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

Alp Simsek
• 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

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

Recall the Holmstrom-Tirole model from the last time

\[ \text{Invest } l_0 = \frac{N_0}{1 - \rho_0} \text{ by borrowing } \rho_0 l_0. \]

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 \( \rho_0 = 0.95 \ldots \)
The bank’s initial balance sheet

<table>
<thead>
<tr>
<th>Assets</th>
<th>Liabilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assets $I_0$</td>
<td>debt, $\rho_0 I_0$</td>
</tr>
<tr>
<td>(say 20)</td>
<td>(say 19)</td>
</tr>
<tr>
<td></td>
<td>net worth, $N_0$</td>
</tr>
<tr>
<td></td>
<td>(say 1)</td>
</tr>
</tbody>
</table>

The bank’s initial leverage ratio is high, $1/(1 - \rho_0) = 20$. 
Consider the balance sheet at date 1 after $R_1$ is realized.

<table>
<thead>
<tr>
<th>Assets</th>
<th>Liabilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Realized returns, $R_1I_0$ (say 20$R_1$)</td>
<td>debt, $\rho_0I_0$ (say 19)</td>
</tr>
<tr>
<td></td>
<td>realized net worth, $N_1$</td>
</tr>
<tr>
<td></td>
<td>(say 20$R_1$ − 19)</td>
</tr>
</tbody>
</table>
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,

\[ N_1 = R_0 l_0 - \rho_0 I_0 = \left(1 + \frac{R_1 - 1}{1 - \rho_0}\right) N_0. \]

Note that high leverage, \( \frac{1}{1 - \rho_0} \), 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 $\rho_0 l_0$ 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,

$$I_1 = \frac{1}{1 - \bar{\rho}_1} N_1,$$

where $N_1 = 20 (R_1) - 19$.

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 $\bar{\rho}_1$ 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

*Estimate

Sources: Standard & Poor’s Financial Services; First American CoreLogic; John Geanakoplos

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In practice, leverage also tends to be procyclical

The bottom panels illustrate a measure of $\bar{\rho}_1$ 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 $\rightarrow$ Uncertainty $\rightarrow$ Nervous lenders $\rightarrow$ Less leverage.

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

For now: Procyclical leverage creates further amplification. Why?
Going back to our example, suppose $\overline{\rho}_1 = 0.9 < 0.95$ after the loss.

\[ I_1 = \frac{1}{1 - \overline{\rho}_1 (R_1)} \]

drops from 20 to 10 $\implies$ 50% drop

20% drop

\[ N_1 = 20R_1 - 19. \]

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

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

Total 1,831,393 1.8% 0.8% 3.5% 6.1%

Courtesy of John Y. Campbell, Stefano Giglio, and Parag Pathak. Used with permission.
Timing of plausibly forced house sales

<table>
<thead>
<tr>
<th>Group</th>
<th>Death</th>
<th>Bankruptcy</th>
<th>Foreclosure</th>
</tr>
</thead>
<tbody>
<tr>
<td>sale 3 yrs before event</td>
<td>12.9%</td>
<td>10.3%</td>
<td></td>
</tr>
<tr>
<td>sale 2 yrs before event</td>
<td>15.2%</td>
<td>10.1%</td>
<td></td>
</tr>
<tr>
<td>sale 1 yr before event</td>
<td>20.6%</td>
<td>9.5%</td>
<td></td>
</tr>
<tr>
<td>sale 1 yr after event</td>
<td>29.1%</td>
<td>30.8%</td>
<td>85.9%</td>
</tr>
<tr>
<td>sale 2 yrs after event</td>
<td>14.8%</td>
<td>22.1%</td>
<td>9.1%</td>
</tr>
<tr>
<td>sale 3 yrs after event</td>
<td>7.4%</td>
<td>17.2%</td>
<td>1.6%</td>
</tr>
</tbody>
</table>

Courtesy of John Y. Campbell, Stefano Giglio, and Parag Pathak. Used with permission.
Plausibly forced sales are associated with lower prices.

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>
<thead>
<tr>
<th></th>
<th>Full sample</th>
<th></th>
<th>Single Family</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Estimate</td>
<td>Std Err</td>
<td>Estimate</td>
<td>Std Err</td>
</tr>
<tr>
<td>Forced (-3 years;+3 years)</td>
<td>-0.197</td>
<td>(0.002)</td>
<td>-0.159</td>
<td>(0.002)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Panel A: All Forced Transactions</td>
<td></td>
</tr>
<tr>
<td>Death, young seller (-3;+3)</td>
<td>-0.053</td>
<td>(0.005)</td>
<td>-0.068</td>
<td>(0.006)</td>
</tr>
<tr>
<td>Death, old seller (-3;+3)</td>
<td>-0.069</td>
<td>(0.002)</td>
<td>-0.082</td>
<td>(0.003)</td>
</tr>
<tr>
<td>Bankruptcy (-3;+3)</td>
<td>-0.035</td>
<td>(0.003)</td>
<td>-0.042</td>
<td>(0.003)</td>
</tr>
<tr>
<td>Foreclosure</td>
<td>-0.314</td>
<td>(0.003)</td>
<td>-0.260</td>
<td>(0.003)</td>
</tr>
<tr>
<td>Panel B: Forced Transactions by Type</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

Especially large discount for foreclosures. This supports fire sales, but read the paper for other contributing factors (vandalism etc).
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?
Convertible arb HFs reduce their positions due to losses and redemptions.
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.
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,

\[ l_1 = \frac{1}{1 - \rho_1} N_1 \text{ where } N_1 = 20R_1 - 19. \]

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:

\[ Q_1 = \sqrt{Q_1} \left( 1 + \overline{G_Q(I_1)} \right) \]

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,

$$R_1 = \frac{D_1 + Q_1}{Q_0} = \overline{R}_1 + G(I_1)$$

for some constant $\overline{R}_1$ and for some function $G(\cdot) = \frac{Q_1 G(Q(\cdot))}{Q_0}$.

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

\[
N_1 = 20 \left( \overline{R_1} + G (I_1) \right) - 19.
\]

More than 1% drop. Why?
More than 20% 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

net worth relation,

\[ I_1 = \frac{1}{(1 - \bar{\rho}_1)(20R_1 - 19)} \]

asset price/return relation,

\[ R_1 = \bar{R}_1 + G(I_1) \]

with lower \( \bar{R}_1 \)

\[ R_1 \]

\[ I_1 \]

I : Net worth channel

II : Fire sales channel
Putting everything together, we have (for the example):

\[ l_1 = \frac{1}{1 - \rho_1} N_1 = \frac{1}{1 - \rho_1 (\bar{R}_1)} (20 (\bar{R}_1 + G(l_1)) - 19). \]

This illustrates three amplification mechanisms (find them!):

- Leverage generates amplified losses (or gains).
- Procyclical leverage, \( \rho_1 (\bar{R}_1) \), generates further amplification.
- Fire sales, \( G(l_1) \), generate further amplification.
Figure: From Brunnermeier (2009), “Deciphering The Liquidity And Credit Crunch 2007-2008”.

1. Amplification from high leverage

2. Amplification from procyclical leverage

3. Fire sales and amplification

4. The LTCM crisis of 1998
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

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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. 
⇒ Additional losses (by August, 52% loss).

LTBM had about $N_0 = $5B. Invested in about $I_0 = $125B.
How much should $R_1$ fall (from 1) for LTBM to lose about 50%? 
This is the first amplification channel we discussed!
After 50% loss, LTCM’s net worth is down to about $2.5B.

These losses force LTCM to reduce its asset holdings:

\[ l_1 = \frac{1}{1 - \rho_1} \approx 62.5B, \text{ much smaller than } 125B. \]

(This assumes \( \rho_1 \approx \rho_0 \approx 25 \). 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 difficult 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
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

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!
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