Risk Management

Financial Markets, Day 4, Class 2

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Outline

- Why Risk Management?
- Market Risk Measurement.
- Regulatory Requirements.

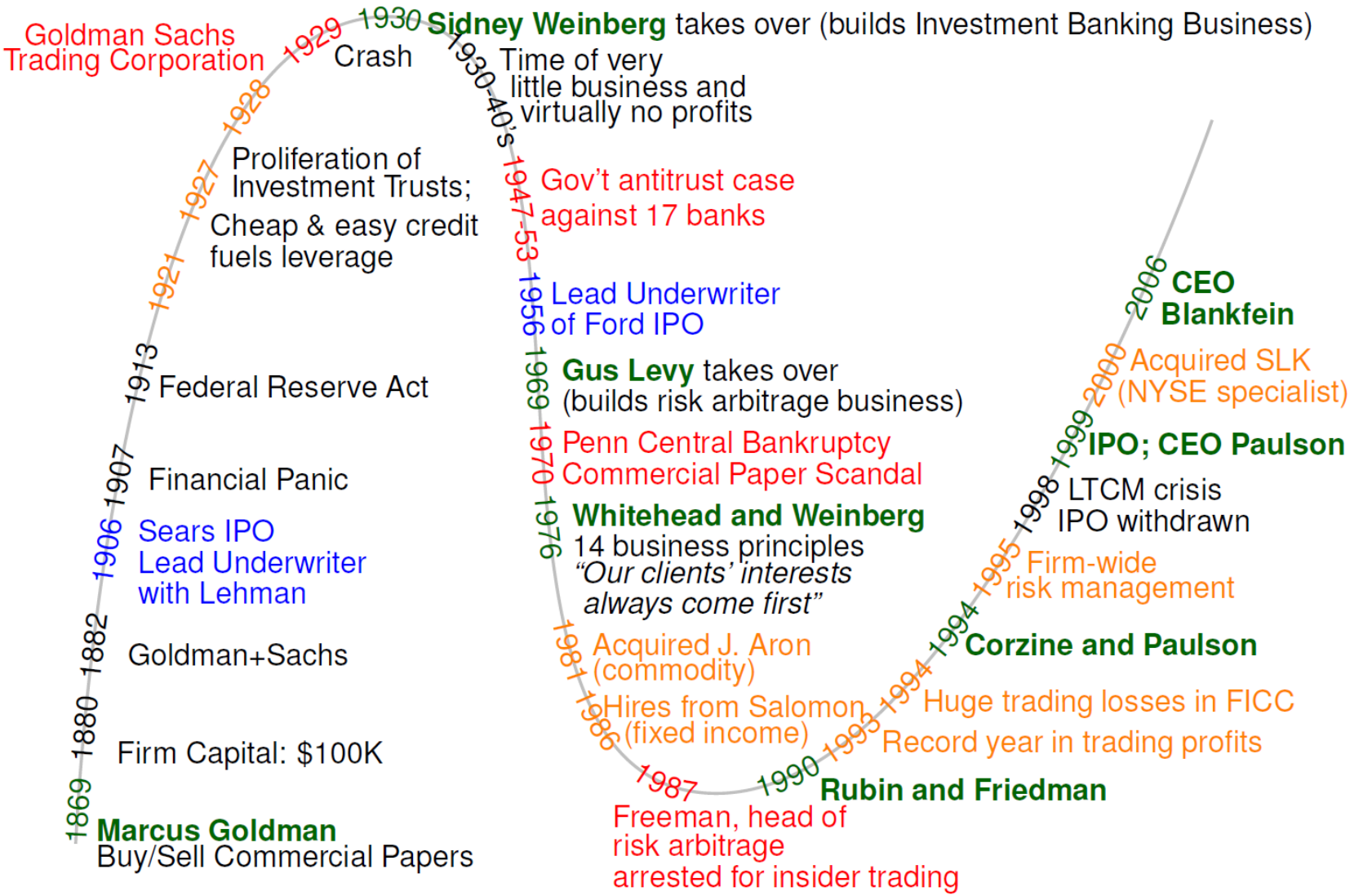
The Economics of Risk Management

- In perfect capital markets, adding or subtracting financial risk has no impact on the market value of a publicly traded corporation or on the welfare of its shareholders.
- Capital markets are not perfect. Market imperfections underlie significant benefits to bearing and controlling financial risks.
- Capital — a Scarce Resource:
  - If new capital could be obtained in perfect financial markets, we would expect a financial firm to raise capital as necessary to avoid the costs of financial distress.
  - In such a setting, purely financial risk would have a relatively small impact, and risk management would likewise be less important.
  - In practice, however, capital is a scarce resource, especially when it is most needed.

The Leverage of Financial Firms

- Compared with other types of corporations, financial firms have relatively liquid balance sheets, made up largely of financial positions.
- This relative liquidity allows a typical financial firm to operate with a high degree of leverage.
- For example, major broker-dealers regulated by SEC frequently have a level of accounting capital that is close to the regulatory minimum of 8% of accounting assets, implying a leverage ratio on the order of 12-to-1.
- Ironically, in light of the relatively high degree of liquidity that fosters high leverage, a significant and sudden financial loss (or reduced access to credit) can cause dramatic illiquidity effects.

The Evolution of an Investment Bank



Assets (Goldman Sachs)

in millions USD	2014	2010	2008	2007
Cash and cash equivalents	57,600	39,788	15,740	10,282
Cash and securities for regulatory and other purposes	51,716	53,731	106,664	119,939
Collateralized agreements:				
Repo Lending and federal funds sold	127,938	188,355	122,021	87,317
Securities borrowed	160,722	166,306	180,795	277,413
Receivables:				
Brokers, dealers and clearing organizations	30,671	10,437	25,899	19,078
Customers and counterparties	63,808	67,703	64,665	129,105
Loans receivable	28,938			
Financial instruments owned	312,248	356,953	328,325	452,595
Other assets	22,599	28,059	30,438	24,067
Total assets	**856,240**	**911,332**	**884,547**	**1,119,796**

Liabilities and Shareholders' Equity (Goldman Sachs)

in millions	2014	2010	2008	2007
Deposits	83,008	38,569	27,643	15,370
Collateralized financings				
Repo financing	88,215	162,345	62,883	159,178
Securities loaned	5,570	11,212	17,060	28,624
Other	22,809	38,377	38,683	65,710
Payables:				
Brokers, dealers and clearing organizations	6,636	3,234	8,585	8,335
Customers and counterparties	206,936	187,270	245,258	310,118
Financial instruments sold short	132,083	140,717	175,972	215,023
Unsecured short-term borrowings	44,540	47,842	52,658	71,557
Unsecured long-term borrowings	167,571	174,399	168,220	164,174
Other liabilities and accrued expenses	16,075	30,011	23,216	38,907
Total liabilities	**773,443**	**833,976**	**820,178**	**1,076,996**
Total shareholders' equity	**82,797**	**77,356**	**64,369**	**42,800**

Assets-to-Equity and Financing (Goldman Sachs)

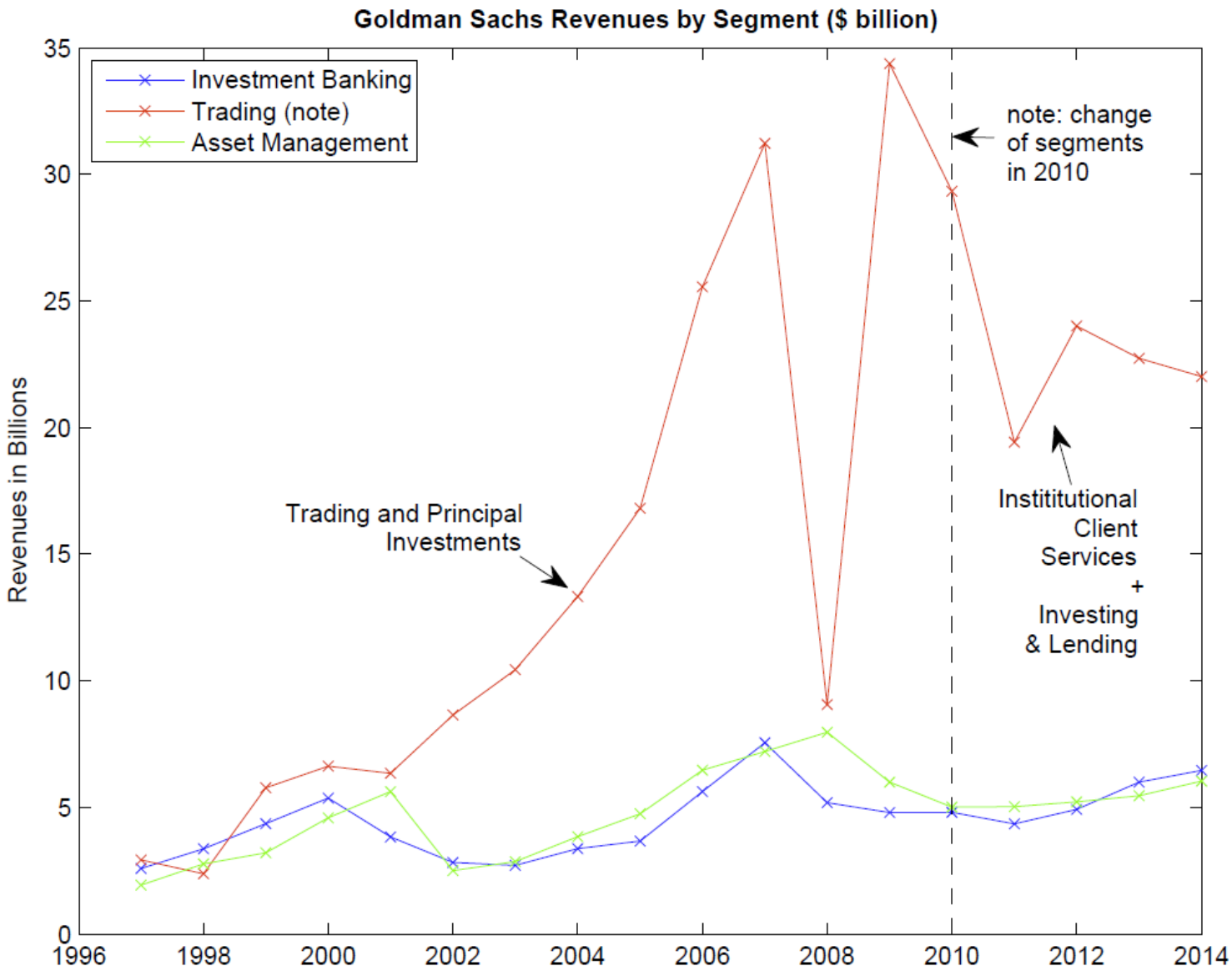
	2014	2010	2008	2007
assets ($m)	856,240	911,332	884,547	1,119,796
equity ($m)	82,797	77,356	64,369	42,800
assets-to-equity ratio	10.3x	11.8x	13.7x	26.2x
total liabilities ($m)	773,443	833,976	820,178	1,076,996
long-term borrowings ($m)	167,571	174,399	168,220	164,174
other long-term financings ($m)	7,249	13,848	17,460	33,300
% long-term financing	22.60%	22.57%	22.64%	18.34%
unsecured short-term ($m)	44,540	47,842	52,658	71,557
% unsecured short-term	5.76%	5.74%	6.42%	6.64%
Repo financing ($m)	88,215	162,345	62,883	159,178
% Repo financing	11.41%	19.47%	7.66%	14.78%

Financial Instruments, Long and Short Positions

from Goldman Sachs 2014 10-K form:

$ in millions	As of December 2014	
	Financial Instruments Owned	Financial Instruments Sold, But Not Yet Purchased
Commercial paper, certificates of deposit, time deposits and other money market instruments	$ 3,654	$ —
U.S. government and federal agency obligations	48,002	12,762
Non-U.S. government and agency obligations	37,059	20,500
Mortgage and other asset-backed loans and securities:		
Loans and securities backed by commercial real estate	6,582 [1]	1
Loans and securities backed by residential real estate	11,717 [2]	—
Bank loans and bridge loans	15,613	464 [4]
Corporate debt securities	21,603	5,800
State and municipal obligations	1,203	—
Other debt obligations	3,257 [3]	2
Equities and convertible debentures	96,442	28,314
Commodities	3,846	1,224
Subtotal	248,978	69,067
Derivatives	63,270	63,016
Total	$312,248	$132,083

Revenues by Segment



Key Risk Categories Faced by Financial Institutions:

- Market Risk (*from Goldman Sachs 2010 10-K form*):
  - Interest rate risk: changes in level, slope and curvature of yield curves, the volatilities of interest rates, mortgage prepayment speeds and credit spreads.
  - Equity price risk: changes in prices and volatilities of individual equities, baskets of equities and equity indices.
  - Currency rate risk: changes in spot prices, forward prices and volatilities of currency rates.
  - Commodity price risk: changes in spot prices, forward prices and volatilities of commodities, such as electricity, natural gas, crude oil, petroleum products, and precious and base metals.

Key Risk Categories Faced by Financial Institutions:

- Counterparty Credit Risk: failure of counterparties to fulfill their contractual duties (default losses); losses in the market value of a position due to counterparty downgrades.
- Liquidity Risk: the risk of increased costs, or inability to adjust financial positions (for example through widening of spreads), or of lost access to credit.
- Operational Risk: fraud, systems failures, trading errors (such as deal mis-pricing).
- Systemic Risk: breakdown in market-wide liquidity, chain-reaction default.

Capital-at-Risk or Value-at-Risk

- For a typical broker-dealer or proprietary trading operation, the larger economic consequences of market risk are felt over relatively short time horizons; often a few weeks, if not days.
- Discussions between regulators and their constituent financial institutions have resulted in a widely applied measure of market risk called "capital-at-risk" or "value-at-risk."
- Fixing a confidence level p (such as 99% or 95%) and a time horizon (such as two weeks or one day), the VAR of a given portfolio measures the loss in market value that is exceeded with probability 1-p.
- A typical reporting of VAR would be the following statement: *"There is a 5% chance the bank will lose more than $5 million over the next trading week."* p=95%, horizon = one week, and VAR=$5 million.

Details of VAR Calculation

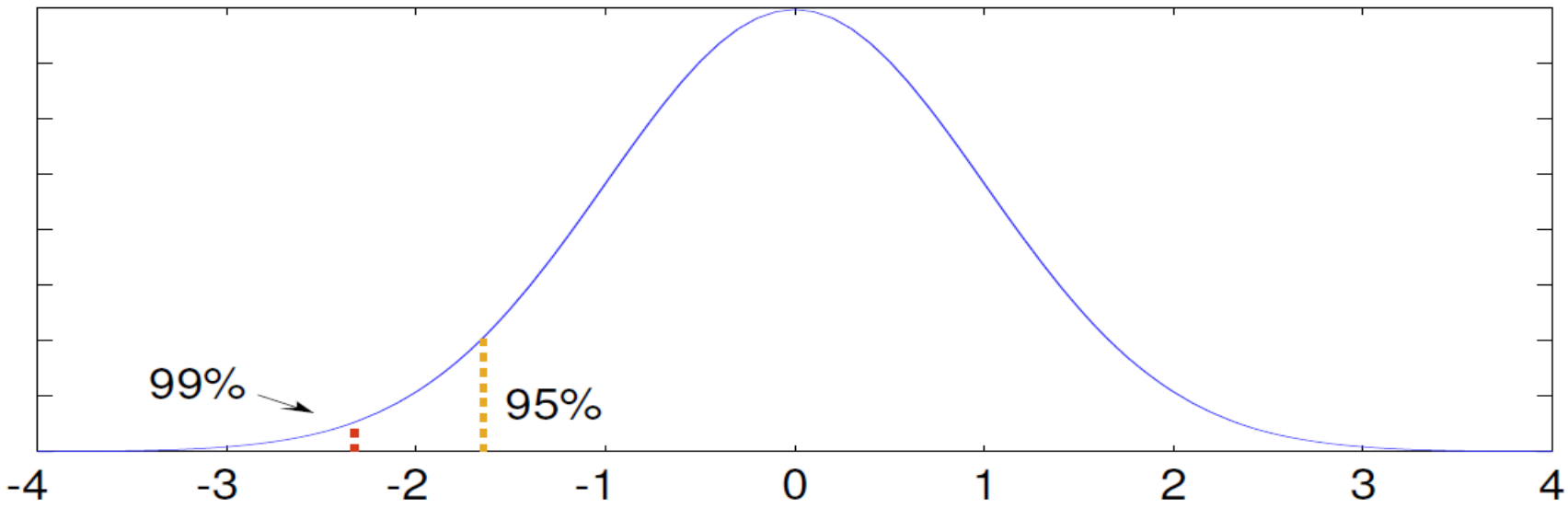
- Consider a portfolio consisting entirely of the S&P 500 index. The current market value of the portfolio is \$100 million.
- Using the historical return data available up to day t, the EWMA model gives us a volatility forecast σ_{t+1} for the next day.
- Over this one-day horizon, the value of the portfolio will be

$$\$100\,\text{M} \times (1 + \tilde{R}_{t+1})$$

  where the volatility forecast for $\tilde{R}_{t+1}$ is σ_{t+1}. As discussed earlier, the mean of $\tilde{R}_{t+1}$ is negligible for the one-day horizon.
- We are interested in knowing the *distribution*, particularly the *tail distribution* of the portfolio value over the next day.

Assuming Normal Distribution

- The 99% confidence level and the 1% worse-case scenario: a -2.326 σ move away from the mean. The 95% confidence level: -1.645 σ.



- The loss in portfolio value associated with the 5% worst-case scenario:

$$\$100\text{M} \times 1.645 \times \sigma_{t+1}$$

- For daily returns on the S&P 500 index, $\sigma \approx 1\%$: VaR=\$1.645M.

Calculating Volatility for a Portfolio

- Suppose that our portfolio has two important risk factors, whose daily returns are R^A and R^B, respectively.
- Performing risk mapping using individual positions, the portfolio weights on these two risk factors are w_A and w_B.
- Let's focus only on the risky part of our portfolio and leave out the cash part. So let's normalize the weights so that $w^A + w^B = 1$. Let's assume our risk portfolio has a market value of \$100 million today.
- We apply EWMA to get time-series of their volatility estimates σ_t^A and σ_t^B, and correlation estimates ρ_t^{AB}. And our portfolio volatility is

$$\sigma_t^2 = w_A^2 \times (\sigma_t^A)^2 + w_B^2 \times (\sigma_t^B)^2 + 2 \times w_A \times w_B \times \rho_t^{AB} \times \sigma_t^A \times \sigma_t^B$$

- It is in fact easier to do this calculation using matrix operations, especially when you have to deal with hundreds of risk factors.

Variance-Covariance Matrix

- Suppose there are N risk factors. Using daily data up to day t, we have

$$\Sigma_{t+1} = \begin{pmatrix} (\sigma_1)^2 & \rho_{12}\sigma_1\sigma_2 & \rho_{13}\sigma_1\sigma_3 & \cdots & \rho_{1N}\sigma_1\sigma_N \\ \rho_{21}\sigma_2\sigma_1 & (\sigma_2)^2 & \rho_{23}\sigma_2\sigma_3 & \cdots & \rho_{2N}\sigma_2\sigma_N \\ \rho_{31}\sigma_3\sigma_1 & \rho_{32}\sigma_3\sigma_2 & (\sigma_3)^2 & \cdots & \rho_{3N}\sigma_3\sigma_N \\ & & & \cdots & \\ \rho_{N1}\sigma_N\sigma_1 & \rho_{N2}\sigma_N\sigma_2 & \rho_{N3}\sigma_N\sigma_3 & \cdots & (\sigma_N)^2 \end{pmatrix}$$

- It is an $N \times N$ matrix. A risk manager deals with this type of matrices everyday and the dimension of the matrix can easily be more than 100, given the institution's portfolio holdings and risk exposures.
- In JPMorgan's RiskMetrics, 480 risk factors were used in 1996. In Goldman's annual report, 70,000 risk factors were mentioned.

Portfolio Volatility

- Mapping individual positions in the firm's portfolio into positions on the risk factors, we get the portfolio weights in the risk-factor space:

$$W_t = \begin{pmatrix} w_1 \\ w_2 \\ w_3 \\ \dots \\ w_N \end{pmatrix},$$

- Then the portfolio volatility is

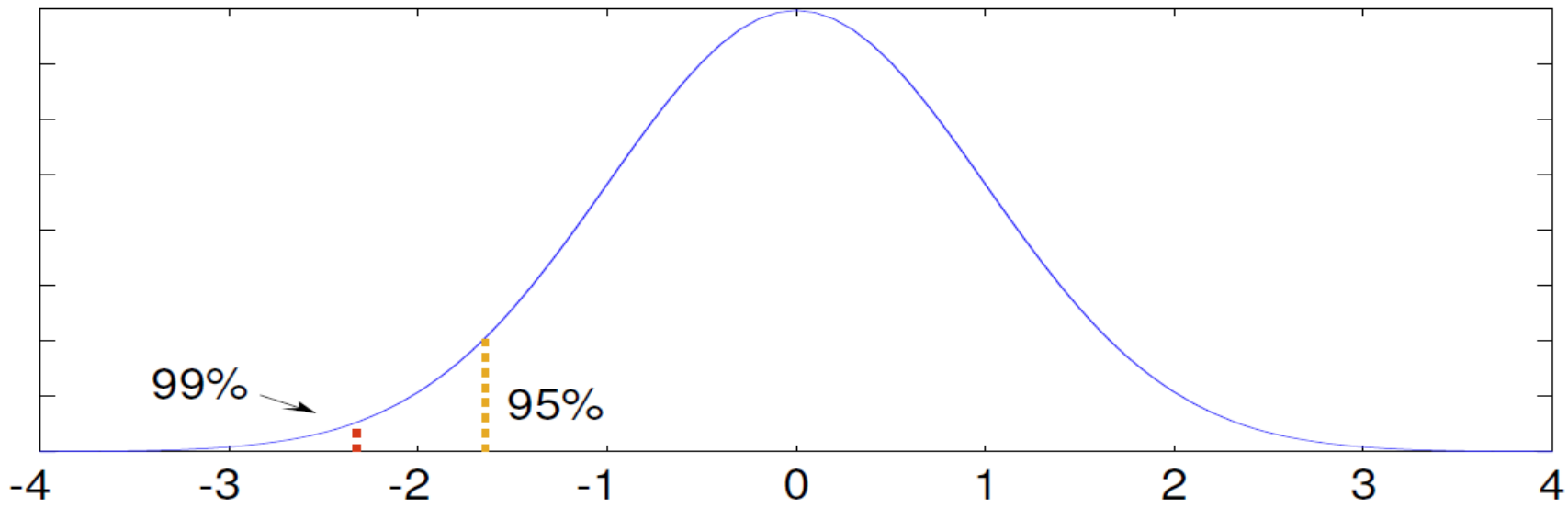
$$\sigma^2_{t+1} = W'_t \times \Sigma_{t+1} \times W_t$$

which involves using mmult and transpose in Excel.

Portfolio VaR

Let σ be the daily volatility estimate of the portfolio. The 95% one-day VaR:

$$\text{VaR} = \text{portfolio value} \times 1.645 \times \sigma$$



Goldman Sachs, Financial Instruments and Average Daily VaR

Financial Instruments (Goldman Sachs)

in millions	2014	2010	2008	2007
Long	312,248	356,953	328,325	452,595
Short	132,083	140,717	175,972	215,023
Long - Short ($m)	180,165	216,236	152,353	237,572

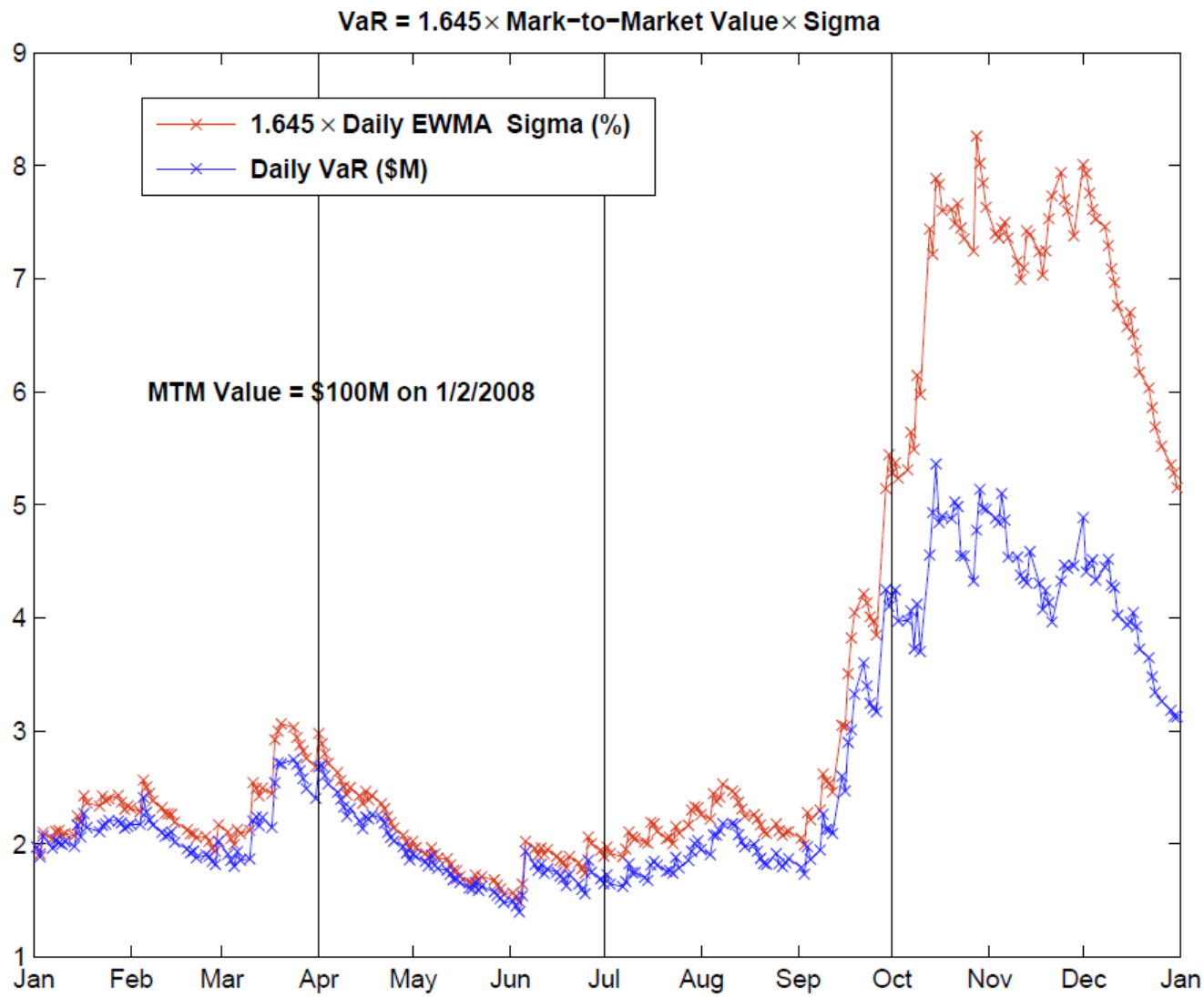
Average Daily VaR (Goldman Sachs)

in millions	2014	2010	2008	2007
Total	72	134	180	138
Interest Rates	51	93	142	85
Equity Prices	26	68	72	100
Currency Rates	19	32	30	23
Commodity Prices	21	33	44	26

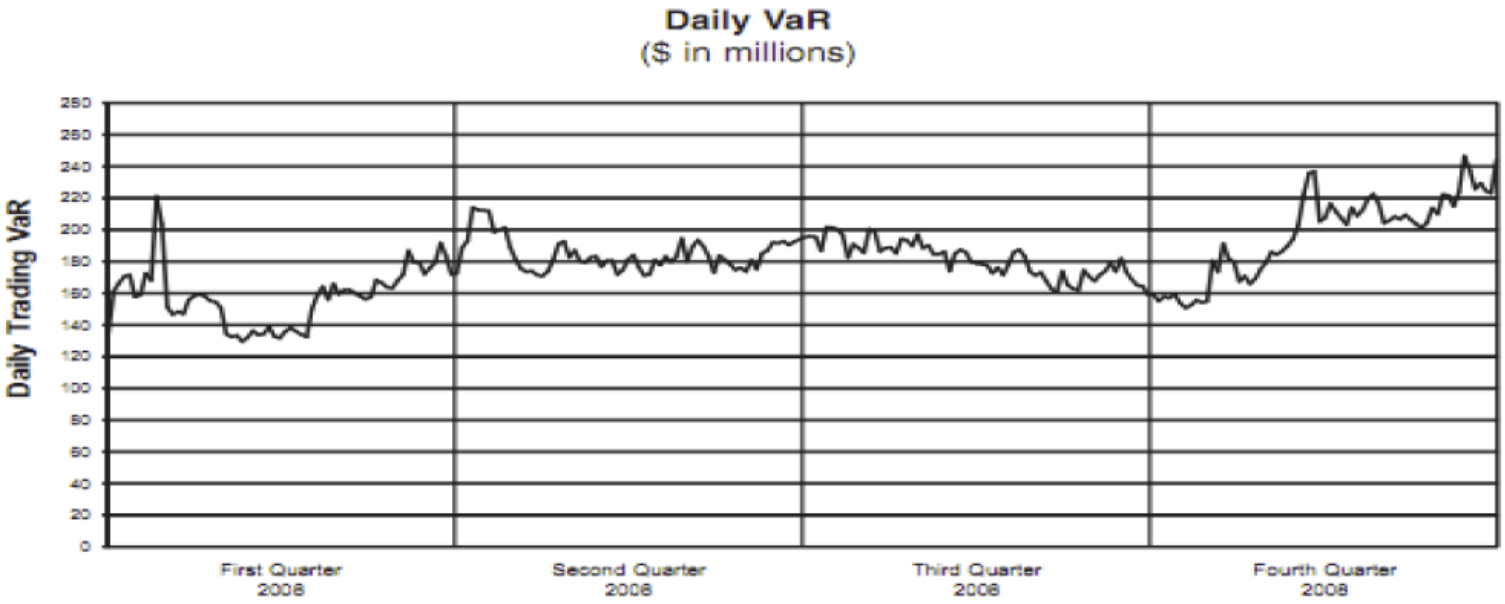
September 15, 2008

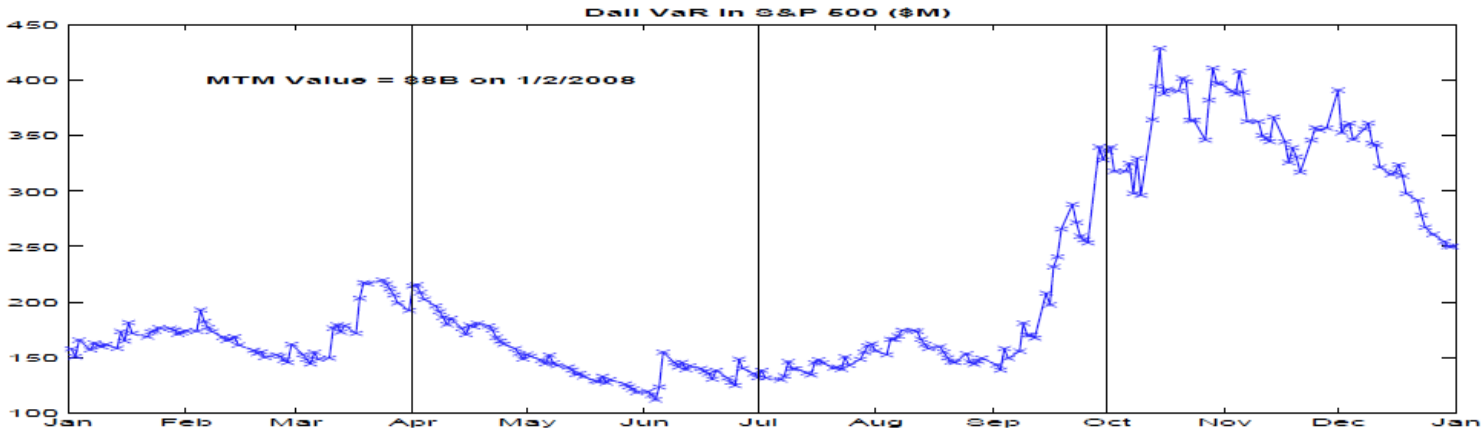
- On September 12, 2008, the Friday before Lehman's bankruptcy filing, our EWMA σ_{t+1} was estimated to be 1.4959%. It's higher than the historical average of 1%, but not alarmingly so.
- It implies a one-day 95% VAR of \$2.46M. In other words, *there is a 5% chance that the portfolio will lose more than \$2.46 million dollars over the next day.*
- The next business day was September 15, 2008 and the S&P 500 index returned -4.71%. This portfolio would lose \$4.71 million.
- In this case, σ_{t+1} failed to capture the large event in advance, which is really to be expected given how σ is calculated: using historical data.
- What about the forward-looking VIX? On September 12, 2008, VIX was at 25.66%, translating to a one-day sigma of $25.66\%/\sqrt{252}$=1.6164%. Slightly higher than the EWMA estimate, but not by much.

Daily VaR vs. Daily Sigma

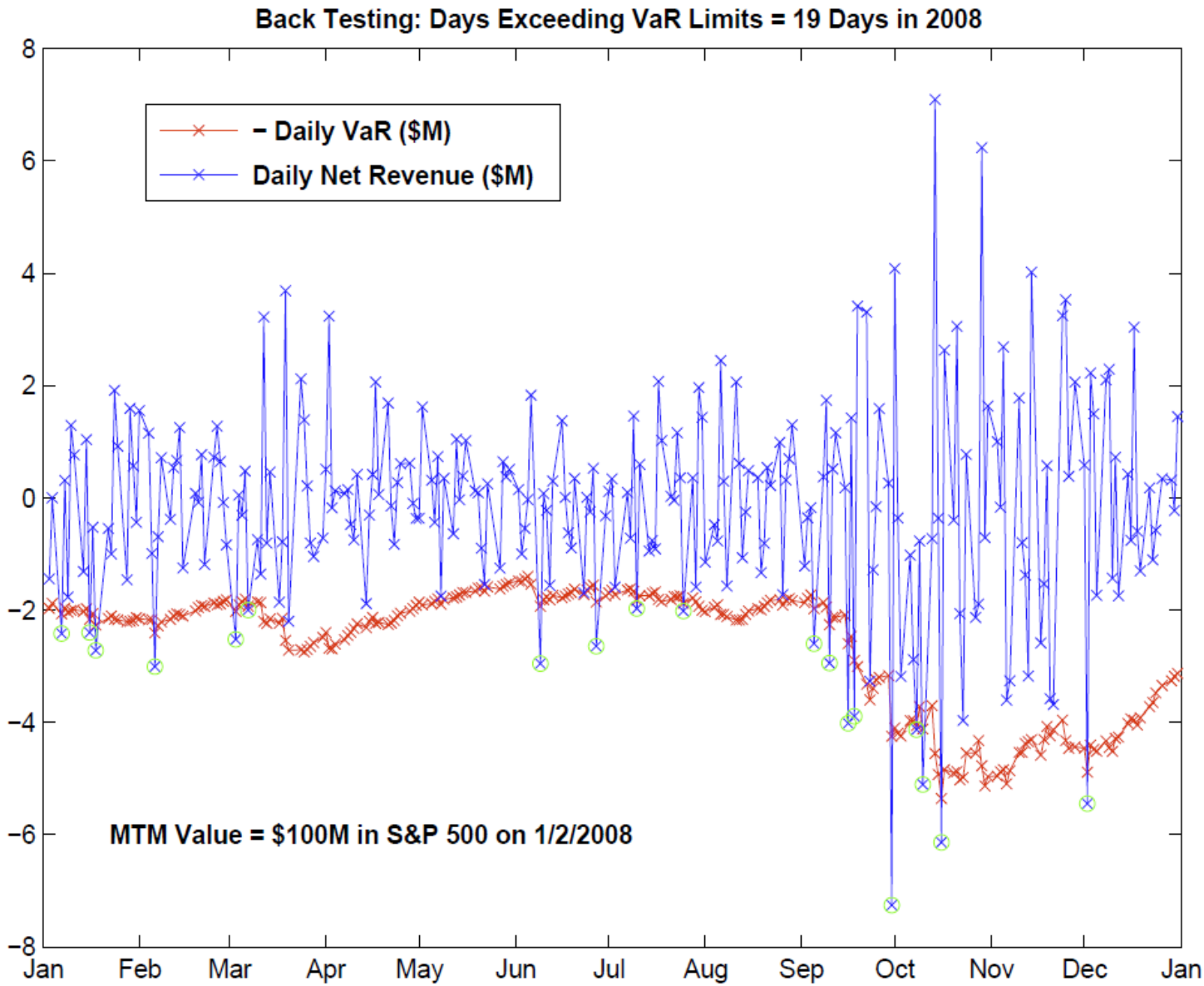


Daily VaR in 2008, Goldman Sachs vs. $8B in S&P 500

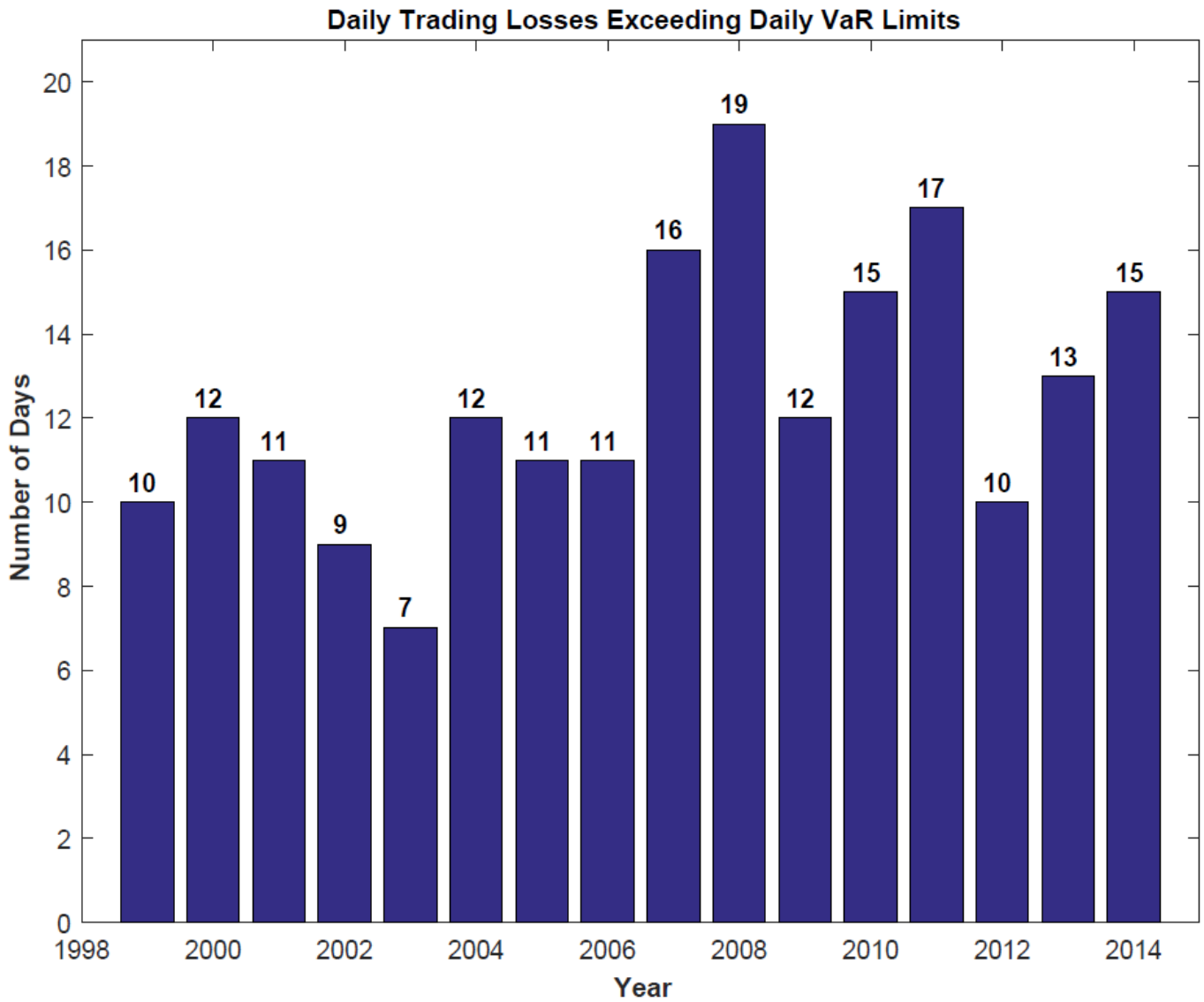




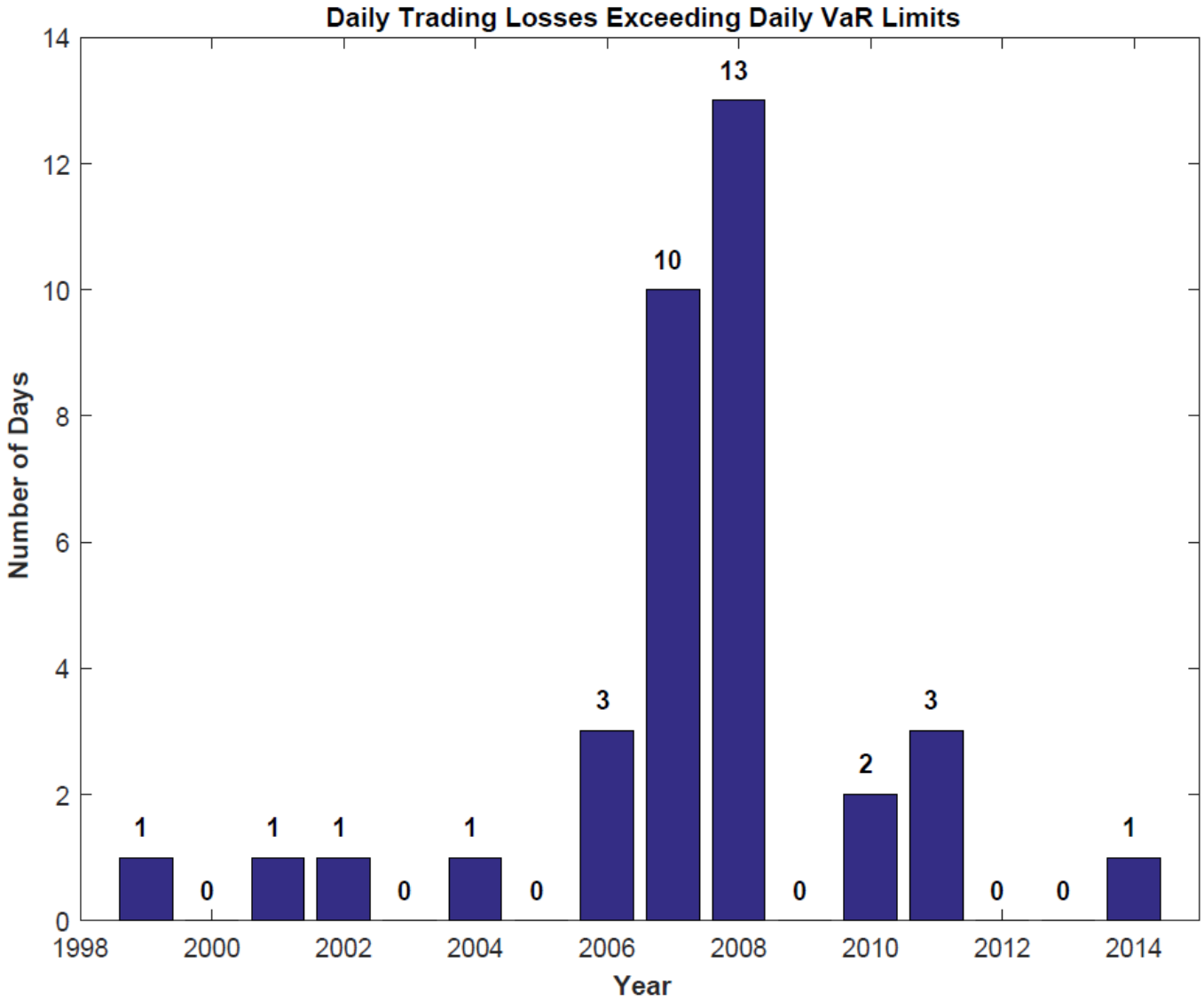
A Portfolio of $100M in S&P 500 on 1/2/2008



Daily Trading Losses Exceeding VaR: S&P 500



Daily Trading Losses Exceeding VaR: Goldman Sachs



Views on VaR

Excerpts from "Risk Mismanagement"

- *"VaR is a useful tool. The more liquid the asset, the better the tool. The more history, the better the tool. The less of both, the worse it is. It helps you understand what you should expect to happen on a daily basis in an environment that is roughly the same." — David Viniar, CFO, Goldman.*
- *"VaR is a peacetime statistic" — Aaron Brown, Risk Manager, AQR*
- *"Relatively useless as a risk-management tool and potentially catastrophic when its use creates a false sense of security among senior managers and watchdogs. This is like an air bag that works all the time, except when you have a car accident."* — David Einhorn, Greenlight Capital.

Gaming the VaR by Stuffing Risk into the Tails

(Excerpts from "Risk Mismanagement")

- To motivate managers, the banks compensate them not just for making big profits but also for making profits with low risks.
- At various levels in the firm, VaR measures are also used to help set risk limits for trading, market making, and investing activities.
- Some managers manipulate the VaR by loading up on "asymmetric risk positions."
- These are products that generate small gains and very rarely have losses. But when they do have losses, they are huge.
- These positions make a manager's VaR look good because those rare losses are outside of the 99% probability. So it does not show up in the VaR number.

VaR as an Internal Monitoring of Risk Exposures

- By now, VAR has become an industry standard to measure market risk.
- SEC requires firms to include a quantitative disclosure of market risks in their financial statements and VaR becomes the main tool for doing so.
- Risk managers use VaR to quantify their firm's risk positions to their board. Top executives usually know their firm's daily VaR within minutes of the market's close (the 415 report at JPMorgan).
- This timely aggregation of individual traders' risk into firmwide risk could be an extremely valuable signal for the top management, if they know how to use it (e.g., the story of Goldman Sachs in December 2006).

VaR as a Guideline for Capital Adequacy

- For investment banks, the calculations of VAR are made not for the purpose of deciding the overall level of capital that the firm must hold, but rather as a benchmark for relative judgments.
- The Basel Committee on Banking Supervision went even further to validate VaR by saying that firms and banks could rely on their own internal VaR calculations to set their capital requirements.
- So as long as their VaR was reasonably low, the amount of money they had to set aside to cover risks that might go bad could also be low.
- But VaR captures only one aspect of market risk, and is too narrowly defined to be used on its own as a sufficient measure of capital adequacy. Not surprisingly, the BIS guidelines for risk capital based on VaR have been heavily criticized.

Stress Test: Responses to "Core Shocks"

- In addition to calculating VaR, a prudent risk manager would stress test his portfolio to see the responses of his portfolio to specific "core shocks."
- These include, for example, parallel yield curve shifts of 100 basis points, up and down, steepening and flattening of the yield curves (2yr - 10yr) by 25 basis points, increase and decrease in swap spreads by 20 basis points, and other scenarios.
- For the equity market, important core shocks include large movements in the aggregate index (e.g., S&P 500) and sudden large increases in index volatility (e.g., the VIX index).

Regulatory Requirements

- Capital Adequacy:
  - Risk weighted assets
  - Regulatory capital and capital ratios
- Liquidity Adequacy (on-going):
  - Leverage Coverage Ratio (LCR): high-quality highly-liquid assets to meet liquidity needs.
  - Net Stable Funding Ratio (NSFR): long-term financing must exceed long-term commitments.

Risk Weighted Assets (Goldman):

$ in millions	As of December 2014 Basel III Advanced	Standardized
Credit RWAs		
Derivatives	**$122,501**	**$180,771**
Commitments, guarantees and loans	**95,209**	**89,783**
Securities financing transactions [1]	**15,618**	**92,116**
Equity investments	**40,146**	**38,526**
Other [2]	**54,470**	**71,499**
Total Credit RWAs	**327,944**	**472,695**
Market RWAs		
Regulatory VaR	**10,238**	**10,238**
Stressed VaR	**29,625**	**29,625**
Incremental risk	**16,950**	**16,950**
Comprehensive risk	**8,150**	**9,855**
Specific risk	**79,918**	**79,853**
Total Market RWAs	**144,881**	**146,521**
Total Operational RWAs	**97,488**	**—**
Total RWAs	**$570,313**	**$619,216**

1. Represents resale and repurchase agreements and securities borrowed and loaned transactions.

2. Includes receivables, other assets, and cash and cash equivalents.

Regulatory Capital (Goldman):

$ in millions	As of December 2014
Common shareholders' equity	$ 73,597
Deductions for goodwill and identifiable intangible assets, net of deferred tax liabilities	(2,787)
Deductions for investments in nonconsolidated financial institutions	(953)
Other adjustments	(27)
Common Equity Tier 1	69,830
Perpetual non-cumulative preferred stock	9,200
Junior subordinated debt issued to trusts	660
Other adjustments	(1,257)
Tier 1 capital	78,433
Qualifying subordinated debt	11,894
Junior subordinated debt issued to trusts	660
Other adjustments	(9)
Tier 2 capital [1]	12,545
Total capital	$ 90,978

Minimum Capital Ratios and Capital Buffers:

	December 2014 Minimum Ratio [1]	January 2015 Minimum Ratio [1]	January 2019 Minimum Ratio
CET1 ratio	4.0%	4.5%	8.5% [4]
Tier 1 capital ratio	5.5%	6.0%	10.0% [4]
Total capital ratio	8.0% [3]	8.0% [3]	12.0% [4]
Tier 1 leverage ratio [2]	4.0%	4.0%	4.0%