Global Financial Systems
Chapter 3
Endogenous Risk

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To accompany
Global Financial Systems: Stability and Risk
http://www.globalfinancialsystems.org/
Published by Pearson 2013
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Book and slides

- The tables and graphs are the same as in the book
- See the book for references to original data sources
- Updated versions of the slides can be downloaded from the book web page
  www.globalfinancialsystems.org
What is risk?

- Systemic risk and 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
Endogenous Risk (ER)
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, General Theory of Employment Interest and Money, 1936.
Endogenous risks vs. Exogenous risks

- **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) vs. a weather hedge (umbrella)
- Poker vs. 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 June 10th 2000

• What happened?
  • Wobbled violently within moments of bridge opening
  • Remain closed for the next 18 months
Millennium Bridge

- New design
- Tested with extensive simulations
- All angles covered
- No endogenous shocks
- Riskless
What endogeneity?

- Pedestrians had some problems
- Bridge closed
What happened?

• Took the engineers some time to discover what happened
What went wrong?

- An engineering answer
  - Cause: horizontal vibrations at 1 hertz
  - Walking pace: 2 steps per second, i.e. 2 hertz
  - Producing 1 hertz horizontal force
- Why should it matter?
  - People swayed to the left and right cancel out each other
  - 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!

Bridge moves

Adjust stance
Given feedback...near certainty!

- Adjust stance
  - Bridge moves
  - Push bridge
Given feedback...near certainty!

Adjust stance

Bridge moves

Push bridge

Further adjust stance
Dual role of prices
Dual role of prices

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

\[
L = \frac{A}{A - D} = \frac{E}{E} = 5 = \frac{1000}{200}
\]
Endogenous risk

Dual Role of Prices

1987

Actual and perceived risk

LTCM

---

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. Its balance sheet becomes:

<table>
<thead>
<tr>
<th>Assets</th>
<th>Liabilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>( A = 9 \frac{500}{9} = 500 )</td>
<td>( E = 500 - 400 = 100 )</td>
</tr>
<tr>
<td>( D = 800 - 9 \frac{400}{9} = 400 )</td>
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</table>
Prices are endogenous
bank exerts significant price impact

\( \lambda \) is the \textit{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. \( D_n = A_n - E_n \).
## Endogenous Risk

### Dual Role of Prices

<table>
<thead>
<tr>
<th>Iteration</th>
<th>$Q$</th>
<th>$P$</th>
<th>$A$</th>
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<tr>
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### Endogenous risk

#### Dual Role of Prices

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#### Actual and perceived risk

#### LTCM
### Dual Role of Prices

1987 Actual and perceived risk

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Demand — Upward sloping

Initial change in price vs. Final change in quantity

- Exogenous
Endogenous risk

Dual Role of Prices

Actual and perceived risk

LTCM

1987

Demand — Upward sloping

Exogenous

Endogenous

Final change in quantity

Initial change in price

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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 ’87 Crash
Black Monday

• October 19, 1987 — the biggest stock market crash since the 19th century
• 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 index values
Put option and Delta

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

\[ \Delta = \frac{d\Pi}{dP} < 0 \]

- Graphically, $\Delta$ is the slope of a curve — the option price against the price of the underlying
Put option and Delta

\[ \Pi(X, P) \]

payoff, or \( \Pi \), at expiration
Put option and Delta

\[ \Pi(X, P) \]

- Payoff, or \( \Pi \), prior to expiration
- Payoff, or \( \Pi \), at expiration

1987 Actual and perceived risk

LTCM
Put option and Delta
Hedging through options

- Options are effective and instruments to hedge
- Delta hedging
  - A portfolio that consists of 1 put option and $\Delta$ stocks is riskless
  - and must earn the risk-free rate
- Traded options don’t always exist — long maturity, 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
- An example — dynamically replicating a put

\[
\begin{align*}
1 \text{ put } & \quad = \quad \Delta \text{ underlying asset} \\
0 \text{ cash } & \quad = \quad -P\Delta + \Pi \text{ cash}
\end{align*}
\]

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

- $\Delta$ of the option becomes more negative as asset price falls
- "sell cheap, buy dear" strategy

![Graph showing the payoff of a synthetic put option]

- Payoff, or $\Pi$, prior to expiration
- Payoff, or $\Pi$, at expiration
- Delta at expiration
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
- $\epsilon$ 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

<table>
<thead>
<tr>
<th>$T - t$</th>
<th>$\epsilon$</th>
<th>$P$</th>
<th>$P^*$</th>
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Dynamic replication strategy

Theoretical price

$T-t$

Endogenous risk  Dual Role of Prices  1987  Actual and perceived risk  LTCM
Endogenous risk

Dual Role of Prices

1987

Actual and perceived risk

LTCM

Dynamic replication strategy

Theoretical price

Actual Price

$T-t$

$9/10, 8/10, 7/10, 6/10, 5/10, 4/10, 3/10, 2/10, 1/10, 0/10$
The crash

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

portfolio insurance

Price falls
Endogenous market dynamics
portfolio insurance

Price falls -> Delta falls, sell
Endogenous market dynamics

portfolio insurance

Price falls → Delta falls, sell → Depress price
Endogenous market dynamics

portfolio insurance

Delta falls, sell

Price falls

Depress price

Delta falls more, sell
Trading rules

- Classic example of destabilizing feedback effect on market dynamics of concerted selling pressures arising from certain mechanical *trading rules*
  - like the *sell–on–loss* considered here.
- The underlying destabilizing behavior 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
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 feedbacks
- Two faces of risk
  - risk reported by most risk forecast models — perceived risk
  - actual underlying risk that is hidden but ever present
Endogenous bubble

Prices
Endogenous bubble

Prices

Perceived risk

1987 Actual and perceived risk

LTCM
Endogenous bubble

- Prices
- Perceived risk
- Actual risk
The 43 year cycle of systemic risk

actual risk builds up

2000 2010 2020 2030 2040
The 43 year cycle of systemic risk

actual risk builds up

2000 2010 2020 2030 2040

hidden trigger
The 43 year cycle of systemic risk

perceived risk indicators flash

actual risk builds up

2000  2010  2020  2030  2040

hidden trigger
The 43 year cycle of systemic risk

- Actual risk builds up
- Perceived risk indicators flash
- Improvised responses
- Hidden trigger

- 2000
- 2010
- 2020
- 2030
- 2040
The 43 year cycle of systemic risk

- **perceived risk**
  - indicators flash

- **actual risk builds up**
  - 2000
  - 2010
  - 2020
  - 2030
  - 2040

- **improvised responses**

- **hidden trigger**

- **MacroPru implemented**

- **1987**
The 43 year cycle of systemic risk

perceived risk
indicators flash

actual risk builds up

2000 2010 2020 2030 2040

improvised responses

hidden trigger

actual risk builds up

MacroPru implemented
The 43 year cycle of systemic risk

- perceived risk indicators flash
- actual risk builds up
- MacroPru implemented
- improvised responses
- actual risk builds up
- hidden trigger

The 43 year cycle
The 43 year cycle of systemic risk

- Perceived risk indicators flash
- MacroPru implemented
- Improvised responses
- Hidden trigger

2000 2010 2020 2030 2040

The 42 year cycle
The 43 year cycle of systemic risk

- Perceived risk indicators flash
- Actual risk
- MacroPru implemented
- Improvised responses
- Hidden trigger

The 42 year cycle
Impact of active risk management

Distribution of Risk

Market outcomes

without active risk management
Impact of active risk management

- Distribution of Risk
- Market outcomes

with active risk management
without active risk management
Impact of active risk management

With active risk management, the distribution of risk is shifted to the left compared to without active risk management. The risk level targeted by active risk management is indicated by the green box, showing a lower risk level in the market outcomes distribution.
Impact of active risk management

- with active risk management
- without active risk management

Distribution of Risk

Market outcomes

Risk of very large and uncommon outcomes
Risk level targeted by active risk management

Actual and perceived risk

LTCM
The LTCM Crisis
Long–Term Capital Management

- Founded by John Meriwether, experts include Robert Merton and Myron Scholes
- Min investment $10mn, charge 2 and 25, 3 yrs 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

- Founded by John Meriwether, experts include Robert Merton and Myron Scholes
- Min investment $10mn, charge 2 and 25, 3 yrs 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 the residential mortgages in US
  - Japanese and European government bonds
  - Interest rate swaps
  - Italy
The bigger picture

- VaR in 1998 indicated that it would take a $10\sigma$ event for it to lose all capital in a single year ($p = 10^{-24}$)
  - probability of default of $7.6 \times 10^{-23}$
  - the earth is $4.5 \times 10^9$ years old and the universe is $1.3 \times 10^{10}$ years old
- Returned $2.7$bn. 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 → 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 vol to go to long–run level
• LTCM became a major supplier of S&P 500 vega
• High leverage to profit from minute difference in value
Endogenous risk

Dual Role of Prices

1987

Actual and perceived risk

LTCM
Endogenous risk

Dual Role of Prices

1987

Actual and perceived risk

LTCM

VIX

Long run mean = 17

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Endogenous risk

Dual Role of Prices

1987

Actual and perceived risk

LTCM

VIX — Close to the crime — 1998
VIX — Close to the crime — 1998
A perfect storm

• Returns: -6.7% May, -10.1% June 1998
• Leverage became 31/1 (capital drops relatively more than assets)
• Salomon Smith Barney closed US bond arbitrage group
• Russia default August 17th, triggered a panic
• Credit spreads widened, volatility shot up to 45% (the unthinkable happened)
• All correlations tended to 1 (as happens in crises)
Endogenous collapse

Margin calls
Endogenous collapse

- Deleveraging
- Margin calls
Endogenous collapse

- Deleveraging
  - Margin calls
  - Adverse price move
Endogenous collapse

- Deleveraging
- Adverse price move
- Distress
- Margin calls

1987 Actual and perceived risk
LTCM Endogenous risk Dual Role of Prices
Deleveraging

- Mutually reinforcing effect of deleveraging
- Distress and margin calls entails short–horizon trading
- Loosing more than $45 million per day
- In the first 3 weeks of Sept, equity tumbled from $2.3bn to $600mn
- Fed organized a $3.625bn rescue
Summary 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 eventually fall, 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.