield	$130,750	CAC	$230,825

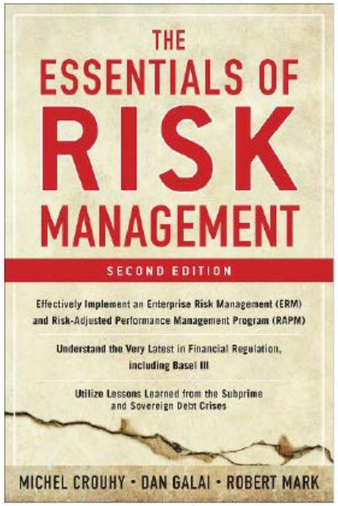
Table 1.2. Volatility or Standard Deviation of Individual Market Yield Moves

Yield Curve (bps per day)		Equity (% per day)	
10-year par yield	7.15	CAC	2.54

Table 1.1. Sample Exposure Report

Yield Curve (per 1 bp down)		Equity (beta-equivalent notional)	
10-year par yield	$18,288	CAC	$9,100,000

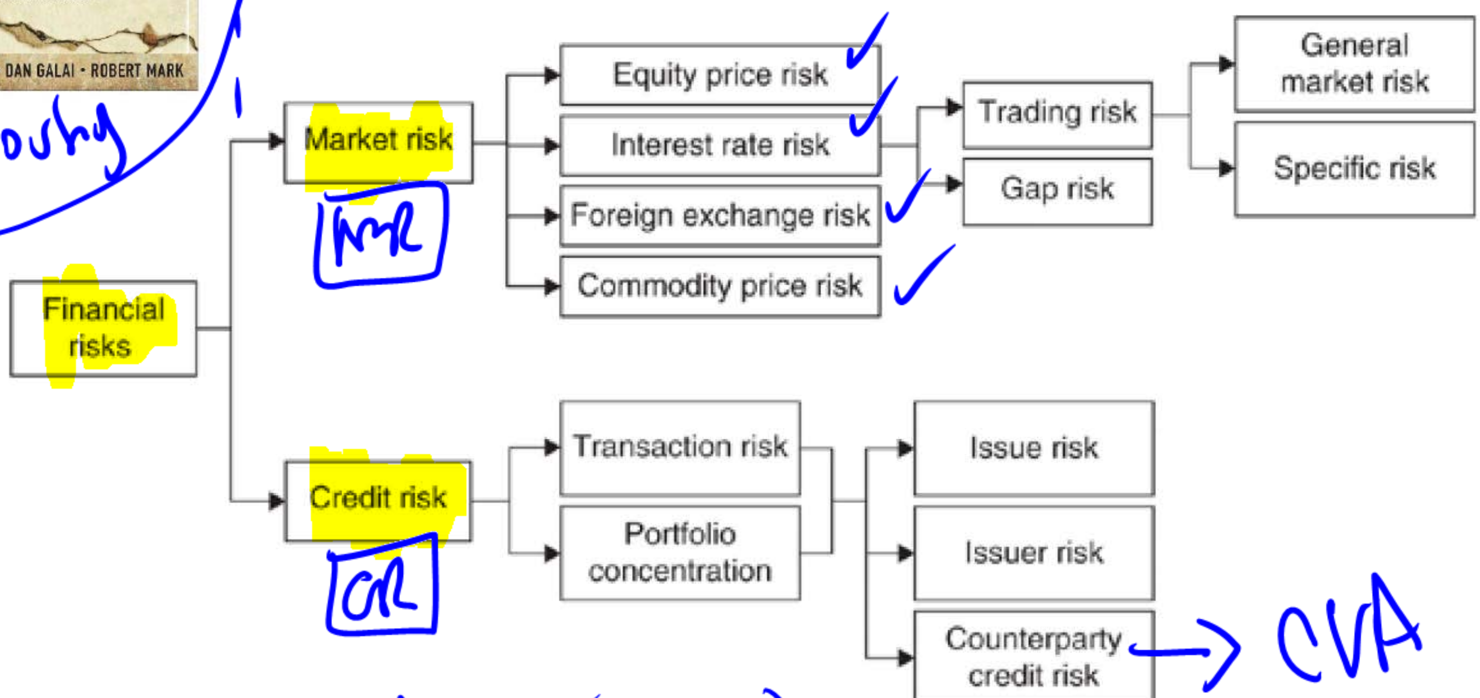
*after Coleman (2011)



Crouhy

TC = 8% ($\boxed{CR}$ + $\boxed{MR}$ + $\boxed{OP}$)

$\boxed{OR}$ { Basic: 5% ; Advanced: prob + Impact = E }



$\boxed{MR}$

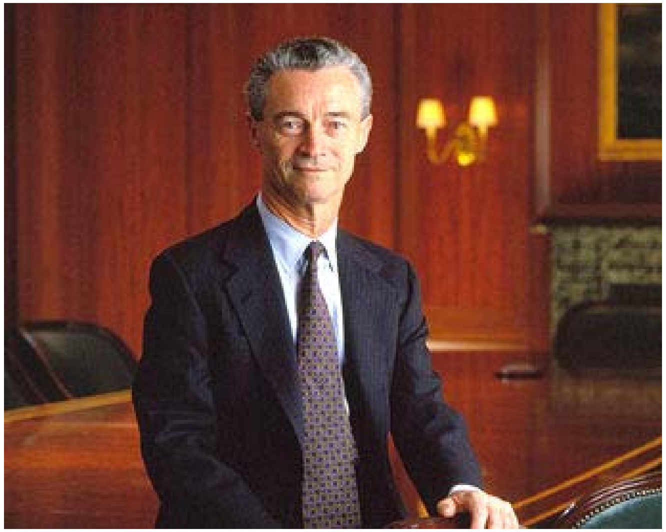
$\boxed{CR}$

→ CVA

→ liquidity (NSFR)

Value at Risk (VaR)

JP Morgan and "inventing VaR"

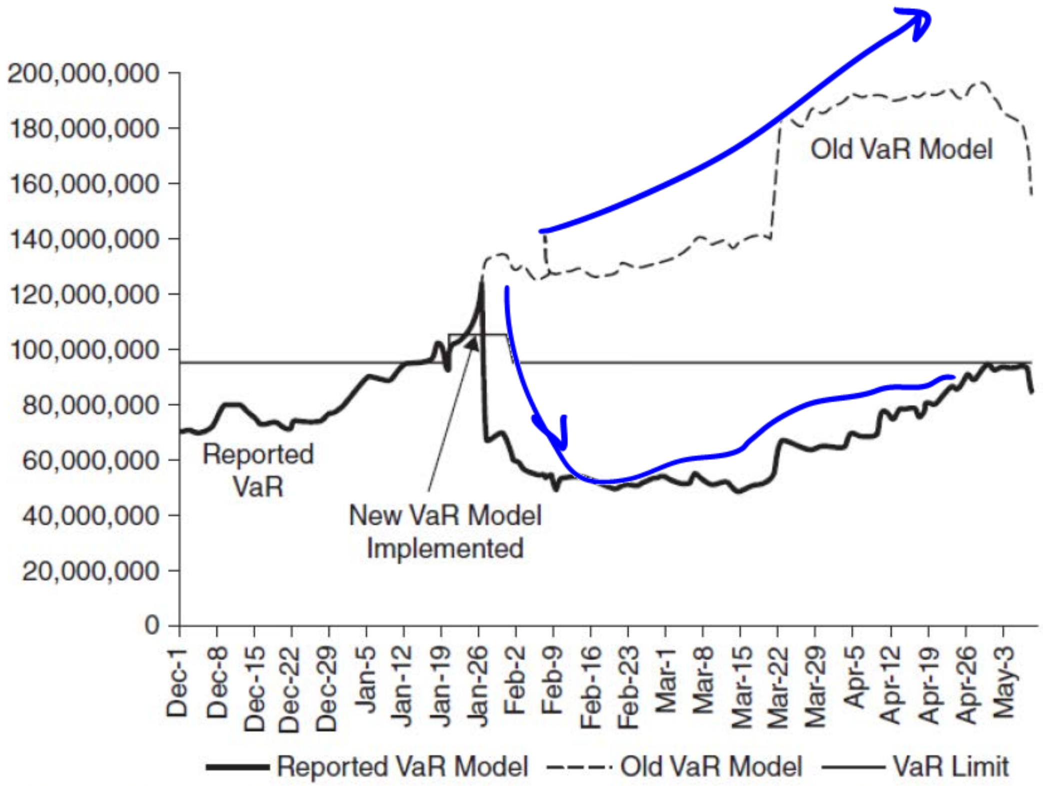


JPMorgan is credited wìth helping to make VaR a widely used measure. The Chairman, Sir Dennis Weatherstone was dissatisfied with the long-risk reports he received every day. These contained a huge amount of detail on the Greek letters for different exposures, but very little that was really useful to top management. He asked for something simpler that focused on the bank's total exposure over the next 24 hours measured across the bank's entìre trading portfolio.

At first his subordinates said this was impossible, but eventually they adapted the Markowìtz portfolio theory to develop a VaR report. This became known as the 4:15 report because it was placed on the chairman's desk at 4:15 pm every day after the close of trading.

John C. Hull, <u>Risk Management and Financial Institutions</u>, Wiley, 2012

JP Morgan and the "London Whale"



United States Senate Permanent Subcommittee on Investigations, *JP Morgan Chase Whale Trades: A Case History of Derivatives Risks and Abuses*, Hearing, March 15, 2013, Exhibits.

During the first half of 2012, JPMorgan Chase lost billions of dollars from exposure to a massive credit derivative portfolio.

The losses were the result of the so-called "London Whale" trades executed by traders in its London office. Initially dismissed by the bank's chief executive as a "tempest in a teapot," the trading losses quickly doubled and then tripled.

In contrast to JPMorgan Chase's reputation for best-in-class risk management, the whale trades exposed a bank culture in which risk limit breaches were routinely disregarded, risk metrics were frequently criticized or downplayed, and risk evaluation models were targeted by bank personnel seeking to produce artificially lower capital requirements."

THE WALL STREET JOURNAL.

MARKETS

'London Whale' Breaks Silence

Bruno Iksil says J.P. Morgan Chase made him a scapegoat

Updated Feb. 22, 2016 9:01 p.m. ET

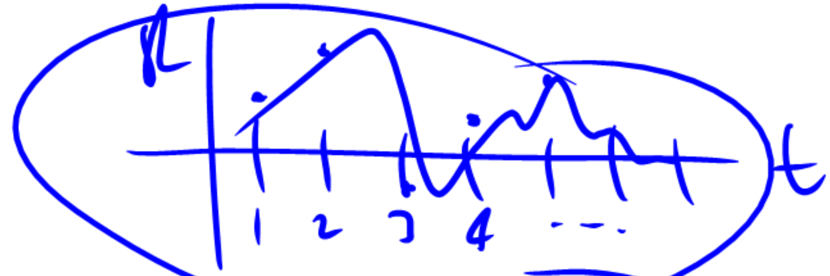
The trader at the center of the "London whale" trading debacle broke nearly four years of silence by taking aim at former employer J.P. Morgan Chase & Co., saying he was made a scapegoat for trades that were "initiated, approved, mandated and monitored" by senior management.

Bruno Iksil also said that he resents the London whale nickname, which was devised by rival traders to dramatize the size of J.P. Morgan's bets in corporate-debt markets.

In a single-spaced letter exceeding three pages and sent to publications including Financial News, Mr. Iksil contends the bank and the news media misrepresented his role in the 2012 episode, which led to more than $6 billion in losses for the nation's largest bank and a handful of personnel changes.

"For no good reason, I was singled out by the media," Mr. Iksil writes.

The losses represented a stain on the reputation of Chief Executive James Dimon, who originally dismissed the idea that the bank was at risk of big losses.



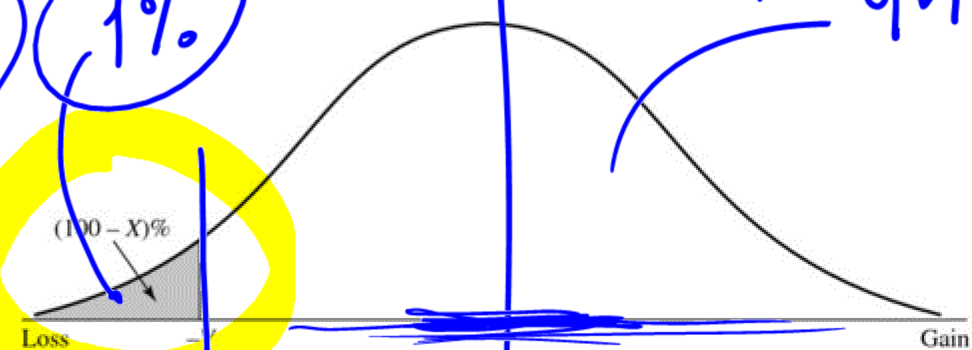
Definition: Value at Risk (VaR)

Value-at-risk (VaR) can be defined as the worst loss that might be expected from holding a security or portfolio over a given period of time (say one day, or 10 days for the purpose of regulatory capital reporting), given a specified level of probability (confidence level).

Bank
VaR (10d, 99%)

Example:
let's say that a position has a daily VaR of $10 million at the 99 percent confidence level, we mean that the realized daily losses from the position will on average be higher than $10 million on only one day in every 100 trading days (i.e., two to three days each year).

VaR (T, X)
VaR (1d, 99%)

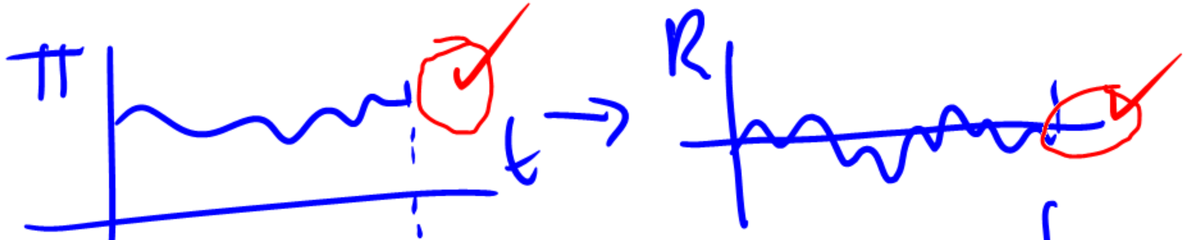


Interpretation of VaR

VaR is **not** the answer to the question: *How much can I lose on my portfolio over a given period of time?* The answer to this question is "everything," or any fraction value of the portfolio.

Instead, VaR offers a probability statement about the **potential change** in the value of a portfolio resulting from a **change in market factors** over a specified period of time.

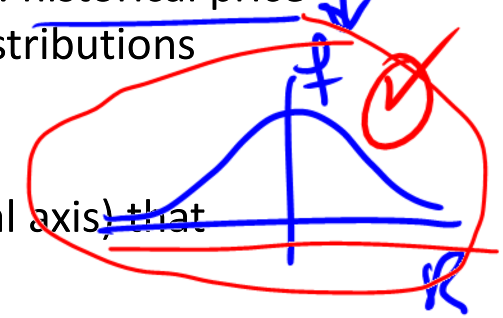
Crucially, the VaR measure also does not state by how much actual losses are likely to exceed the VaR figure; it simply states how likely (or unlikely) it is that the VaR measure will be exceeded.



Calculating VaR

First, derive the forward distribution of the returns on the portfolio, at the chosen horizon (in this case, one day).

This distribution can be derived using three different approaches: historical price distributions (nonparametric VaR); assumptions about normal distributions (parametric VaR); and Monte Carlo simulation.

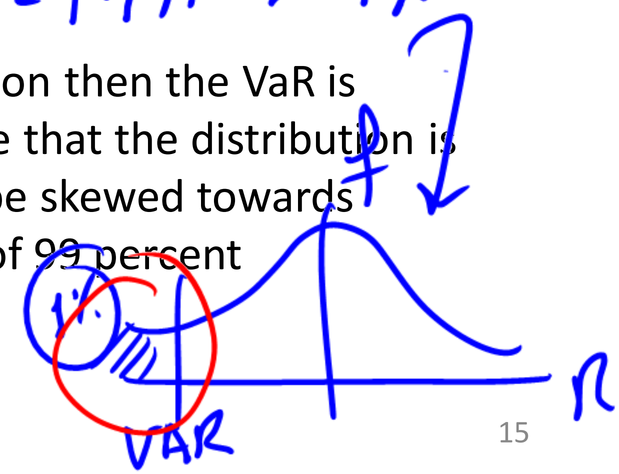


This distribution is then plotted to indicate how likely it is (vertical axis) that losses of a particular dollar value (horizontal axis) will occur.

Second, identify the required percentile of this distribution so that a particular loss number can be identified.

X=99% → 1%

By choosing the first percentile of the (empirical) distribution then the VaR is measured at the 99 percent confidence level. If we assume that the distribution is a normal, rather than an arbitrary distribution that could be skewed towards particularly light/heavy losses) then at a confidence level of 99 percent corresponds to a VaR of 2.33 standard deviations.



95% 9%

VaR(10d) = VaR(1d)·√10

From 1-Day VaR to 10-Day VaR

=

$$T\text{-day VaR} = 1\text{-day VaR} \times \sqrt{T}$$

VaR is often used to manage market risk over a 1-day time horizon. For this purpose, it's necessary to derive VaR from the daily distribution of the portfolio values.

4

$\sqrt{4}$

However, regulators have set a time horizon of 10 days for the purpose of VaR calculations that are used to report regulatory capital requirements. Ideally, this "10-day VaR" would be derived from a corresponding distribution of results over a 10-day horizon. This is problematic, however, as it implies that the time series of data used for the analysis must be much longer-indeed, 10 times longer-than that employed in any one-day VaR analysis.

As a result, many banks employ a work-around that allows them to derive an approximation of 10-day VaR from daily VaR data by multiplying the daily VaR by the square root of time (here, 10 days). The "square root of time" rule is endorsed by the regulators.

Methods for Estimating VaR

The Three VaR Methods:

First Method: analytic variance-covariance approach (aka parametric VaR)

Under the analytic variance-covariance approach or "delta normal" approach, we assume that the risk factors and the portfolio values are log-normally distributed or, equivalently, that their log returns (the log of the returns) are normally distributed.

Greeks -

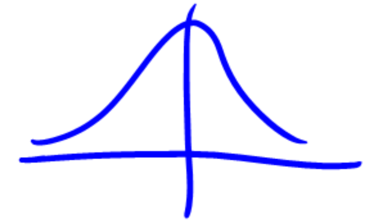
This makes the calculation much simpler, since the normal distribution is completely characterized by its first two moments, and the analyst can derive the mean and the variance of the portfolio return distribution from

(a) The multivariate distribution of the risk factors
(b) The composition of the portfolio

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

The Three VaR Methods:

Second Method: historical simulation (aka non-parametric VaR)



The historical simulation approach to VaR calculation is conceptually simple and does not oblige the user to make any assumptions about the distribution. However, at least two or three years of historical data are necessary to produce meaningful results. Three steps are involved:

(1) Select a sample of actual daily risk factor changes over a given period of time, say 500 days (i.e., two years' worth of trading days), using the same period of time for all the factors.

(2) Apply those daily changes to the current value of the risk factors, revaluing the current portfolio as many times as the number of days in the historical sample. Sum these changes across all positions, keeping the days synchronized.

(3) Construct the histogram of portfolio values and identify the VaR that isolates the first percentile of the distribution in the left¬hand tail (assuming VaR is derived at the 99 percent confidence level).

Advantages

Historical

The major attraction of historical simulation is that the method is completely **nonparametric** (i.e., we don't need to worry about setting pa-rameters) and does not depend on any assumptions about the distribution of the risk factors.

The nonparametric nature of historical simulation also obviates the need to estimate **volatilities and correlations**. Historical volatilities and correlations are already reflected in the data set, so all we need to calculate are the synchronous risk-factor returns over a given historical period.

Historical simulation has also no problem accommodating **fat tails in distributions**, since the historical returns already reflect actual synchronous moves in the market across all risk factors.

Disadvantages

The main drawback of historical simulation is its **complete dependence** on a particular set of historical data.

The underlying assumption is that the past, as captured in this historical data set, is a **reliable representation of the future**.

The Three VaR Methods:
Third Method: Monte Carlo Simulation

Consists of repeatedly simulating the random processes that govern market prices and rates. Each simulation (scenario) generates a possible value for the portfolio at the target horizon (e.g., 10 days). It involves three steps:

(a) Specify all the relevant riskfactors, their stochastic processes and parameter estimates
(b) Construct price paths. Price paths are constructed using random numbers produced and advancing one step at a time (daily) the numerical solution to the stochastic processes
(c) Value the portfolio for each path (scenario).

The process is repeated a large number of times, say 10,000 times, to generate the distribution, at the risk horizon, of the portfolio return. VaR at the 99 percent confidence level is then simply derived as the distance to the mean of the first percentile of the distribution, as for our other calculation methods.

Advantages

It can accommodate any distribution of risk factors to allow for fat-tailed distributions, where extreme events are expected to occur more commonly than in normal distributions, and "jumps" or discontinuities in price processes.

Monte Carlo simulation, like historical simulation, allows the analyst to calculate the confidence interval of VaR

Monte Carlo simulation permits to carry out sensitivity analyses by changing the market parameters used in the analysis, such as the term structure of interest rates.

Disadvantages

Good estimates the parameters of the distributions, such as the means, the variances, and the covariances are required.

A major limitation is the amount of computer resources it requires, especially for large complex portfolios.

Expected Shortfall

FRTB (Basel III) conditional VaR

Expected Shortfall (ES)

Expected Shortfall also sometimes referred to as conditional value at risk, conditional tail expectation, or expected tail loss.

Whereas VaR asks the question: "How bad can things get?" expected shortfall asks: **"If things do get bad, what is the expected loss?"**

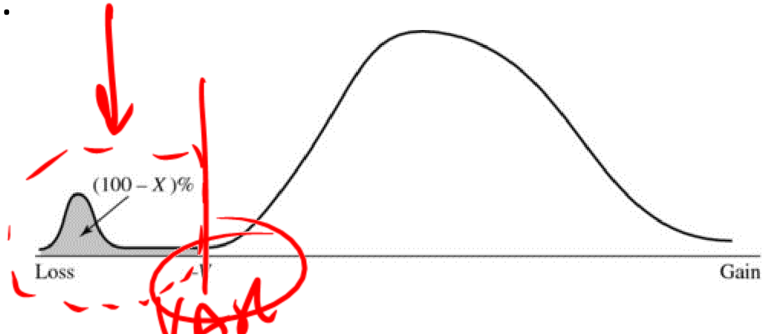
Expected shortfall, like VaR, is a function of two parameters: T (the time horizon) and X (the confidence level).

It is the expected loss during time T conditional on the loss being greater than the Xth percentile of the loss distribution.

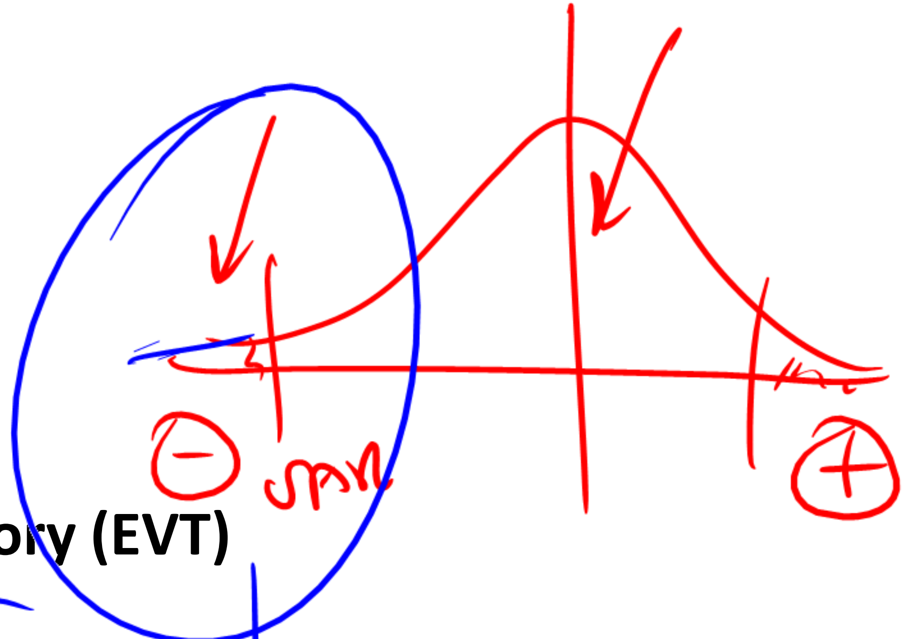
Example: suppose that X=99, T is 10 days, and the VaR is $64 million. The expected shortfall is the average amount lost over a 10-day period assuming that the loss is greater than $64 million.

ES

$$ES = \mu + \sigma \frac{e^{-Y^2/2}}{\sqrt{2\pi}(1-X)}$$



Extreme Value Theory (EVT)



asymptotic

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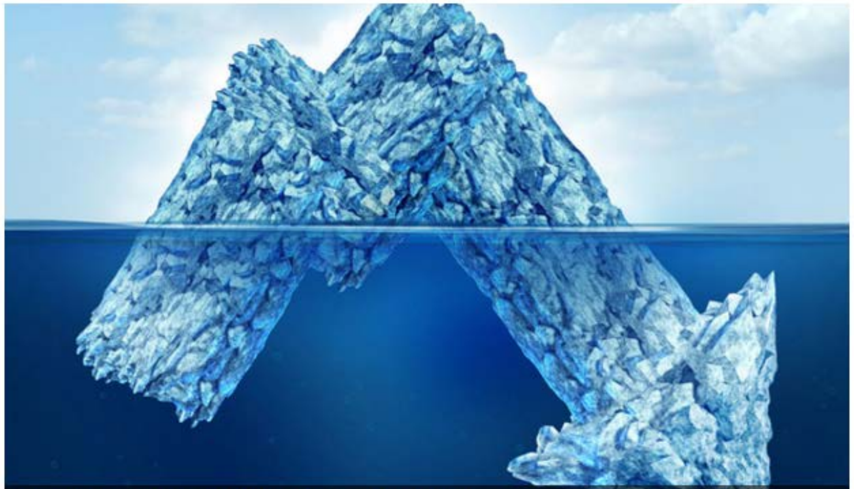
RISK MANAGEMENT

Extreme value theory has hidden risks, research finds

Method for calculating capital based on sparse data can lead to additional model risk

Alexander Campbell

14 January 2016



Risks of extreme value theory have been hidden until now

Extreme value theory (EVT) has been hailed as a solution to the problem of calculating capital requirements based on sparse data about tail risks. But academics in Regensburg and Sydney have discovered that the use of EVT may in fact involve more model risk than traditional methods

Extreme value theory (EVT)

EVT can be viewed as an extension of the central limit theorem, which states that the average of independent random variables tends to the normal distribution, irrespective of the original distribution. This deals with the mean, or center, of the distribution.

For risk management purposes, the tails of the distribution are of interest. The EVT theorem says that the limit distribution for values x beyond a cutoff point u belongs to the family below where y=(x-u)/P. To simplify, we defined the loss x as a positive number so that y is also positive.

The distribution is characterized (a) a scale parameter, and (b) a shape parameter that determines the speed at which the tail disappears.

$$F(y) = 1 - (1 + \xi y)^{-1/\xi}, \ \xi \neq 0$$
$$F(y) = 1 - exp(-y), \ \xi = 0$$

Extreme value theory (EVT)

VaR, as well as CVaR, can be derived in closed-form solution from the analytical distribution of EVT.

This requires estimation of the tail parameter and of the dispersion parameter.

This can be performed using a variety of statistical approaches. One method is maximum likelihood. First, we define a cutoff point u. This needs to be chosen so that there are a sufficient number of observations in the tail. However, the theory is most valid far into the tail. A good, ad hoc, choice is to choose u so as to include 5% of the data in the tail. For example, if we have T = 1,000 observations, we would consider only the 50 in the left tail. Second, we consider only losses beyond u and then maximize the likelihood of the observations over the two parameters.

VaR Laboratory: General Electric


LED


2015
2015

NEW YORK STOCK EXCHANGE

GENERAL ELECTRIC COMPANY (NYSE:GE)

QUOTE COMPANY INFORMATION NEWS SEC FILINGS OPTIONS

QUOTE

General Electric Co

LAST PRICE	DAY CHANGE		BID	BID SIZE	ASK	ASK SIZE
29.14	-0.26 | -0.88%		29.13	20	29.20	4
MON FEB 29, 2016 04:00 PM | USD | DELAYED Closed			HIGH	LOW	VOLUME	PREV CLOSE
			29.55	29.12	33.56mil	29.40
OPEN	52WK LOW	52W L (DATE)	52WK HIGH	52W H (DATE)	MKT CAP	
29.44	19.37	08-24-2015	31.49	12-31-2015	297.21 bil	

PRICE CHART

COMPARE INDICATORS DISPLAY

Mar 01, 2006 - Feb 26, 2016 Daily 1 D 5 D 1 Mth 3 Mth YTD 1 Yr 3 Yr 5 Yr 10 Yr Max

Mar 01, 2006 - Feb 26, 2016 ● GE

▶ Share this chart | Export data to file

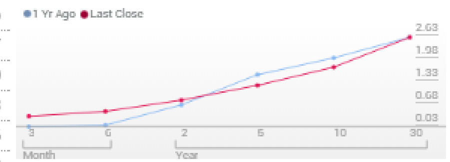
INDICES

INDEX	VALUE	CHANGE $ (%)
NYSE Composite	$9,559.53	-$60.25 (-0.62%)
NYSE U.S. 100 Index	$7,849.17	-$75.04 (-0.94%)
Dow Jones	$16,516.50	-$123.47 (-0.74%)
S&P 500	$1,932.23	-$15.81 (-0.81%)

As of 9:31 PM EST, February 29, 2016

TREASURY YIELDS

MATURITY	%YIELD
6 Month	0.47
2 Years	0.80
5 Years	1.23
10 Years	1.76
30 Years	2.63

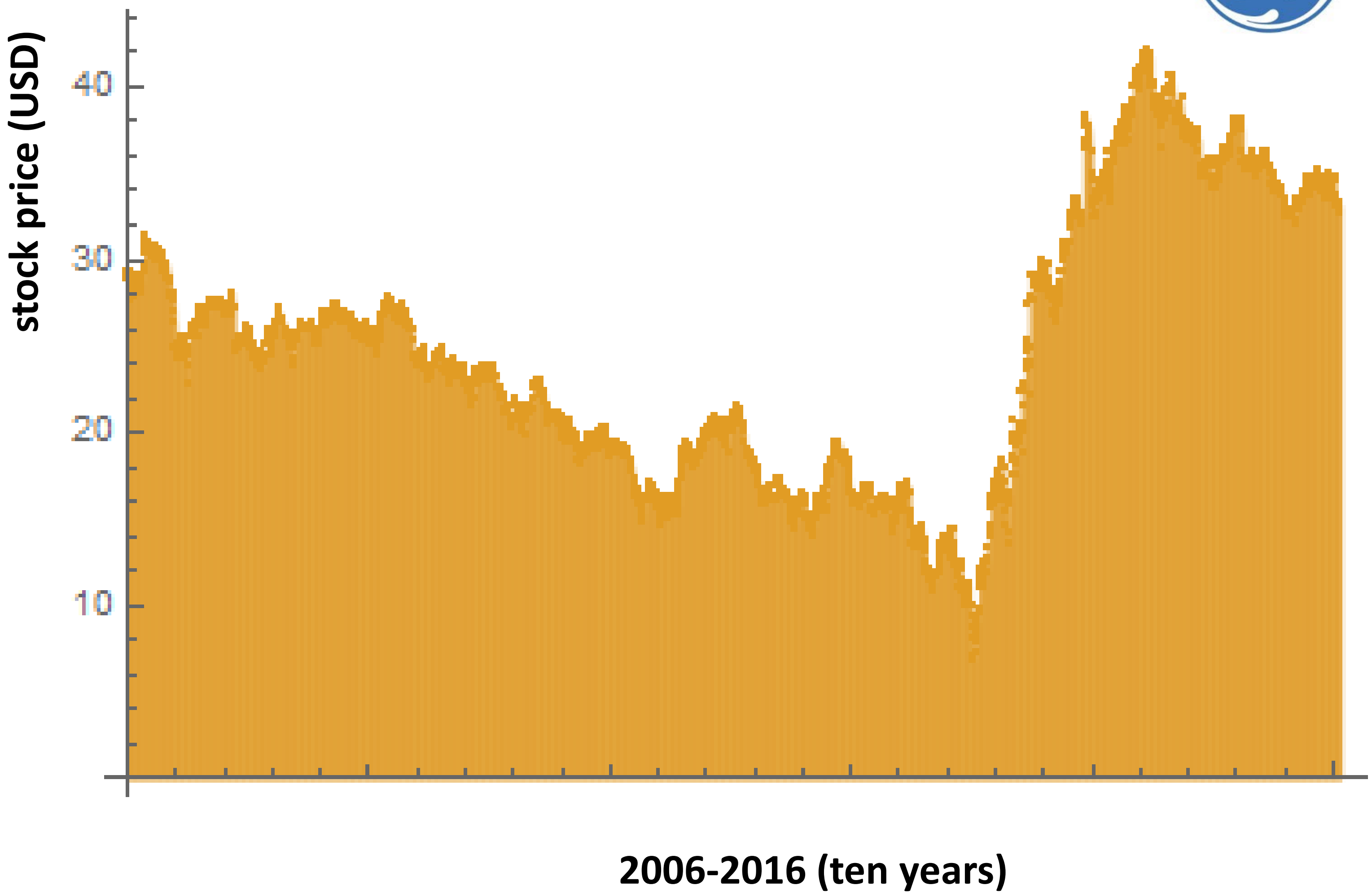


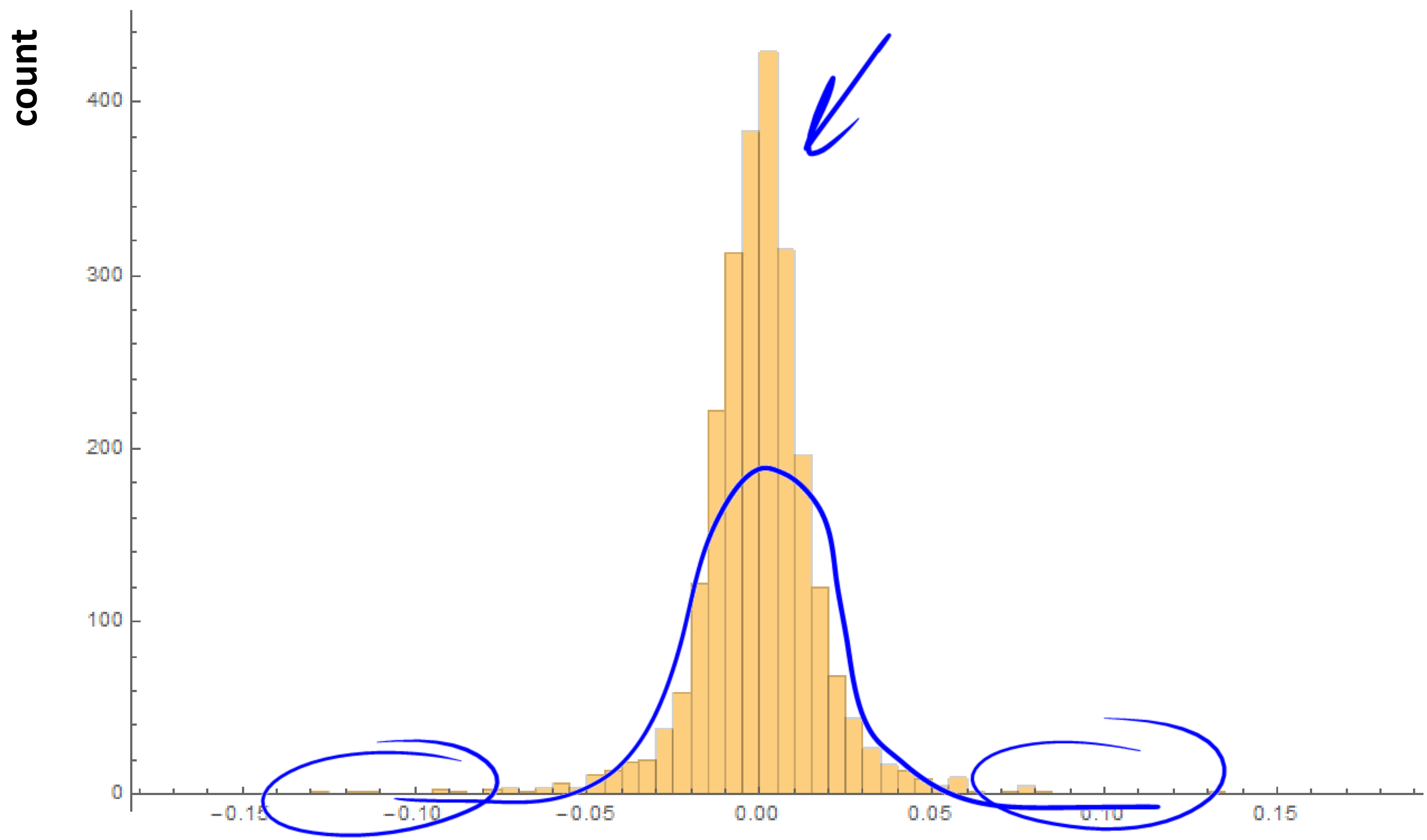
Data as of last close

COMMODITIES

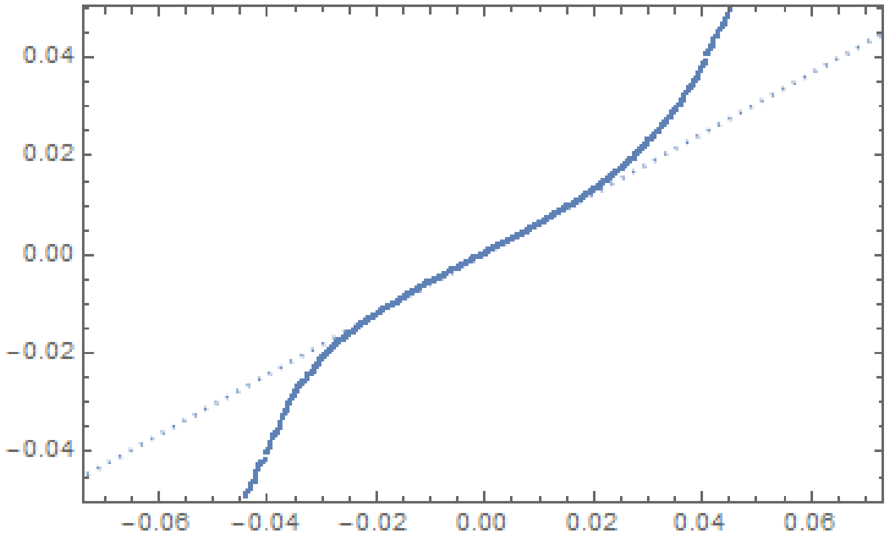
COMMODITY	EXPIRY	VALUE	CHANGE $ (%)
NYSE Liffe Gold	Apr 16	$1,234.00	-$0.40 -0.03%
ICE Brent Crude	Mar 16	$36.69	+$0.11 +0.32%
UK Natural Gas	Mar 16	$29.31	-$0.03 -0.10%

CQF

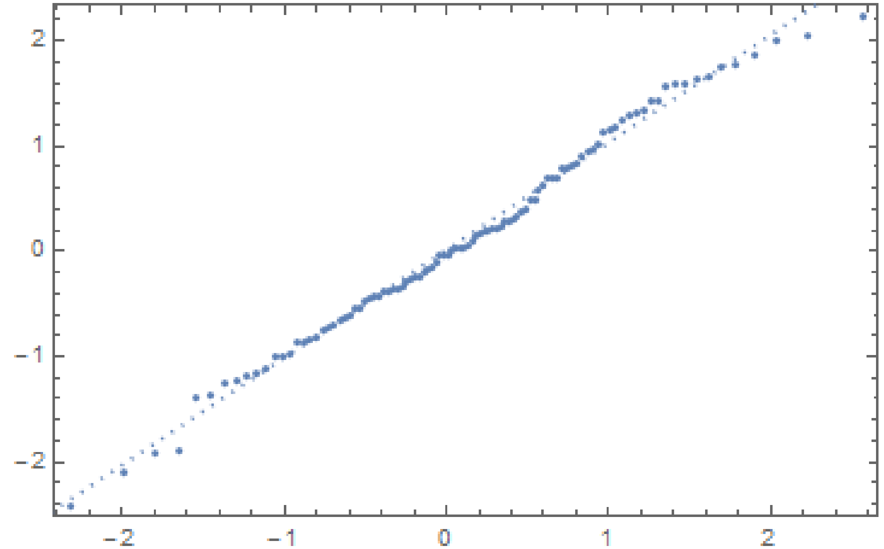




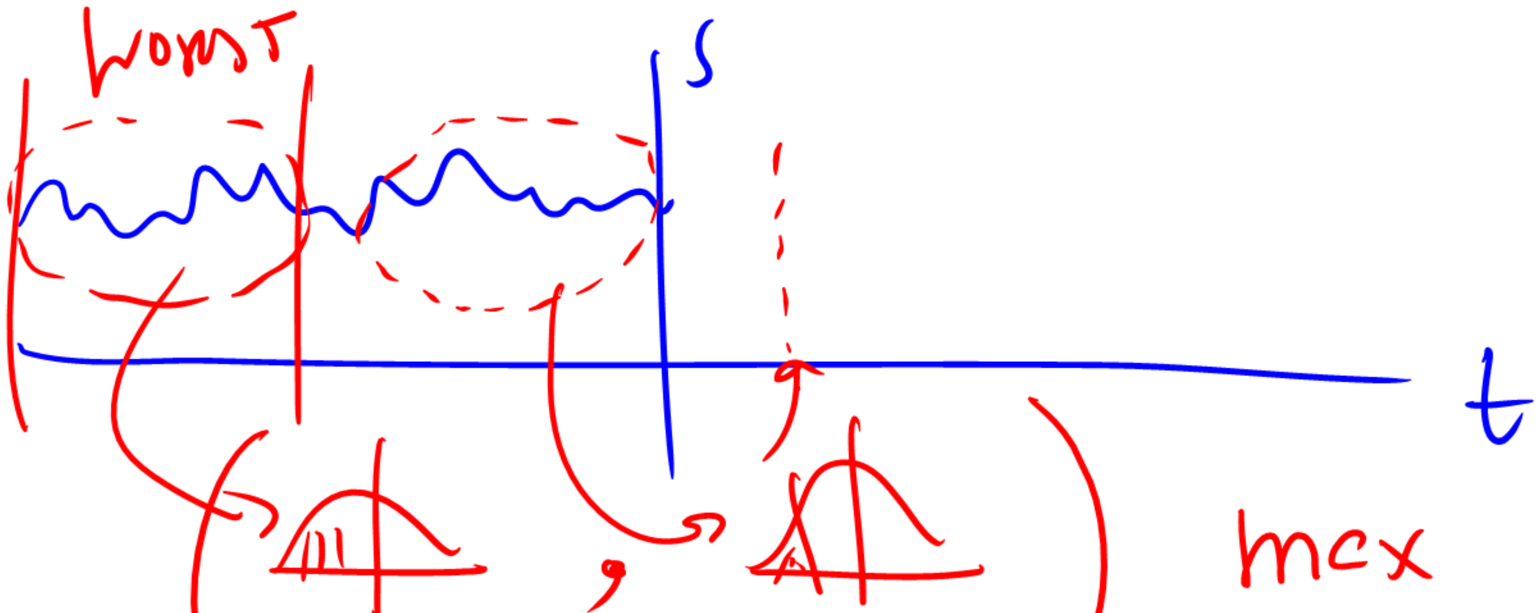
Arithmetic return



QQ plot (GE)



QQ plot (normal deviates)



max

Case Study: Stressed VAR

Basel 2.5

Cap charge.

Stressed VAR (sVAR)

In January 2009, the Basel Committee for Banking Supervision (BCBS) proposed supplementing the current VaR-based trading book framework with, among other measures, an incremental risk capital charge (IRC), which includes default risk as well as migration risk for unsecuritised credit products and a stressed value-at-risk requirement.

As observed losses in banks' trading books during the financial crisis have been significantly higher than the minimum capital requirements under the Pillar 1 market risk rules, the BCBS proposed to enhance the framework through requiring banks to calculate, in addition to the current VaR, a stressed VaR taking into account a one-year observation period relating to significant losses. The additional stressed VaR requirement is expected to help reduce the pro-cyclicality of the minimum capital requirements for market risk.

The amendments to the Capital Requirements Directive by Directive 2010/76/EU (CRD III) relating to Stressed VaR in the trading book are a direct translation of the proposals from Basel. The European Banking Authority is requested to monitor the range of practices in this area and to provide guidelines on Stressed VaR models.

European Banking Authority (EBA) Consultation Paper on the Draft Guidelines on Stressed Value At Risk (Stressed VaR)
(CP 48) November 2011

EUROPEAN BANKING AUTHORITY

https://www.eba.europa.eu/documents/10180/37853/EBA-BS-2011-166r-(CP48-on-GL-Stressed-VaR)-FINAL.pdf

Guidelines

The objectives of the guidelines on Stressed VaR are to determine:

A) Length of the stressed period

The requirement set out in the CRD is that the historical data used to calibrate the Stressed VaR measure have to cover a continuous 12-month period.

B) The approach for identifying the appropriate historical period

Guidelines

1. In order to choose a historical period for calibration purposes institutions shall formulate a methodology for identifying a stressed period relevant to their current portfolios, based on **one of the following two ways**:

i. judgement-based approaches; or
ii. formulaic approaches.

Guidelines

2. A **judgement-based approach** is one that does not use a detailed quantitative analysis to identify the precise period to use for calibration, but rather relies on a higher level analysis of the risks inherent in an institution’s current portfolio and past periods of stress related to those risk factors.

This judgement-based approach shall include quantitative elements of analysis.

Guidelines

3. A **formulaic approach** instead applies, in addition to expert judgement, a more systematic quantitative analysis to identify the historical period representing a significant stress for an institution's current portfolio. This more systematic approach could be employed in a number of ways, for example:

Guidelines

i. A **risk-factor based approach**: an institution ~~identifies a restricted~~ number of risk factors which are considered to be a relevant proxy for the movement in value of its portfolio.

The historical data for these risk factors can then be fully analysed to identify the most stressed period (through either identification of the period of highest volatility of the risk factors, or the inferred period that would for example produce the highest VaR measure) in the historical data window.

Guidelines

ii. **A VaR based approach**: the historical period is identified by running either the full VaR engine or an approximation over a historical period to identify the 12-month period which produces the highest resulting measure for the current portfolio.

Guidelines

4. While either approach can be used by institutions, the **use of the formulaic approach, where possible, shall be preferred** for the identification of the historical period. This approach shall be employed to determine a historical period that would provide a conservative capital outcome rather than just selecting the period of highest volatility.

Guidelines

5. Institutions **may also combine both approaches** to limit the computational burden of the formulaic approach, by using the judgement-based approach to restrict the historical data periods to be considered in the formulaic approach.

Guidelines

6. Irrespective of the approach used, institutions must **provide evidence that the stressed period is relevant for their current portfolio** and that they have considered a range of potential historical periods in their analyses.

The institutions also have to prove that the **portfolio on which the identification of the stressed periods is based is representative of the institutions' current portfolio**, e.g. by applying the approach to identify the stressed period to other typical or previous portfolios.

Guidelines

7. In all cases **no weighting of historical data shall be applied** when determining the relevant historical period or when calibrating the Stressed VaR model, as the weighting of data in a stressed period would not result in a true reflection of the potential stressed losses that could occur for an institution's portfolio.

Guidelines

$+\varepsilon \quad -\varepsilon$

8. Finally, institutions could consider the use of **antithetic data** when calibrating the Stressed VaR model. This would be particularly relevant between two regular reviews of the stressed period in the case of a dynamic portfolio.