



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

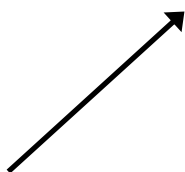
The Pricing of Market Liquidity Risk: Introducing Liquidity Betas

- 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:

<u>total systematic risk</u>	<u>component</u>	<u>sign</u>	<u>interpretation</u>
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$\text{Cov}(R^i - C^i, R^M - C^M) =$	$\text{Cov}(R^i, R^M)$	+	standard market beta
	$+ \text{Cov}(C^i, C^M)$	+	commonality in liquidity
	$- \text{Cov}(R^i, C^M)$	-	return exposure to market liquidity
	$- \text{Cov}(C^i, R^M)$	-	liquidity exposure to market risk



- **Three liquidity betas**, after division by $\text{Var}(R^M - C^M)$

The Pricing of Market Liquidity Risk: Liquidity-Adjusted CAPM

➤ Liquidity-adjusted CAPM:

$$E_t(r_{t+1}) = r^f + E_t(c_{t+1}) + \lambda_t (\beta_t^M + \beta_t^{L1} - \beta_t^{L2} - \beta_t^{L3})$$

$$\beta_t^{L1} = \frac{\text{cov}_t(c_{t+1}^i, c_{t+1}^M)}{\text{var}_t(r_{t+1}^M - c_{t+1}^M)} \quad \beta_t^{L2} = \frac{\text{cov}_t(r_{t+1}^i, c_{t+1}^M)}{\text{var}_t(r_{t+1}^M - c_{t+1}^M)} \quad \beta_t^{L3} = \frac{\text{cov}_t(c_{t+1}^i, r_{t+1}^M)}{\text{var}_t(r_{t+1}^M - c_{t+1}^M)} \quad \lambda_t = E(r_{t+1}^M - c_{t+1}^M - r^f)$$

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 (*Journal of Financial Economics*, 2005)

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
 λ_t is increased
 Liquidity risk increased
 → 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^- :

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

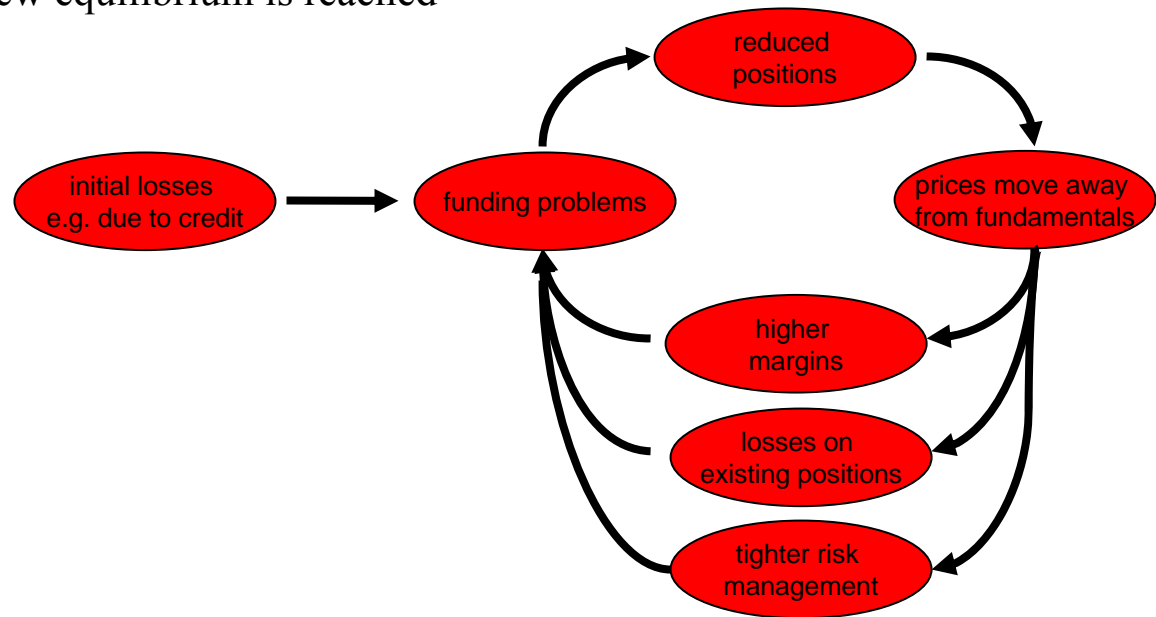
- If speculators are well funded (large capital W and/or low margins m), then
 - they can trade more (larger x^+ and x^-)
→ which enhances market liquidity
 - “Funding liquidity” is a driver of market liquidity
- There is also feedback in the opposite direction:
 - Better market liquidity can lower margins 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)

Market Liquidity Risk Across Securities: Commonality and Differences

- 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 φ

$$\text{profit}^j / \text{capital-use}^j = \varphi \quad (\text{I})$$

- Note that:

$$C^j = \text{market illiquidity}^j = \text{trading cost of liquidity-demander}^j = \text{profit of speculators}^j \quad (\text{II})$$

$$m^j = \text{margin}^j = \text{capital-use of security}^j \quad (\text{III})$$

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

$$C^j / m^j = \varphi \quad \Rightarrow$$

$$C^j = m^j * \varphi$$

- 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

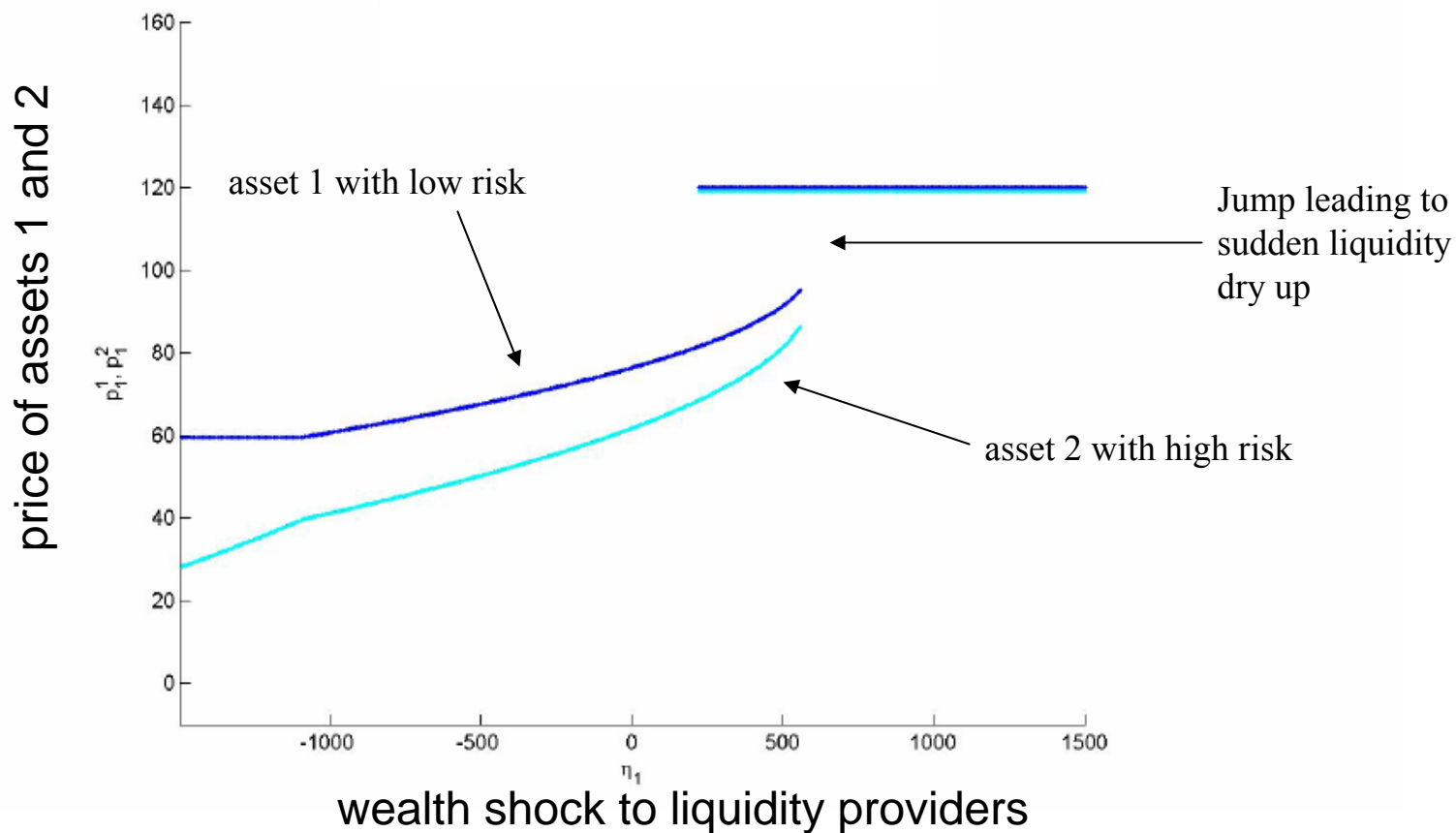
- Flight to quality / flight to liquidity:
 - when capital is scarce, traders withdraw more from “capital intensive” high-margin securities

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

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

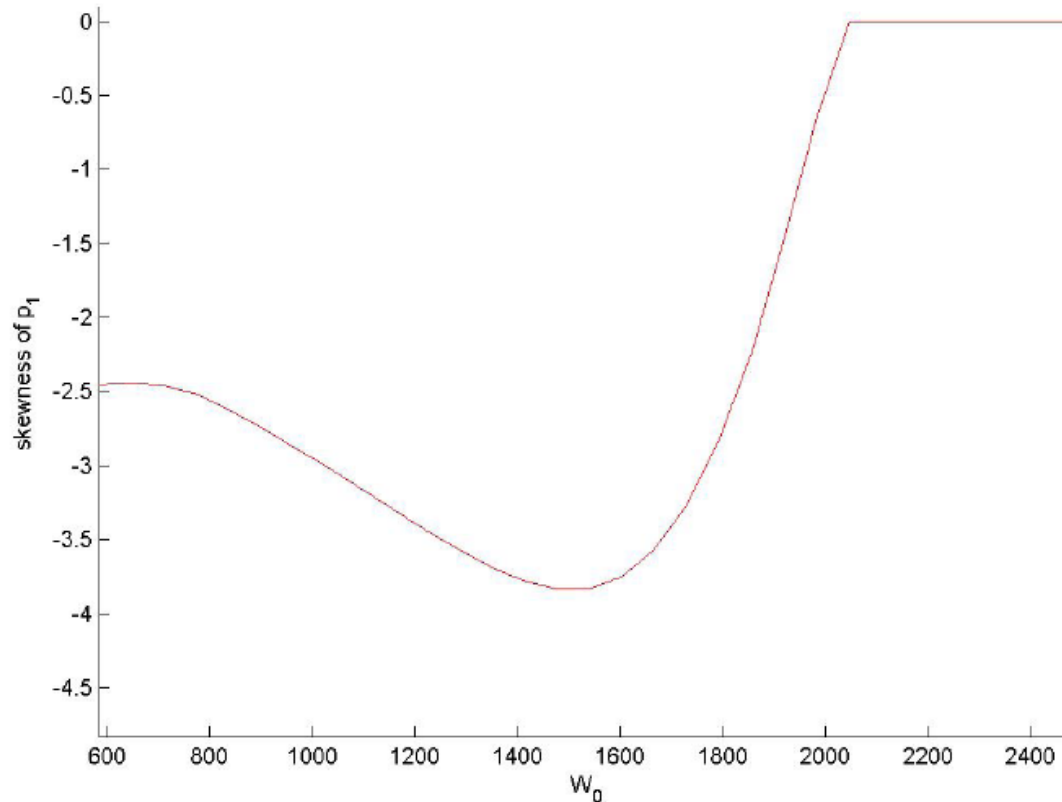
Commonality of Liquidity and Flight to Quality: Example

Two asset example: $\underline{\sigma}^2 = 7.5 > 5 = \underline{\sigma}^1$



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)

Source: Brunnermeier and Pedersen (2008)

Examples of Liquidity Events



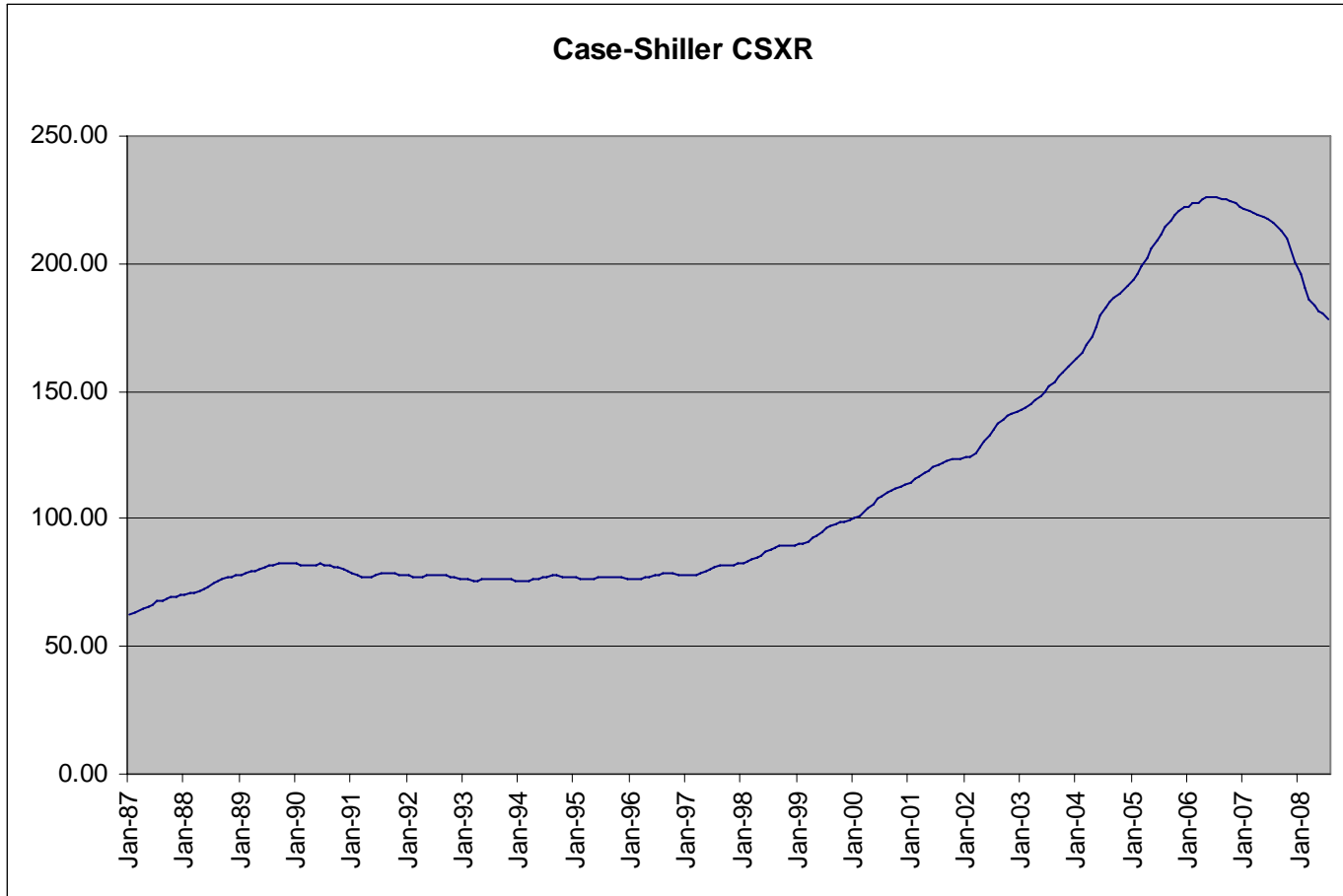
Examples of Liquidity Events

- 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

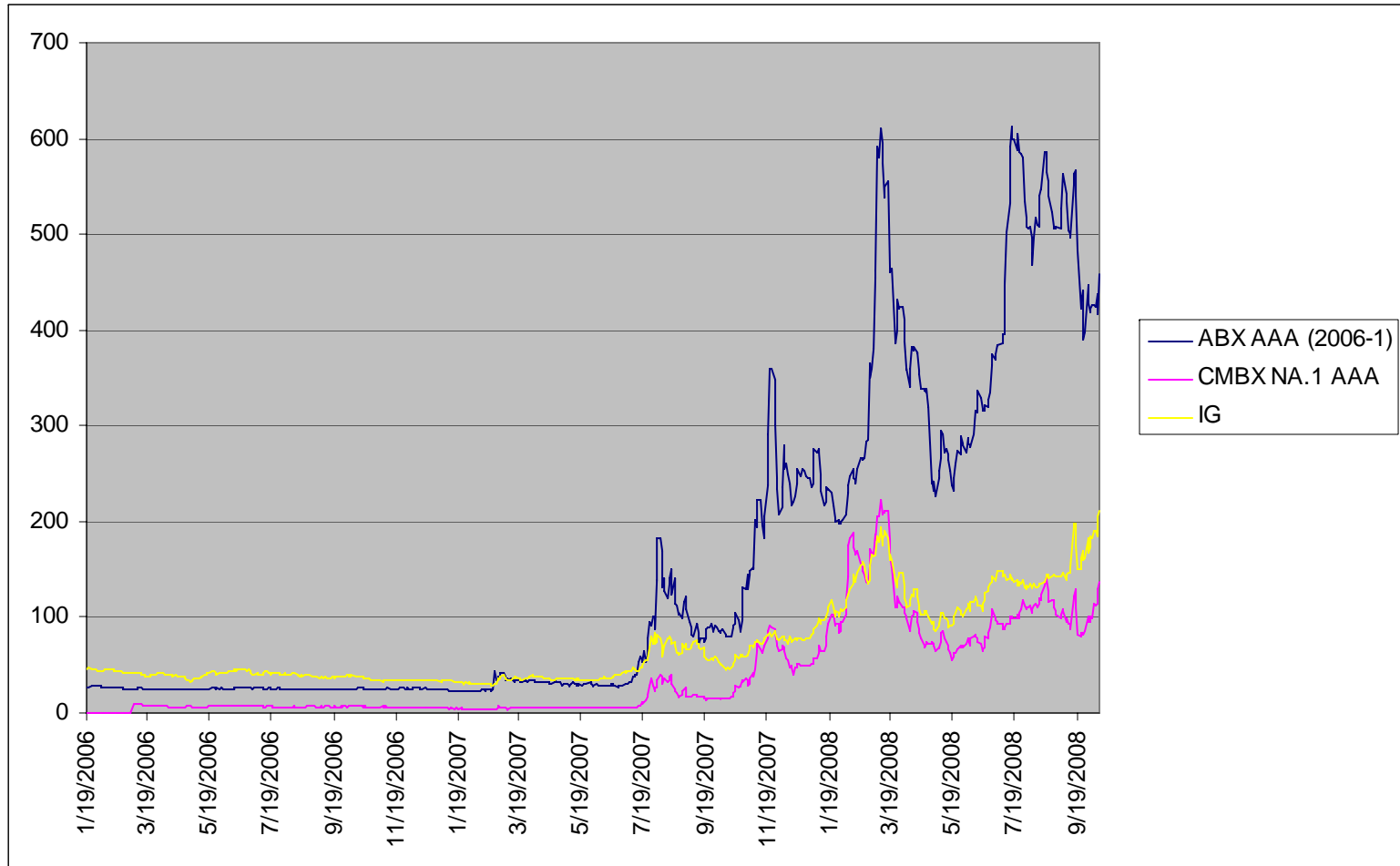
The Current Crisis

- 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!)

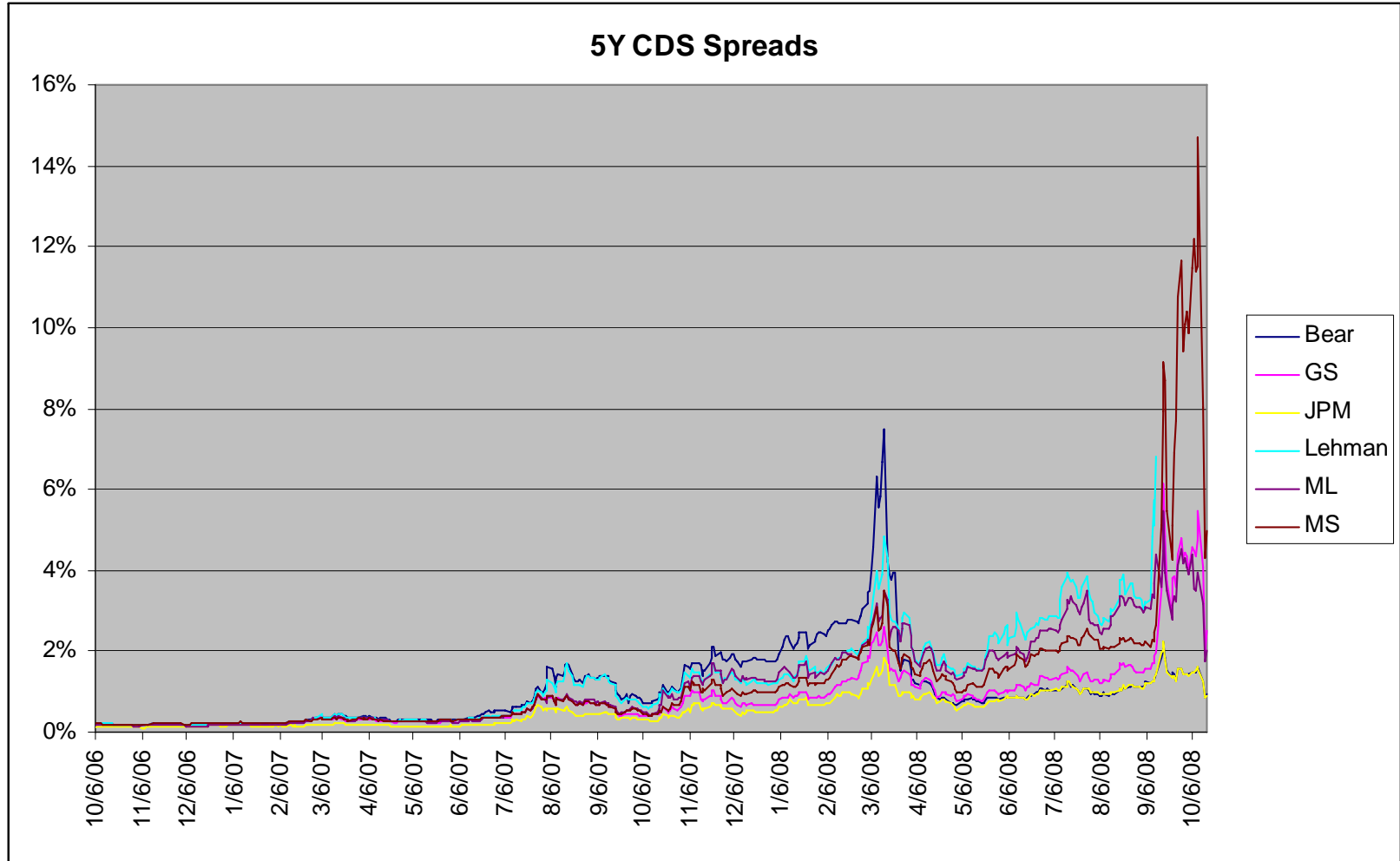
The Trigger: Housing Bubble and Bust



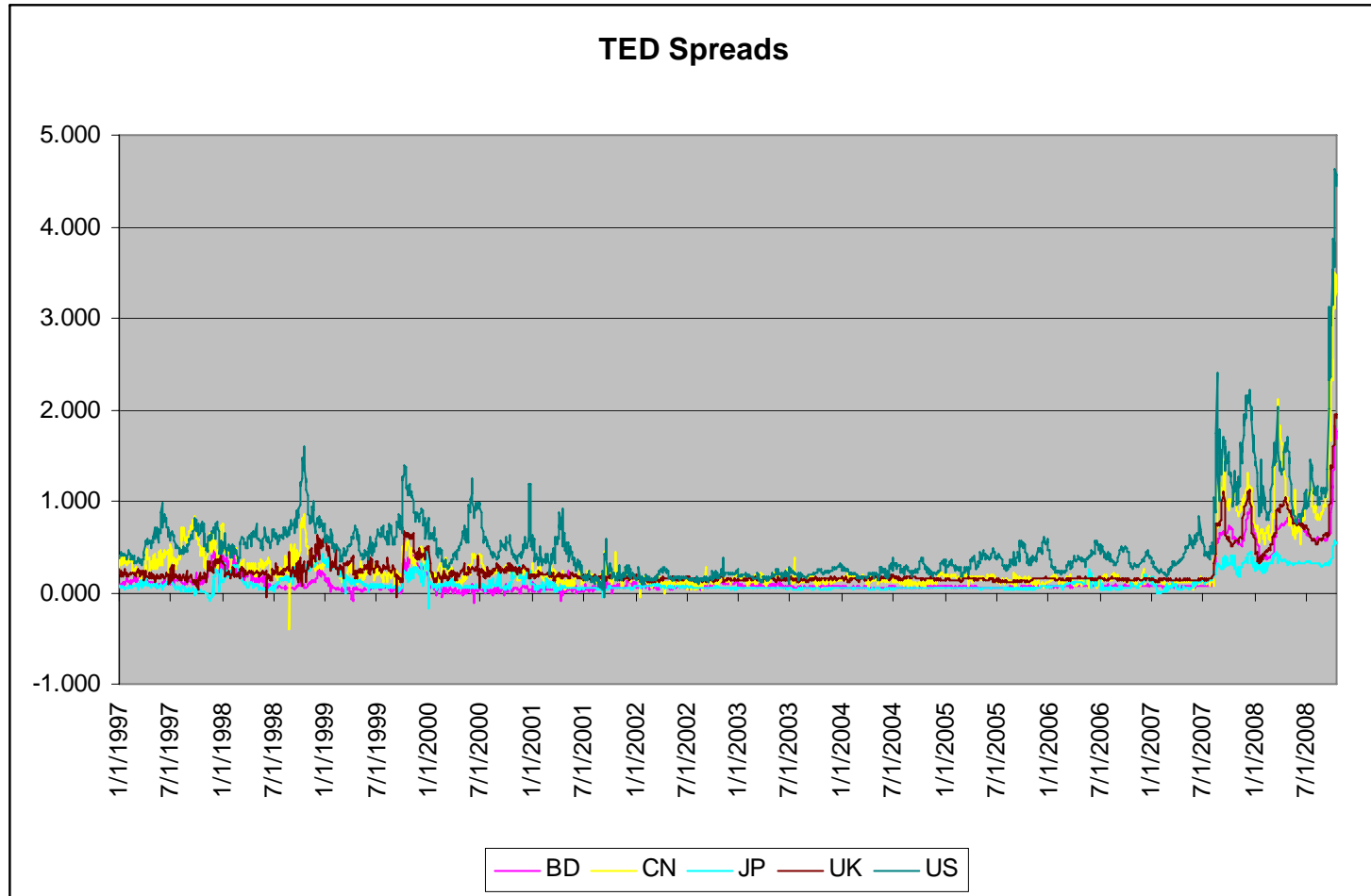
Housing Bust hits Mortgage-Based Credit Markets and Beyond



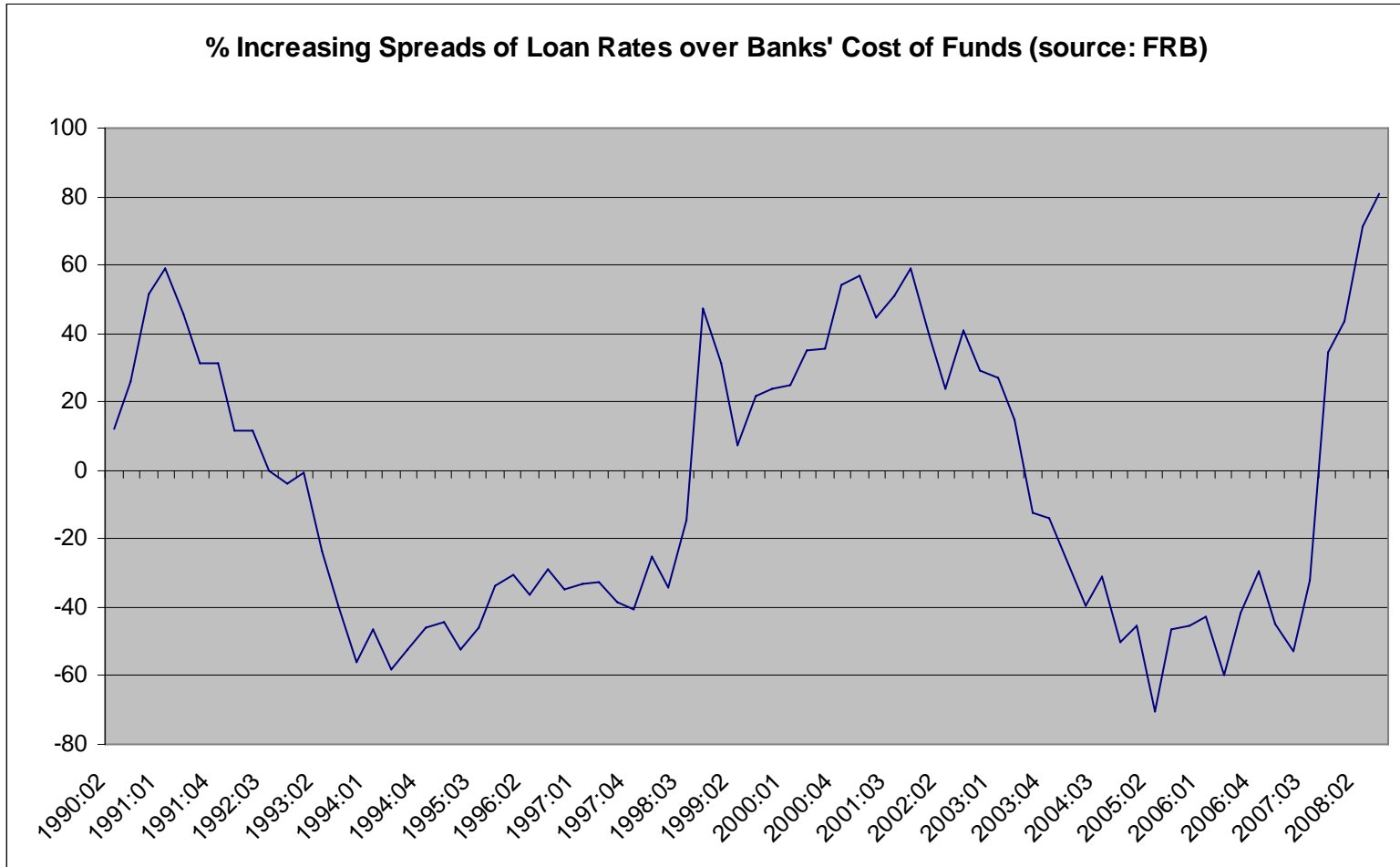
This Creates Losses and Funding Liquidity Problems for Banks



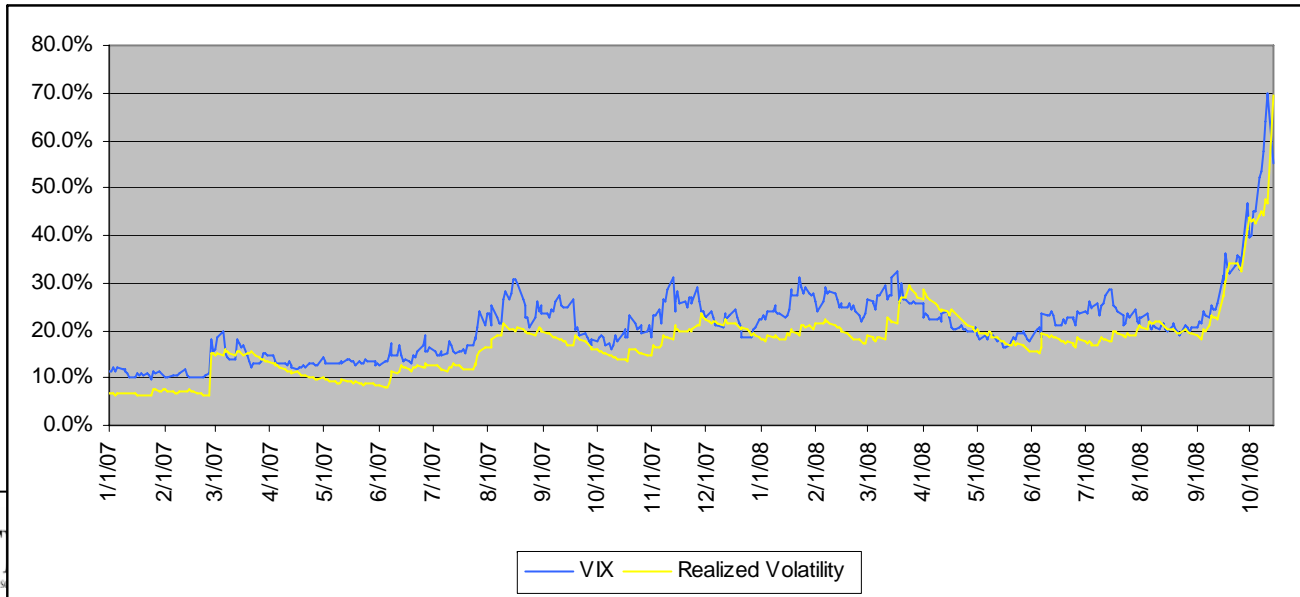
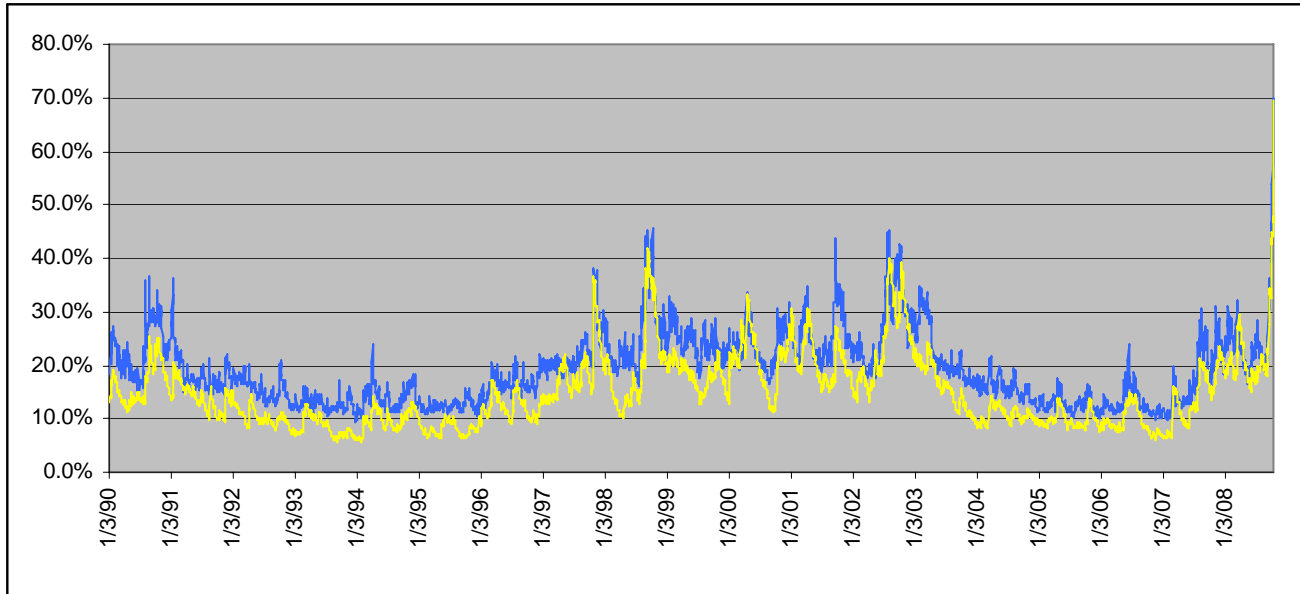
Banks Tighten Risk Management and Reduce Inter-bank Lending: Funding Spreads Rise



Funding Liquidity Problems for Everyone: Banks Unwillingness to Lend



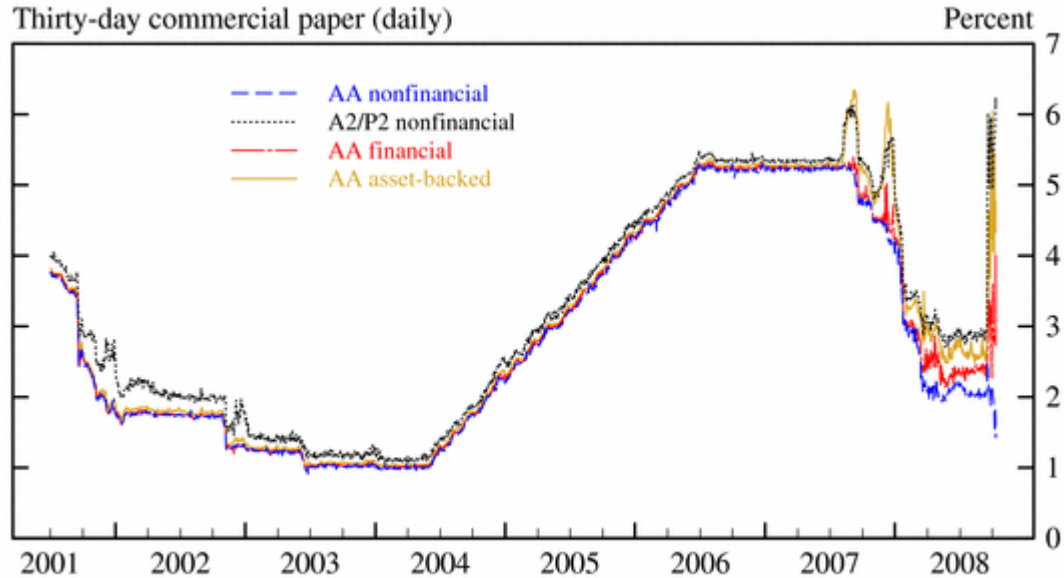
Further Funding Problems: Volatility Spikes, increasing Margins



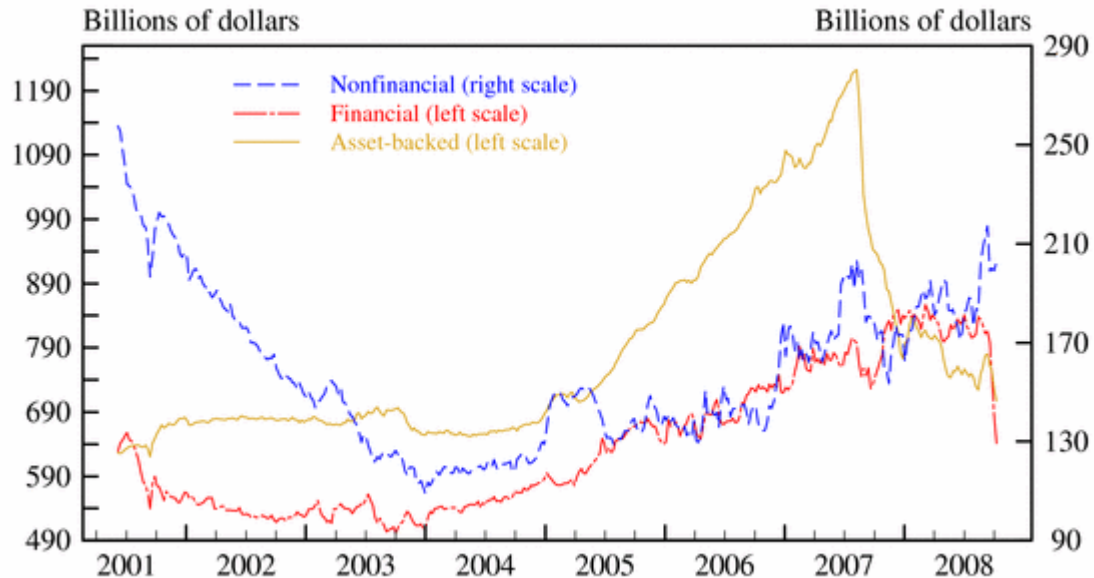
— VIX — Realized Volatility

Further Funding Problems: Commercial Paper Market

Rates

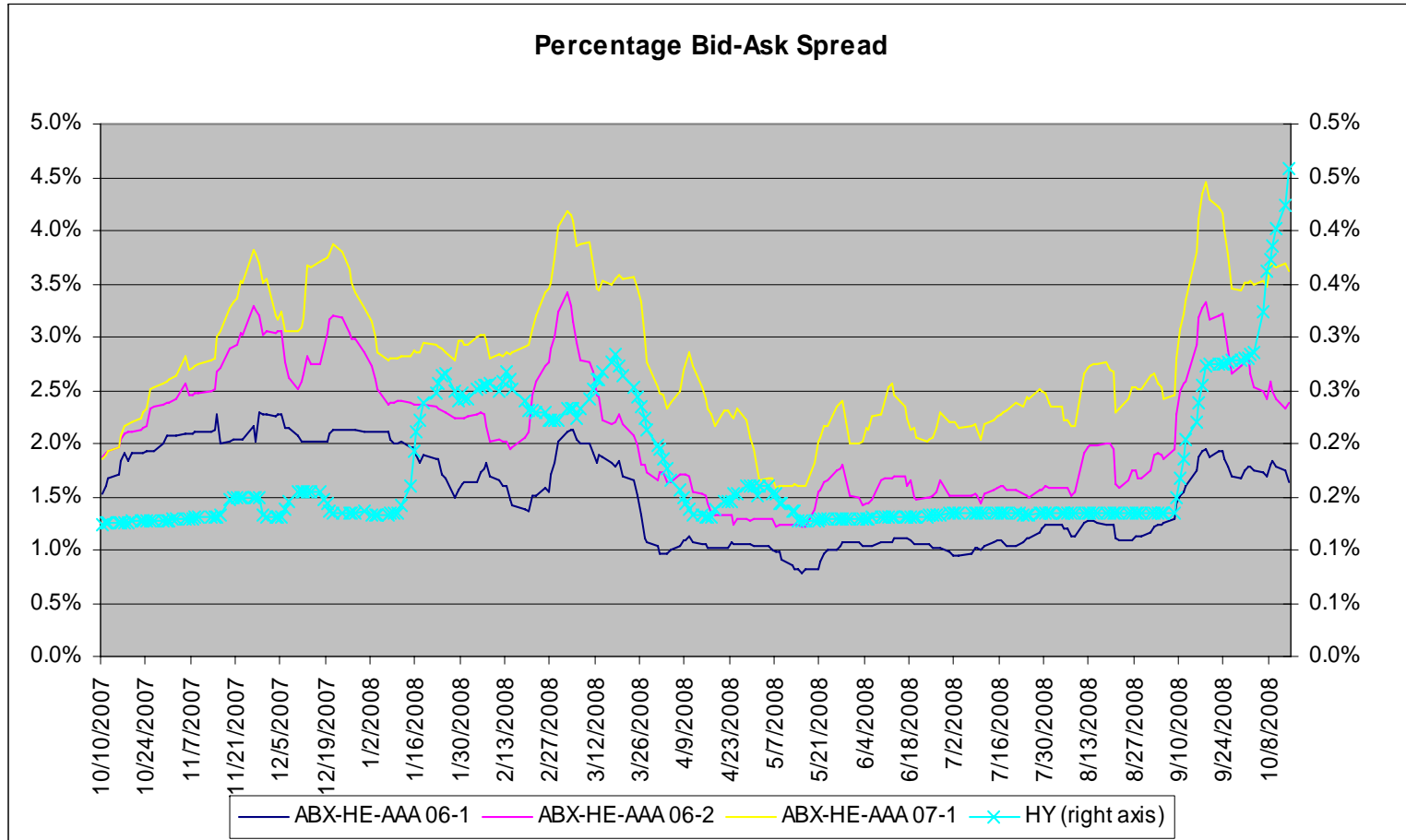


Outstandings

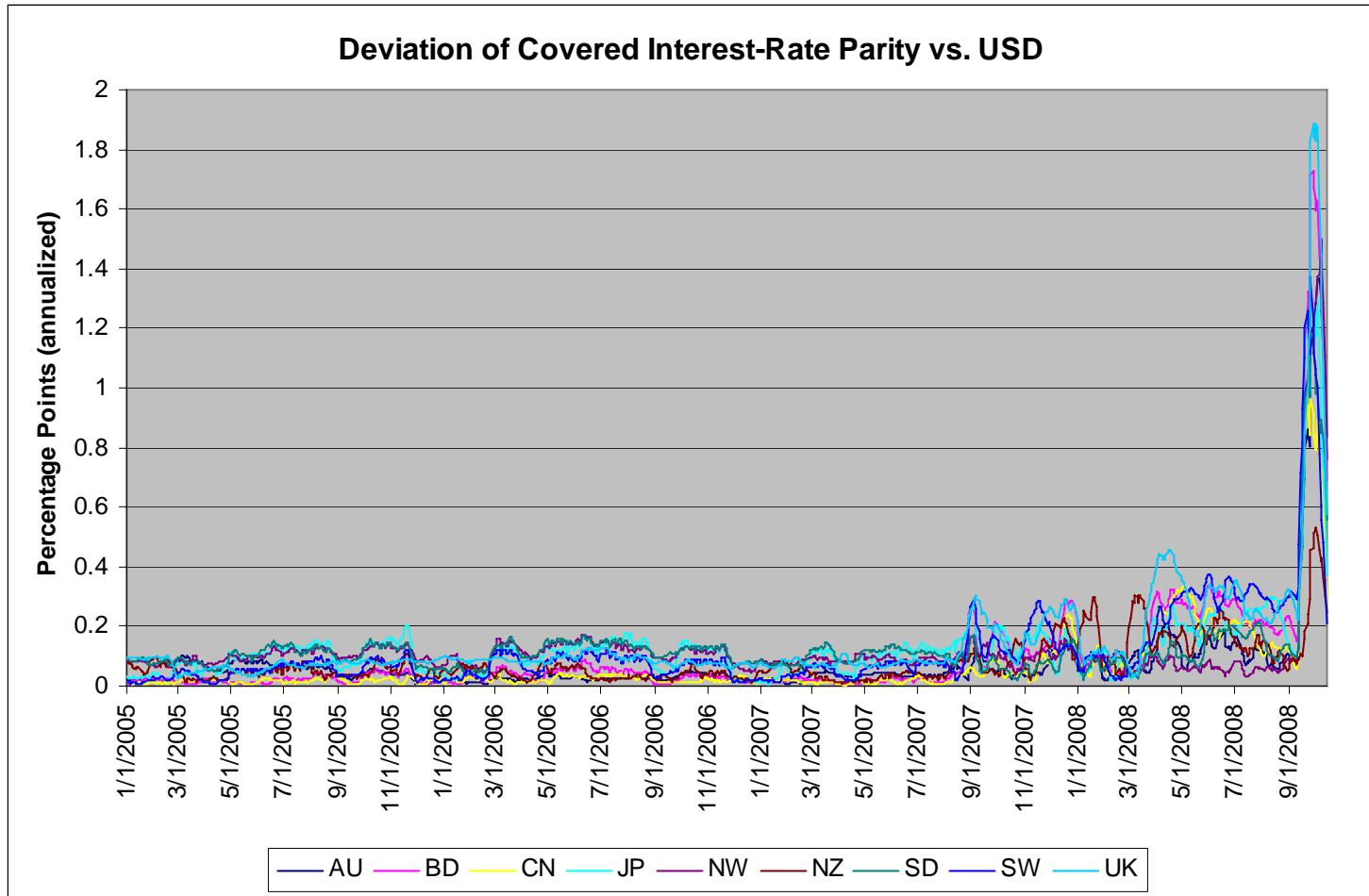


Source:
Federal Reserve Bank

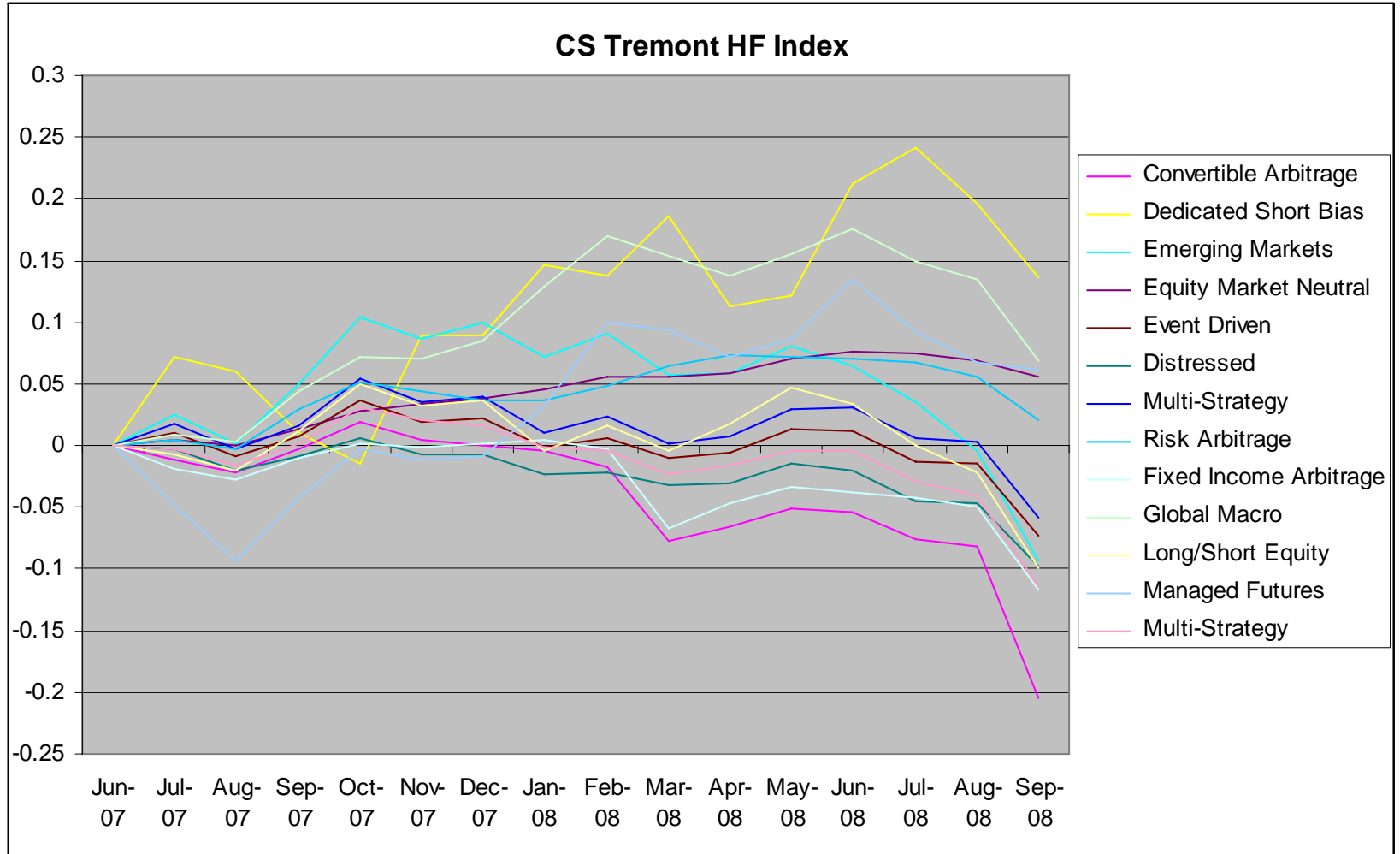
Market Liquidity Deteriorates: Bid-Ask Spreads



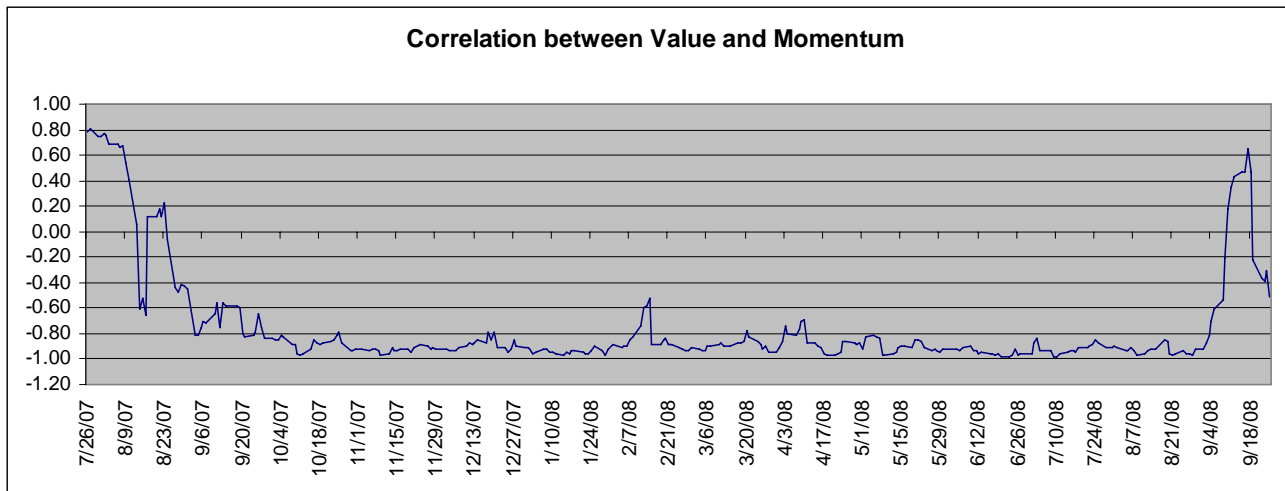
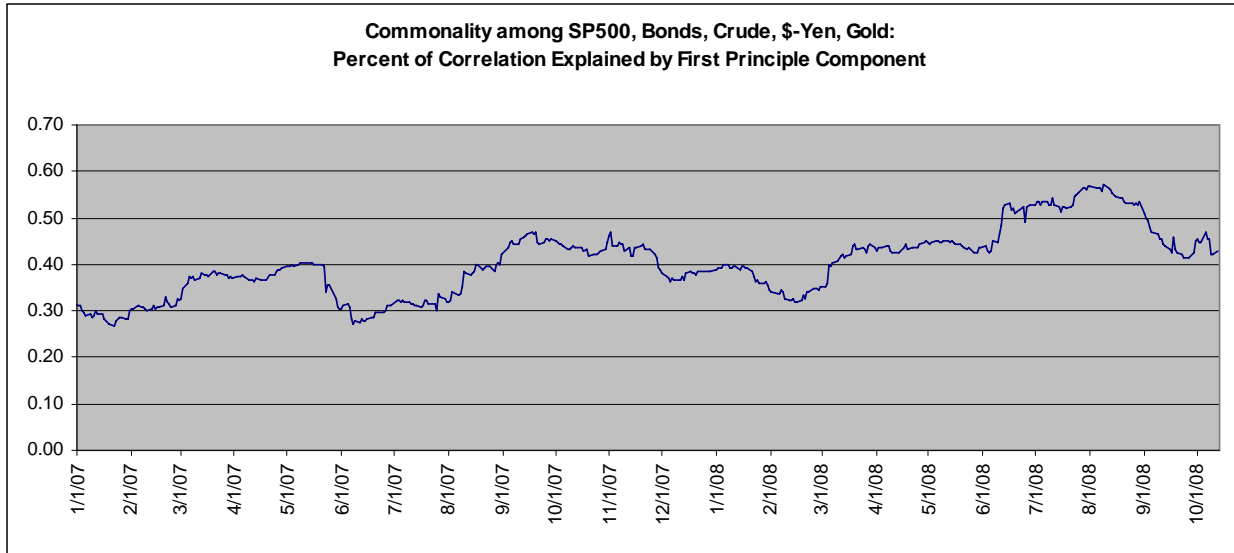
Extreme Liquidity Crisis: Covered Interest Rate Parity Fails



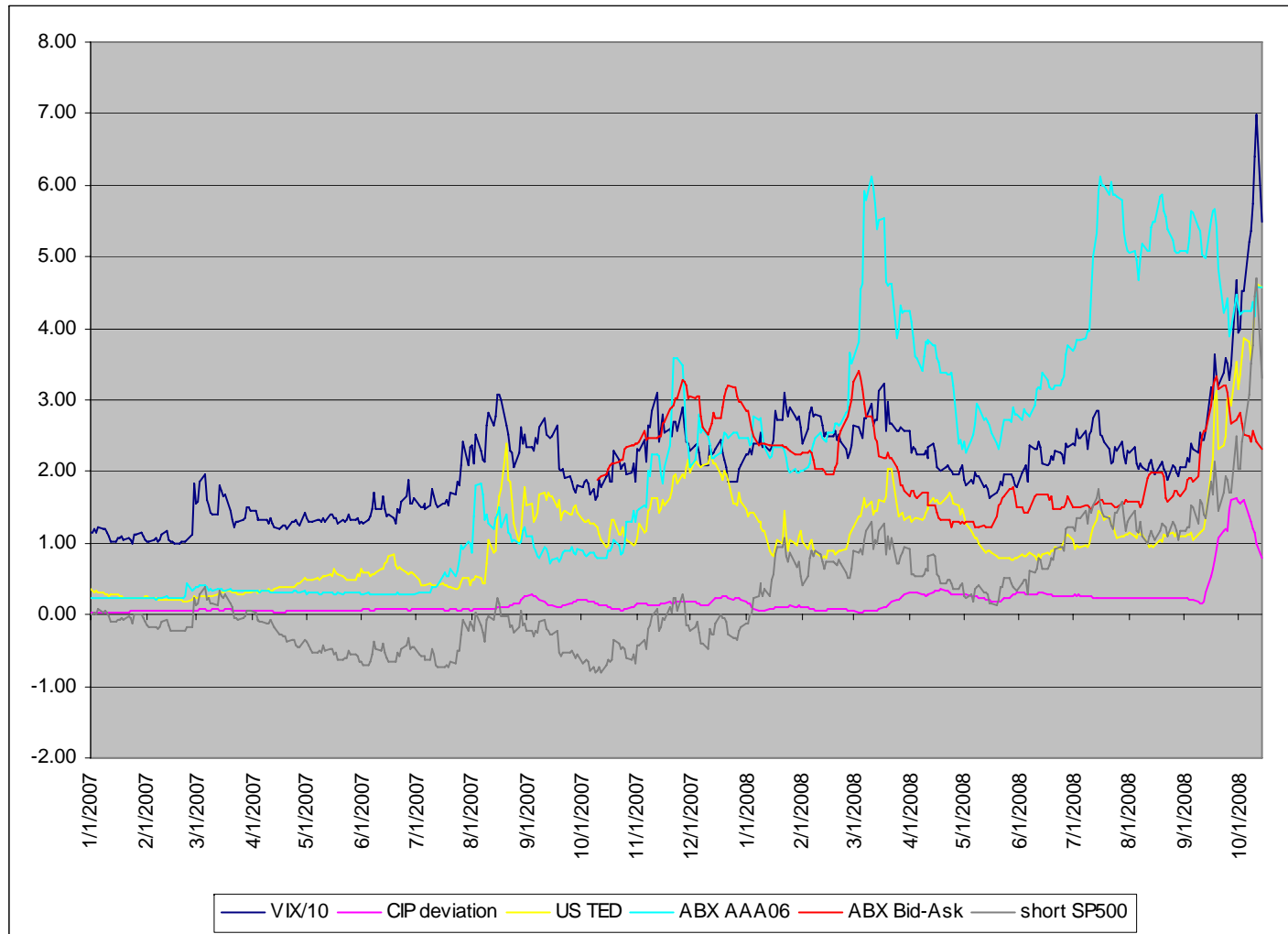
Prices Drop, Especially of Illiquid Assets: Losses by Hedge Funds



Correlations Increase: Everything Trades on Liquidity



All These Liquidity Effects are Connected in Equilibrium



- 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

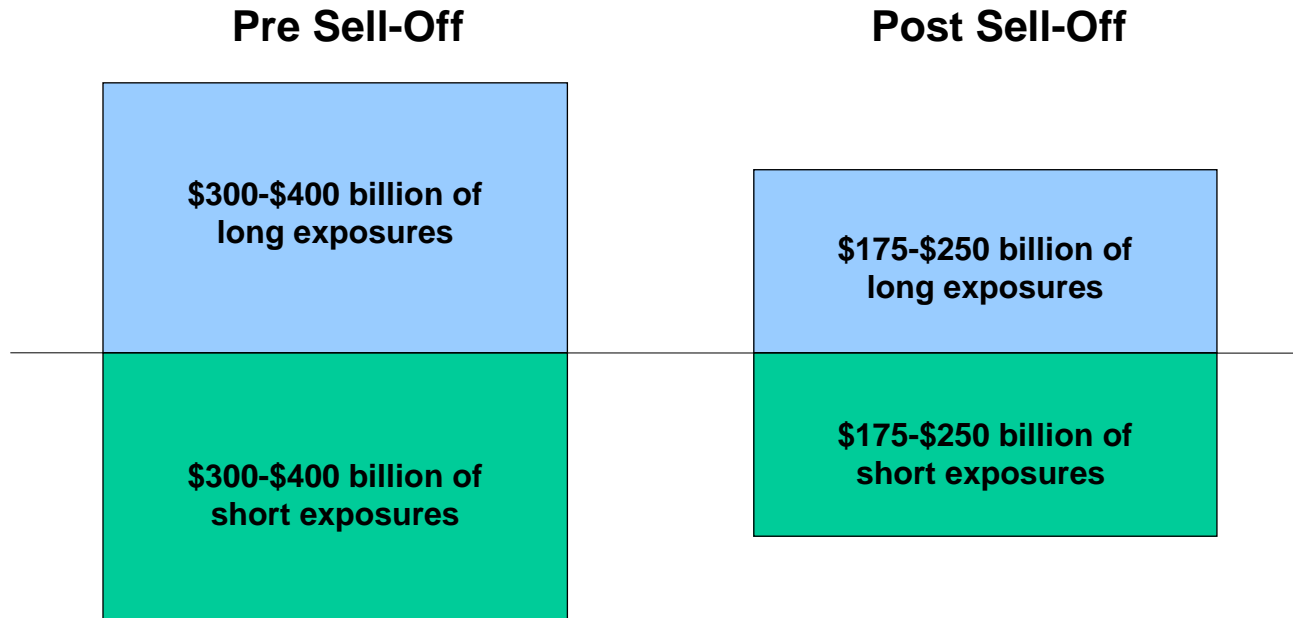
➤ July 2007:

- 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

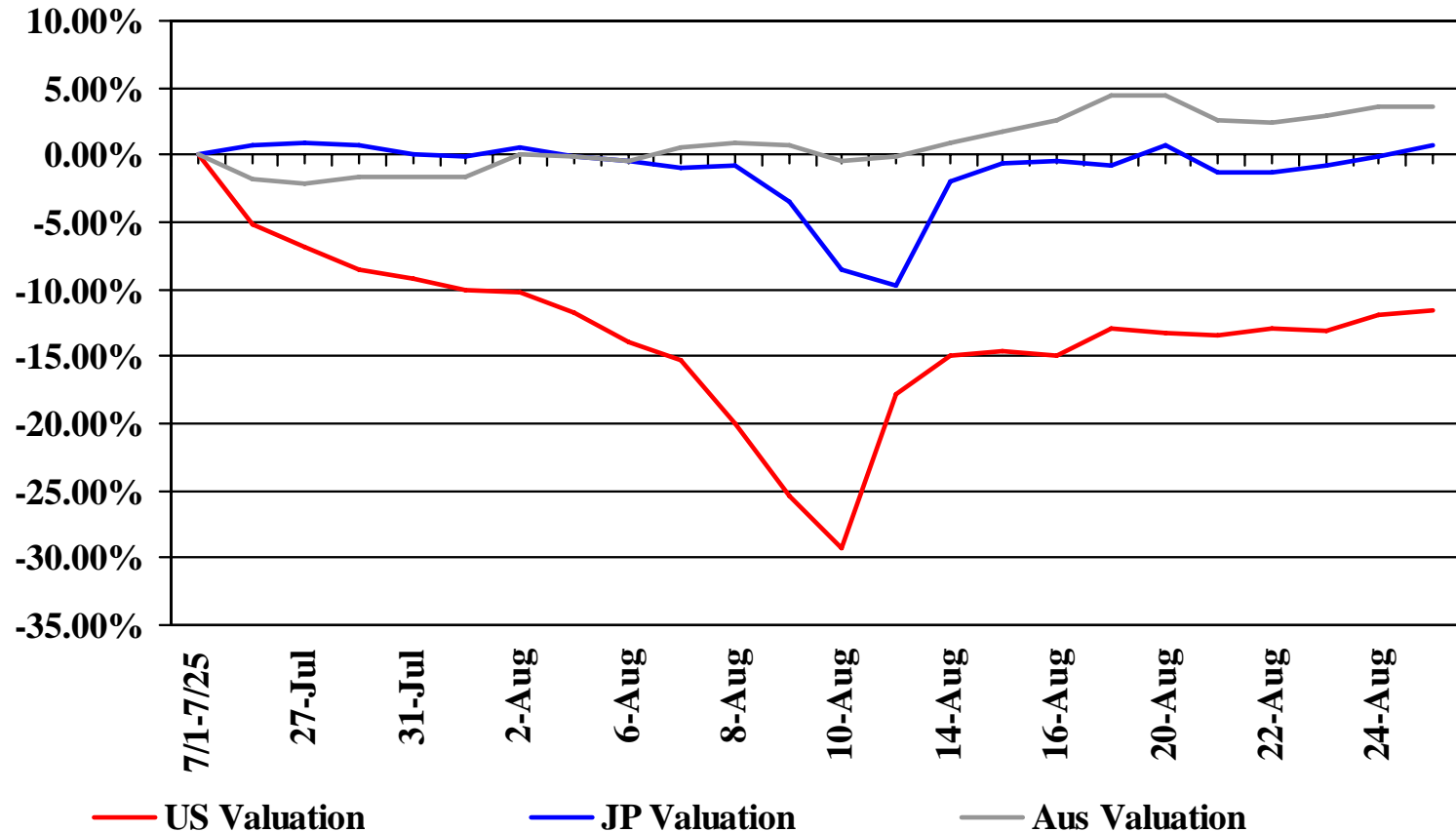
- Major de-levering of quant strategies
- Spill-over
 - from value to other quant factors
 - from the US to international markets
- Since the large price movements were created by de-leveraging, prices bounced back

Estimated Reduction of Overall Quant Positions



Spillover from US to other Markets

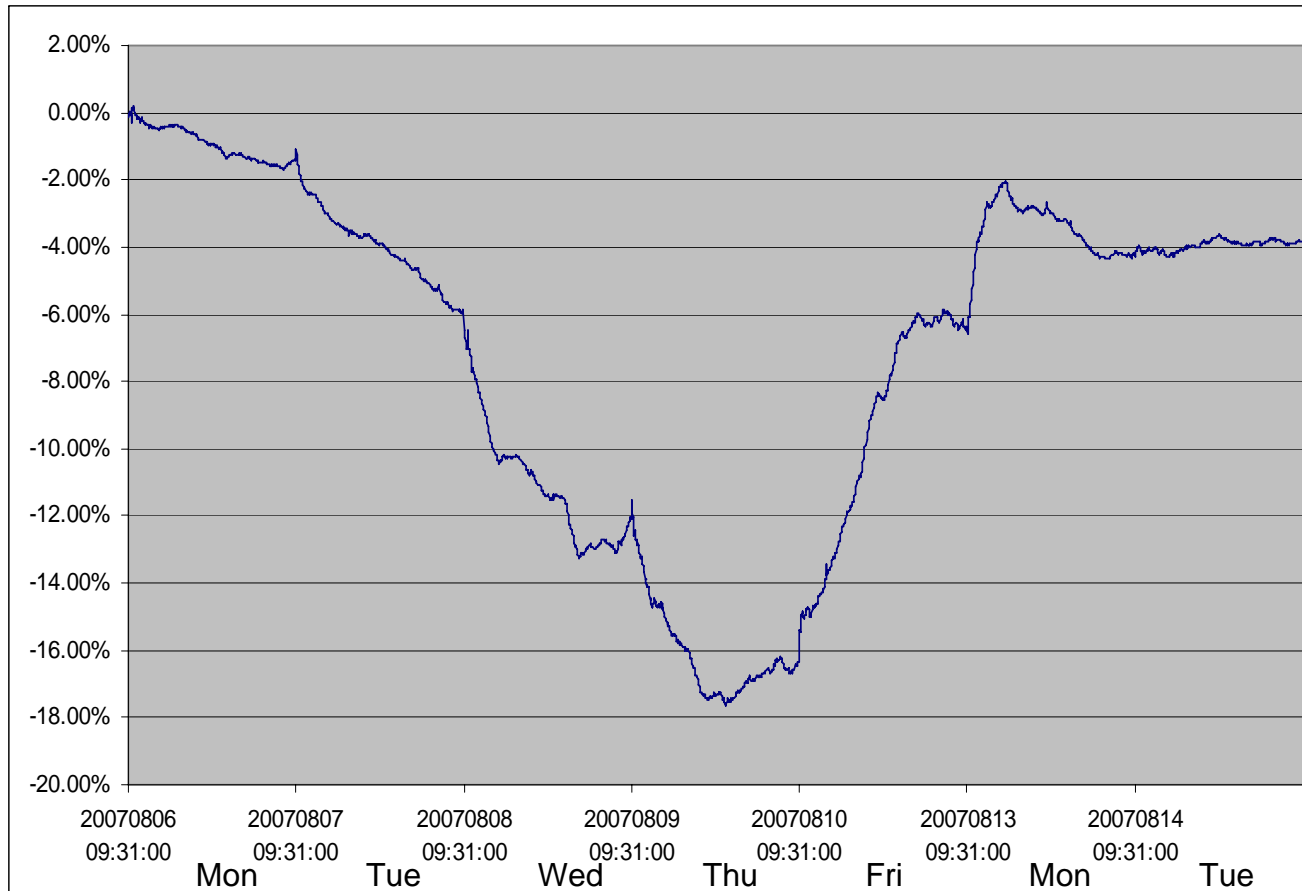
Valuation Factor Returns, July 1 – August 24



Minute-by-Minute Cumulative Return to Value Factor, August 6 - 14

7 % annualized vol $\sim 7\% / \text{Sqrt}(252) = 44$ bps daily vol (vol. estimates from BARRA)

Move largest for illiquid stocks



Evidence of Liquidity Event due to Unwinding

		Mon	Tue	Wed	Thu	Fri	Mon	Tue
Return		-1.34%	-4.52%	-6.20%	-4.23%	9.82%	2.20%	0.35%
# Stds	(1 std is 0.44%)	-3	-10	-14	-10	22	5	1
P-value "normal" day		0.23%	0.00%	0.00%	0.00%	0.00%	0.00%	42%
Positive returns (%)	10 minute intervals	31%	10%	32%	41%	75%	43%	56%
Negative returns (%)		69%	90%	68%	59%	25%	57%	44%
Positive returns (%)	1 minute intervals	42%	32%	35%	42%	67%	47%	52%
Negative returns (%)		58%	68%	65%	58%	33%	53%	48%
P-value random walk		0.10%	0.00%	0.00%	0.10%	0.00%	24%	39%

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

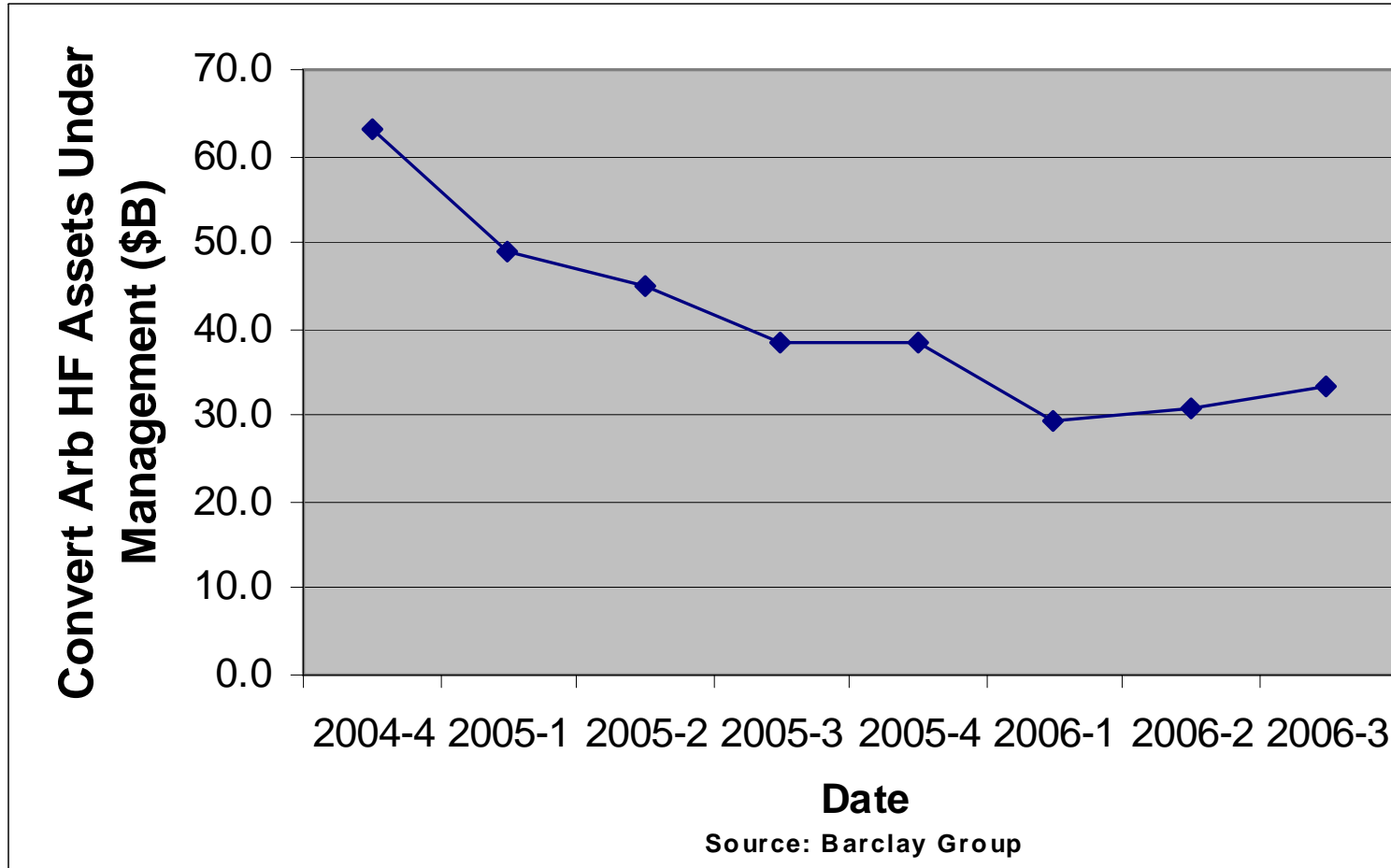
Convertible Bond Arbitrage Capital Outflows in 2005

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

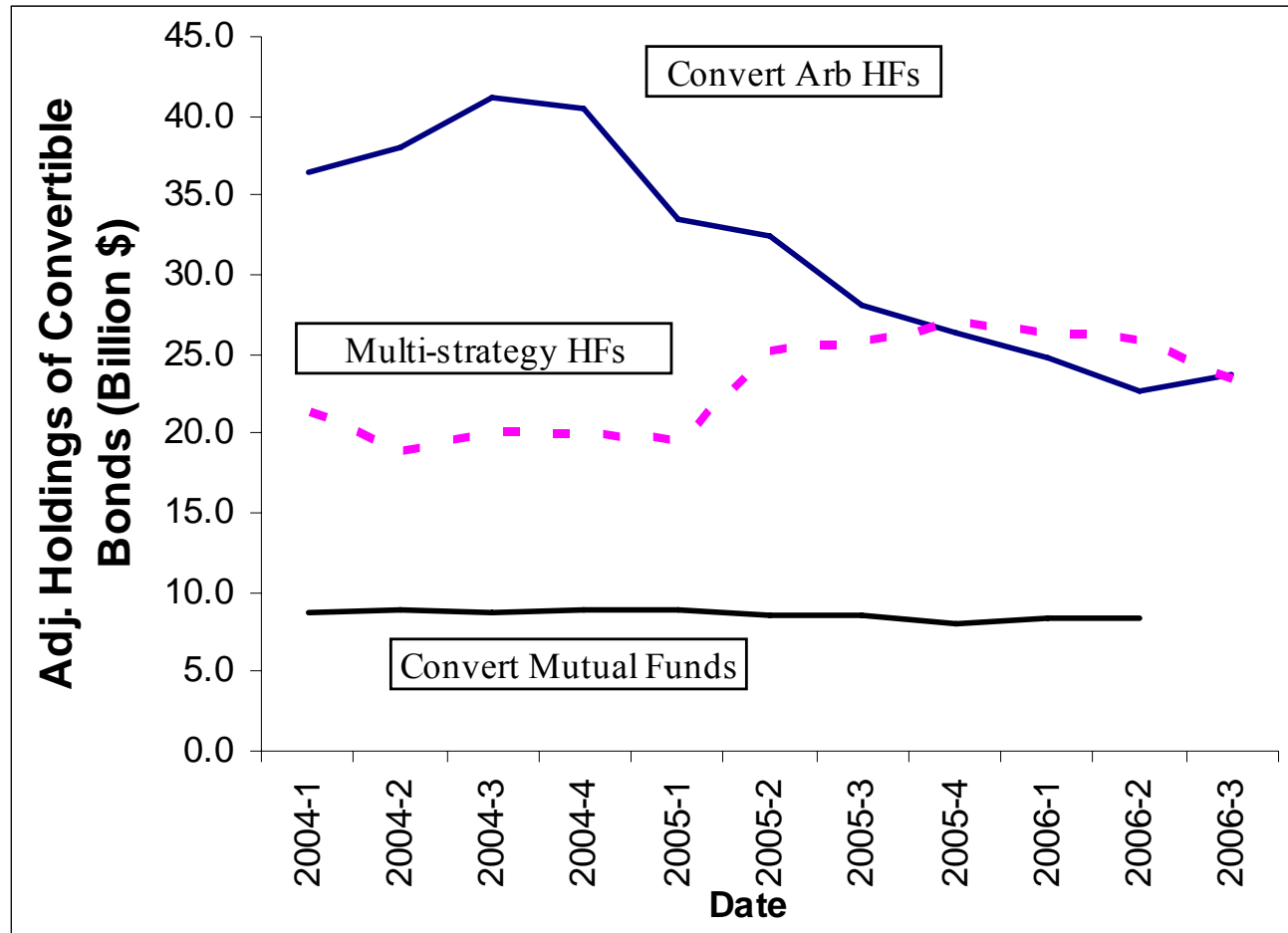
- Capital outflows in 2005:
 - 2005Q1: 20% capital redeemed
 - 2005Q1 – 2006Q1: assets fell by half

- Convert Arb HFs sold convertible bonds

Redemptions in 2005

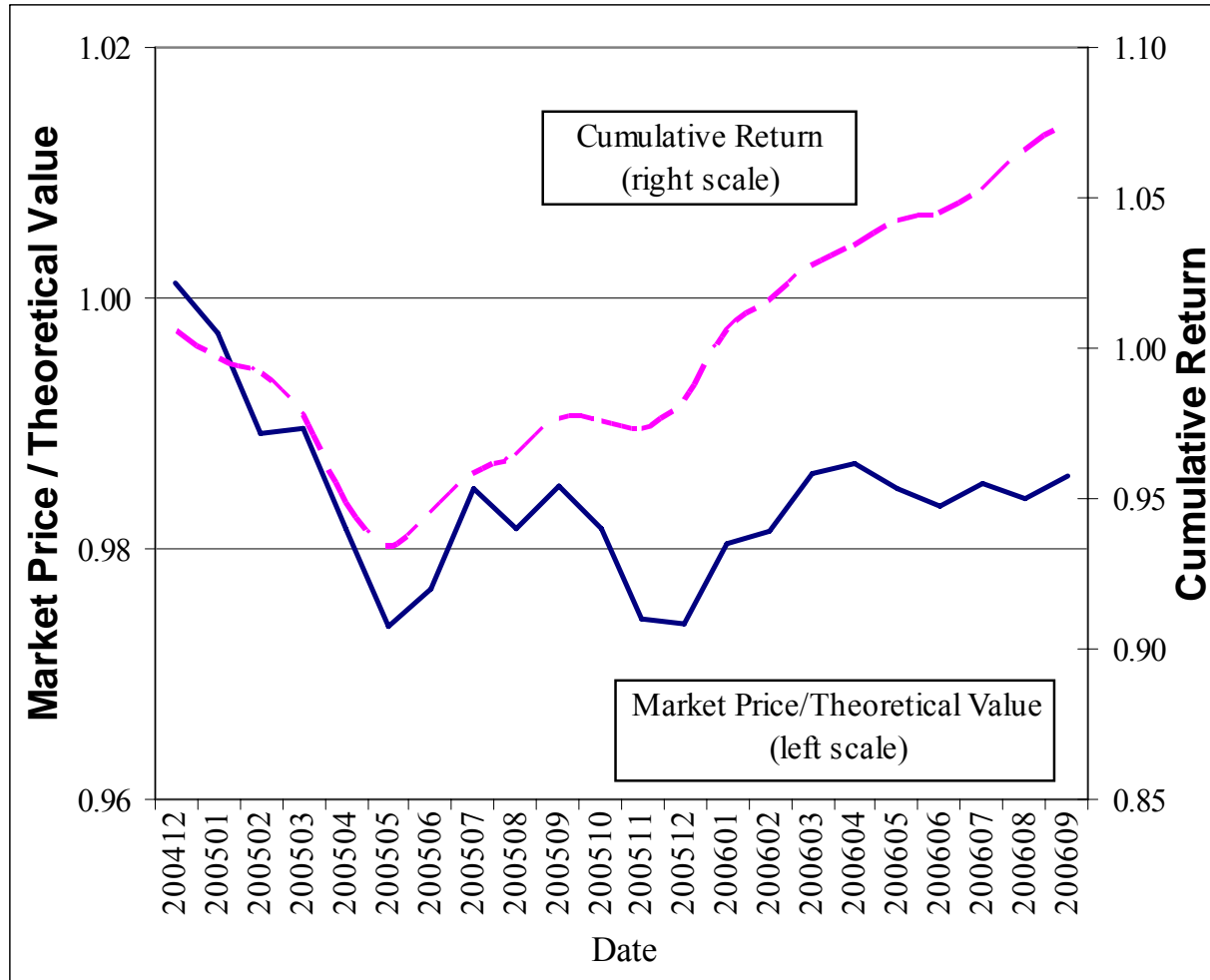


Redemptions Led to Selling: Adjusted Holdings of Convertible Bonds



Source: Mitchell, Pedersen, and Pulvino (*American Economic Review*, 2007)

Convertible Bond Arbitrage Returns and Market Price / Theoretical Value



Source: Mitchell, Pedersen, and Pulvino (*American Economic Review*, 2007)

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

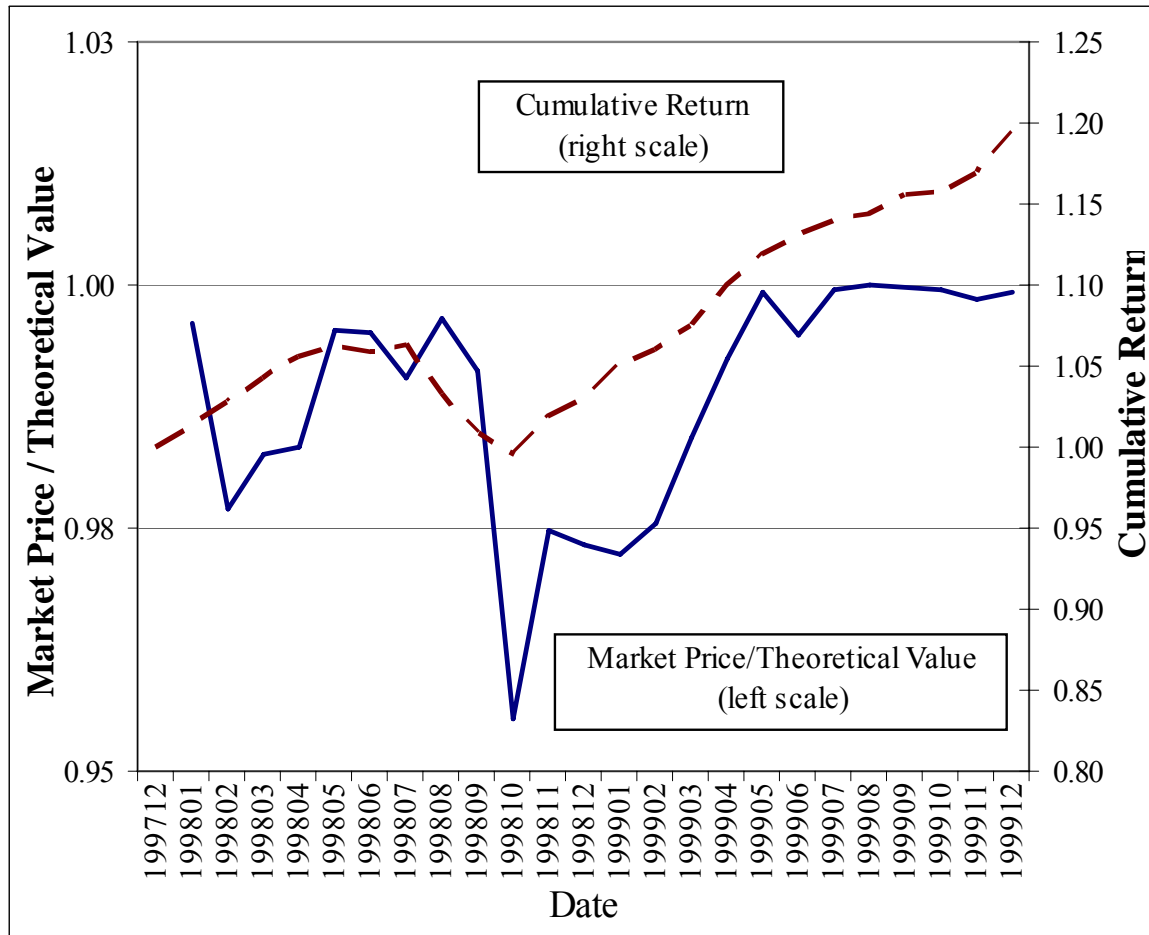
- Decided to liquidate convertible bonds at time of significant cheapness

- 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



Source: Mitchell, Pedersen, and Pulvino (*American Economic Review*, 2007)

1987 Crash: Implications for Merger Arbitrage

- Oct. 14-16: U.S. House Ways and Means Committee proposed legislation
- 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.’ ”

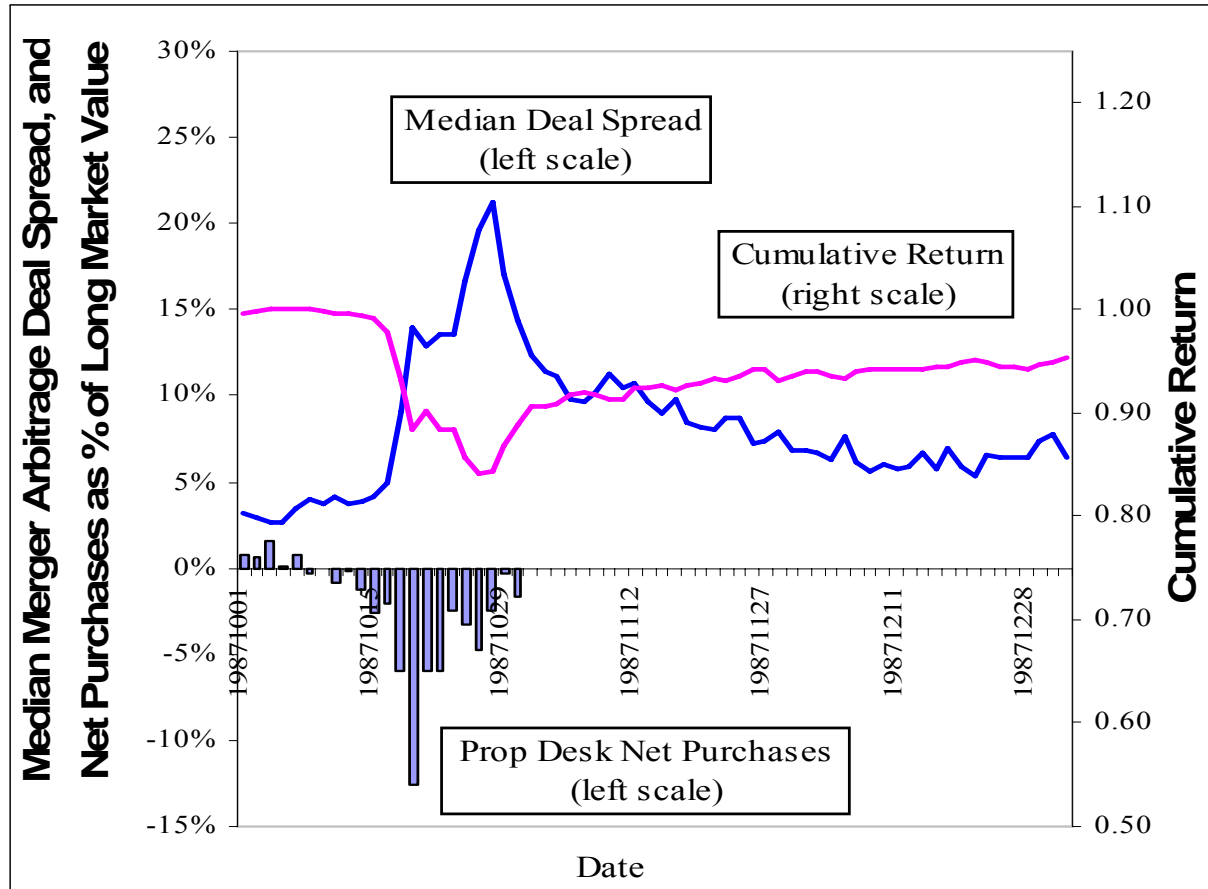
Background on Merger Arbitrage

- 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%

$$\text{deal spread} = \frac{\text{offer value} - \text{target price}}{\text{target price}}$$

- 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



Source: Mitchell, Pedersen, and Pulvino (*American Economic Review*, 2007)

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:
 - Short sellers 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

- **“Carry Trades and Currency Crashes,”** Markus Brunnermeier, Stefan Nagel, and Lasse Heje Pedersen (2008)
NBER Macroeconomics Annual, forthcoming. [Link](#)
- **“Market Liquidity and Funding Liquidity,”** Markus Brunnermeier and Lasse Heje Pedersen (2008)
Review of Financial Studies, forthcoming. [Link](#)
- **“Demand-Based Option Pricing,”** Nicolae Garleanu, Lasse Heje Pedersen, and Allen Poteshman (2008)
Review of Financial Studies, forthcoming. [Link](#)
- **“Valuation in Over-the-Counter Markets,”** Darrell Duffie, Nicolae Garleanu, and Lasse H. Pedersen (2007)
The Review of Financial Studies, vol. 20, no. 5, pp 1865-1900. [Link](#)
- **“Liquidity and Risk Management”** Nicolae Garleanu and Lasse Heje Pedersen (2007)
American Economic Review, P&P, 2007, vol. 97, no. 2, pp. 193-197. [Link](#)
- **“Slow Moving Capital,”** Mark Mitchell, Lasse Heje Pedersen, and Todd Pulvino (2007)
The American Economic Review, P&P, 2007, vol. 97, no. 2, pp. 215-220. [Link](#)
- **“Asset Pricing with Liquidity Risk,”** Viral Acharya and Lasse Heje Pedersen (2005)
Journal of Financial Economics, vol. 77, pp. 375-410. [Link](#)
- **“Predatory Trading,”** Markus K. Brunnermeier and Lasse Heje Pedersen (2005)
The Journal of Finance, vol. 60, no. 4, pp. 1825-1863. [Link](#)
- **“Liquidity and Asset Prices,”** Yakov Amihud, Haim Mendelson, and Lasse Heje Pedersen (2005)
Foundations and Trends in Finance, vol.1, no. 4, pp. 269-364. [Link](#)
- **“Securities Lending, Shorting, and Pricing,”** Darrell Duffie, Nicolae Garleanu, and Lasse Heje Pedersen (2002)
Journal of Financial Economics, vol. 66, pp. 307-339. [Link](#)