Global Financial Systems
Chapter 3
Endogenous Risk

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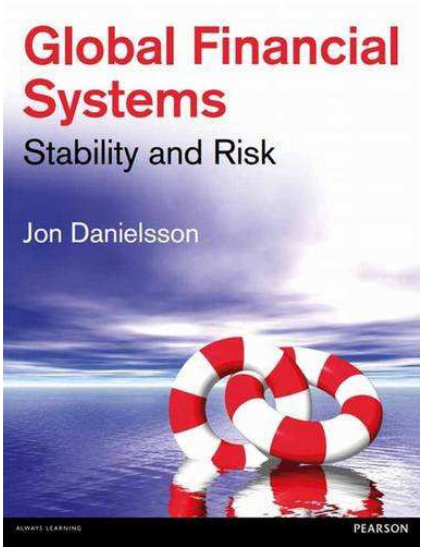
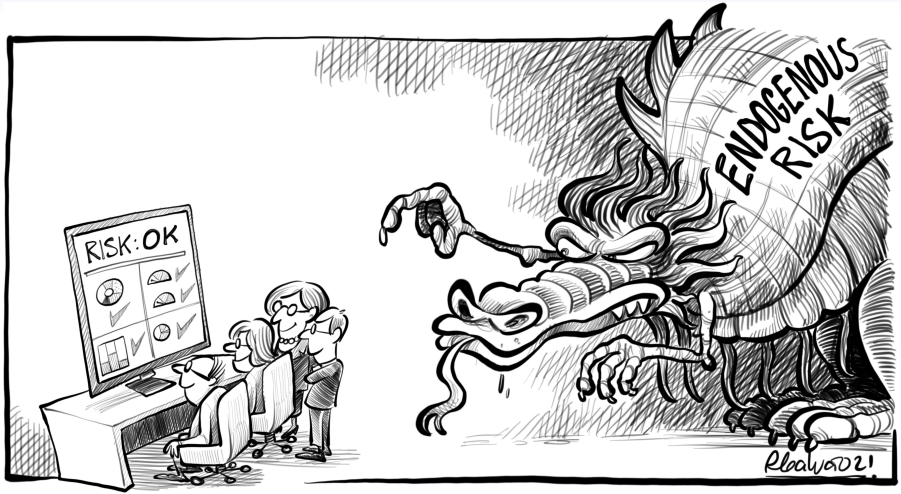
Book and slides



- Updated versions of the slides can be downloaded from the book web page `www.globalfinancialsystems.org`



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Endogenous Risk (ER)

What is Risk?

- Systemic risk, financial stability, and economic growth are directly dependent on risk
- The Goldilocks challenge
  - Not too much and not too little, just right
- But then we have to know what risk is

Butterflies and Hurricanes

- Chaos theorists talk about how a butterfly in Hong Kong can cause a hurricane in the Caribbean
- What is important is the *mechanism* allowing this to happen
- The trigger (the butterfly) is incidental
- And the hurricane the unfortunate outcome
- Focus of study and policy should be the mechanism

Keynesian Beauty Contest

"It is not a case of choosing those [faces] which, to the best of ones judgement, are really the prettiest, nor even those which average opinion genuinely thinks the prettiest. We have reached the third degree where we devote our intelligences to anticipating what average opinion expects the average opinion to be. And there are some, I believe, who practice the fourth, fifth and higher degrees."

Keynes (1936)

Endogenous Risk Versus Exogenous Risk

Daníelsson and Shin (2002)

- *Endogenous risk*: the risk from shocks that are generated and amplified *within* the financial system
- *Exogenous risk*: shocks that arrive from *outside* the financial system
- Analogies
  - A financial hedge (futures contract) versus a weather hedge (umbrella)
  - Poker versus Roulette
- Essentially, situations where an agent affects outcomes
  vs.
  situations where the agent cannot

Millennium Bridge

- First new Thames crossing for over a hundred years
  - New design, extensive tests, riskless
  - Opened by the Queen on 10 June 2000
- What happened?
  - Wobbled violently within moments of the bridge opening
  - Remained closed for the next 18 months

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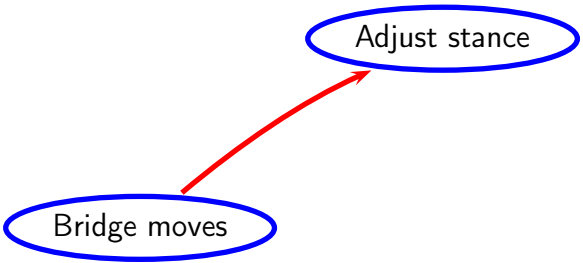
What Went Wrong?

- An engineering answer
  - Cause: horizontal vibrations at 1 hertz
  - Walking pace: two steps per second, i.e. two hertz
  - Producing one-hertz horizontal force
- Why should it matter?
  - If the pedestrians sway randomly to the left and right, they cancel each other out
  - It is Only a problem when people walk in step like soldiers marching
  - Probability of a thousand people walking at random ending up walking exactly in step? — *close to zero*
  - If individual steps are independent events, but

Given Feedback, Near Certainty!

Bridge moves

Given Feedback, Near Certainty!



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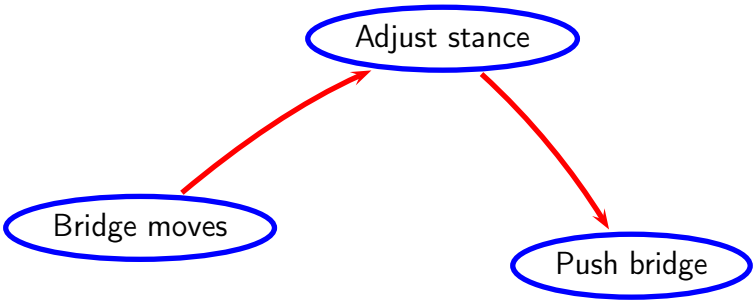

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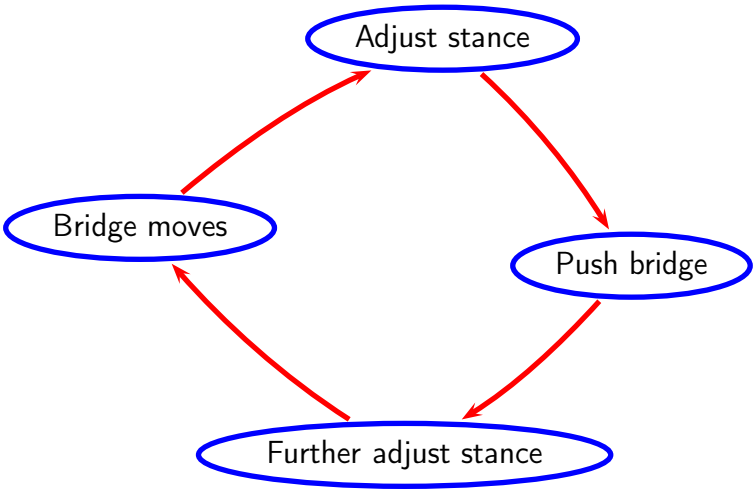


Dual Role Of Prices

Dual Role of Prices

Daníelsson, Shin, and Zigrand (2012)

- Prices of financial assets play two important roles. The first is quite familiar
  1. Prices reflect the underlying fundamentals
  2. Prices are also an imperative for action

Endogenous Market Prices; Leverage Constraints And Upward Sloping Demand

- Leverage constraint $L = 5$ (assets to equity)
- Initial (time 0) values
  - Prices, $P_0 = \$10$
  - Number of assets, $Q_0 = 100$
  - Assets, $A_0 = \$1000$
  - Debt, $D_0 = \$800$
  - Equity, $E_0 = A_0 - D_0 = \$200$
- Leverage

$$L = \frac{A}{A - D = E} = 5 = \frac{1000}{200}$$

Balance Sheets

Assets	Liabilities
1000	Equity 200
	Debt 800

Prices fall to $P_1 = \$9$ at time 1

Assets	Liabilities
900	Equity 100
	Debt 800

Leverage to 9, bank needs to *sell assets and repay debt*

Prices Are Exogenous

$$L_1 = \frac{A_1}{A_1 - D_1} = \frac{P_1 Q_1}{P_1 Q_1 - (D_0 - P_1 (Q_0 - Q_1))}$$

So

$$Q_1 = -L \frac{D_0 - P_1 Q_0}{P_1}$$

In our case, $Q_1 = \frac{500}{9}$, so the bank sells \$400 worth of assets, and its balance sheet becomes:

Assets	Liabilities
$A = 9\frac{500}{9} = 500$	$E = 500 - 400 = 100$
	$D = 800 - 9\frac{400}{9} = 400$

Prices Are Endogenous; Bank Exerts Significant Price Impact

λ is the *price impact factor*, and $P_1 Q_1$ the amount the bank wants to sell, in our case 400

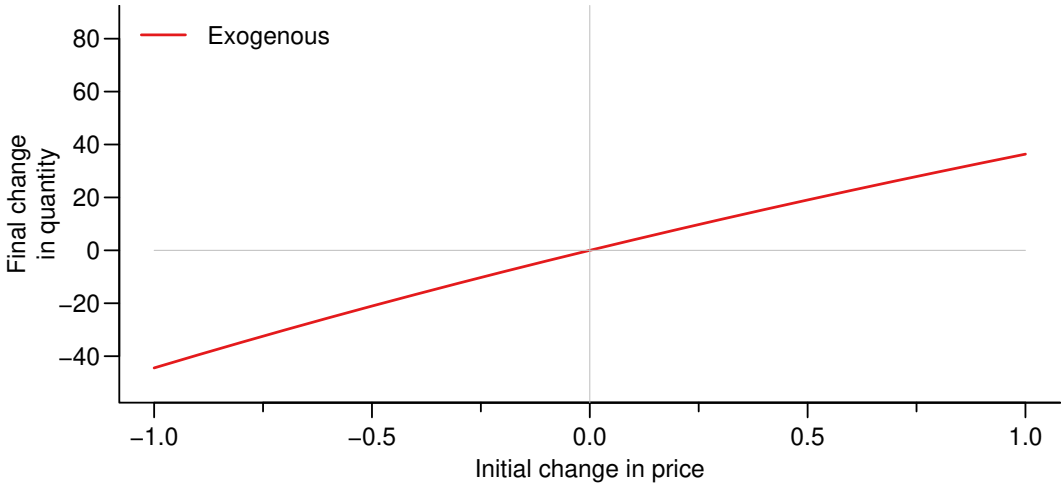
Make $\lambda = 0.001$

1. $P_n = P_{n-1} + \lambda P_{n-1}(Q_{n-1} - Q_{n-2})$;
2. $Q_n = L(Q_{n-1} - D_{n-1}/P_n)$;
3. $A_n = P_n Q_n$;
4. $E_n = A_n / L$;
5. $D_n = A_n - E_n$.

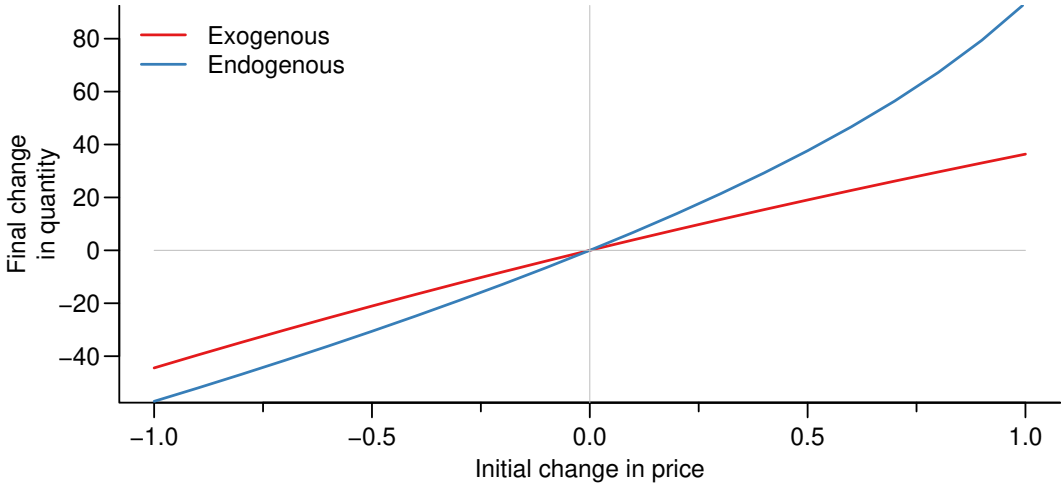
Prices Are Endogenous; Iterate

Iteration	Q	P	A
1	100.000	10.000	1000.000
2	55.556	9.000	500.000
⋮	⋮	⋮	⋮
9	42.934	8.492	364.585
10	42.934	8.492	364.585

Demand is Upward Sloping



Demand is Upward Sloping



Butterflies And Financial Crises

- Demonstrates how a small exogenous shock can trigger a large outcome
- The constraints dictate a "*sell cheap, buy dear*" strategy
- Precisely the kind of vicious feedback loops that destabilize markets
- This is the mechanism that allows the butterfly to create the hurricane

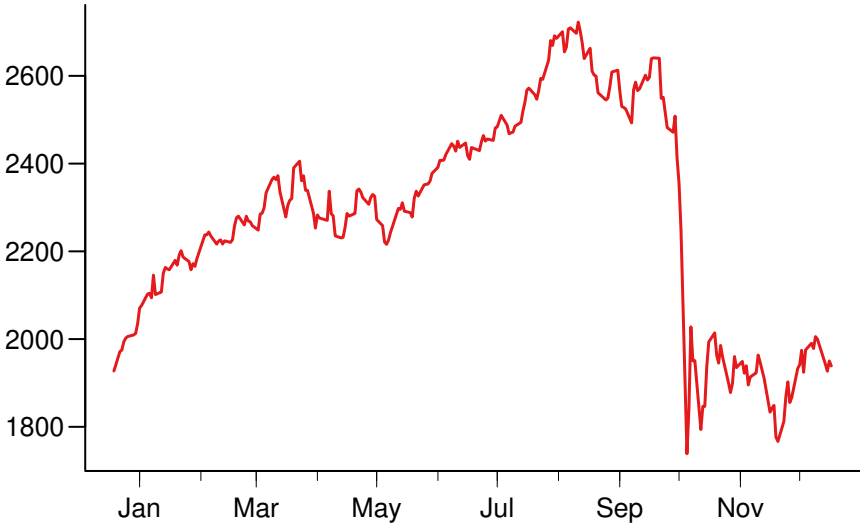
Dynamic Strategies And The 1987 Crash

Black Monday

Gennotte and Leland (1990)

- 19 October 1987
- The biggest stock market crash in history
- Global stock markets crashed around 23%
- A key reason for the crash was *portfolio insurance*
- That is, the use of an automatic trading strategy

1987 Dow Jones Industrial Average



Put Option and Delta

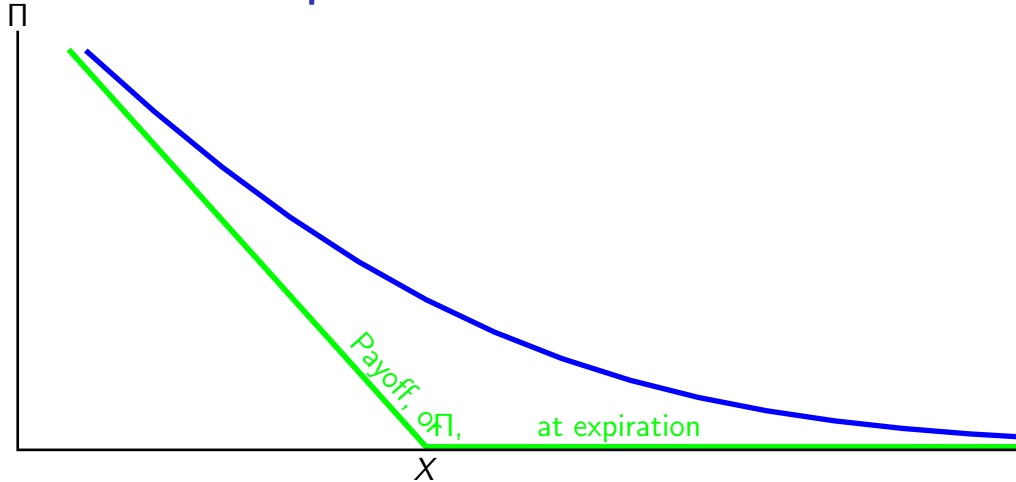
Daníelsson, Shin, and Zigrand (2012)

- A *put option* gives the holder the right to sell an asset at an agreed *strike price* (X)
- *Delta* (Δ) of a put option is the rate of change of its price (Π) with respect to the change in price of the underlying asset, P

$$\Delta = \frac{d\Pi}{dP} < 0$$

- Graphically, Δ is the slope of a curve – the option price against the price of the underlying

Put Option and Delta



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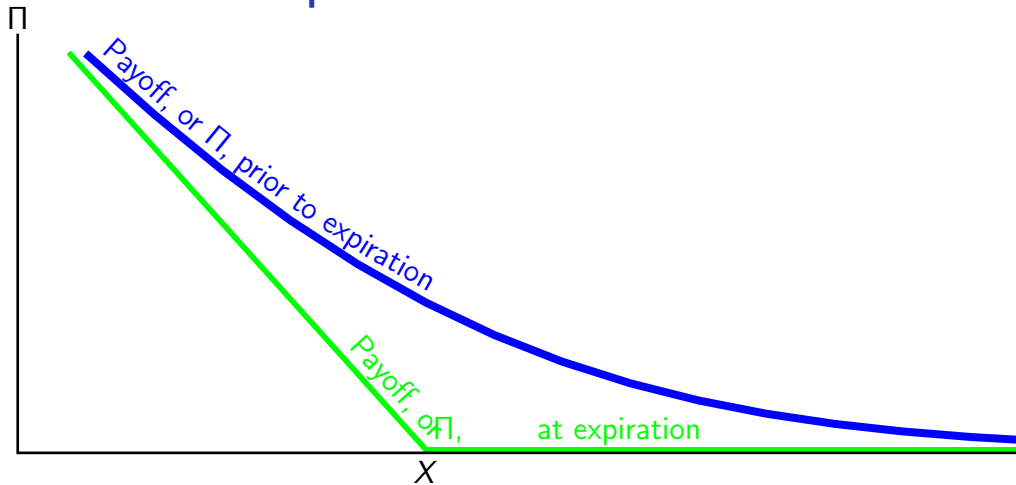

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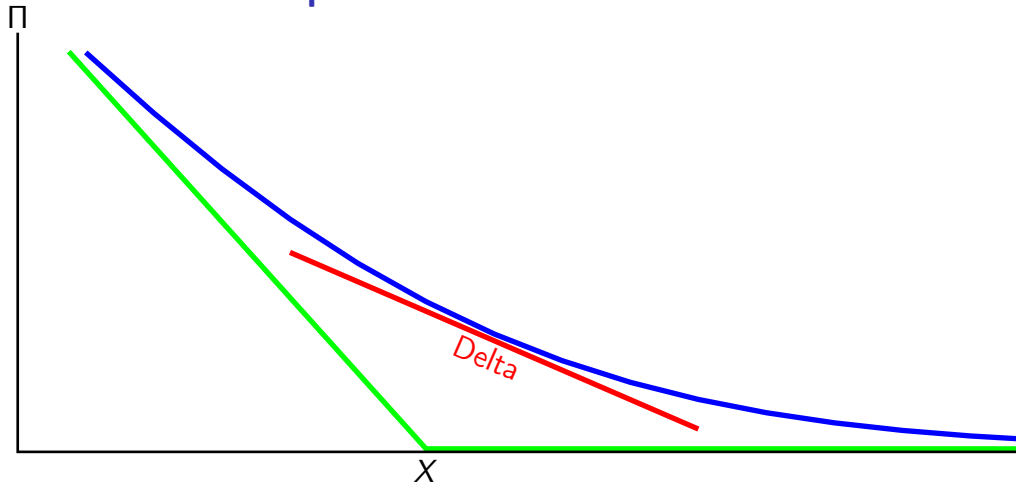


Hedging Through Options

- Options are effective instruments to hedge
- Delta hedging
  - A portfolio that consists of 1 put option and Δ stocks is riskless
  - And must earn the risk-free rate
- Traded options don't always exist – long maturity, over-the-counter (OTC) markets

Synthetic Options

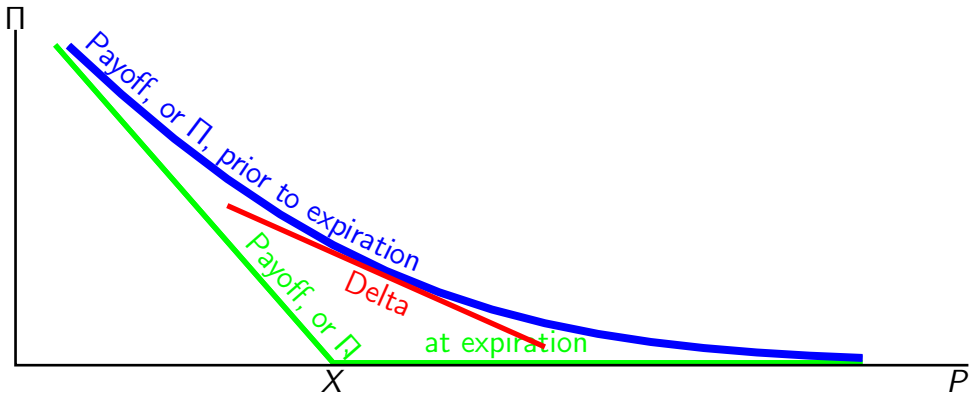
- Financial engineering: turn one asset into another
- *Synthetic replication*: create an option by a combination of cash and the underlying asset
- Dynamically replicating a put

$$\left.\begin{matrix} 1 & \text{Put} \\ 0 & \text{Cash} \end{matrix}\right\} = \begin{cases} \Delta & \text{Underlying asset} \\ -P\Delta + \Pi & \text{Cash} \end{cases}$$

- Δ of a put option is always negative
- Replicating portfolio: short $|\Delta|$ units of underlying asset at price P at all times

Synthetic Put

- Δ of the option becomes more negative as the asset price falls
- *"Sell cheap, buy dear"* strategy



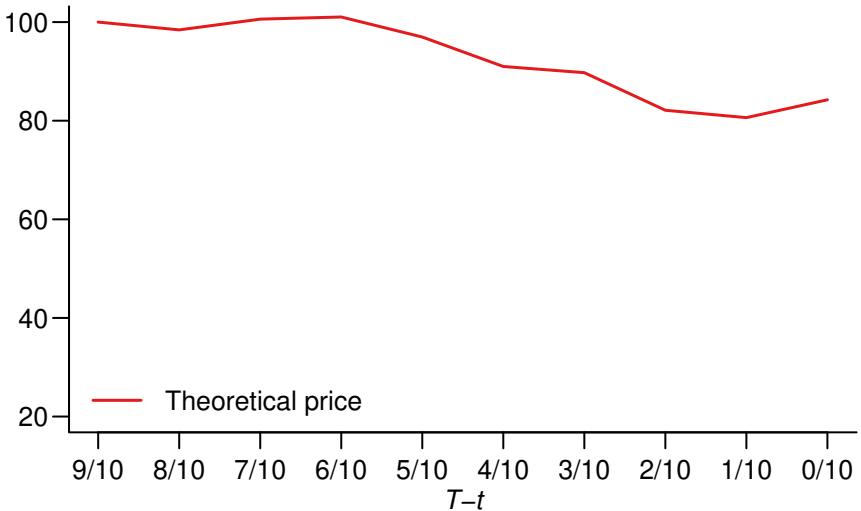
Simulation

- Strike price at \$90
- The risk-free rate at 0%
- The annual volatility at 25%
- Time to maturity is 9 weeks
- Initial price \$100
- ϵ is shock
- Black–Sholes put is \$0.8012
- Use superscript * to denote the actual outcomes, so for example P refers to the theoretic price and P^* to the actual price

Dynamic Replication Strategy

$T-t$	ϵ	P	P^*	Δ	Δ^*	C	C^*
9/10		100.0	100.0	-0.14	-0.14	14.3	14.3
8/10	-0.016	98.4	98.4	-0.17	-0.17	16.8	16.8
7/10	0.022	100.6	98.1	-0.10	-0.16	10.3	16.1
6/10	0.004	101.0	99.3	-0.08	-0.12	7.9	11.5
5/10	-0.040	97.0	99.9	-0.16	-0.08	15.5	8.4
4/10	-0.062	91.0	96.8	-0.42	-0.14	39.6	13.6
3/10	-0.014	89.7	90.2	-0.51	-0.47	47.1	43.6
2/10	-0.085	82.1	52.6	-0.97	-1.00	84.9	71.5
1/10	-0.018	80.6	23.8	-1.00	-1.00	87.5	71.5
0/10	0.045	84.2	24.8	-1.00	-1.00	87.6	71.5

Dynamic Replication Strategy (Cont.)



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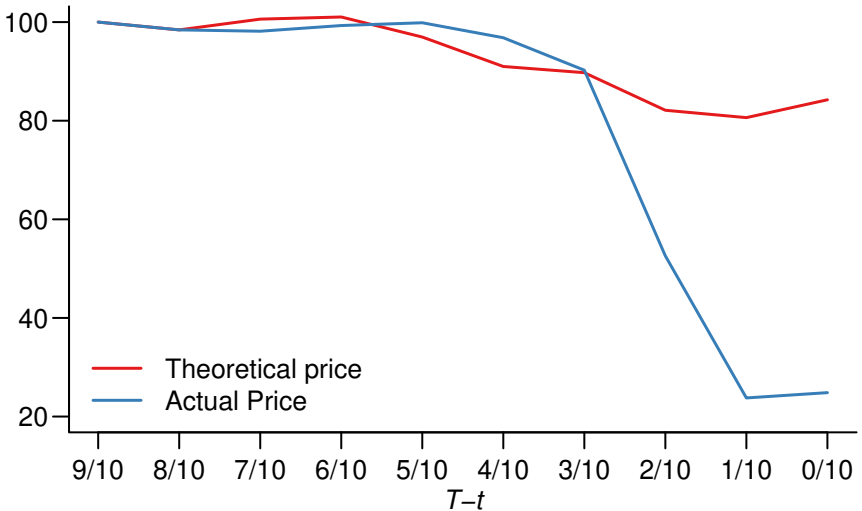


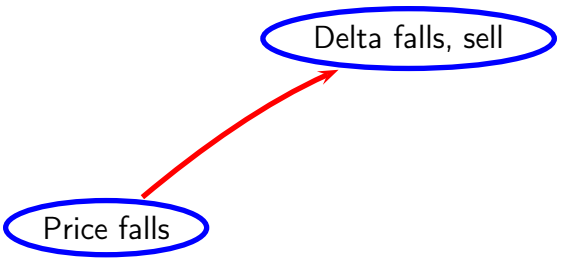
The Crash

- $60-90 billion in formal portfolio insurance (3% of pre-crash market capitalisation)
- 14 Oct (Wednesday) to 16 Oct (Friday)
  - Market decline of 10%
  - Sales dictated by dynamic hedging, $12 billion
  - Actual sales (cash + futures), $4 billion
  - Substantial pent-up selling pressure on Monday

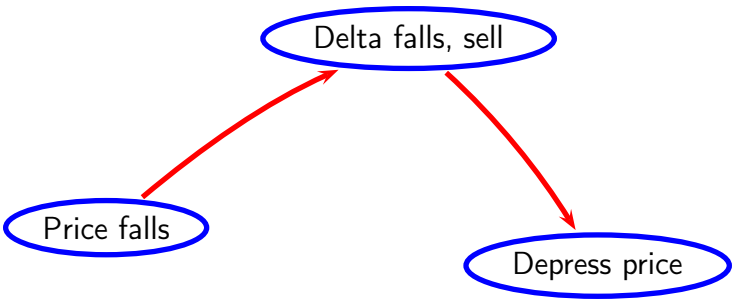
Endogenous Market Dynamics; Portfolio Insurance

Price falls

Endogenous Market Dynamics; Portfolio Insurance



Endogenous Market Dynamics; Portfolio Insurance



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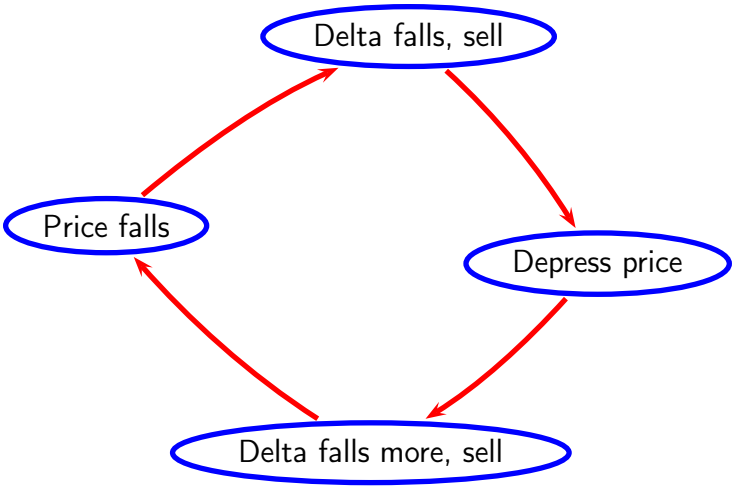
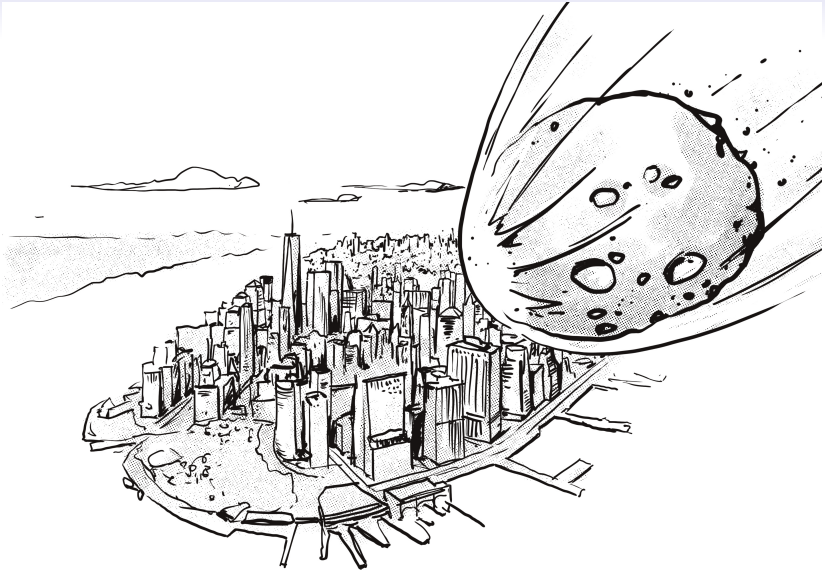


Trading Rules

- Classic example of destabilising feedback effect on market dynamics of concerted selling pressures arising from certain mechanical *trading rules*
  - Like the *sell-on-loss* considered here.
- The underlying destabilising behaviour is completely invisible so long as trading activity remains below some critical but unknown threshold
- Only when this threshold is exceeded does the endogenous risk becomes apparent, causing a market crash
- Clearly demonstrates the difference between *perceived risk* and *actual risk*.

Actual and Perceived Risk



A Baby Risk Model

- Suppose returns are given by

$$y_t = \frac{P_t - P_{t-1}}{P_{t-1}}$$

- Suppose we measure exogenous risk by volatility

$$\text{volatility}_t^2 = \text{variance} = \frac{1}{N-1}\sum_{i=1}^{N}(y_{t-i} - \text{mean})^2$$

- Measured risk is a function of historical prices
- Recall the example of the dam bursting in Chapter 1

Recall When Risk Is Created

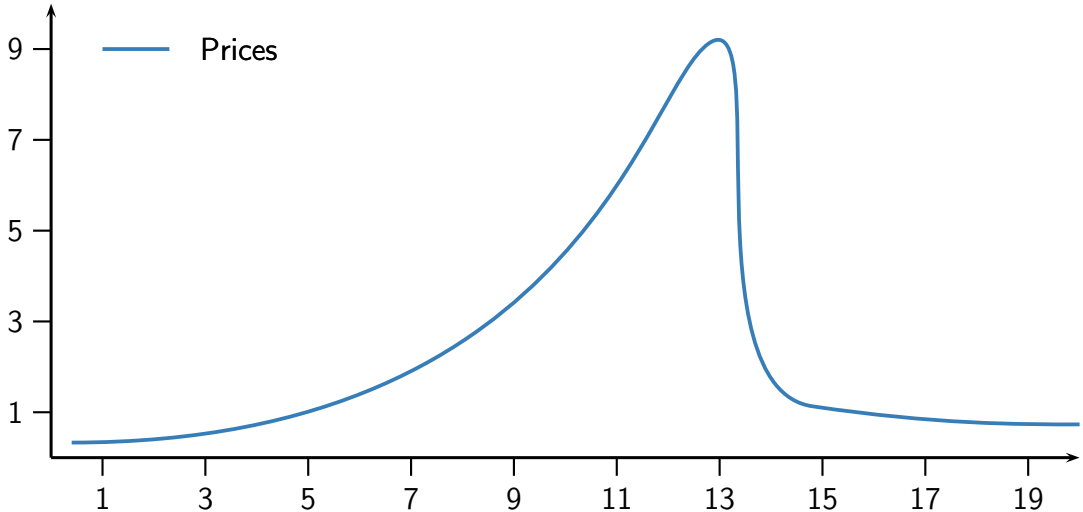
"The received wisdom is that risk increases in recessions and falls in booms. In contrast, it may be more helpful to think of risk as increasing during upswings, as financial imbalances build up, and materialising in recessions."
Andrew Crockett, then head of the BIS, 2000

- Consistent with Minsky's financial instability hypothesis

Relevance of Endogenous Risk

- When individuals observe *and* react – affecting their operating environment
- Financial system is not invariant under observation
- We cycle between virtuous and vicious feedback
- Two faces of risk
  - Risk reported by most risk forecast models — exogenous (perceived) risk
  - Endogenous (actual) underlying risk that is hidden but ever-present

Endogenous Bubble



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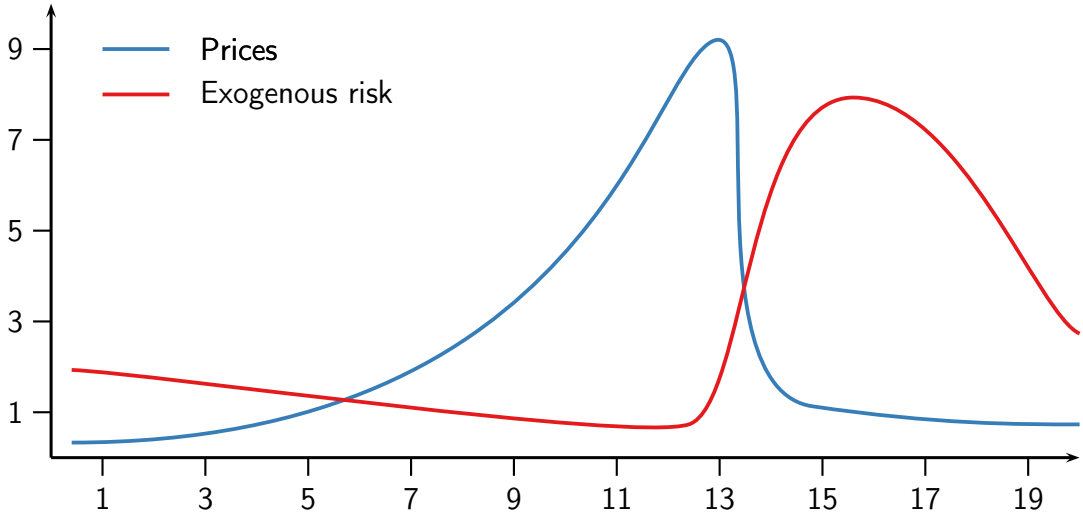

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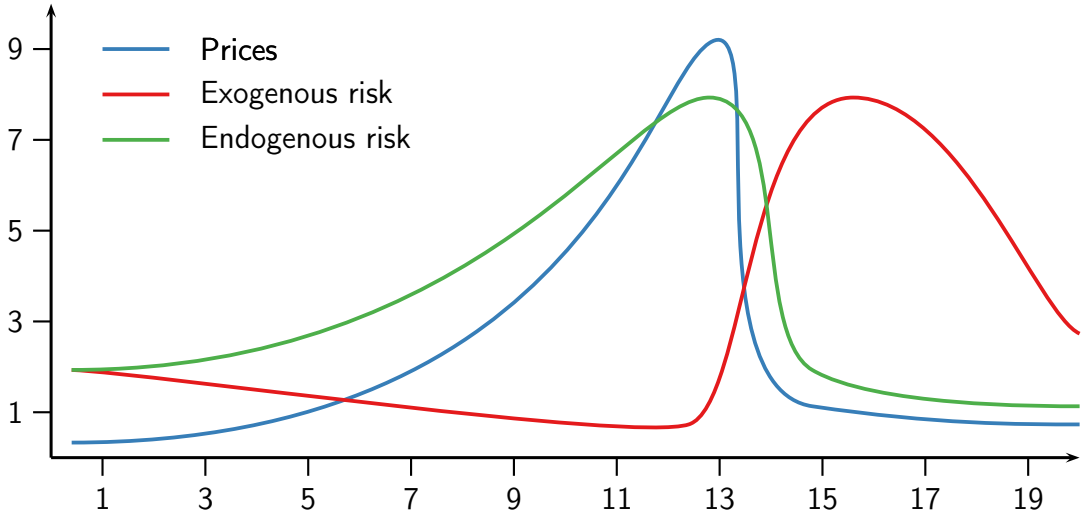
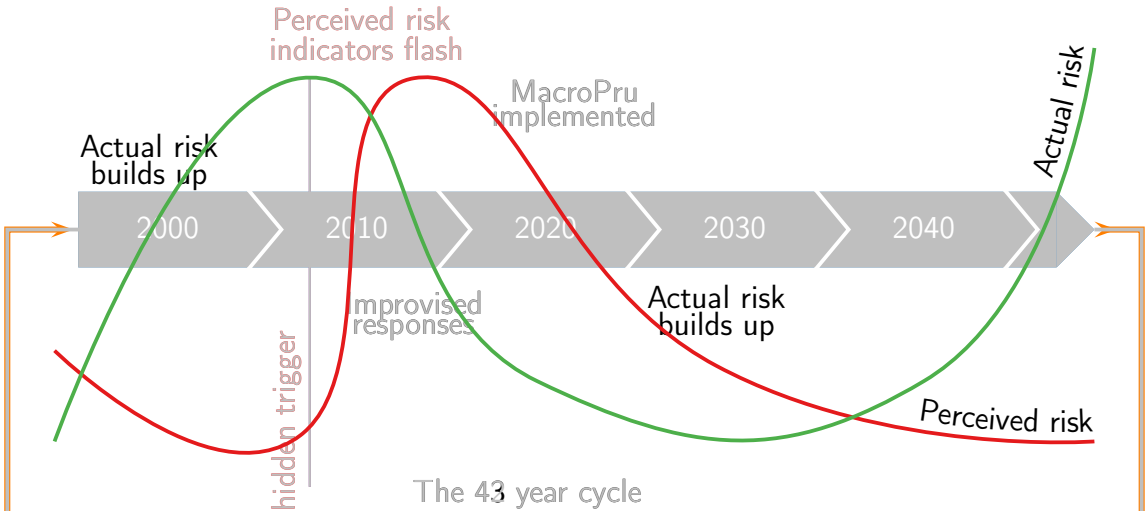


The 43 Year Cycle Of Systemic Risk



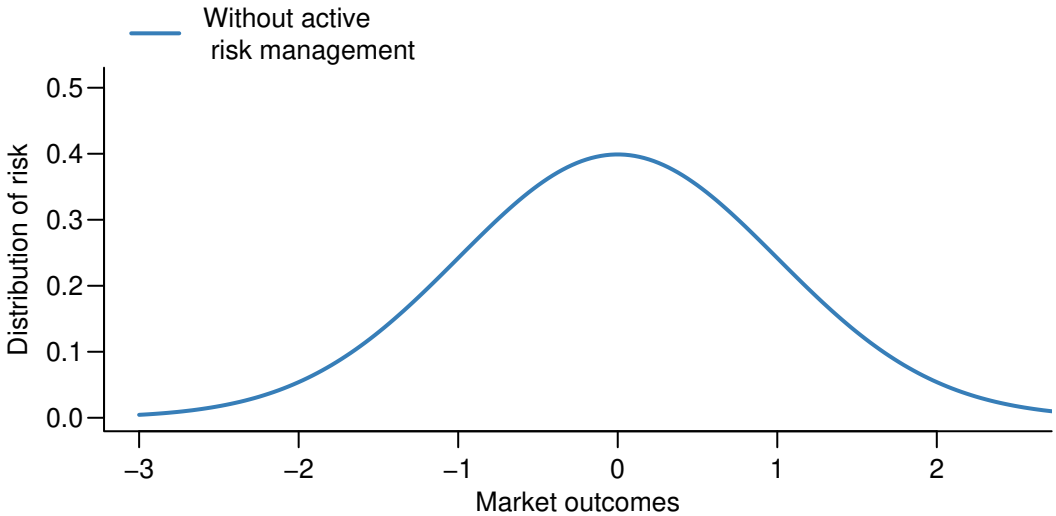
Exam 2021

- Consider the day at the height of the Covid-19 market turmoil in the middle of March 2020. Would you expect perceived risk to increase over the subsequent few days? Would you expect actual risk to increase over the subsequent few days?

The Impact Of Managing Risk

- Imagine two different worlds
  - A. There are no regulations about risk, and banks are all doing their own thing
  - B. We have harmonised regulations and stakeholders that Demand state-of-the-art risk management
- Which world is more stable?
- It depends
- Because the management of risk controls only one part of the domain of risk

Impact of Active Risk Management



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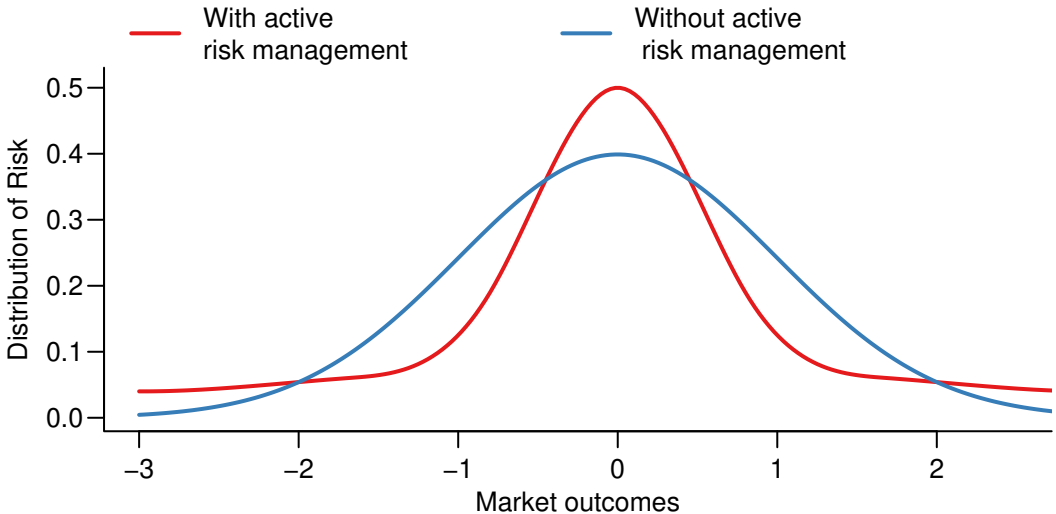

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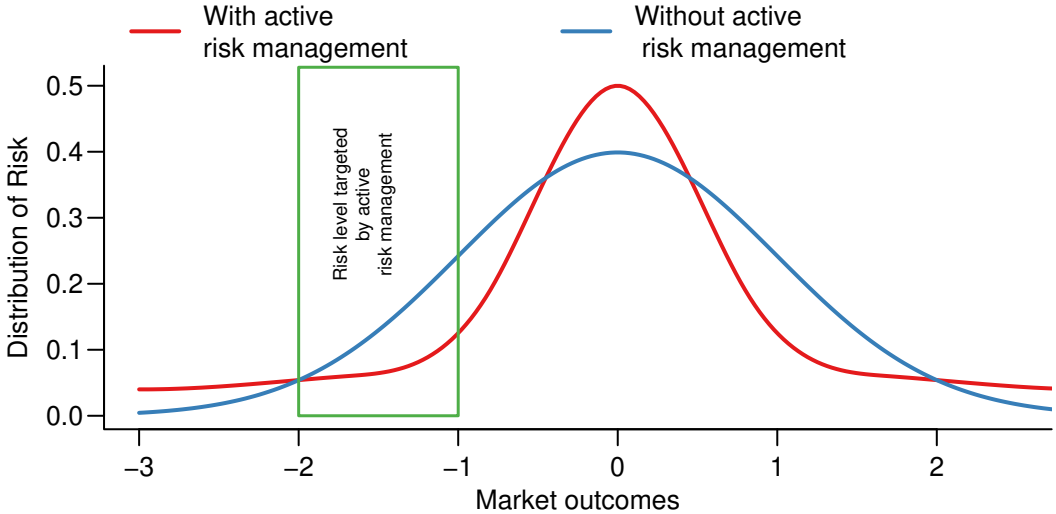

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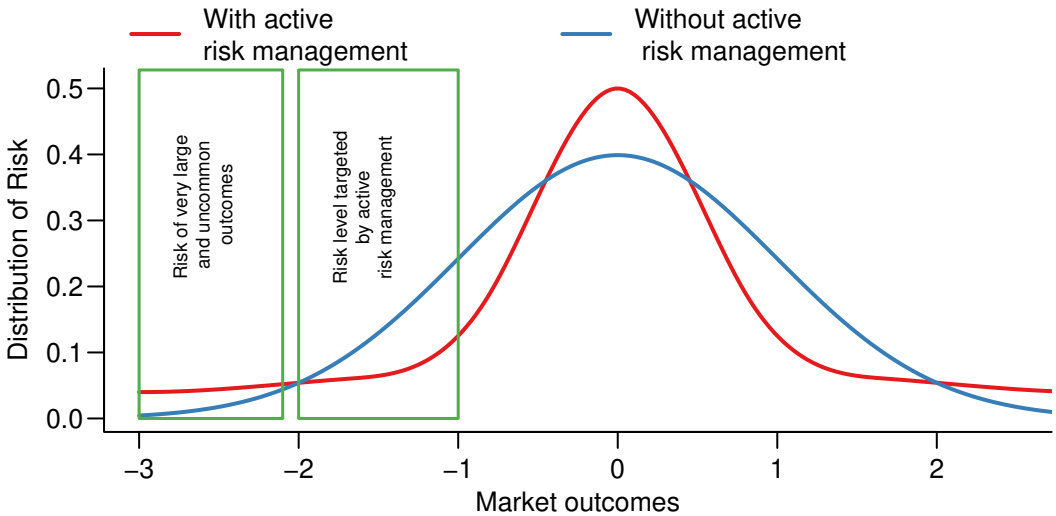


The Long Term Capital Management (LTCM) Crisis

Long–Term Capital Management

Lowenstein (2000), Lewis (1989)

- Founded by John Meriwether, experts include Robert Merton and Myron Scholes
- Minimum investment $10 million, charge 2 and 25, three-year lock-in
- $1.01 billion in capital to start with
- Performance
  - First two years: 43%, and 41%, after fees
  - Net capital in September 1997 was $6.7 billion
  - Leveraged to $126.4 billion (19 times)

~~Long~~Short–Term Capital Management

Lowenstein (2000), Lewis (1989)

- Founded by John Meriwether, experts include Robert Merton and Myron Scholes
- Minimum investment $10 million, charge 2 and 25, three-year lock-in
- $1.01 billion in capital to start with
- Performance
  - First two years: 43%, and 41%, after fees
  - Net capital in September 1997 was $6.7 billion
  - Leveraged to $126.4 billion (19 times)
- *Failed spectacularly in 1998*

Leverage

- "*LTCM would make money by being a vacuum sucking up nickels that no one else could see.*"
  - Myron Scholes
- Drove very hard bargains on financing

Trading Strategies

- Convergence or relative value trades
- Examples:
  - Fixed rate residential mortgages in the US
  - Japanese and European government bonds
  - Interest rate swaps
  - Italy

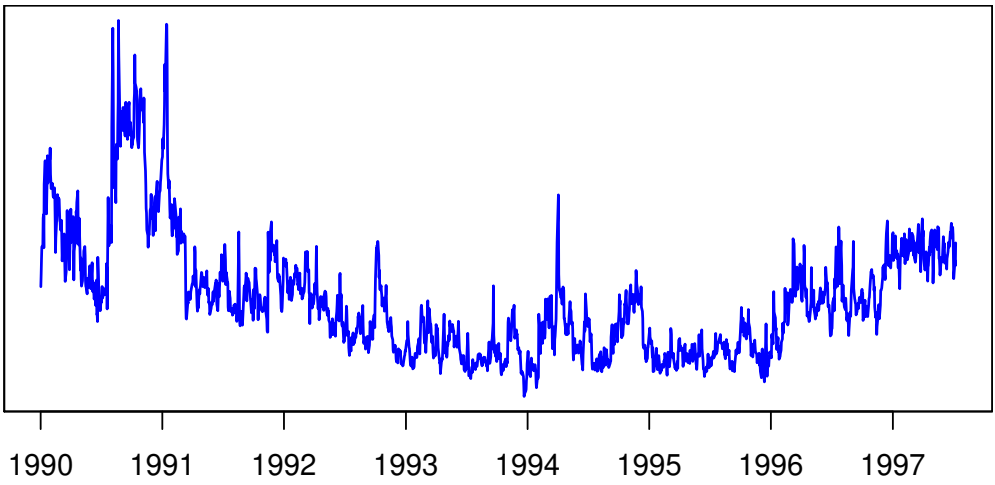
The Bigger Picture

- VaR in 1998 indicated that it would take a *10σ event* for it to lose all capital in a single year ($p = 10^{-24}$)
  - Probability of default of 7.6×10^{-23}
  - The earth is 4.5×10^9 years old and the universe is 1.3×10^{10} years old
- Returned $2.7 billion to investors in December 1997 (focus on investing own money)
- (And we worry about incentives in bonuses!)
- Copycat funds, proprietary trading desks of creditor banks
  $\rightarrow$ Narrowing of spreads
- Venturing into uncharted territory in search of profitable trades

"Central Bank Of Volatility"

- The biggest trade in 1998 was to sell/write long-dated options
- Expect volatility to go to long-run level
- LTCM became a major supplier of S&P 500 vega
- High leverage to profit from minute differences in value

VIX



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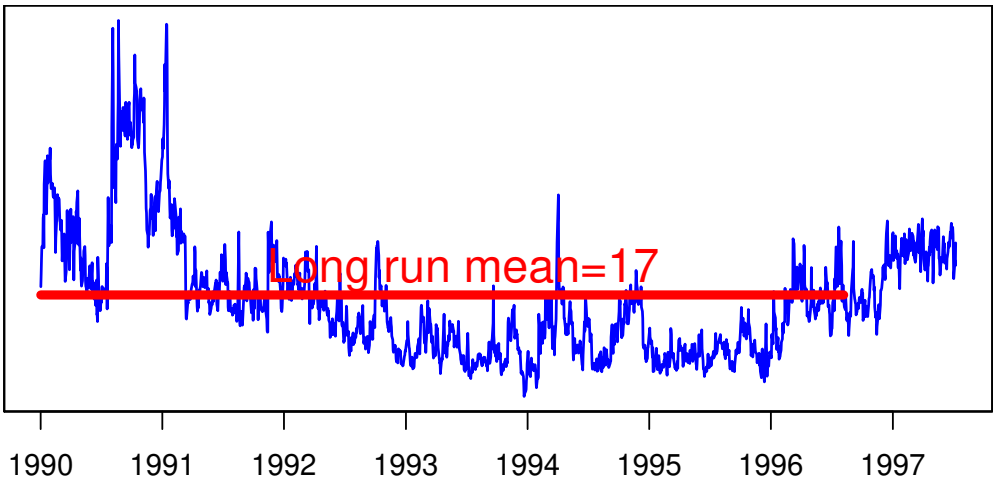
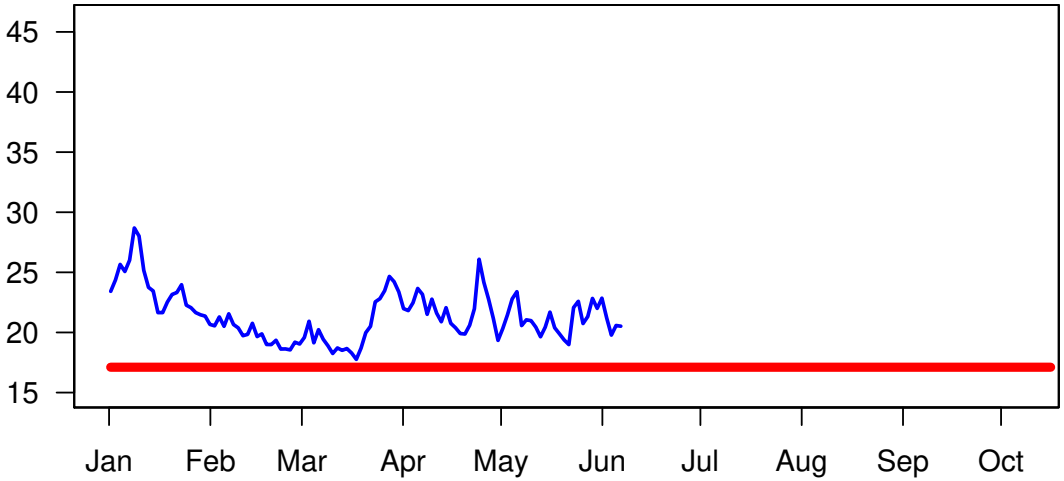


VIX – Close to The Crisis – 1998



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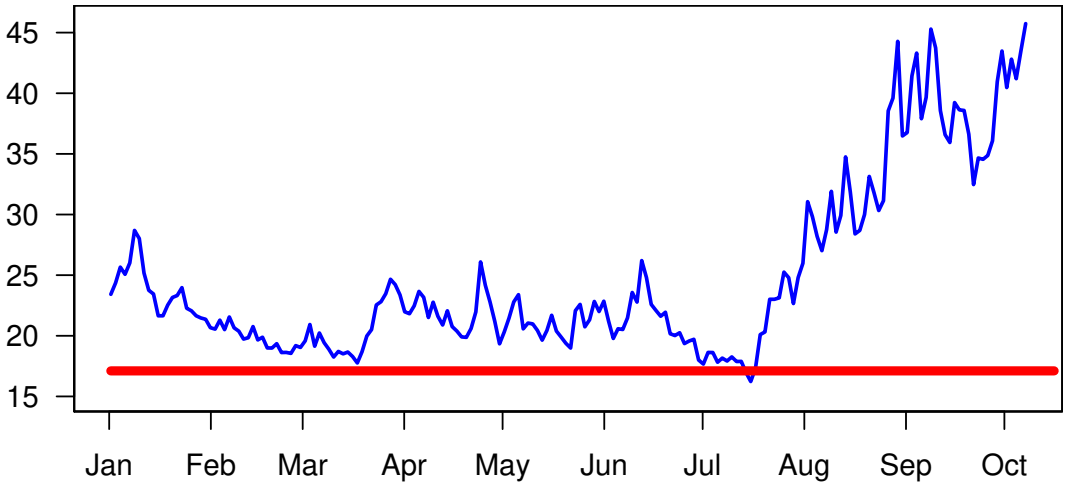


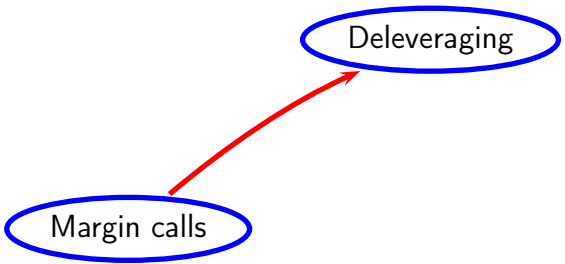
A Perfect Storm

- Returns: -6.7% in May, -10.1% in June
- Leverage became 31/1 (capital drops relatively more than assets)
- Salomon Smith Barney closed US bond arbitrage group
- Russia default 17 August, triggered a panic
- Credit spreads widened, volatility shot up to 45% (the unthinkable happened)
- All correlations tended to one (as happens in crises)

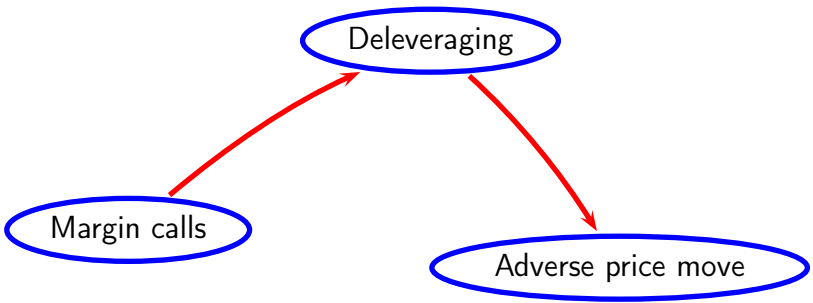
Endogenous Collapse

Margin calls

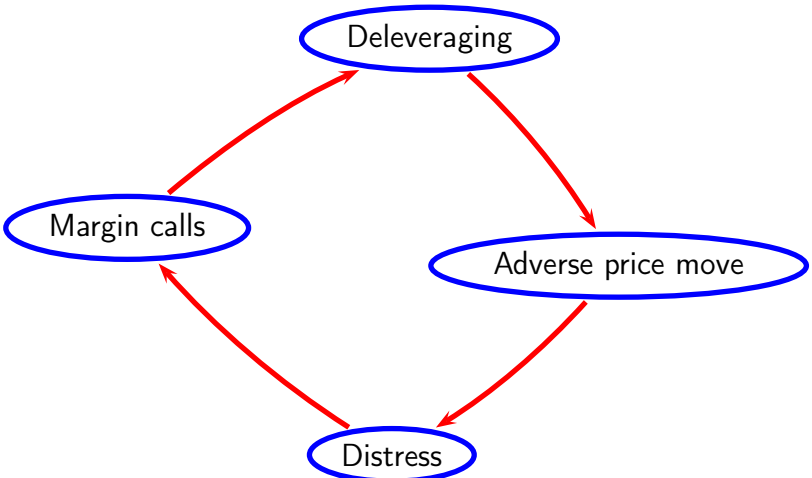
Endogenous Collapse



Endogenous Collapse



Endogenous Collapse



Deleveraging

- Mutually reinforcing effect of deleveraging
- Distress and margin calls entail short-horizon trading
- Lost more than $45 million per day
- Equity tumbled from $2.3 billion to $600 million in the first three weeks of September
- Fed organised a $3.625 billion rescue

Preconditions For Endogenous Risk

- Individual economic agents react to outcomes
- Individual actions affect outcomes
- To believe that LTCM was just hugely unlucky is to commit the same mistake as the engineers of the Millennium Bridge
- Far from a probability close to zero, the collapse was near certain given the right conditions

Irrationality of Markets?

- LTCM invested in a mean-reverting asset, expecting VIX to fall eventually, bringing significant profits
- Profits were made, but only by those who bailed LTCM out
- The explanation is provided by an observation often attributed incorrectly to Keynes

"The market can stay irrational longer than you can stay solvent."

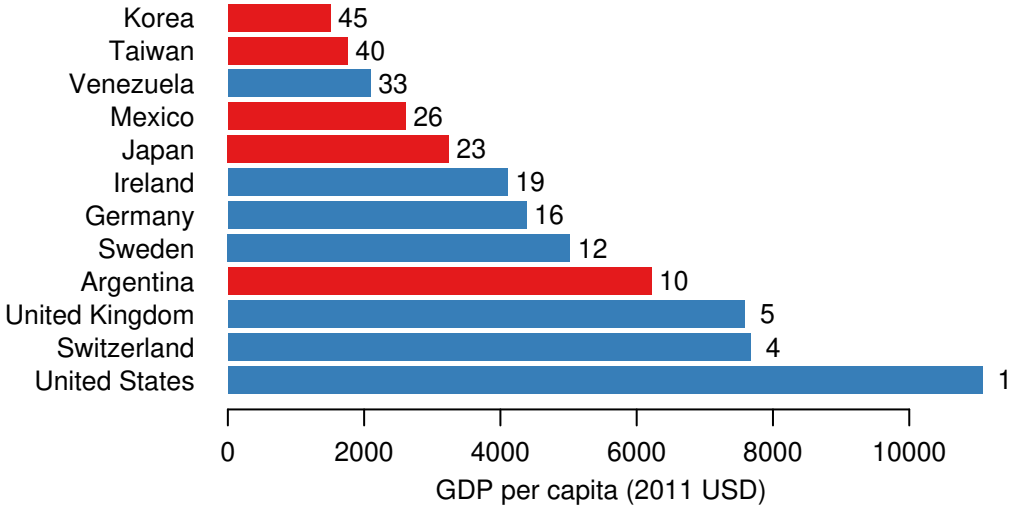
- The very high levels of VIX were explicitly caused by the uncertainty created by the presence of LTCM
- *A necessary condition* for the VIX to return to its long-run mean was the failure of LTCM

How data lies

The driver of extreme risk is politics

- 2008, Italy, Trump, Ukraine, Taiwan, Venezuela, Middle East, real estate, inflation, ...
- Because politics allows the risk to emerge and prevents timely solutions
- The inability to deal with environmental risk is entirely political
- As is the demographic challenge
- Politics works against those who want to prevent undesirable outcomes
- Booms deliver short-term tangible benefits
- And not many want to pay now to solve possible future problems

GDP and rank in 1923

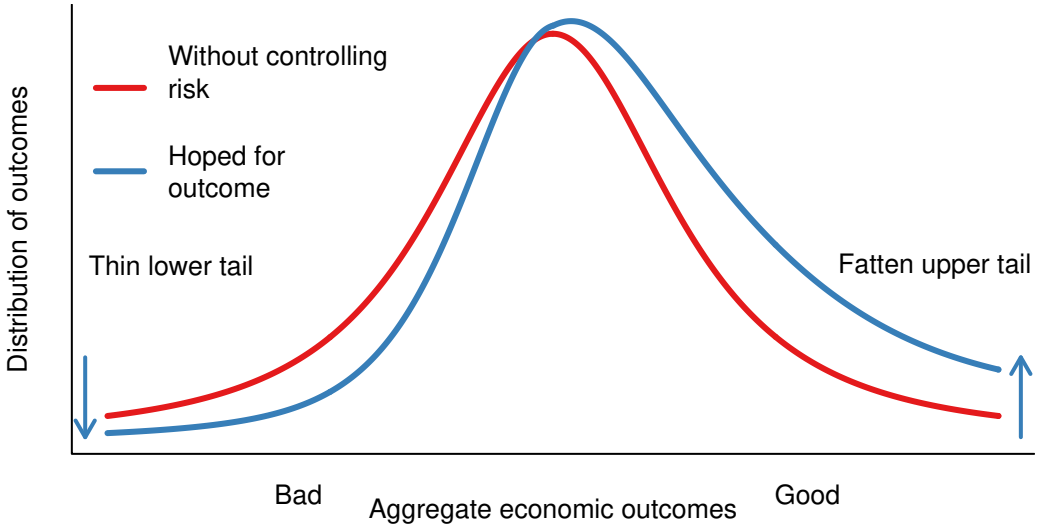


Its all about risk

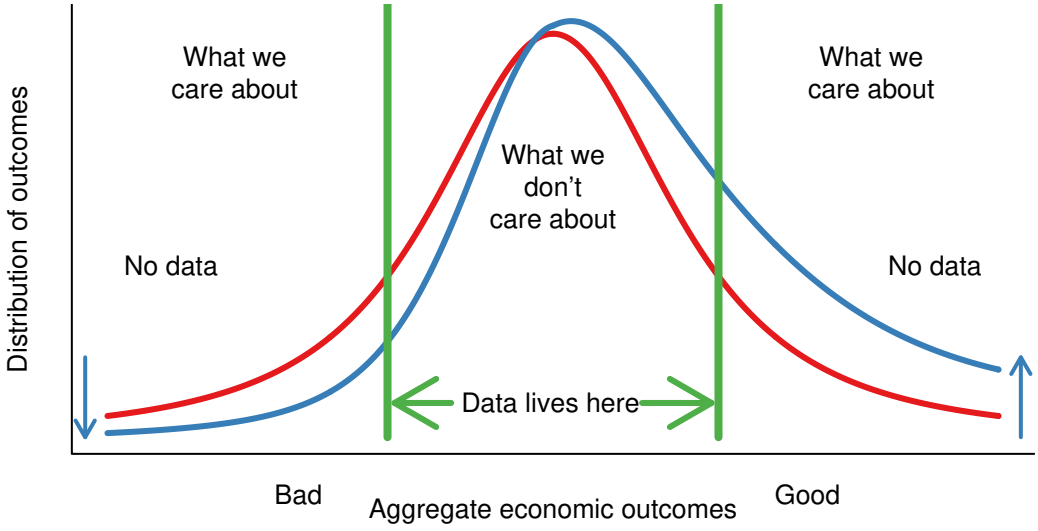
or perhaps uncertainty or unknown-unknowns?

What do we want?

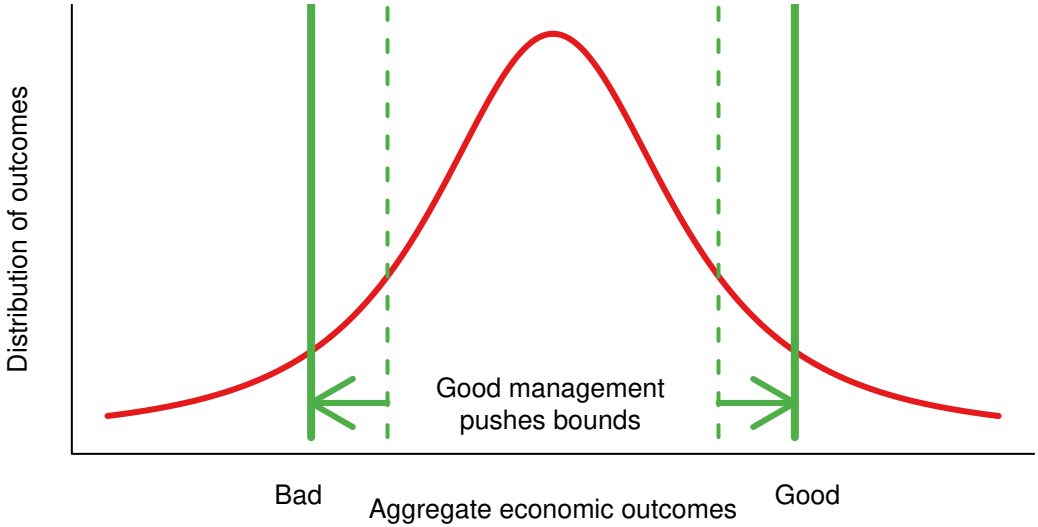
What we want


Without controlling risk
Hoped for outcome
Thin lower tail
Fatten upper tail
Distribution of outcomes
Bad
Aggregate economic outcomes
Good

What we get


What we care about
What we don't care about
What we care about
No data
No data
Data lives here
Distribution of outcomes
Bad
Aggregate economic outcomes
Good

And if we are good at our jobs



How financial institutions optimise (chapter 1)

- Maximise profits given the acceptable risk
- Roy's (1952) criterion is useful
- Maximise profits subject to not going bankrupt
- That means financial institutions optimise for profits most of the time, perhaps 999 days out of 1,000
- However, on that one last day, when great upheaval hits the system, and a crisis is on the horizon, survival, rather than profit, is what they care most about
- The "one day out of a thousand" problem

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