14.09: Financial Crises
Lecture 3: Leverage, Fire Sales, and Amplification Mechanisms

Alp Simsek

Crises and amplification mechanisms

- Banking crises are often triggered by events that seem "small" in retrospect.
- In the recent crisis, estimated initial losses in the U.S. subprime market were less than $500 billion. This is not too large: comparable to the losses in the U.S. stock market on some bad days.
- But these losses triggered a worldwide financial crisis. They were associated with extremely large declines in economic activity (see Blanchard (2009, "The Crisis: Basic Mechanisms and Appropriate Policies").

- This lecture: How (and when) do small financial shocks have amplified effects?

Roadmap

Leverage and amplification mechanisms

Recall the Holmstrom-Tirole model from the last time

$$\text{Invest } I_0 = \frac{N_0}{1-\overline{\rho}_0} \text{ by borrowing } \overline{\rho}_0 I_0.$$

We put the time subscripts to emphasize the timing. Bank made investments at date 0 and returns are realized at date 1.

The realization, R_1, will induce a new net worth for banks, N_1.

Suppose banks will reinvest at date 1 given N_1, denoted by I_1.

New question: How would the realization R_1 affect N_1, and thus I_1.

Let's work out an example with initial $N_0 = 1$ and $\overline{\rho}_0 = 0.95$...

The bank's initial balance sheet

Assets	Liabilities
Assets I_0 (say 20)	debt, $\rho_0 I_0$ (say 19)
	net worth, N_0 (say 1)

The bank's initial leverage ratio is high, $1/\left(1-\rho_0\right)=20$.

The bank's realized balance sheet

Consider the balance sheet at date 1 after R_1 is realized.

Assets	Liabilities
Realized returns, $R_1 I_0$ (say $20R_1$)	debt, $\rho_0 I_0$ (say 19)
	realized net worth, N_1 (say $20R_1 - 19$)

Leverage amplifies losses (and gains)

So in this example, we have

$$N_1 = 20R_1 - 19.$$

If $R_1 = 1$, then bank breaks even and $N_1 = N_0 = 1$.

Suppose instead $R_1 = 1.01$. What is N_1 in this case?

Suppose instead $R_1 = 0.99$. What is N_1 in this case?

1% change in R_1 has a large (20%) effect on N_1. Why?

Leverage amplifies losses (and gains)

More generally, the bank's realized net worth can be written as,

$$N_1 = R_0 I_0 - \rho_0 I_0 = \left(1 + \frac{R_1 - 1}{1 - \bar{\rho}_0}\right) N_0.$$

Note that high leverage, $\frac{1}{1-\bar{\rho}_0}$, amplifies gains but also **losses**.

Going beyond the math, what is the economic intuition for this result?

Leverage amplifies due to debt being a constant promise

The bank's debt is fixed regardless of its realized returns R_1.

It has to pay $\rho_0 I_0$ regardless of returns R_1 are high or low.

Put differently, all the changes in returns are absorbed by N_1.

This feature of debt creates amplification of losses (and gains).

But should Fs' claims be necessarily be fixed regardless of R_1?

So far, we simply assumed it. This is a deep issue. Will come back.

Leverage amplifies initial losses (and gains)

The drop in banks' net worth, N_1, reduces its new investment, I_1.

Suppose the same model is repeated at date 1 so that,

$$\overbrace{I_1}^{20\%\text{ drop}} = \frac{1}{1-\overline{\rho}_1} \overbrace{N_1}^{20\%\text{ drop}}, \text{ where } N_1 = 20 \overbrace{R_1}^{1\%\text{ drop}} - 19.$$

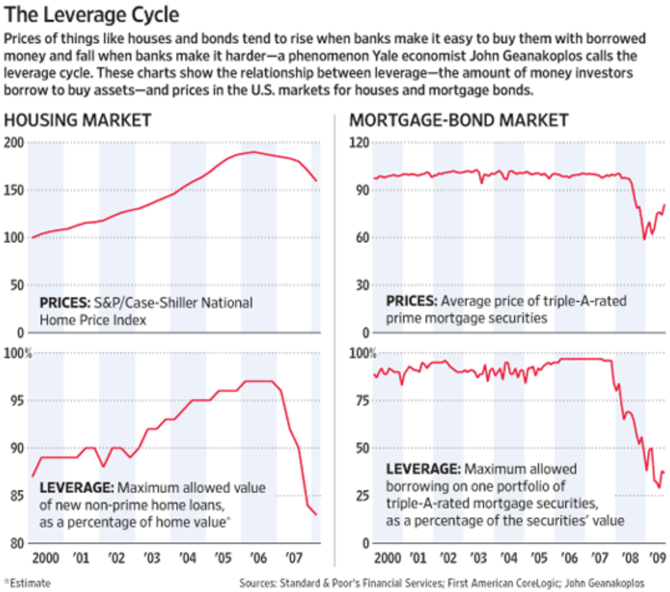
1% drop in R_1 translates into an amplified drop in N_1.

This translates into an amplified drop in I_1. Why?

In practice, maximum leverage $\overline{\rho}_1$ also tends to be **procyclical**...

Roadmap

1. Amplification from high leverage
2. Amplification from procyclical leverage
3. Fire sales and amplification
4. The LTCM crisis of 1998


The Leverage Cycle
Prices of things like houses and bonds tend to rise when banks make it easy to buy them with borrowed money and fall when banks make it harder—a phenomenon Yale economist John Geanakoplos calls the leverage cycle. These charts show the relationship between leverage—the amount of money investors borrow to buy assets—and prices in the U.S. markets for houses and mortgage bonds.
HOUSING MARKET
PRICES: S&P/Case-Shiller National Home Price Index
LEVERAGE: Maximum allowed value of new non-prime home loans, as a percentage of home value*
MORTGAGE-BOND MARKET
PRICES: Average price of triple-A-rated prime mortgage securities
LEVERAGE: Maximum allowed borrowing on one portfolio of triple-A-rated mortgage securities, as a percentage of the securities' value
2000 '01 '02 '03 '04 '05 '06 '07
2000 '01 '02 '03 '04 '05 '06 '07 '08 '09
*Estimate
Sources: Standard & Poor's Financial Services; First American CoreLogic; John Geanakoplos

In practice, leverage also tends to be procyclical

The bottom panels illustrate a measure of $\overline{\rho}_1$ for different assets.

Leverage ratios seem procyclical in the sense that they are high in good times (with high R_1) but low in bad times (with low R_1).

Geanakoplos (2009), "The Leverage Cycle" proposed a theory of procyclical leverage based on changes in uncertainty.

Bad times $\Longrightarrow$ Uncertainty $\Longrightarrow$ Nervous lenders $\Longrightarrow$ Less leverage.

We will come back to and formalize this argument next week.

For now: Procyclical leverage creates further amplification. Why?

Procyclical leverage creates further amplification

Going back to our example, suppose $\overline{\rho}_1 = 0.9 < 0.95$ after the loss.

$$\overbrace{l_1}^{\text{60\% drop}} = \underbrace{\frac{1}{1 - \overline{\rho}_1 (R_1)}}_{\text{drops from 20 to 10} \implies \text{50\% drop}} \overbrace{N_1}^{\text{20\% drop}}, \text{ where } N_1 = 20R_1 - 19.$$

Procyclical leverage ratio creates further amplification!

Borrowing becomes more difficult ($\overline{\rho}_1$ collapses) precisely when banks make losses and need to borrow the most!

Roadmap

Another source of amplification: Fire sales

Another problem in practice is that R_1 is also endogenous. Many banks (or bank like institutions) invest in financial assets. For such assets, the realized return can be written as,

$$R_1 = \frac{Q_1 + D_1}{Q_0}.$$

Here, Q_0, Q_1 denote the price and D_1 denotes dividend/payoff at 1. Imagine buying the asset at date 0, receiving D_1, and selling the asset at date 1 to cash out. Then your return would be R_1.

Another source of amplification: Fire sales

In financial markets, prices Q_0, Q_1 are typically "endogenous."

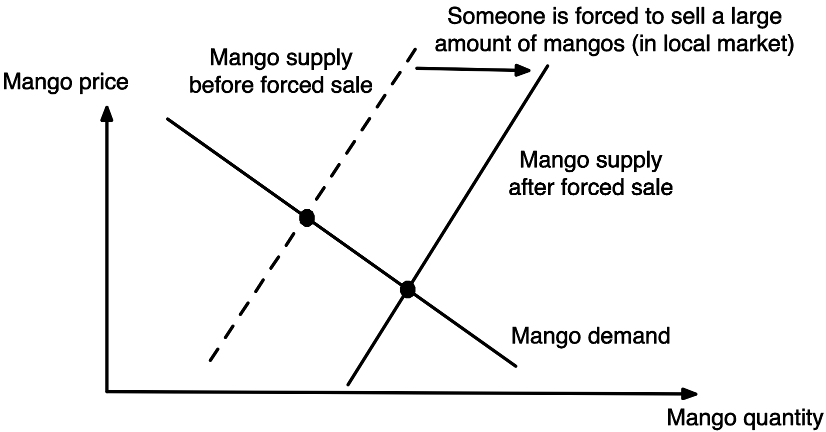
This makes R_1 endogenous: What the bank does can affect R_1.

In particular, low investment I_1 can lower Q_1, and ultimately, R_1.

This amplification channel is known as **fire sales**.

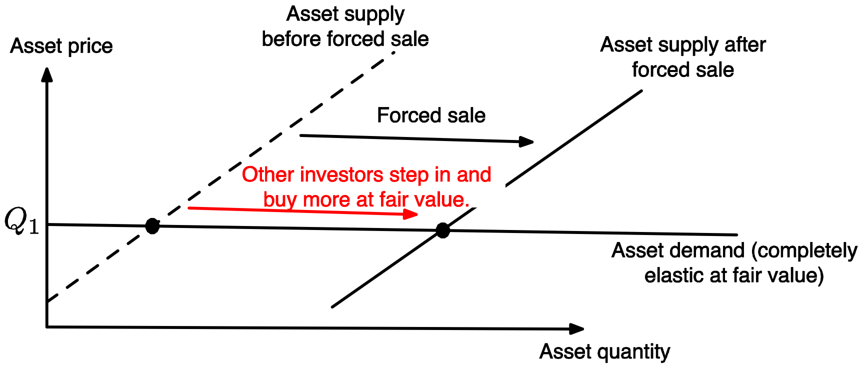
To illustrate, we need a little bit of background on asset pricing...

Forced mango sales would reduce the mango price



Can we draw an analogy from goods to assets? In theory? In practice?

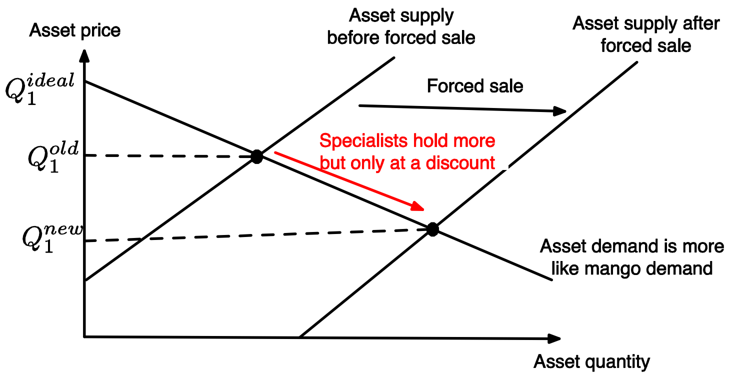
Basic asset pricing theory: Forced sales don't matter



Fair value, Q_1, is present discounted value of future dividends/payoffs.

The discount rate incorporates risk, but is largely unchanged with sale.

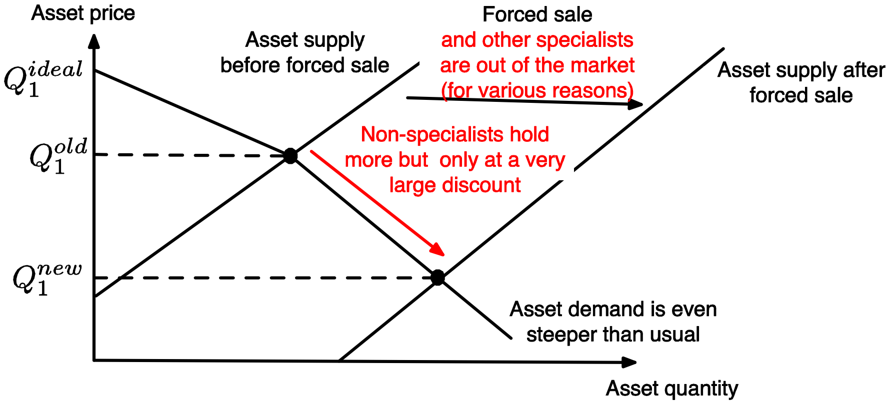
Asset pricing in practice: Somewhere in between



Asset prices in practice are somehwere in between. Imagine Q_1^{ideal}, Q_1^{old}, Q_1^{new} are different but close to one another.

There are (various) advanced asset pricing theories that capture this.

Fire sales: Considerable market impact (larger than usual)



The result heavily relies on specialists being out. Why are they out?

Why are specialists out? Common shocks/distress

Shleifer-Vishny (1992): "Liquidation Values and Debt Capacity..."

First to emphasize/formalize fire sales. Illustrate with a parable:

Consider indebted farmer with low current cash flow.

Cannot reschedule debt or borrow more.

Must liquidate (sell) the farm to pay back its creditors.

Potential buyers:

- High valuation (specialists): Neighbor farmer.
- Low valuation (non-specialists): Convert to **baseball field**

Neighbor is **simultaneously distressed** (industry wide shocks) and **thus she is also borrowing constrained**.

The farm is sold to low valuation user at a **fire sale price (**much lower than the value at best use, Q_1^{ideal}).

Fire sales happen in real assets such as farms or houses

Campbell, Giglio, Pathak (AER, 2011), “Forces Sales and House Prices.”

They analyze house sale prices in Massachusetts between 1987-2009.

They investigate sale prices around events that might plausibly involve fore sales: the death or bankruptcy of owner, the foreclosure by a bank.

They compare the sale price relative to price of comparable houses...

Table 1 - Frequency and Timing of Forced Sales

Panel A: Number of Forced Transactions by Year

Year	Total Observations	Deaths	Bankruptcies	Foreclosures	Total Forced
1987	87,257	1.1%	-	0.0%	1.1%
1988	78,461	0.9%	-	0.0%	0.9%
1989	65,728	0.9%	-	0.3%	1.2%
1990	54,062	1.0%	-	1.1%	2.1%
1991	57,013	1.1%	0.1%	5.2%	6.4%
1992	68,471	1.2%	0.2%	8.2%	9.6%
1993	74,556	1.6%	0.3%	9.4%	11.4%
1994	81,058	1.8%	0.5%	8.3%	10.5%
1995	75,909	1.8%	0.6%	7.0%	9.3%
1996	84,046	1.6%	0.7%	4.9%	7.3%
1997	90,163	1.8%	0.8%	4.3%	6.9%
1998	99,770	1.9%	0.9%	3.0%	5.7%
1999	103,247	1.8%	1.1%	2.3%	5.2%
2000	95,036	1.9%	1.1%	1.8%	4.8%
2001	89,555	2.0%	1.2%	1.4%	4.5%
2002	92,582	2.2%	1.2%	1.2%	4.6%
2003	94,692	2.3%	1.4%	0.7%	4.5%
2004	105,630	2.5%	1.4%	0.7%	4.6%
2005	101,929	2.4%	1.3%	0.8%	4.5%
2006	86,243	2.3%	1.3%	1.6%	5.2%
2007	77,526	2.2%	0.9%	5.3%	8.4%
2008	60,483	1.9%	0.7%	14.0%	16.6%
2009(Q1)	7,976	2.1%	0.7%	25.7%	28.5%
Total	1,831,393	1.8%	0.8%	3.5%	6.1%

Timing of plausibly forced house sales

Panel B: Timing of Forced Transactions Relative to Forcing Event

Group	Death	Bankruptcy	Foreclosure
sale 3 yrs before event	12.9%	10.3%	
sale 2 yrs before event	15.2%	10.1%	
sale 1 yr before event	20.6%	9.5%	
sale 1 yr after event	29.1%	30.8%	85.9%
sale 2 yrs after event	14.8%	22.1%	9.1%
sale 3 yrs after event	7.4%	17.2%	1.6%

Plausibly forced sales are associated with lower prices

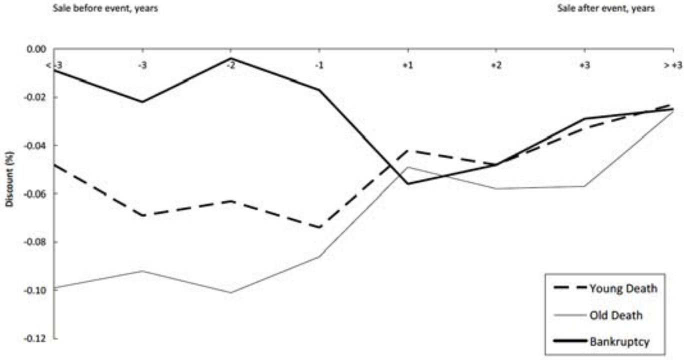


Figure 2: Forced Sales Discount and Time Between Sale and Event

Courtesy of John Y. Campbell, Stefano Giglio, and Parag Pathak. Used with permission.

The timing for bankruptcy sales is especially indicative of a fire sale mechanism (as opposed to other factors, e.g., poor maintenance).

The price discount is particularly large for foreclosures

Table 2 - Price Discount for Forced Sales

	Full sample		*Single Family*		
	Estimate	Std Err	Estimate	Std Err	Es
	(1)	(2)	(3)	(4)	
			Panel A: All Forced Transactions		
Forced (-3 years;+3 years)	-0.197	(0.002)	-0.159	(0.002)	-
			Panel B: Forced Transactions by Type		
Death, young seller (-3;+3)	-0.053	(0.005)	-0.068	(0.006)	-
Death, old seller (-3;+3)	-0.069	(0.002)	-0.082	(0.003)	-
Bankruptcy (-3;+3)	-0.035	(0.003)	-0.042	(0.003)	-
Foreclosure	-0.314	(0.003)	-0.260	(0.003)	-

Especially large discount for foreclosures. This supports fire sales, but read the paper for other contributing factors (vandalism etc).

How about financial assets? Slow moving capital

- Fire sales can also happen in financial assets such as bonds, CDOs...
- With financial assets, another contributing factor to fire sales is that there might be few specialists (or neighbors) to begin with.
- This is especially the case for niche and complex financial assets that are harder to price (require more effort/research etc).
- We expect there to be enough specialists to absorb "reasonable" sales or purchases that happen in regular days.
- But an unusually large sale could create havoc.
- Other specialists would eventually come in, but this takes time.
- This is known as slow-moving capital (referring to specialist capital).

Evidence on fire sales/slow moving capital

Empirical studies show there can be fire sales also in financial markets.

Next slide is an illustration from Mitchell, Pedersen, Pulvino (2007).

Convertible bonds: Complex asset with a formula for fair valuation.

Convertible hedge funds: Specialize in valuing these assets.

In 2005, they had to lower their positions due to financial problems.

How did these fire sales affect the price of convertible bonds?

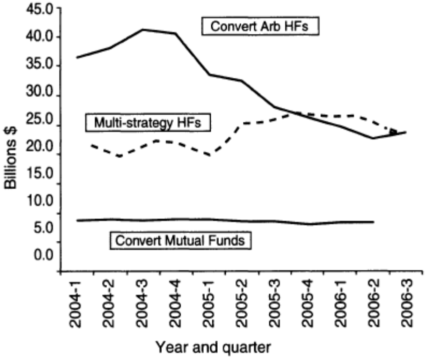


FIGURE 1. ADJUSTED HOLDINGS OF CONVERTIBLE BONDS IN BILLIONS OF DOLLARS

Courtesy of Mark Mitchell, Lasse Heje Pedersen, and Todd Pulvino. Used with permission.

Convertible arb HFs reduce their positions due to losses and redemptions.

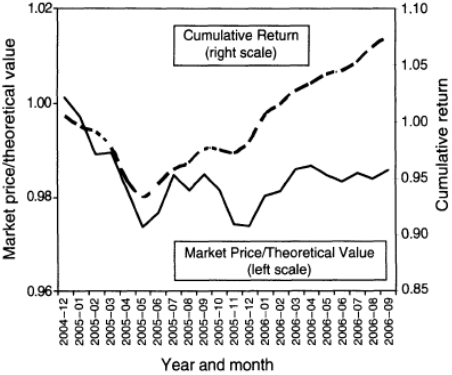


FIGURE 2. PRICE-TO-THEORETICAL-VALUE OF CONVERTIBLE BONDS, AND RETURN OF CONVERTIBLE BOND HEDGE FUNDS (2004/12-2006/09)

Other investors did not immediately step in (since highly specialized) and the price fell below the theoretical value for an extended period.

Multi-strategy HFs eventually step in (previous slide) but takes time.

Fire sales generate further amplification

To learn more about fire sales, read the survey by Shleifer-Vishny.

Kiyotaki and Moore (1997), "Credit Cycles" illustrate that fire sales can generate further amplification.

We can illustrate this in our framework. We had the example,

$$I_1 = \frac{1}{1-\bar{\rho}_1} N_1 \text{ where } N_1 = 20R_1 - 19.$$

We also mentioned that

$$R_1 = \frac{Q_1 + D_1}{Q_0}.$$

Fire sales generate further amplification

Now let us add the assumption that asset prices are given by:

$$Q_1 = \underbrace{\overline{Q}_1}_{\text{factors exogenous to our model}} \left(1 + \overbrace{G_Q\left(I_1\right)}^{\text{fire sale influence}}\right).$$

Here, $G_Q(\cdot)$ is an increasing function. Low I_1 captures forced asset sales by the bank, which lowers $G_Q(I_1)$ and the price.

Normalize so that if bank were to break even at that 1 (so that $N_1 = N_0$), then we also have $G_Q(I_1) = 0$ and $Q_1 = \overline{Q}_1$.

Taking Q_0, D_1 as constant (not our focus) this also implies,

$$R_1 = \frac{D_1 + Q_1}{Q_0} = \underbrace{\overline{R}_1}_{\text{exogenous factors}} + \overbrace{G(I_1)}^{\text{supply-demand influence/fire sales}}$$

for some constant $\overline{R}_1$ and for some function $G(\cdot) = \frac{\overline{Q}_1 G_Q(\cdot)}{\overline{Q}_0}$.

Note that $G(\cdot)$ is also an increasing function. What is the intuition?

Earlier analysis is special case with $G(I_1) = 0$ and unresponsive to I_1.

The responsiveness of $G(\cdot)$ captures the severity of fire sales.

What is the effect of a 1% shock on net worth in this case?

Fire sales generate further amplification

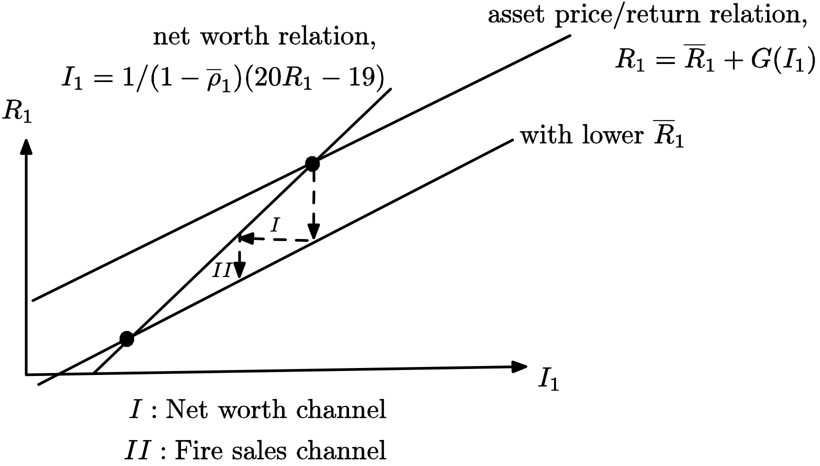
$$N_1 = 20 \underbrace{\underbrace{\left(\overbrace{\overline{R}_1}^{1\% \text{ drop} \implies} + G \overbrace{(I_1)}^{\text{large drop (why?)}} \right)}_{\text{More than } \mathbf{1\%} \text{ drop. Why?}} - 19.}_{\text{More than } \mathbf{20\%} \text{ drop. Why?.}}$$

What is the intuition behind the bottom two lines?

So fire sales create further amplification.

The drop in N_1 further reduces investment I_1 (why), repeating the mechanism and triggering downward spiral...

Fire sale and NW channels trigger a spiral



Summary of amplification mechanisms

Putting everything together, we have (for the example):

$$I_1 = \frac{1}{1-\rho_1} N_1 = \frac{1}{1-\rho_1\left(\overline{R}_1\right)} \left(20\left(\overline{R}_1 + G\left(I_1\right)\right) - 19\right).$$

This illustrates three amplification mechanisms (find them!):

Leverage generates amplified losses (or gains).

Procyclical leverage, $\rho_1\left(\overline{R}_1\right)$, generates further amplification.

Fire sales, $G\left(I_1\right)$, generate further amplification.

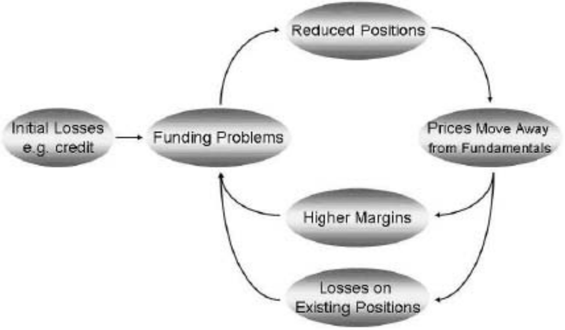


Figure: From Brunnermeier (2009), "Deciphering The Liquidity And Credit Crunch 2007-2008".

Next: Case study (LTCM) that illustrates some of the mechanisms.

Using Jorion (2000), "Risk Management Lessons from LTCM."

Roadmap

A cautionary tale of high leverage: LTCM

The hedge fund, LTCM, was founded in 1994 by star trader John Meriwether and other traders who left Salomon Bros. after 1991.

Bob Merton and Myron Scholes (Nobelists) joined them.

They did relative value arbitrage: Find two very similar assets, buy the cheap one, and (short) sell the expensive one:

- On-the-run vs. off-the-run Treasuries,
- Mortgage-backed securities (MBS) vs. treasuries,
- High-yield vs. low-yield bonds in the Euro area.

These strategies make profit if the prices of two assets converge.

But they (temporarily) make losses if prices diverge further. Why?

LTCM had great success in early years

LTCM strategies deliver high returns only if leveraged.

Capital \$5-7 billion in 1996-97.

Total assets about \$125 billion, so 25:1 leverage.

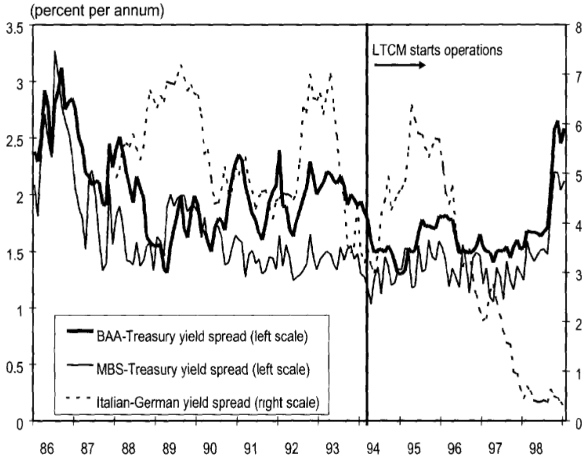
Fees were 2% of capital + 25% of profits (\$1.5 billion in 1997).

Prices indeed converged and they had a great run for a while.

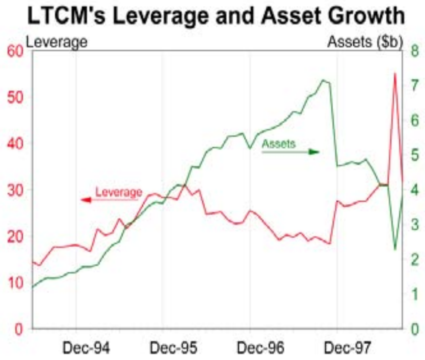
But this also meant they ran out of investment opportunities.

At the end of 1997, LTCM returned \$2.7 billion to investors...

History of spreads



LTCM's leverage and asset growth



Returning capital (lowering N_0) brought leverage ratio back to 25.

In retrospect, this was not a very prudent thing to do. Why?

Crisis in 1998: The shock

Preliminary problems in May and June 1998 from falling MBS prices (16% loss from end 1997).

August 17, 1998 Russia announced surprise debt restructuring.

"Flight to liquidity": prices of most fixed income assets declined.
$\Longrightarrow$ Additional losses (by August, 52% loss).

LTCM had about $N_0 =$\$5B. Invested in about $I_0 =$\$125B.

How much should R_1 fall (from 1) for LTCM to lose about 50%?

This is the first amplification channel we discussed!

Leverage amplified LTCM's losses

After 50% loss, LTCM's net worth is down to about \$2.5B

These losses force LTCM to reduce its asset holdings:

$$I_1 = \frac{1}{1-\rho_1} N_1 \simeq \$62.5B, \text{ much smaller than \$125B.}$$

(This assumes $\rho_1 \simeq \rho_0 \simeq 25$. If leverage ratio was procyclical, then the required reduction is even larger. Why?)

Raising capital is another possibility but not easy

As an alternative to reducing I_1, LTCM also tried to increase N_1 by raising capital, i.e., bringing in new owners to the fund.

We ruled this possibility out in our model.

Also diffi cult in practice, especially in times of turmoil.

LTCM sought additional capital but obtained none.

No-one wants to put money into a fund that just lost 52%!

It did not help that they force-returned capital earlier.

So LTCM has to reduce I_1, i.e., sell about \$60B of its assets....

Large asset sales reduce prices further

Asset sales by LTCM further reduce prices. Why?

Price falls might have been accelerated by predatory trading.

Business Week (February 26, 2001): "If lenders know that a hedge fund needs to sell something quickly, they will sell the same asset—driving the price down even faster. Goldman Sachs & Co. and other counterparties to LTCM did exactly that in 1998."

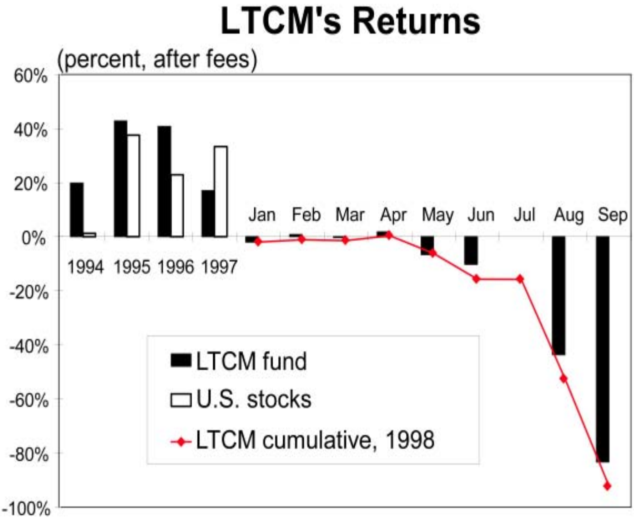
Predatory trading might be another reason why specialists were out. But this is somewhat speculative (Goldman denies allegations).

Even without this, we would expect the price to drop. Why?

The declining price falls further increase LTCM's losses.

September 23 bailout organized by Federal Reserve Bank of New York (92% loss).

LTCM dramatically loses almost all net worth



Taking stock: Some lessons from LTCM

High leverage creates fragility, even if you have a genius team!

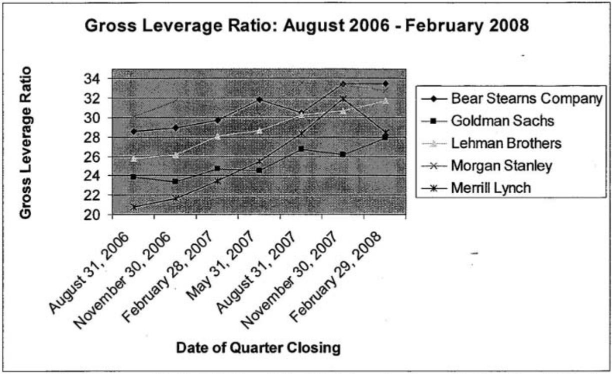
Small price movements/unexpected events can generate large losses.

These losses induce fire sales and induce price drops/further losses.

Procyclical leverage might further exacerbate these losses.

Taking stock: Some lessons from LTCM

Figure 1. CSE Firms- Gross Leverage Ratios



Source: This data was provided by TM. They obtained the information from public filings (*i.e.*, 10-K) and Bloomberg. We verified each firm's year-end gross leverage ratio amount, but did not verify its quarterly ratios.

A view of the subprime crisis: Many LTCMs failing simultaneously!

Next time: Why do financial institutions make losses?

But why did LTCM or other institutions make these losses?

We will continue our discussion of LTCM next time.

Finish reading the LTCM case. Also start reading the Bear Stearns/JP Morgan case. Can read pages 1-8 (until the section on financial stresses).

Taking stock: Amplification mechanisms

There are more amplification mechanisms that we will see next week.

Leverage, procyclical leverage, fire sales are important ones.

Also help us understand why shocks to banks particularly damaging.

Banks are leveraged and subject to fire sales (specialized assets).

Tech bubble bust much milder since investors in tech stocks (like you and me) are not highly leveraged. Losses are contained.

Subprime crisis much more severe since the losses are amplified!