Lecture 4: Fire Sales and the Asset Market Feedback

Alp Simsek

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Introduction: Amplification from asset prices

- So far: Demand for insurance. Some reasons why supply is limited.
- Next: Assume underinsurance and focus on amplification mechanisms.
- An important source of amplification seems to be asset prices.
  - During a severe crisis, prices of risky assets fall.
  - This lowers Es net worth, which might further increase distress.
- But why do asset prices fall? Is it just fundamentals?
- They typically "recover." Countercyclical risk premia.

Today: Fire sales, asset market feedback. Role of leverage.

- We start with a related topic, limits to arbitrage.

Roadmap

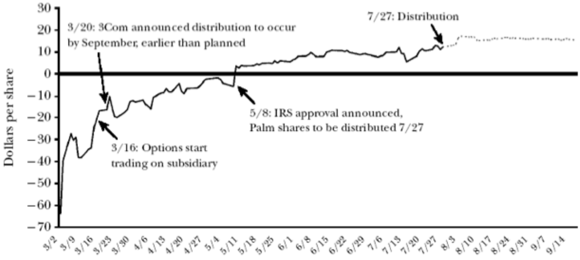
1. Limits to arbitrage and fire sales
2. Asset market feedback
3. A case study: LTCM

Negative stub values (from Lamont and Thaler)

- Arbitrage is ruled out in traditional asset pricing models.
- In practice, there is occasionally close-arb opportunities.

Figure 3

3Com/Palm Stub, 3/2/00–9/18/00



Another example: Siamese twins (from Lamont and Thaler)

Figure 1
Pricing of Royal Dutch Relative to Shell
(deviation from parity)

A theory of limits to arbitrage

Ingredients for limits to arbitrage:

1. Heterogeneous valuations (noise traders, arbs).
2. "Noise trading" opens an "arbitrage" wedge.
3. Arbs are unable to close the wedge for a few reasons (Shleifer and Vishny, 1997):
    - Constraints on positions, e.g., short selling difficult or costly.
    - Arbitrage requires capital (margins for long/short positions).
    - Uncertainty and performance based arbitrage (PBA):
        - Arb might be fundamentally risky.
        - Arb might be risky in the short run. Short horizons. Why?

A related phenomenon is fire sales

Shleifer-Vishny (1992) parable to illustrate **fire sales**:

- 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:
  - Low valuation: Baseball field or deep pocket investor.
  - High valuation: Neighbor farmer.
- Neighbor is **simultaneously distressed** (industry wide shocks) and **thus also borrowing constrained**.
- The farm is sold to low valuation user at **fire sale price** (lower than value at best use).

Example from Mitchell, Pedersen, Pulvino (2007)

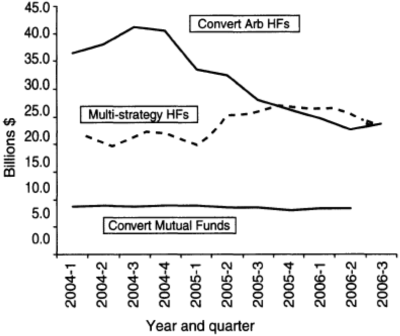


FIGURE 1. ADJUSTED HOLDINGS OF CONVERTIBLE BONDS IN BILLIONS OF DOLLARS

Convertible hedge funds had to lower their positions because their financiers pulled out (due to low realized returns).

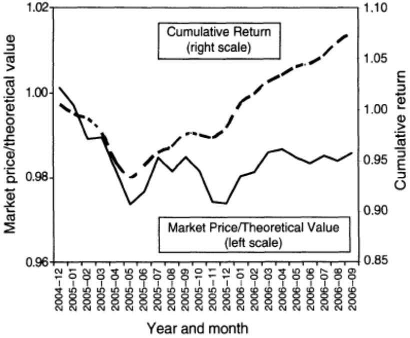


FIGURE 2. PRICE-TO-THEORETICAL-VALUE OF CONVERTIBLE BONDS, AND RETURN OF CONVERTIBLE BOND HEDGE FUNDS (2004/12-2006/09)

Other investors did not step in and the price fell below the theoretical value for an extended period.

A theory of fie sales

Ingredients for fire sales:

1. Heterogeneous valuations (distressed seller, various buyers).
2. Sales by distressed agents pushes the price.
3. High valuation users unable to buy because they are simultaneously distressed.

- Note the parallels between limits-to-arbitrage and fire sales.
- **Next:** Kiyotaki-Moore (1997) model to illustrate fire-sales and amplification.

Roadmap

Asset market feedback and amplification

Kiyotaki-Moore (1997) main result: **Asset market feedback.**

- A shock that simultaneously hits many Es triggers fire sales.
- This further lowers Es net worth.
- Low net worth lowers prices further and exacerbates the crisis.

Leverage (underinsurance) key for the argument.

Consider a dynamic environment with Es and Fs

- An economy with periods $t \in \{0, 1, .., \}$ and a single consumption good (dollar).
- Two types of investors: Measure one of Es and Fs, with preferences: $\sum_t \beta^t c_t$.
- Fs have a large endowment, e in all periods. Ensures that the interest rate is fixed at $1 + r \equiv 1/\beta$.
- Fixed supply (of $\overline{k}$ units) capital, which does not depreciate.
- Let q_t denote the price of capital and k_t and $\tilde{k}_t$ denote E's and Fs' capital holdings. Capital market clearing:

$$k_t + \tilde{k}_t = \overline{k}. \tag{1}$$

E faces a collateral constraint

- Given capital k_t, E produces $F(k_t) = ak_t$ with **limited pledgeability**.
  - Date $t+1$ value of E's assets: $(a + q_{t+1}) k_{t+1}$,
  - Pledgeable assets: $q_{t+1} k_{t+1}$.
- **Collateral constraint:**

$$b_{t+1} \leq q_{t+1} k_{t+1}.$$

Friction (Hart and Moore, 1994): Inalienability of human capital.

E chooses her borrowing, consumption, and investment

- E also faces a **flow of funds** constraint **(FF)**:

$$c_t + q_t k_{t+1} = n_t + \frac{1}{1+r} b_{t+1} \text{ for each } t \geq 0, \tag{2}$$

where her net worth is given by:

$$n_t = (a + q_t) k_t - b_t.$$

Net worth is endogenous because it depends on the asset price and past investment decisions.

- **E's problem**: Given the initial condition (a_0, b_0, k_0) and the price sequence $\{q_t\}_{t=0}^{\infty}$, choose $\{c_t, k_{t+1}, b_{t+1}\}_{t=0}^{\infty}$ to maximize $\sum_{t=0}^{\infty} \beta^t c_t$ subject to (FF) and (CC).
(Allow $a_0 \neq a$. Will consider shocks to this)

Fs' technology and problem

- Fs have a backyard production technology $\tilde{y}_{t+1} = G\left(\tilde{k}_t\right)$, where $G(\cdot)$ is strictly increasing, concave, and satisfies Inada-type conditions: $G'(0) = \infty$ and $G'\left(\overline{k}\right) < a$.
- Fs' flow-of-funds constraint:

$$\tilde{c}_t + q_t\left(\tilde{k}_{t+1} - \tilde{k}_t\right) = e + b_t - \frac{1}{1+r}b_{t+1} + G\left(\tilde{k}_t\right) \text{ for each } t \geq 0.$$

- Fs choose $\left\{\tilde{c}_t, \tilde{k}_{t+1}\right\}_{t=0}^{\infty}$ to maximize $\sum_{t=0}^{\infty}\left(\frac{1}{1+r}\right)^t \tilde{c}_t$.

- Since e is large (by assumption), Fs always have $\tilde{c}_t > 0$ and is unconstrained in choosing $\tilde{k}_{t+1}$. FOC implies:

$$q_t - \frac{1}{1+r}q_{t+1} = \frac{1}{1+r}G'\left(\tilde{k}_{t+1}\right).$$

Fs are the low valuation users of Shleifer-Vishny

- Using capital market clearing (1), F's FOC yields a **downward sloping residual demand curve**:

$$\underbrace{q_t - \frac{1}{1+r} q_{t+1}}_{\text{rental rate (user cost) of capital}} = \frac{1}{1+r} G' \left(\underbrace{\overline{k} - k_{t+1}}_{\text{residual demand by F}} \right). \quad (3)$$

The more has to be sold to F, the lower is the price.

- Note that this is equivalent to the following asset pricing equation:

$$q_t = \sum_{j=1}^{\infty} \left(\frac{1}{1+r} \right)^j G' \left(\overline{k} - k_{t+j} \right). \quad (4)$$

Fs are passive and can be replaced by Eq. (3) or Eq. (4).

Definition of equilibrium

Definition

Equilibrium is a collection of allocations $\{c_t, k_t, b_t\}_{t=0}^{\infty}$ and prices $\{q_t\}_{t=0}^{\infty}$ such that E chooses her allocation optimally subject to (FF) and (CC), and prices satisfy the downward sloping demand equation Eq. (3) [which captures Fs' optimization plus capital market clearing].

Next:

- Benchmark without financial frictions.
- Equilibrium with frictions and the asset market feedback.

Frictionless benchmark features a constant asset price

- First consider the benchmark with no borrowing constraints.
- FOC for E's problem:

$$q_t - \frac{1}{1+r} q_{t+1} = \frac{1}{1+r} a. \tag{5}$$

- Combining this with Eq. (3), the unconstrained capital level is uniquely solved as $k_{t+1} \equiv k^*$ that satisfies:

$$a = G' \left(\overline{k} - k^* \right).$$

- Rolling over (5), the unconstrained price level is:

$$q^* = \frac{a}{r}.$$

Es' initial net worth has no effect on investment or asset price.

Characterizing the equilibrium with constraints

Suppose $k_0 < k^*$ and conjecture an equilibrium (verify later) in which:

1. For $t < T^{cons}$ (T^{cons} can be zero), E is constrained: consumes nothing (i.e., $c_t = 0$) and borrows as much as possible (i.e., $b_{t+1} = q_{t+1}k_{t+1}$) to invest in the asset. Constrained to choose $k_{t+1} < k^*$.
2. For $t \geq T^{cons}$, E is unconstrained. Price of capital and the level of investment are:

$$q_t = q^* = \frac{a}{r} \text{ and } k_{t+1} = k^*.$$

When constrained, E makes a leveraged investment

- Under the conjecture, $c_t = 0$ and $b_{t+1} = q_{t+1} k_{t+1}$ for $t < T^{cons}$.
- Plugging these into (FF) implies that E makes a leveraged investment:

$$\underbrace{\left(q_t - \frac{1}{1+r} q_{t+1} \right)}_{\text{downpayment per unit investment}} k_{t+1} = \underbrace{n_t}_{\text{net worth}} .$$

- **Observation:** With the collateral constraint, the required downpayment is the same as the rental rate of capital.
- In view of this, we can write the previous equation as:

$$\frac{1}{1+r} G' \left(\overline{k} - k_{t+1} \right) k_{t+1} = n_t \text{ for } t < T^{cons}. \quad (6)$$

- Defines implicit function, $k^{next}(n_t)$, increasing in n_t. **Intuition?**

How to characterize the equilibrium?

Equilibrium is the intersection of two equations that relate k_1 and q_0:

1. **Net worth relation (backward looking):** Plugging in the initial level of net worth, $n_0 = a_0 + q_0 k_0 - b_0$, initial investment is given by:
$$k_1 = k^{next}\left(a_0 + q_0 k_0 - b_0\right).$$
2. **Asset pricing relation (forward looking):** that characterizes q_0 in terms of k_1,
$$q_0 = q_0^{pricing}\left(k_1\right).$$

To obtain the asset pricing relation, we first need to characterize the evolution of capital for a given level of k_1.

Evolution of capital given initial investment

- Consider the evolution of capital given initial investment level, k_1.
- Note that (CC) is binding for each $t < T^{cons}$, which implies:

$$n_{t+1} = (a + q_{t+1}) k_{t+1} - b_{t+1} = ak_{t+1}.$$

- The evolution of capital is then given by:

$$k_{t+1} = \min \left(k^{next} (ak_t), k^* \right) \text{ for each } t \geq 1. \quad (7)$$

- Using Eq. (6) and steady-state relation, $G' \left(\bar{k} - k^* \right) = a$, prove:
  1. If $k_t < \frac{k^*}{1+r}$, then $k^{next} (ak_t) \in ((1 + r) k_t, k^*)$.
  2. If $k_t \geq \frac{k^*}{1+r}$, then $k^{next} (ak^*) \geq k^*$ and $k_{t+1} = k^*$.

Given any $k_1 < k^*$, capital level grows and eventually reaches k^*.

Obtaining the asset pricing relation

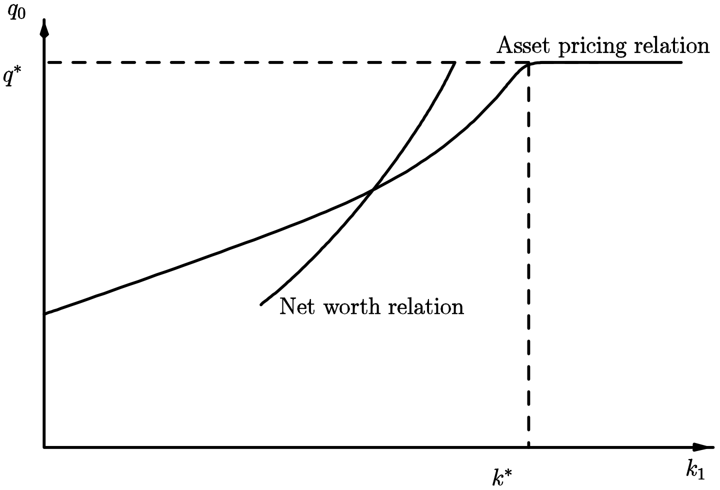
- Eq. (7) uniquely defines the path of capital, $\{k_t\}_{t=1}^{\infty}$.
- Moreover, increasing k_1 increases each k_t. **Intuition?**
- Eq. (4) then uniquely determines the asset price:

$$q_0^{pricing}(k_1) = \sum_{j=1}^{\infty} \left(\frac{1}{1+r} \right)^j G'\left(\overline{k} - k_j\right).$$

- Note that this is an increasing relation. **Intuition?**

- Net worth relation, $k_1 = k^{next}(a_0 + q_0 k_0 - b_0)$, is also increasing. Therefore...

Picture of a (stable) equilibrium



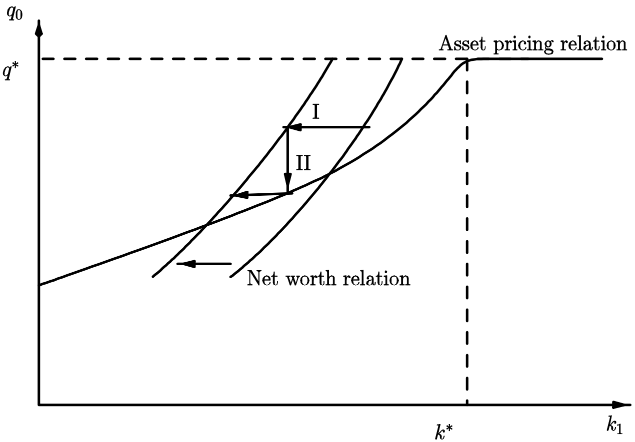
Consider a shock to E's net worth

- What happens if there are multiple intersections?
- **Next:** Assume there is a unique intersection (or consider the local neighborhood of an intersection) and consider a financial shock:

A temporary productivity shock that lowers date 0 output from $a_0 = a$ to $a_0 = a - \Delta a$. (Equivalently, can consider a debt-deflation that increases b_0 to $b_0 + \Delta b$).

- Recall that this would have no effect in the frictionless benchmark.

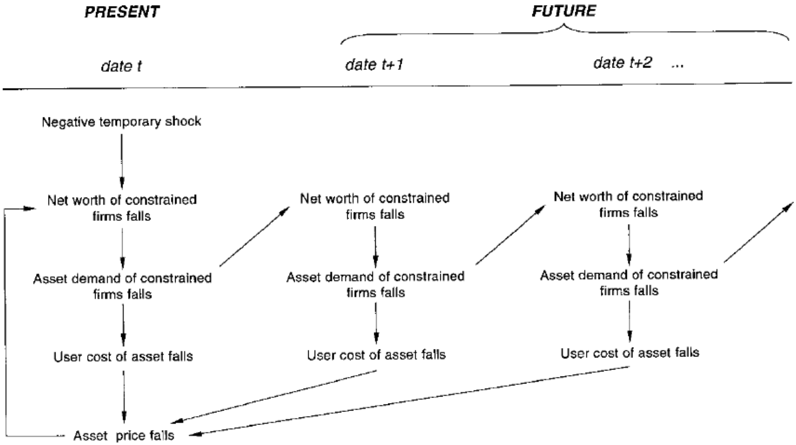
Asset market feedback amplifies the net worth channel



Channel I: Balance sheet channel

Channel II: Asset market feedback

Picture from KM: Dynamic linkages



The role of non-contingent debt

- Suppose initial debt is contingent on the value of the asset:

$$b_0(s) = q_0(s)\,k_0.$$

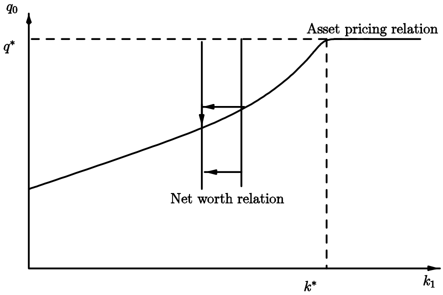
- Or suppose can default without recourse: $b_0(s) = \min(b_0, q_0(s)\,k)$.
- E's net worth in these versions of the model:

$$n_0(s) = a(s) + q_0(s)\,k_0 - b_0(s) = a(s).$$

  - Net worth relation: $k_1 = k^{next}(a(s))$ is independent of $q_0(s)$.
  - **Price feedback is gone (**see next slide). **Intuition?**

- Does Hart-Moore friction imply non-contingent or contingent debt?

The role of non-contingent debt



- Amplification requires non-contingent debt (and recourse if collateral).
- Empirically reasonable but not supported by the Hart-Moore friction.
- More generally, need underinsurance. Open problem.

Roadmap

1. Limits to arbitrage and fire sales
2. Asset market feedback
3. A case study: LTCM

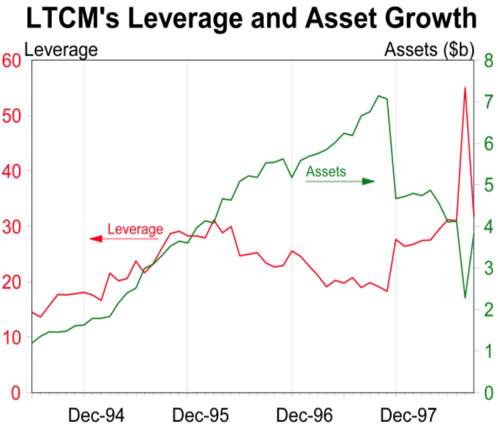
An example for the mechanisms: LTCM

- LTCM was founded in 1994 by John Meriwether and other traders who left Salomon Bros. after the Treasury bond scandal of 1991.
- Bob Merton and Myron Scholes joined them.
- Strategies bet on convergence of prices of closely related securities, e.g.
  - On-the-run vs. off-the-run Treasuries,
  - Mortgage-backed securities (MBS) vs. treasuries,
  - High-yield vs. low-yield bonds in the Euro area.
- Within each pair, the securities are normally highly correlated.
- Across pairs, the long positions normally have low correlation.

Evolution of risk

- 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).
- Problem: narrowing spreads meant high profits but poorer future investment opportunities.
- At the end of 1997, LTCM returned \$2.7 billion to investors to increase leverage.

LTCM's leverage and asset growth



Crisis in 1998: The shock

- Preliminary problems in May and June 1998 from widening MBS spread (16% loss from end 1997).
- August 17, 1998 Russia announced surprise debt restructuring.
- "Flight to liquidity": all credit spreads widened.

$\Longrightarrow$ Additional losses (by August, 52% loss).

Leverage amplifies the shock

- LTCM had about \$5B capital. Invested in about \$125B assets.
- It takes about 2% reduction in value of assets for LTCM to lose about 50% of its capital.

What happens after the loss:

- After such a loss, LTCM's new balance sheet:
  - About \$2.5B capital,
  - About \$122.5B assets.
- New leverage ratio is about 49:1 (actual number 55:1).
- The leverage ratio mechanically increases. LTCM has to reduce its leverage ratio (margin calls).

How to reduce the leverage ratio?

Two ways to reduce the leverage ratio:

1. Raise new capital: Ruled out by KM.
   Difficult shortly after you made a big loss (52% loss). Also difficult during a turmoil.

   LTCM sought additional capital September 2 but obtained none.

2. **Deleveraging:** Sell assets.

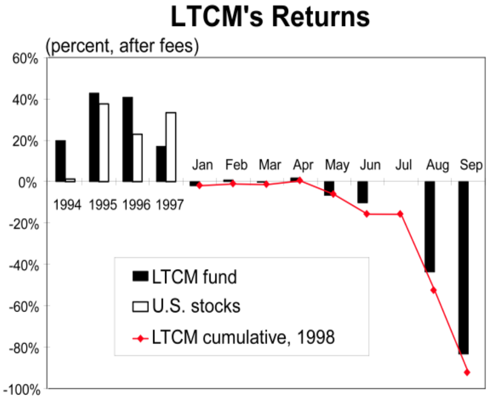
   To get back to 25:1 ratio, LTCM has to sell about $60B of its assets!

Large asset sales reduce prices further

- **KM channel:** Deleveraging leads to fire sales.
- Fire sales are accelerated by predatory trading (Brunnermeier and Pedersen, 2005):

  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."

- **KM channel:** Price feedback further increases LTCM's losses.
- September 23 bailout organized by Federal Reserve Bank of New York (92% loss).


LTCM's Returns
(percent, after fees)
60%
40%
20%
0%
-20%
-40%
-60%
-80%
-100%
1994
1995
1996
1997
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
LTCM fund
U.S. stocks
LTCM cumulative, 1998

Taking stock: Fire sales and asset market feedback

- **Limits to arbitrage, fire sales:** Heterogeneous valuations and borrowing constraints.
- **Asset market feedback:** Fire sales exacerbate financial distress.
- Leverage (non-contingent debt, underinsurance) plays a key role.

Next time: Understanding **the leverage ratios**. Further amplification.