Liquidity Risk and the Structure of Financial Crises

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October, 2008

Prepared for the
Internal Monetary Fund
and Federal Reserve Board

See also my related blog: http://sternfinance.blogspot.com
A Report from an Academic Returning from the Trenches
Overview of Talk

➢ Theory
  • What is liquidity risk?
  • How should liquidity risk affect prices and returns?
  • What happens during liquidity crisis?

➢ Evidence from notable liquidity crisis:
  • The current crisis
  • 2007 quant equity
  • 2005 convertible bond market
  • 1998 LTCM
  • 1987 stock market crash

➢ Conclusion
  • Will it happen again?
  • How do we solve the crisis and reduce the risk of future ones?
  • Liquidity risk lessons
What is Liquidity Risk

- Market liquidity:
  - A security is considered liquid if it is “easy” to trade: Low bid-ask spread, small price impact, high resilience, easy search (in OTC markets)

- Market liquidity risk:
  - The risk that the market liquidity worsens when you need to unwind

- Funding liquidity:
  - A trader’s available funding from own capital and (collateralized) loans

- Funding liquidity risk:
  - The risk that a trader cannot fund his position and is forced to unwind
The Pricing of Market Liquidity Risk: Introducing Liquidity Betas

- Investors care about returns net of trading costs
  - They want to be compensated for illiquidity and liquidity risk
  - CAPM holds for net returns in an OLG model.

- Decomposing systematic risk of return net of trading costs:

  \[
  \text{total systematic risk component} = \text{sign} \times \text{interpretation}
  \]

  \[
  \text{Cov}(R^i - C^i, R^M - C^M) = \text{Cov}(R^i, R^M) + \text{standard market beta} \\
  + \text{Cov}(C^i, C^M) + \text{commonality in liquidity} \\
  - \text{Cov}(R^i, C^M) - \text{return exposure to market liquidity} \\
  - \text{Cov}(C^i, R^M) - \text{liquidity exposure to market risk}
  \]

- Three liquidity betas, after division by \( Var(R^M - C^M) \)
The Pricing of Market Liquidity Risk: Liquidity-Adjusted CAPM

Liquidity-adjusted CAPM:

\[ E_t(r_{t+1}) = r^f + E_t(c_{t+1}) + \lambda_t (\beta^M_t + \beta^{L1}_t - \beta^{L2}_t - \beta^{L3}_t) \]

\[ \beta^{L1}_t = \frac{\text{cov}_t(c^i_{t+1}, c^M_{t+1})}{\text{var}_t(r^M_{t+1} - c^M_{t+1})} \]
\[ \beta^{L2}_t = \frac{\text{cov}_t(r^i_{t+1}, c^M_{t+1})}{\text{var}_t(r^M_{t+1} - c^M_{t+1})} \]
\[ \beta^{L3}_t = \frac{\text{cov}_t(c^i_{t+1}, r^M_{t+1})}{\text{var}_t(r^M_{t+1} - c^M_{t+1})} \]
\[ \lambda_t = E_t(r^M_{t+1} - c^M_{t+1} - r^f) \]

Empirical tests consistent with predictions: explanatory power in the cross-section, positive risk premium, expected signs of betas.

- An increase in illiquidity increases the required return:

\[ \frac{\partial}{\partial C_t} E_t(r_{t+1} - r^f) > 0 \]

- and contemporaneous returns are low

\[ \text{cov}_t(c_t, r_t) < 0 \]

- Source: Acharya and Pedersen


Real World Examples

- Securities with high liquidity risk:
  
  high average return empirically

- Lesson from LTCM:
  
  liquidity important risk factor

- Current crisis:

  \( C_t \) is increased

  \( \lambda_t \) is increased

  Liquidity risk increased

  \( \rightarrow \) Prices are down
What Drives Market Liquidity Risk

- Liquidity is provided by market makers, hedge funds, prop. traders, “speculators”

- Speculators must be able to fund their positions, both long positions $x^+$ and short ones $x^-:

\[ \sum_j \left( x_t^{j+} m_t^{j+} + x_t^{j-} m_t^{j-} \right) \leq W_t \]

- If speculators are well funded (large capital $W$ and/or low margins $m$), then
  - they can trade more (larger $x^+$ and $x^-$)
    → which enhances market liquidity
  - “Funding liquidity” is a driver of market liquidity

- There is also feedback in the opposite direction:
  - Better market liquidity can lower margins because
    - financiers more willing to lend when they can more easily and quickly sell the collateral
    - market liquidity can lower volatility
    → eases funding restriction

- This mutual feedback can give rise to liquidity spirals
Liquidity Spirals

- Some traders hit or near **margin constraints** (or risk limits) and **reduce positions**, which
  - moves prices against them (and others with similar positions) leading to **further losses**
  - increases volatility and reduces market liquidity, leading to **increased margins** and **tightened risk management** (including reduction in counterparty exposure)

- These effects continue until a new equilibrium is reached
  - loss-spiral
  - margin-spiral
  - risk-management-spiral

Sources: Garleanu and Pedersen (2007) and Brunnermeier and Pedersen (2008)
Speculators consider each security $j$ to maximize expected profit per capital use
- So, in equilibrium, profit-per-capital-use must be equal for all securities
- The common profit per capital use is the shadow cost of capital, denoted $\phi$

\[
\frac{\text{profit}^j}{\text{capital-use}^j} = \phi
\]  \hspace{1cm} (I)

Note that:
- $C^j = \text{market illiquidity}^j = \text{trading cost of liquidity-demander}^j = \text{profit of speculators}^j$  \hspace{1cm} (II)
- $m^j = \text{margin}^j = \text{capital-use of security}^j$  \hspace{1cm} (III)

Combining (I), (II), and (III) yields

\[
C^j / m^j = \phi \quad \Rightarrow \quad C^j = m^j \cdot \phi
\]

I.e. equilibrium a security’s market liquidity is the product of
- its capital use i.e. margin
  - which depends on its risk, trading characteristics
- the general scarcity of speculator capital, i.e. funding liquidity

See Brunnermeier and Pedersen (2007) for a formal theory.

Real World Example:
- Currently funding liquidity is low, i.e. bank balance sheet is scarce
- Hence, market liquidity is low, especially for high margin securities like convertible bonds
Market Liquidity and Funding Liquidity: Explaining the Stylized Facts

- Sudden liquidity “dry-ups”
  - liquidity spirals for market and funding liquidity
  - destabilizing margins, risk controls, redemptions

- Commonality of liquidity:
  - these funding problems affect many securities

- Market liquidity correlated with volatility:
  - volatile securities require more capital to finance

- Flight to quality / flight to liquidity:
  - when capital is scarce, traders withdraw more from “capital intensive” high-margin securities

- Market liquidity moves with the market
  - because funding conditions do

See Brunnermeier and Pedersen (2007) for a formal theory.
Commonality of Liquidity and Flight to Quality: Example

Two asset example: $\sigma^2 = 7.5 > 5 = \sigma^1$
Funding Liquidity Leads to Conditional Skewness and Kurtosis

- Price moves associated with losses for liquidity providers: amplified by liquidity spirals
- Price moves associated with gains: not amplified

Real World Example:
FX carry trade unwind

“investment currencies go up by the stairs and down by the elevator”

Source: Brunnermeier, Nagel, and Pedersen (2008)
Examples of Liquidity Events
Examples of Liquidity Events

- What happens in the real world liquidity crisis:
  - Current crisis
  - 2007 August quant equity
  - 2005 Convertible bonds
  - 1998 LTCM and convertible bonds
  - 1987 Stock market crash and merger arbitrage
The Current Crisis

- Housing bubble and burst

- Large losses in the levered financial sector

- Liquidity spirals as
  - banks’ balance sheets deteriorate
  - banks de-lever, selling assets
  - risk management tighten, lending reduced, counterparty exposures minimized
  - margins increase
  - liquidity vanishes
  - prices drop

- Extreme liquidity risk
  - Extreme funding liquidity risk: your bank may default
  - Extreme market liquidity risk: dealers shutting down (no bids!)
The Trigger: Housing Bubble and Bust

![Graph of Case-Shiller CSXR](image-url)
This Creates Losses and Funding Liquidity Problems for Banks
Banks Tighten Risk Management and Reduce Inter-bank Lending: Funding Spreads Rise

TED Spreads

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Funding Liquidity Problems for Everyone: Banks Unwillingness to Lend

% Increasing Spreads of Loan Rates over Banks' Cost of Funds (source: FRB)

100 90 80 70 60 50 40 30 20 10 0 -10 -20 -30 -40 -50 -60 -70 -80

Further Funding Problems: Volatility Spikes, increasing Margins
Further Funding Problems: Commercial Paper Market

Rates

Outstandings

Source: Federal Reserve Bank
Market Liquidity Deteriorates: Bid-Ask Spreads

Percentage Bid-Ask Spread

ABX-HE-AAA 06-1  ABX-HE-AAA 06-2  ABX-HE-AAA 07-1  HY (right axis)
Extreme Liquidity Crisis: Covered Interest Rate Parity Fails

Deviation of Covered Interest-Rate Parity vs. USD

Percentage Points (annualized)


AU  BD  CN  JP  NW  NZ  SD  SW  UK

NYU Stern
Prices Drop, Especially of Illiquid Assets: Losses by Hedge Funds
Correlations Increase: Everything Trades on Liquidity

Commonality among SP500, Bonds, Crude, $-Yen, Gold:
Percent of Correlation Explained by First Principle Component

Correlation between Value and Momentum
All These Liquidity Effects are Connected in Equilibrium
August 2007 Quant Equity Event
Background: What is a Quant Hedge Fund

- Traditional non-quant hedge funds: “discretionary trading”:
  - Buy/sell based on an analyst’s overall assessment of certain selected securities

- Quantitative method:
  - Define trading rules explicitly
  - Back test using historical data
  - Build a system that implements trading idea systematically
  - Using economics, novel data, and novel data processing to identify relationships market participants may miss
    - Finding subtle relationships that the market does not easily understand
    - Superior processing of ideas using a wealth of data that cannot be easily processed using non-quantitative methods
Chronology of the 2007 Quant Event

- **July 2007:**
  - Credit spreads started to widen after sub-prime mortgage turmoil
  - Losses in certain multi-strategy hedge funds, who started reducing risk and raise cash by selling liquid instruments
  - Money pulled out of potential LBO candidates with strong value and cash flow characteristics, hurting the value strategy
  - Fund-of-fund hit loss triggers and redeem from certain hedge funds
  - Value stocks behave poorly with unusual correlation structure

- **August 2007**
  - Major de-leveraging of quant strategies
  - Spill-over
    - from value to other quant factors
    - from the US to international markets
  - Since the large price movements were created by de-leveraging, prices bounced back
Estimated Reduction of Overall Quant Positions

Pre Sell-Off

$300-$400 billion of long exposures

$300-$400 billion of short exposures

Post Sell-Off

$175-$250 billion of long exposures

$175-$250 billion of short exposures
Spillover from US to other Markets

Valuation Factor Returns, July 1 – August 24

-35.00%  -30.00%  -25.00%  -20.00%  -15.00%  -10.00%  -5.00%  0.00%  5.00%  10.00%


US Valuation  JP Valuation  Aus Valuation
**Minute-by-Minute Cumulative Return to Value Factor, August 6 - 14**

7% annualized vol ~ 7% / Sqrt(252) = 44 bps daily vol (vol. estimates from BARRA)

Move largest for illiquid stocks
## Evidence of Liquidity Event due to Unwinding

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<th>Mon</th>
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<tr>
<td><strong>Return</strong></td>
<td>-1.34%</td>
<td>-4.52%</td>
<td>-6.20%</td>
<td>-4.23%</td>
<td>9.82%</td>
<td>2.20%</td>
<td>0.35%</td>
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<tr>
<td><strong># Stds</strong> (1 std is 0.44%)</td>
<td>-3</td>
<td>-10</td>
<td>-14</td>
<td>-10</td>
<td>22</td>
<td>5</td>
<td>1</td>
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<tr>
<td><strong>P-value &quot;normal&quot; day</strong></td>
<td>0.23%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
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<td><strong>Positive returns (%)</strong></td>
<td>31%</td>
<td>10%</td>
<td>32%</td>
<td>41%</td>
<td>75%</td>
<td>43%</td>
<td>56%</td>
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<td><strong>Negative returns (%)</strong></td>
<td>69%</td>
<td>90%</td>
<td>68%</td>
<td>59%</td>
<td>25%</td>
<td>57%</td>
<td>44%</td>
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<td><strong>Positive returns (%)</strong></td>
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<td>35%</td>
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<td>67%</td>
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<td><strong>Negative returns (%)</strong></td>
<td>58%</td>
<td>68%</td>
<td>65%</td>
<td>58%</td>
<td>33%</td>
<td>53%</td>
<td>48%</td>
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<td><strong>P-value random walk</strong></td>
<td>0.10%</td>
<td>0.00%</td>
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<td>0.10%</td>
<td>0.00%</td>
<td>24%</td>
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Interpretation

- Liquidity events can happen even in the most liquid markets in the world

- Market and funding liquidity are related

- Liquidity shocks are
  - sudden
  - common and spill over
  - affect mostly risky and illiquid securities

- Everyone seeks the highest alpha portfolio
  - The best quants are likely to be correlated
  - One needs to stay one step ahead

- Prices drop more and rebound slower in more illiquid markets
  - Cf. Duffie, Garleanu, Pedersen (Review of Financial Studies, 2007)
2005 Convertible Bond Event

- Capital outflow due to redemptions from convertible bond hedge funds

- Single-strategy hedge funds:
  - forced sellers of convertible bonds

- Multi-strategy hedge funds
  - had a choice: what do you think that they did?

- What happens to the price of convertible bonds?
Background: What is a Convertible Bond

- Convertible bond:
  - Corporate bond + call option (+ more)

- Theoretical value can be inferred from
  - Issuer stock price
  - Stock price volatility
  - Option-implied volatility
  - Risk-free interest rates
  - Credit spreads
  - Just like the price of a “Gin and Tonic” can be inferred from the respective prices of gin and tonic, and the amounts of each needed
Convertible Bond Arbitrage

- Buy convertible bond if it trades at a discount
- Short the issuer’s stock
- Potentially:
  - Short risk-free bonds
  - Short non-convertible bonds (or buy CDS)
  - Short stock options
Convertible Bond Arbitrage Capital Outflows in 2005

- Natural liquidity providers: Convertible Bond Arbitrage Hedge Funds (HFs)

- Capital outflows in 2005:
  - 2005Q1: 20% capital redeemed
  - 2005Q1 – 2006Q1: assets fell by half

- Convert Arb HFs sold convertible bonds
Redemptions in 2005

Source: Barclay Group
Redemptions Led to Selling: Adjusted Holdings of Convertible Bonds

Convertible Bond Arbitrage Returns and Market Price / Theoretical Value

Interpretation

- Prices drop and rebound

- Price-to-fundamentals lowest around redemption notices (45 days before end of June and end of December)

- Returns negative, then positive

- Response by other traders:
  - Multi-strategy hedge funds
  - Mutual funds
The Case of Amaranth

- In 2005, Amaranth had
  - Losses in convertible bonds
  - Profits in energy trading
  - Overall profit and no capital problems

- Decided to liquidate convertible bonds at time of significant cheapness

- Collapsed in 2006 due to losses in energy
LTCM Blowup in 1998: Implications for Convertible Bonds

- Large hedge fund LTCM had losses due to Russian default, option positions, etc.
- Had to liquidate large position in convertible bonds
- What happened to the price of the bonds and how was the subsequent return?
Convertible Bond Arbitrage Returns and Market Price / Theoretical Value

1987 Crash: Implications for Merger Arbitrage

- Oct. 19 (Black Monday) and 20: crash
- Oct: 21-31:
  - Stock market rebounds
  - Congress backs off proposed legislation
  - But, merger-arbitrage proprietary traders
    - had lost a significant amount of capital
    - Did they start buying or keep selling?
    - What happened to merger spreads?

- Berkshire Hathaway Annual Report (Warren Buffett):

  “During 1988 we made unusually large profits from [risk] arbitrage … the trick, a la Peter Sellers in the movie, has simply been ‘Being There.’”
Background on Merger Arbitrage

- In a merger, “target” is bought at a premium, say 20-30%.
- At announcement, target price increases to a value close to the offer value.
- But, there remains a “deal spread,” typically around 3%

\[
deal\ space = \frac{\text{offer value} - \text{target price}}{\text{target price}}
\]

- Due to
  - Risk of deal failure
  - Selling pressure: Mutual funds sell after announcement
- Merger arbitrageurs buy target
  - Stock deal: hedge by shorting acquirer
  - Cash deal: no hedge
Merger Arbitrage and the 1987 Crash

Conclusions
Conclusion: Will Liquidity Events Happen Again?

- Yes, almost surely in some markets
  - Certain trades often get crowded over time
  - Sudden losses can lead to simultaneous unwind and liquidity spirals

- Liquidity crisis is part of the equilibrium:
  - If there was no risk of crisis, traders will have an incentive to lever up more

- Crises are (somewhat) rare
  - Banks try to stay liquid and traders actively try to stay away from margin constraint
  - Most likely to occur in illiquid markets in which levered specialized traders play a large role
  - Least likely in liquid market using unique strategies
Conclusion: How do We Solve the Crisis and Reduce the Risk of Future Ones?

- Recapitalize banks
  - Raise new capital, dilute old equity, possibly reduce face value of old debt
  - Quick resolution bankruptcy for institutions with systemic risk, i.e. causing liquidity spirals

- Improve funding markets and trust
  - Broaden bank guarantees, open discount window (collateralized funding with reasonable margins), ensure CP market

- Risk management
  - must acknowledge systemic risk due to liquidity spirals
  - Policy and regulations must consider system, as opposed to each institution in isolation
How do We Solve the Crisis and Reduce the Risk of Future Ones, Continued

- Trading with a clearing house preferable
  - allows netting out
  - reduce counterparty co-dependencies
  - increases transparency

- Stock transaction taxes not a good idea:
  - moves trading away and into the land of OTC derivatives with no clearing house
  - reduces liquidity and, hence, increases firms’ cost of capital (liquidity-adjusted CAPM)
  - importance of the ability to raise capital is what this crisis is all about

- Shortselling ban is not a good idea:
  - Shortsellers bring new information to the market, increase liquidity, and reduce bubbles (remember the housing bubble started this crisis)
  - Prohibiting shortselling does not solve the general funding problem.
  - Temporarily banning new short sales of financial institutions can be justified if there is risk of predatory trading, but often firms on trouble look for scapegoats
Conclusion: Liquidity Risk Lessons

- Liquidity risk important for
  - security prices (liquidity-adjusted CAPM)
  - risk management
  - the speed of arbitrage

- Funding liquidity of banks and “speculators” is a driver of market liquidity risk

- Liquidity crisis:
  - Driven by liquidity spirals:
    - loss spiral
    - margin spiral
    - risk management spiral
  - Liquidity providers become demanders
  - New capital arrives slowly
  - Prices drop and rebound
Related Papers