Market Liquidity and Funding Liquidity: An Overview

Sixth Annual Volatility Institute Conference

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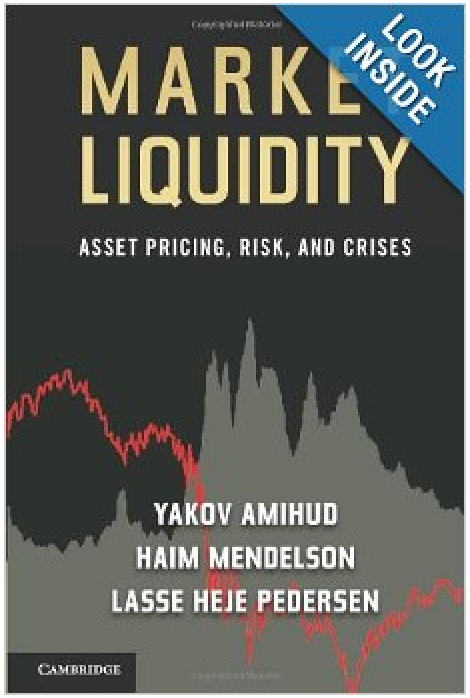


Market Liquidity and Funding Liquidity

Overview of talk: market and funding liquidity drive

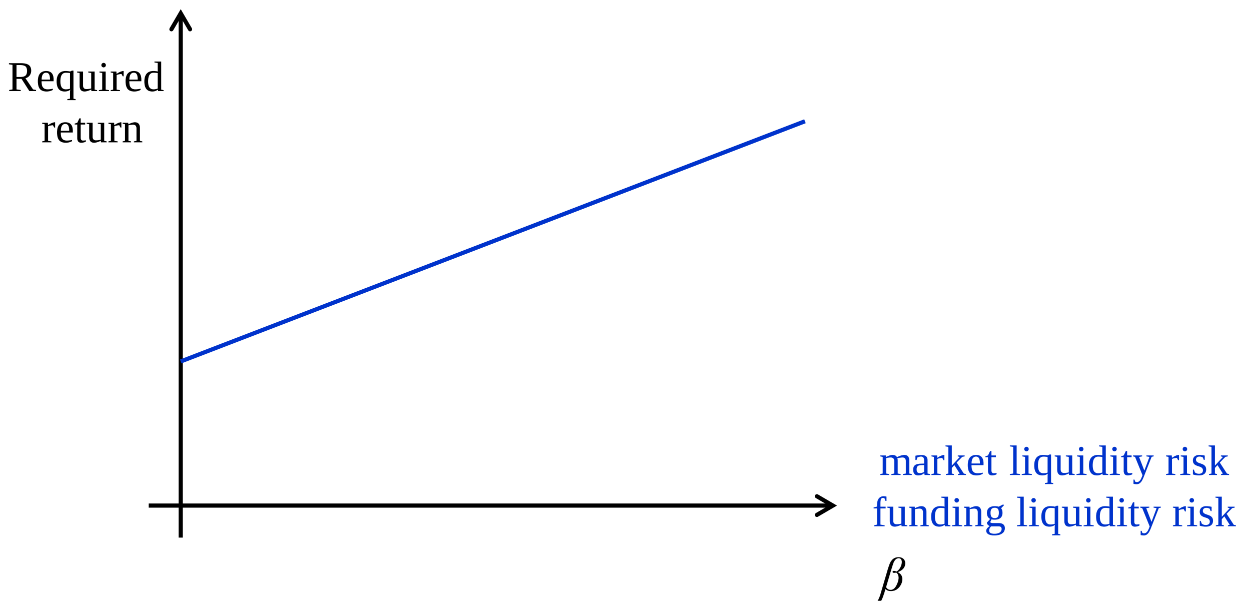
- asset prices
  - portfolio choice
  - risk management
  - performance measurement
- derivative pricing
  - exercise behavior
- macro economics
- monetary policy

Overview of Key Ideas

- Standard theory of asset pricing vs. liquidity risk drives asset prices

endogenously affected by liquidity risk

$$E_t(r^s_{t+1}) = r^f_t + \beta^s_t \,\lambda_t \; + \text{market liquidity risk compensation} + \text{funding liquidity risk compensation}$$



- Market and funding liquidity interact

Overview of Key Ideas, Continued

- Liquidity risk affects risk management
  - Cash management, position sizing based on market liquidity, risk limits
  - Examples:
    - LTCM
    - Metallgesellschaft
    - Pension funds hedging their long-term liabilities
    - Banks and mortgage institutions: run risk

- Liquidity risk affects performance measurement
  - Consider if performance is due to exposure to
    - Market liquidity risk
    - Tying up funding due to leverage (or potential future use of balance sheet)

- Liquidity risk affects the macroeconomy
  - Example: the liquidity risk in the banking system started the recession

- Liquidity risk affects monetary policy
  - Unconventional monetary policy attempts to fix this

- Liquidity risk can create opportunities

Roadmap of This Talk

- **Market liquidity risk, crises, and asset prices**
- Funding liquidity risk, crises, and asset prices
- Macro economics and monetary policy
- Liquidity spirals: when everyone runs for the exit
- Conclusion

Liquidity-Adjusted CAPM

Proposition. [Acharya and Pedersen (2005), Prop.1]

The CAPM holds for net returns $E(r^i\text{-}c^i)$

$$\mathrm{E}_t\left(r_{t+1}^i - c_{t+1}^i\right) = r^f + \lambda_t \frac{\mathrm{cov}_t\left(r_{t+1}^i - c_{t+1}^i, r_{t+1}^M - c_{t+1}^M\right)}{\mathrm{var}_t\left(r_{t+1}^M - c_{t+1}^M\right)}$$

which means that required gross returns $E(r^i)$ depend on expected market liquidity $E(c^i)$, market beta, and three market liquidity risks:

$$\mathrm{E}_t\left(r_{t+1}^i\right) = r^f + \mathrm{E}_t\left(c_{t+1}^i\right) + \lambda_t\left(\beta_t^{r^i,r^M} + \beta_t^{c^i,c^M} - \beta_t^{r^i,c^M} - \beta_t^{c^i,r^M}\right)$$

where

$$\beta_t^{r^i,r^M} = \mathrm{cov}_t\left(r_{t+1}^i, r_{t+1}^M\right) / \mathrm{var}_t\left(r_{t+1}^M - c_{t+1}^M\right) \quad \text{market beta}$$

$$\beta_t^{c^i,c^M} = \mathrm{cov}_t\left(c_{t+1}^i, c_{t+1}^M\right) / \mathrm{var}_t\left(r_{t+1}^M - c_{t+1}^M\right) \quad \text{commonality in liquidity}$$

$$\beta_t^{r^i,c^M} = \mathrm{cov}_t\left(r_{t+1}^i, c_{t+1}^M\right) / \mathrm{var}_t\left(r_{t+1}^M - c_{t+1}^M\right) \quad \text{return sensitivity to aggregate liquidity}$$

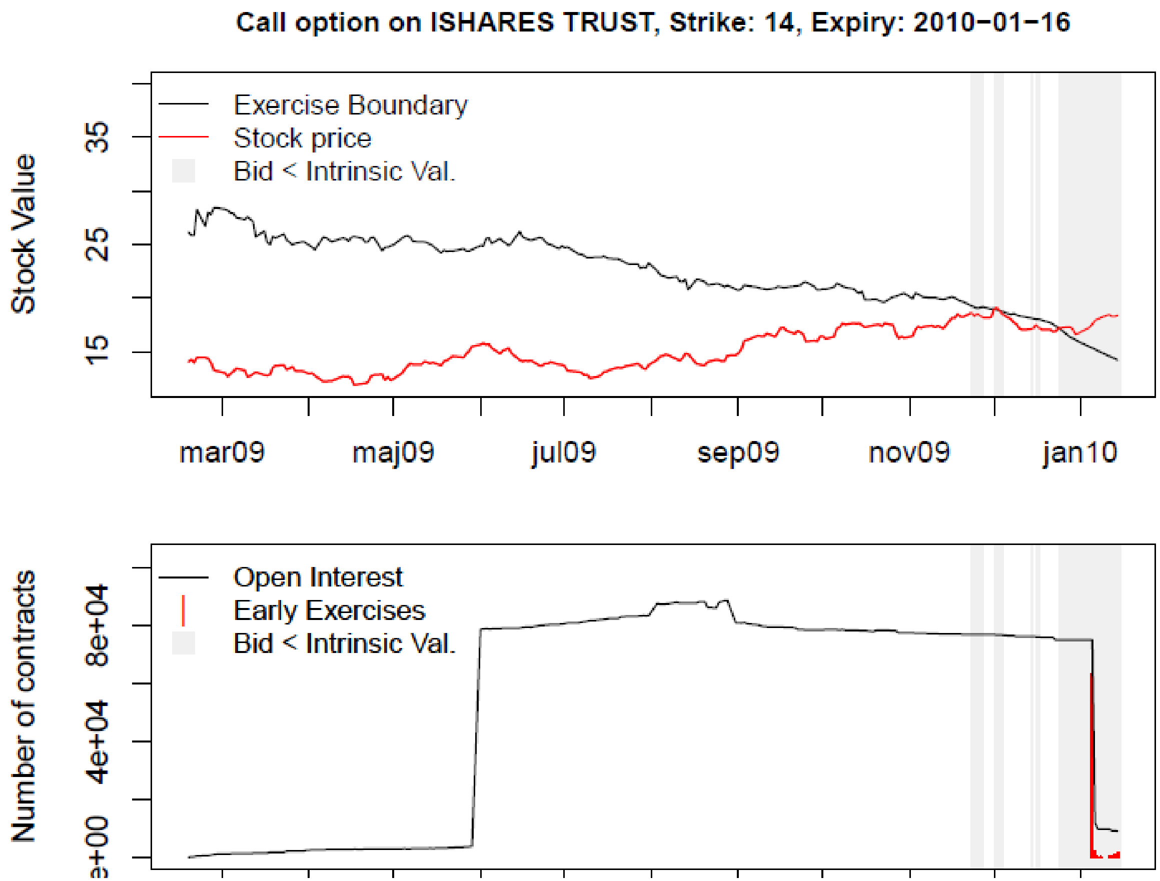
$$\beta_t^{c^i,r^M} = \mathrm{cov}_t\left(c_{t+1}^i, r_{t+1}^M\right) / \mathrm{var}_t\left(r_{t+1}^M - c_{t+1}^M\right) \quad \text{liquidity sensitivity to economic conditions}$$

- **Option prices** also affected by liquidity (Garleanu, Poteshman, Pedersen, RFS 2009)

Early Option Exercise: Never Say Never

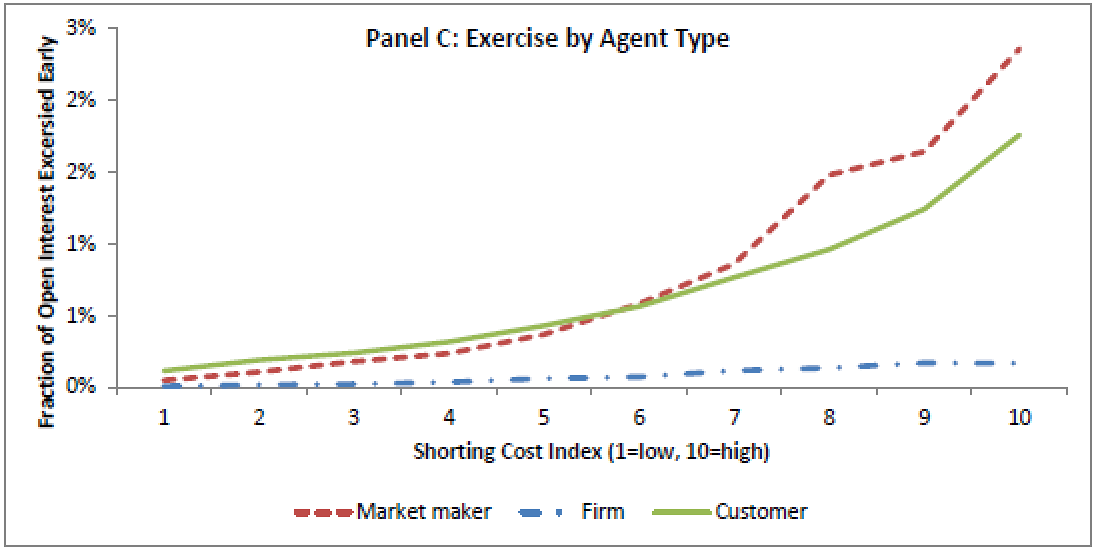
- Classic results without frictions:
  - **Never exercise** an American call option, except at maturity before dividend payment (Merton's rule)
  - **Never convert** a convertible bond (Brennan and Schwartz (1977), Ingersoll (1977))

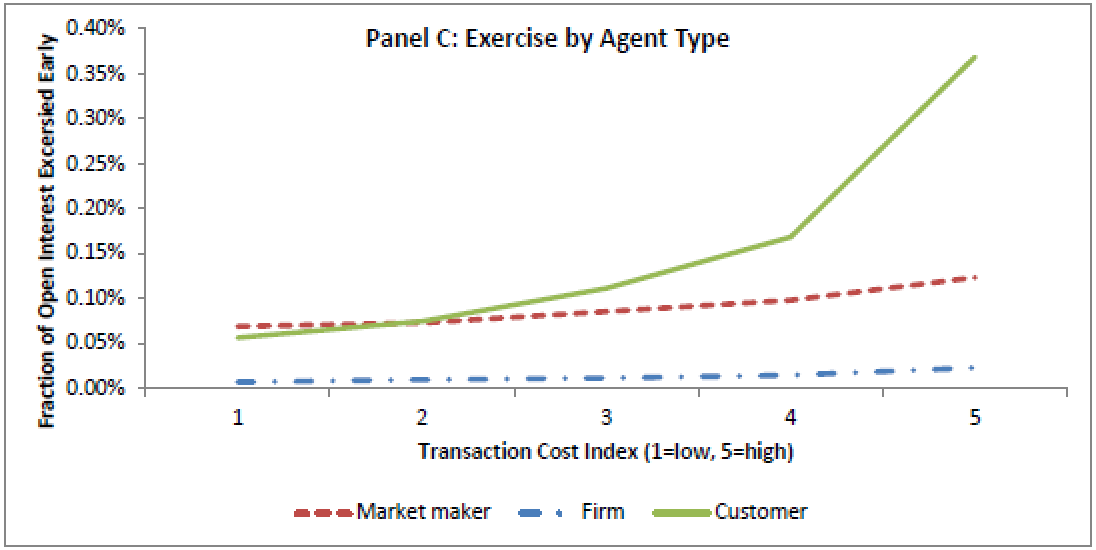
- "Early Option Exercise: Never Say Never" Jensen and Pedersen (2013)
  - Merton's rule overturned theoretically with liquidity frictions



Early Option Exercise: Never Say Never

- Model with frictions have predictions for exercise and conversions consistent with the evidence based on data on
  - Actual frictions
  - Prices
  - Actual exercises
  - Actual conversions





Roadmap of This Talk

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Proposition. [Garleanu and Pedersen, Prop. 2]

The equilibrium required return for any security s is:

$$E_t\left(r_{t+1}^s\right) = r^f + \beta_t^s \lambda_t + \psi_t x_t m_t^s$$

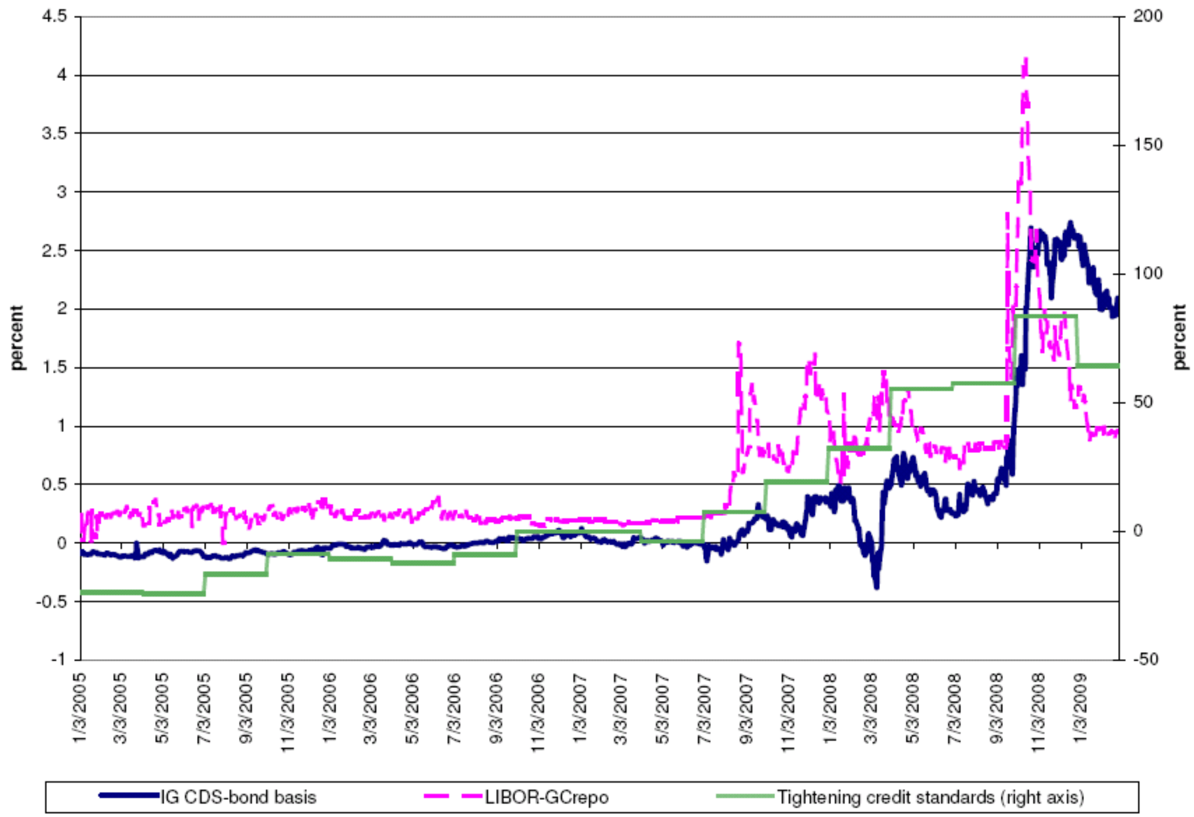
where ψ_t is the leveraged agents' Lagrange multiplier, measuring the tightness of funding constraints, x_t is the fraction of constrained agents, m_t^s is the margin requirement of security s, and λ_t is the risk premium:

$$\lambda_t = E_t\left(r_{t+1}^M\right) - r^f - \psi_t$$

- Tests:
  1. Find securities with the same fundamental risk β and different margin requirement *m*.
     - Garleanu and Pedersen (2011) "Margin-Based Asset Pricing and Deviations from the Law of One Price", Ashcraft, Garleanu, and Pedersen (2010)
  2. Find securities with the different fundamental risk β and the same margin requirement *m*.
     - Frazzini and Pedersen (2010, 2011), and Asness, Frazzini, and Pedersen (2011)

Evidence on Margin CAPM: Deviations from Law of One Price (LoOP)

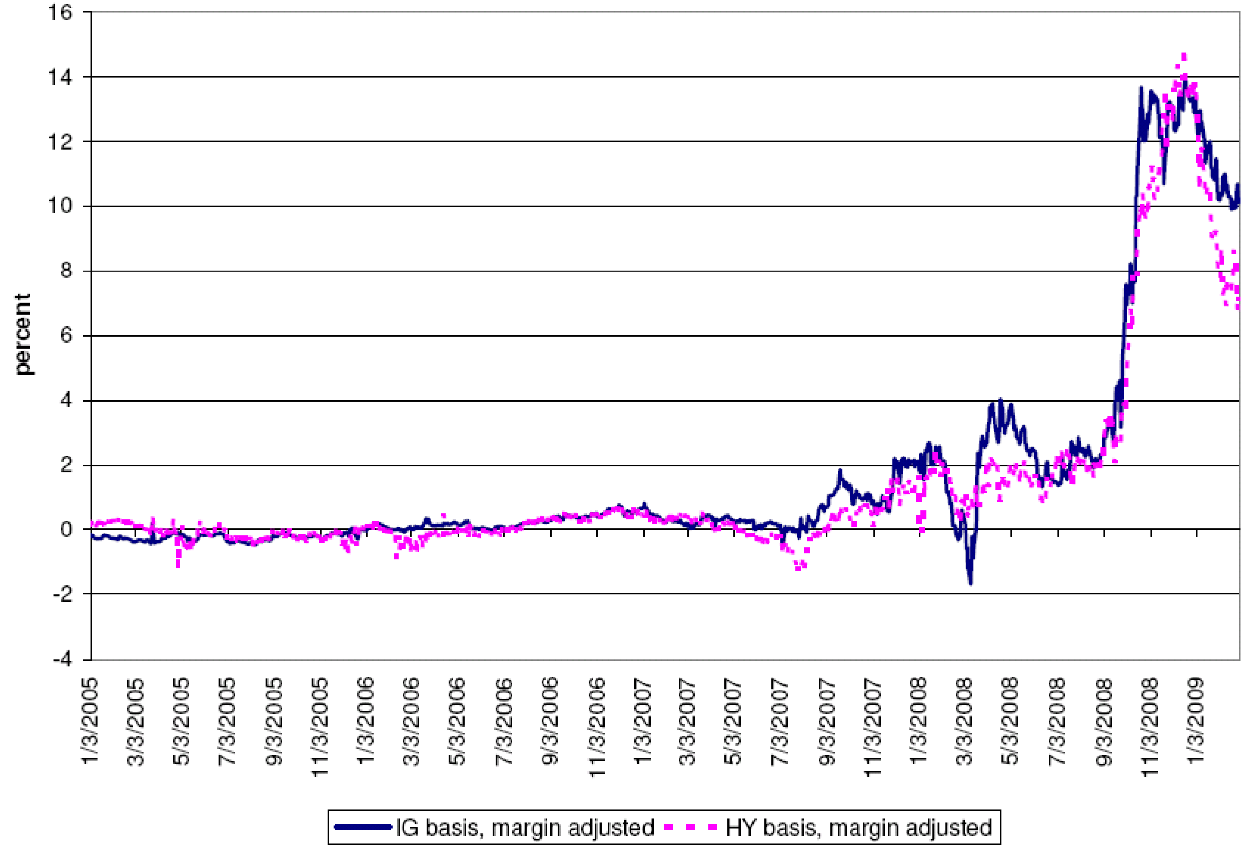
- Spread (solid line) between the yield of
  - Corporate bonds with high margin requirements (and high yield during the crisis) vs.
  - CDS with similar fundamentals but lower margin requirement



- Time-series evidence: Deviation from LoOP lines up with funding liquidity measures:
  - credit tightness (green line, from the Board of Governors survey)
  - LIBOR-repo spread (pink line)

Evidence on Margin CAPM: Deviations from Law of One Price

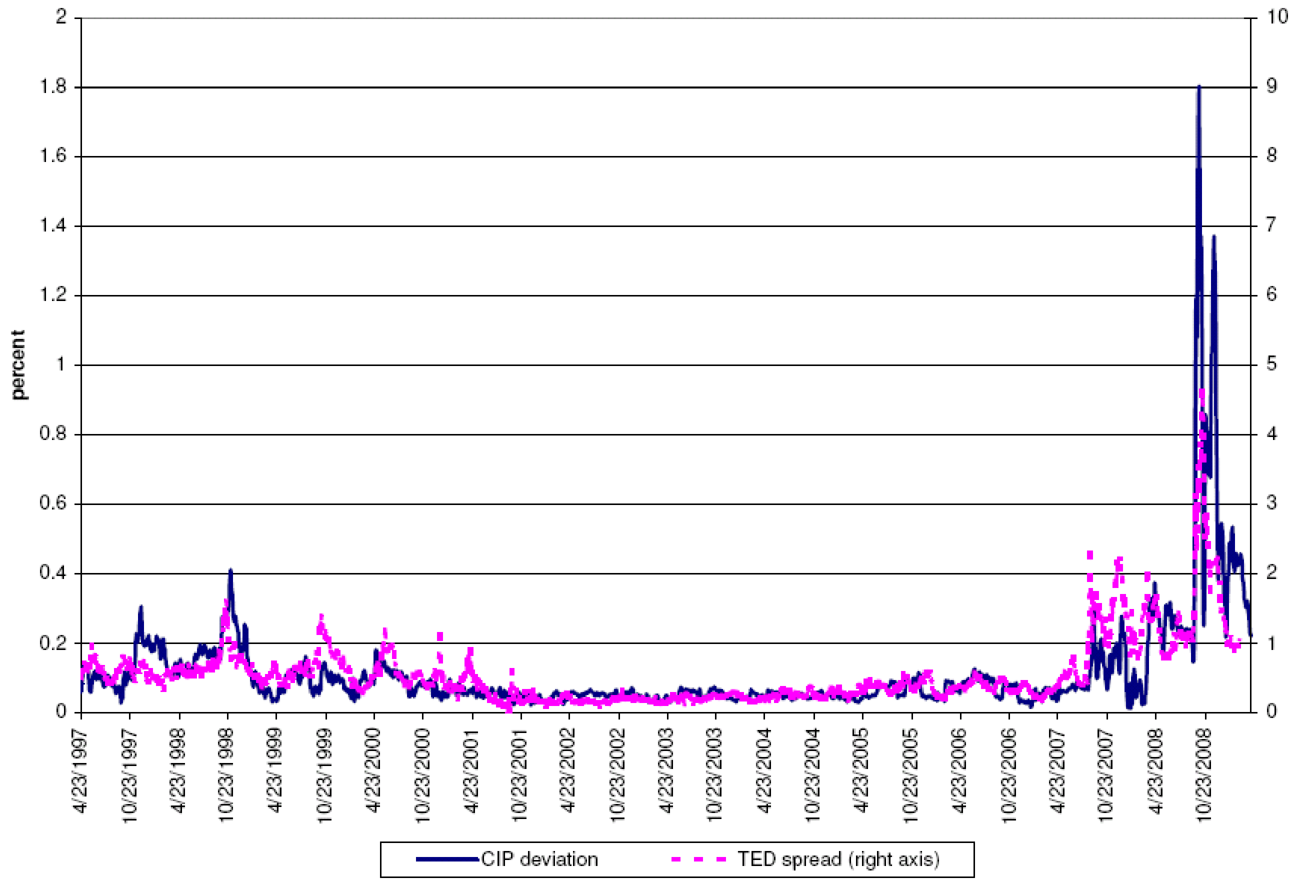
- Law of One Price Deviation: Spread between CDS and corporate bonds
- Cross-sectional evidence:
  - The deviation from the LoOP was larger for high yield (HY) securities than for investment grade (IG) securities, consistent with margin requirements being higher for HY
  - Once margin requirements are adjusted for, deviations line up in the cross section:



Source: Garleanu and Pedersen (2011), "Margin-Based Asset Pricing and Deviations from the Law of One Price"

Evidence on Funding Liquidity: Deviations from LoOP

- Law of One Price Deviation: Covered interest-rate parity
- Deviation lines up with a measure of funding liquidity frictions, the TED spread:



Source: Garleanu and Pedersen (2011), "Margin-Based Asset Pricing and Deviations from the Law of One Price"

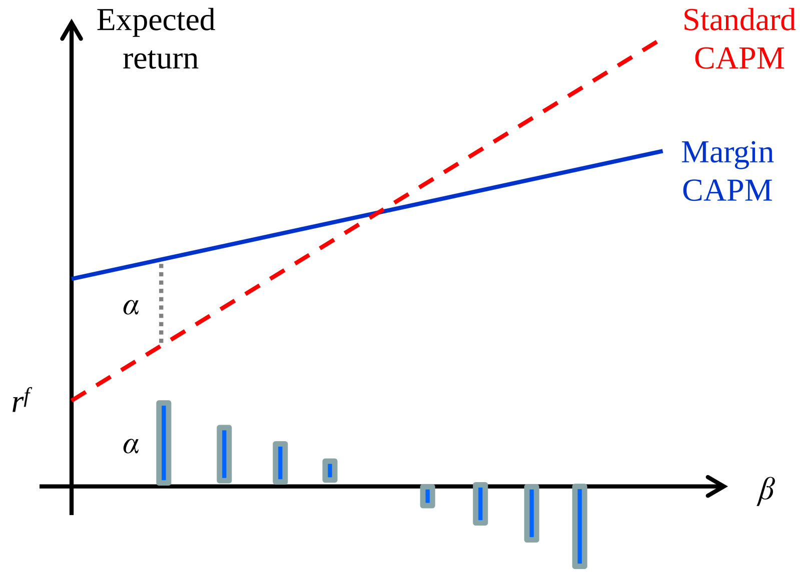
Implications of Funding Liquidity: High Beta is Low Alpha

Proposition. [Frazzini and Pedersen, Prop. 1] *When securities have the same margin requirement:*

$$E_t\left(r_{t+1}^s\right) = r^f + \psi_t + \beta_t^s \lambda_t$$

where the risk premium is $\lambda_t = E_t\left(r_{t+1}^M\right) - r^f - \psi_t$ *, and* ψ *is the average Lagrange multiplier, measuring the tightness of funding constraints. A security's alpha with respect to the market decreases in the security's market beta:*

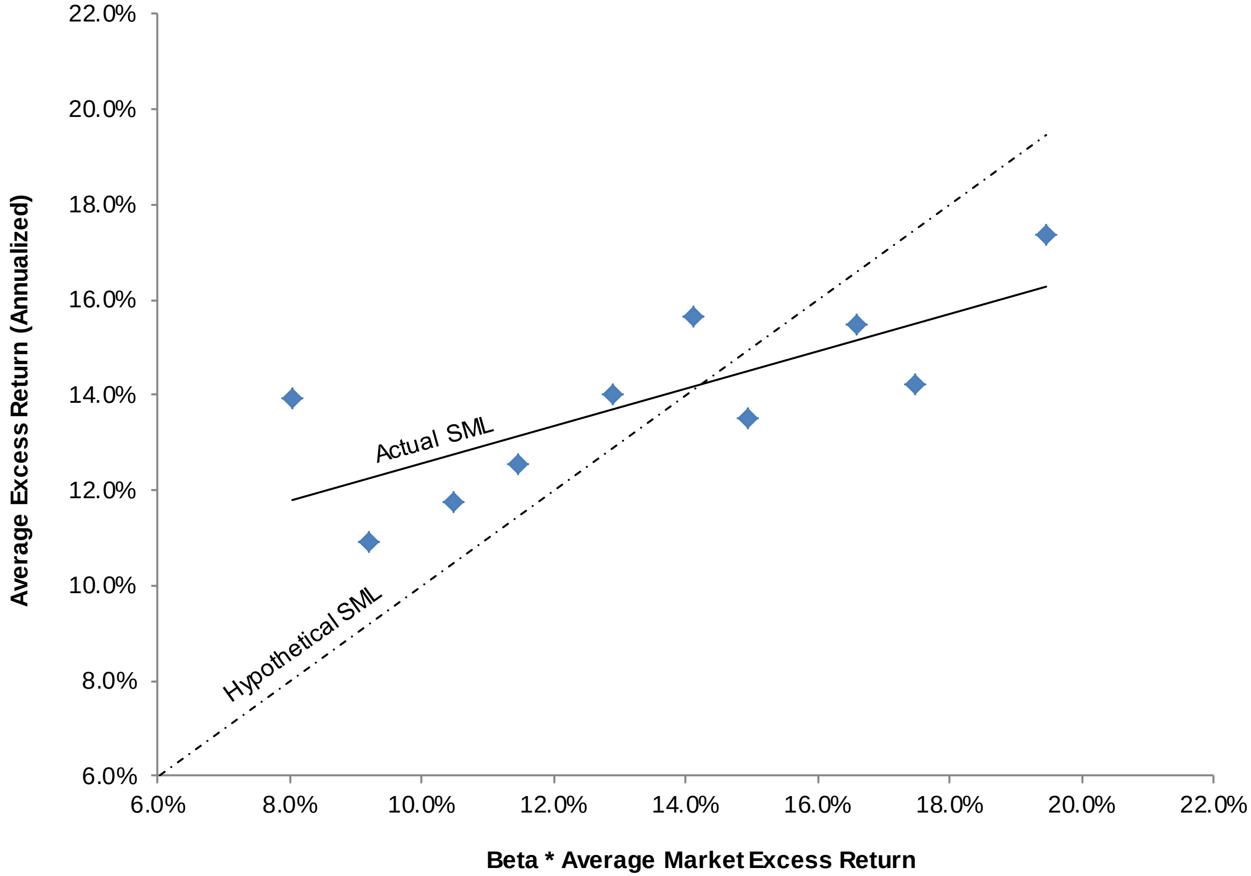
$$\alpha_t^s = \psi_t\left(1 - \beta_t^s\right)$$



Source: "Betting Against Beta," Andrea Frazzini and Lasse Heje Pedersen (JFE, 2014)

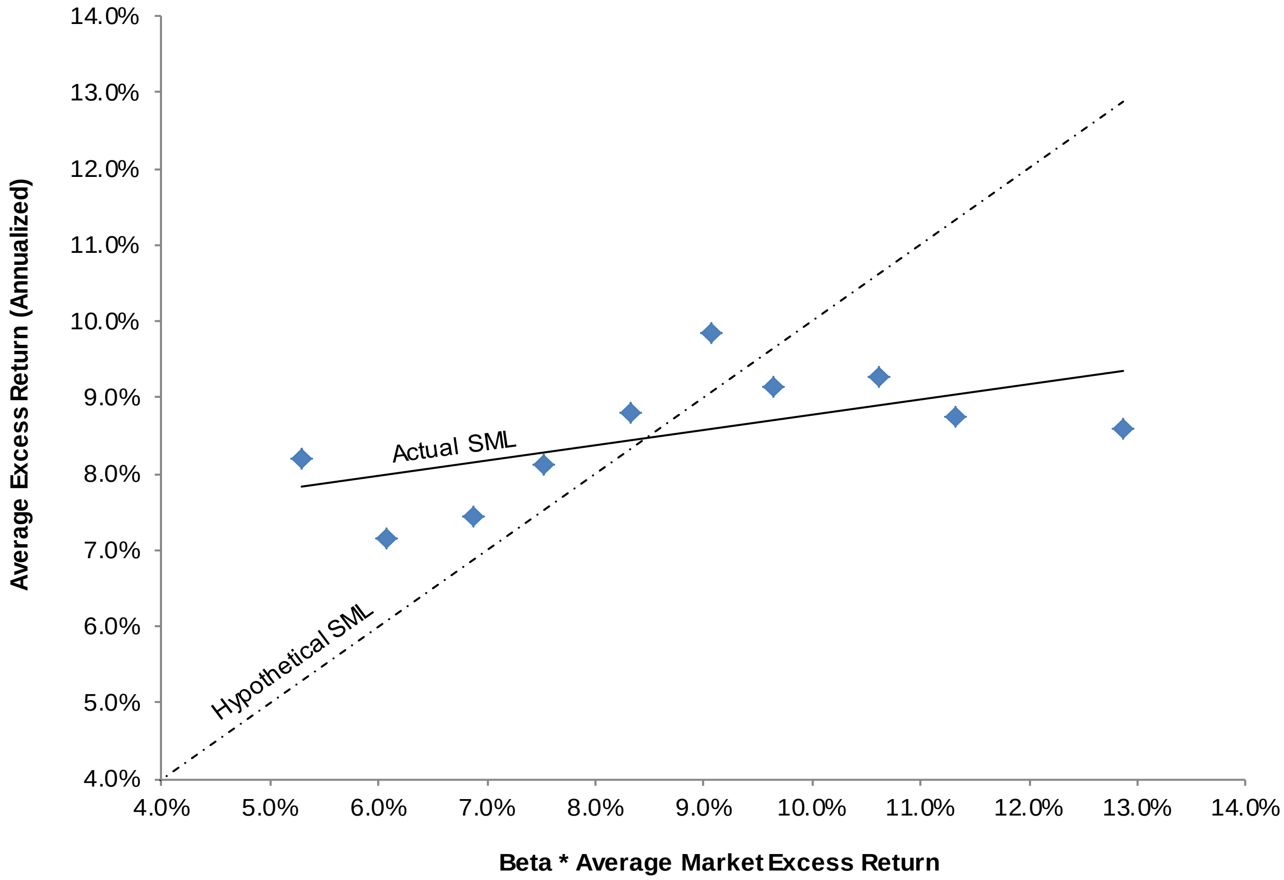
Evidence on High Beta is Low Alpha: Black, Jensen, and Scholes (1972)

- Theoretical and Empirical Security Market Lines of Ten Beta-sorted Portfolios (1931 to 1965)



Evidence on High Beta is Low Alpha: Updated Stock Sample

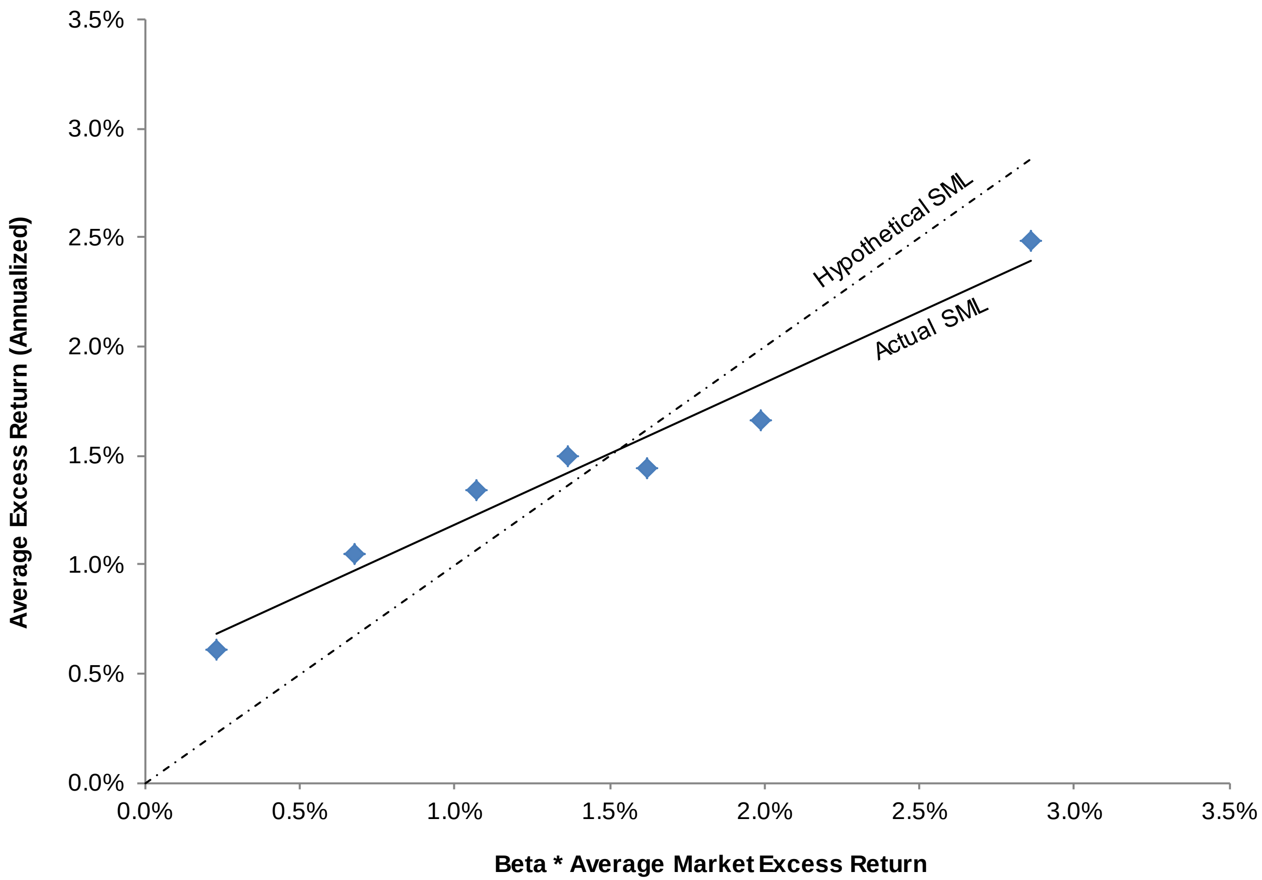
- Theoretical and Empirical Security Market Lines of Ten Beta-sorted Portfolios (1926 to 2010)



Source: "Betting Against Beta," Andrea Frazzini and Lasse Heje Pedersen (JFE, 2014)

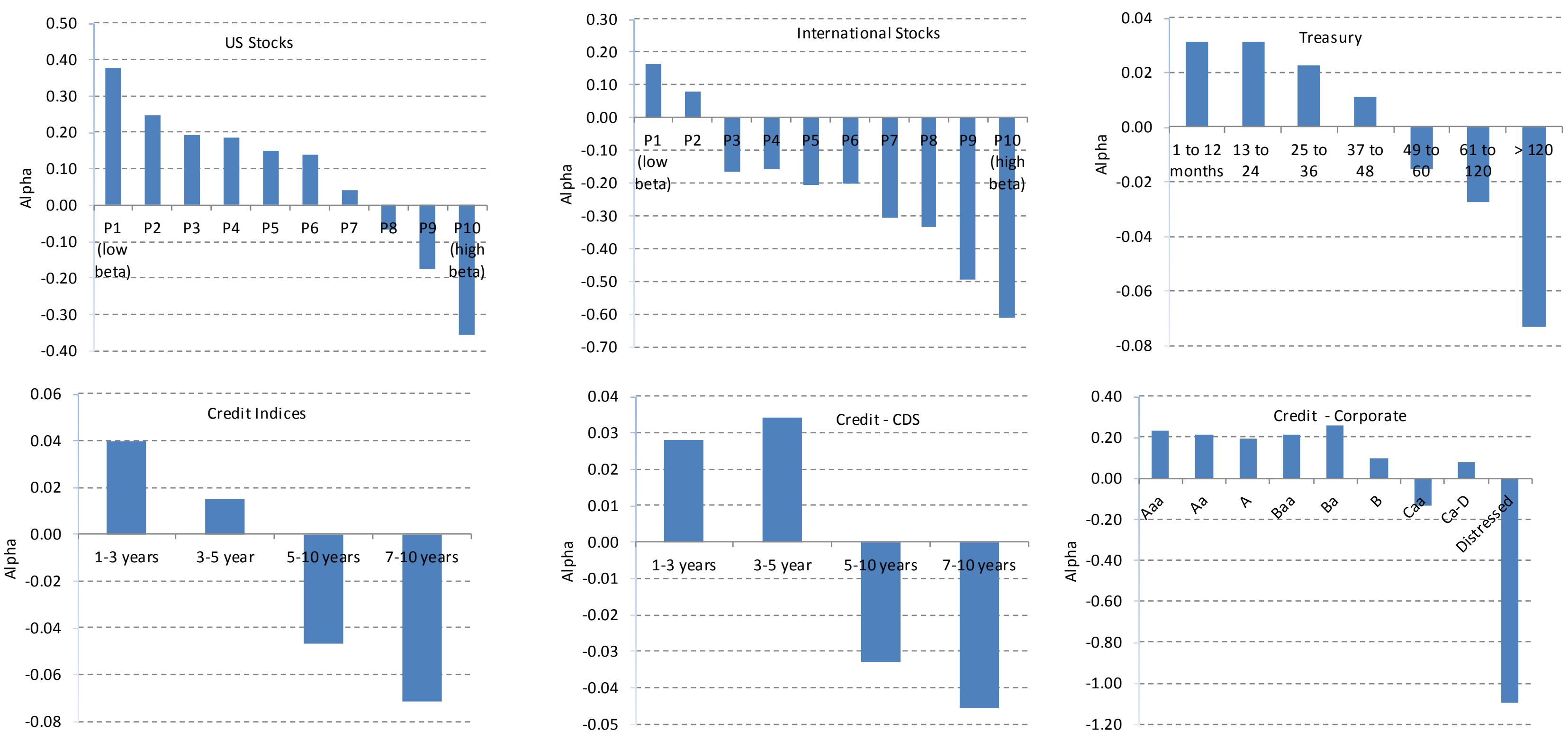
Evidence on High Beta is Low Alpha: Bonds

➢ Theoretical and Empirical Security Market Lines of Seven Maturity-sorted U.S. Bond Portfolios (1952 to 2010)



Source: “Betting Against Beta,” Andrea Frazzini and Lasse Heje Pedersen (JFE, 2014)

Evidence on High Beta is Low Alpha: Within Asset Classes



Source: “Betting Against Beta,” Andrea Frazzini and Lasse Heje Pedersen (JFE, 2014)

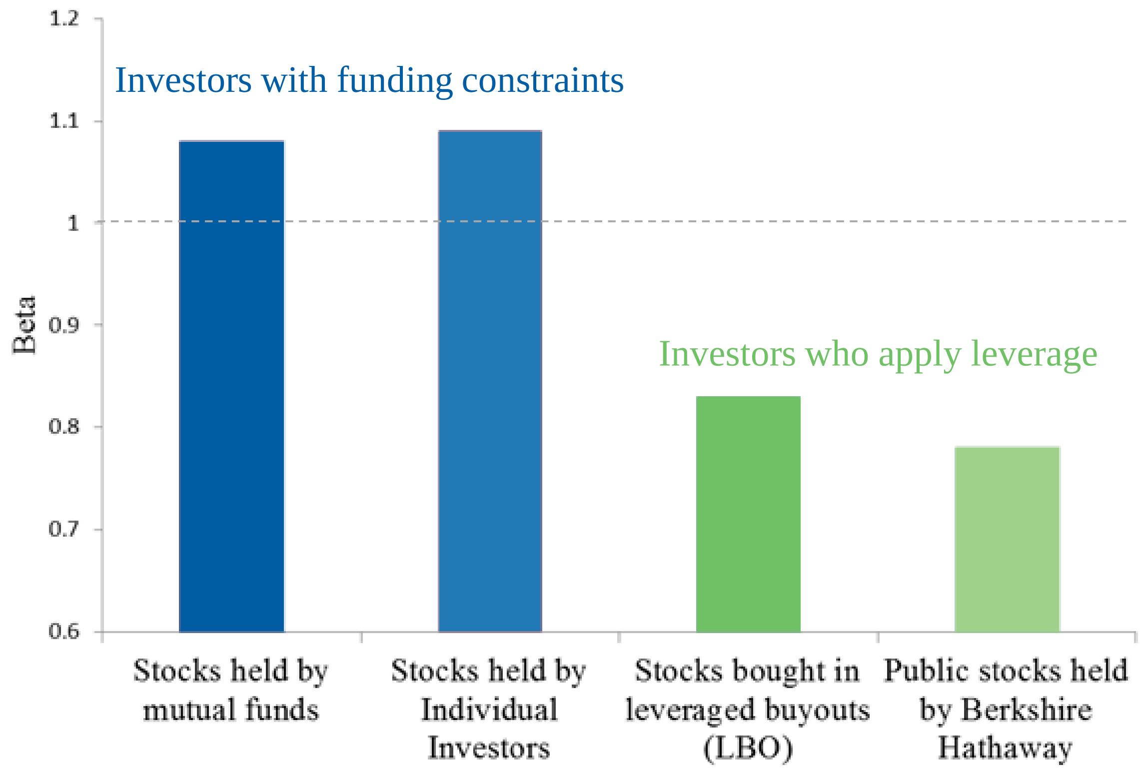
Embedded Leverage

- "Embedded Leverage," working paper, Frazzini and Pedersen:
  - Institutional response to leverage constraints
  - Demand for securities that embed leverage, supplied at a cost
  - Test predictions for index options, equity options, leveraged ETFs
  - Broader implications for economics: security design, pooling and tranching, SIVs, regulation

	Equity Options					Index Options					ETFs
Embedded Leverage (t-1)	**-0.72**	**-1.53**	**-1.90**	**-1.85**	**-1.70**	**-1.21**	**-1.43**	**-1.53**	**-1.53**	**-1.40**	**-0.26**
	-(5.40)	-(9.37)	-(10.88)	-(10.39)	-(10.26)	-(7.30)	-(8.57)	-(8.31)	-(8.38)	-(7.55)	-(2.35)
Log(open interest) (t-1)		**-0.52**	**1.57**	**1.47**	**1.56**		0.02	**0.38**	**0.42**	**0.56**	
		-(2.23)	(4.58)	(4.95)	(5.59)		(0.13)	(3.32)	(3.66)	(3.18)	
Log(total open interest) (t-1)		0.25	**-0.92**	-1.13	-1.12		0.47	**0.61**	0.26	1.25	
		(0.65)	-(3.67)	-(1.34)	-(1.46)		(1.78)	(2.56)	(0.22)	(0.77)	
Months to expiration (t-1)		**-1.27**	**-1.14**	**-1.07**	**-1.96**		-0.13	-0.30	-0.28	**-2.14**	
		-(2.02)	-(2.48)	-(2.29)	-(4.45)		-(0.18)	-(0.48)	-(0.45)	-(2.68)	
Moneyness (t-1)		**-0.24**	-0.08	-0.09	-0.09		**-0.19**	0.00	0.06	0.14	
		-(2.31)	-(0.60)	-(1.14)	-(1.06)		-(2.69)	(0.04)	(0.54)	(0.81)	
Implied volatility (t-1)		**-36.28**	**-45.13**	**-44.22**	**-43.73**		-39.33	**-63.06**	**-63.17**	-38.76	
		-(7.36)	-(10.25)	-(6.25)	-(6.42)		-(1.30)	-(2.58)	-(2.60)	-(0.98)	
1-Month spot volatility (t-1)		3.77	2.48	-2.49	-2.08		21.63	68.55	**136.57**	119.49	
		(0.69)	(0.58)	-(0.65)	-(0.59)		(0.46)	(0.97)	(3.23)	(1.80)	
12-Month spot volatility (t-1)		**10.48**	6.77	**7.30**	**6.50**		-4.51	-84.77	**-174.94**	**-176.14**	
		(2.22)	(1.56)	(2.67)	(2.50)		-(0.08)	-(1.25)	-(3.32)	-(2.20)	
Option Vega (t-1)			**-0.03**	**-0.03**	**-0.05**			**-0.01**	**-0.02**	**-0.03**	
			-(3.23)	-(2.56)	-(3.29)			-(2.74)	-(3.18)	-(3.70)	
Option Gamma (t-1) *100			-0.35	-0.20	**-0.24**			**2.05**	**2.38**	**2.85**	
			-(1.32)	-(1.66)	-(2.18)			(3.08)	(3.10)	(2.49)	
Stock return (t)			-10.66	**-11.51**	**-13.77**			**173.48**	-34.74	-45.01	
			-(1.90)	-(2.18)	-(2.98)			(2.42)	-(0.29)	-(0.40)	
Option turnover (t)			**8.73**	**8.62**	**10.08**			0.98	1.02	2.03	
			(12.42)	(12.39)	(12.87)			(1.29)	(1.32)	(1.83)	
Total option turnover (t)			**9.60**	**11.73**	**12.01**			**3.50**	**4.89**	**4.88**	
			(3.30)	(4.56)	(5.13)			(2.50)	(2.34)	(2.27)	
Option B/A Spread (t-1)			**14.37**	**14.62**	**17.16**			4.68	4.39	8.37	
			(4.73)	(4.69)	(4.54)			(0.76)	(0.73)	(0.92)	
Total option B/A Spread (t-1)			4.56	-4.40	-8.33			-11.53	-27.07	-52.79	
			(0.44)	-(0.54)	-(1.04)			-(0.44)	-(0.98)	-(1.75)	

Funding Constraints Affect Portfolio Choice

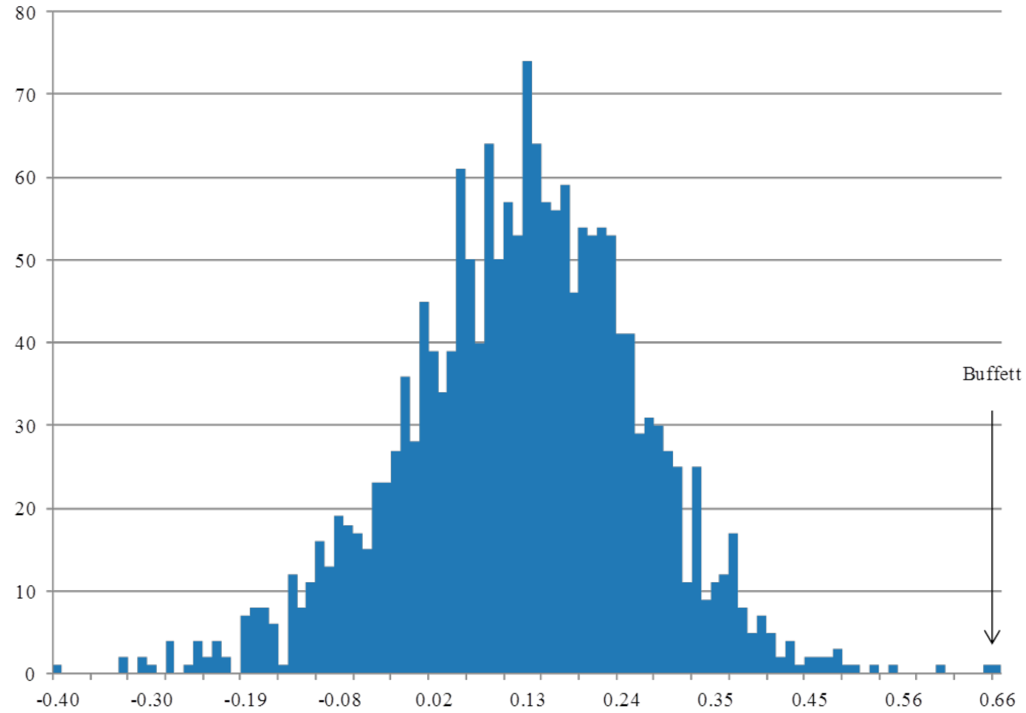
- Systematic deviation from CAPM-prediction that everyone holds the same portfolio
  - Constrained investors hold risky assets
  - Less constrained investors leverage safer assets
  - Consistent with theory of Betting Against Beta
- Source: **Betting Against Beta**, Frazzini and Pedersen (2013), *JFE* forthcoming



Buffett's Alpha

- The theory of liquidity and asset pricing can even help explain Buffett's alpha

- Buffett has delivered outstanding results over a very long time period
  - Unique access to leverage
  - Leverages low-risk, high-quality, value stocks
  - Short sells options, i.e. securities with embedded leverage



- See "Buffett's Alpha," working paper, Frazzini, Kabiller, and Pedersen

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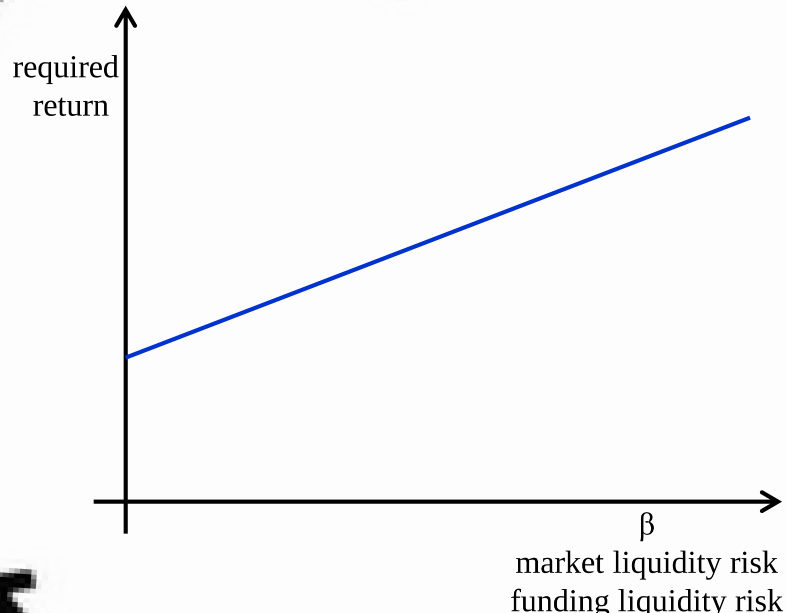
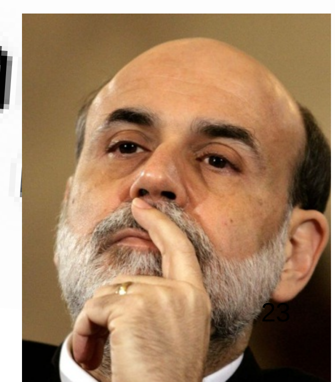
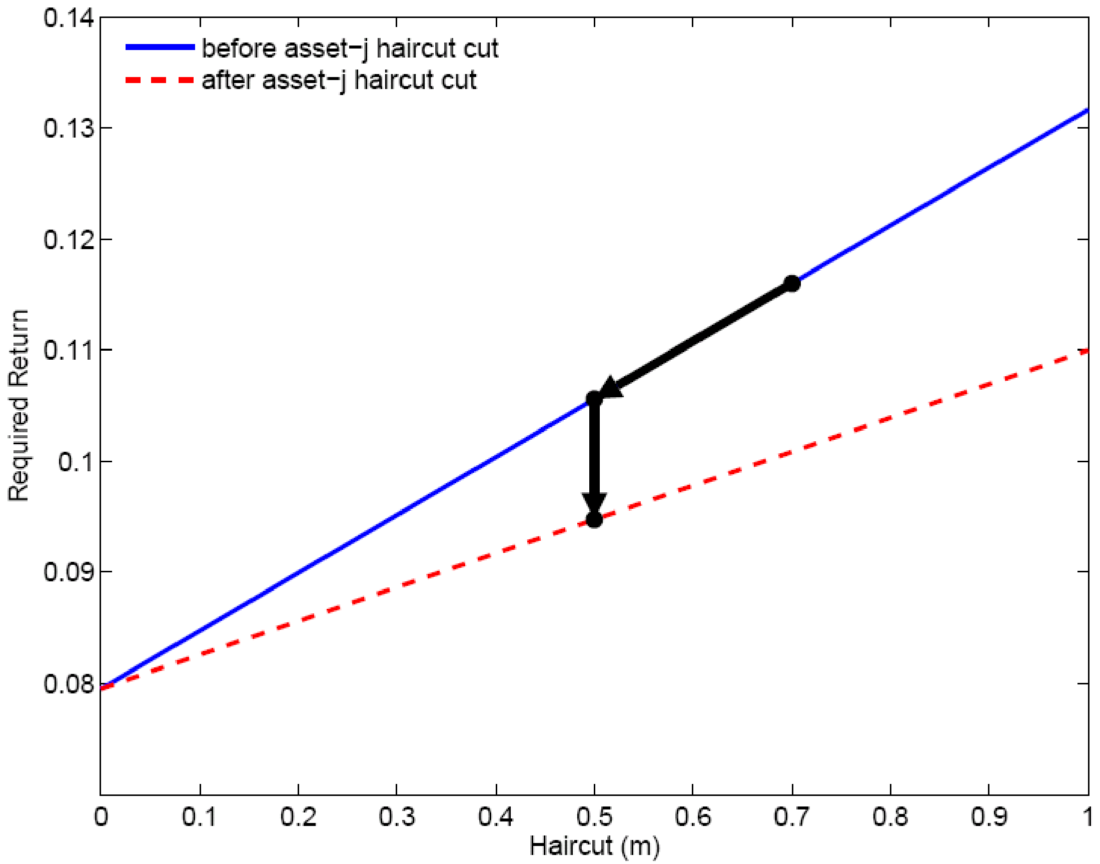
Liquidity Risk and Monetary Policy





Evidence on Funding Liquidity: Effect of Monetary Policy

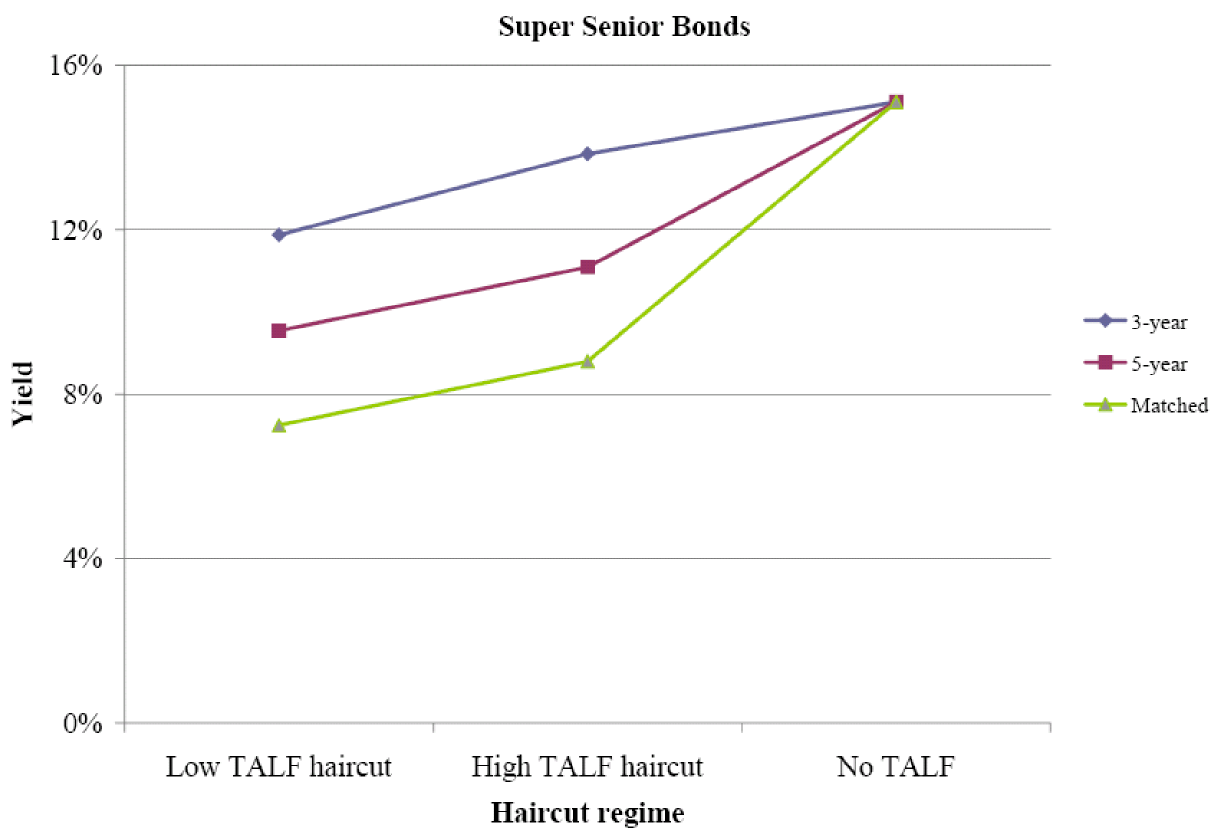
- Haircut cuts through central bank lending facilities alleviate funding liquidity frictions
  - by moving the affected securities down the haircut-return line
  - by flattening the whole haircut-return line as people's funding conditions are improved



Source: Ashcraft, Garleanu, and Pedersen (2010), "Two Monetary Tools: Interest Rates and Haircuts"

Evidence on Funding Liquidity: Effect of Monetary Policy

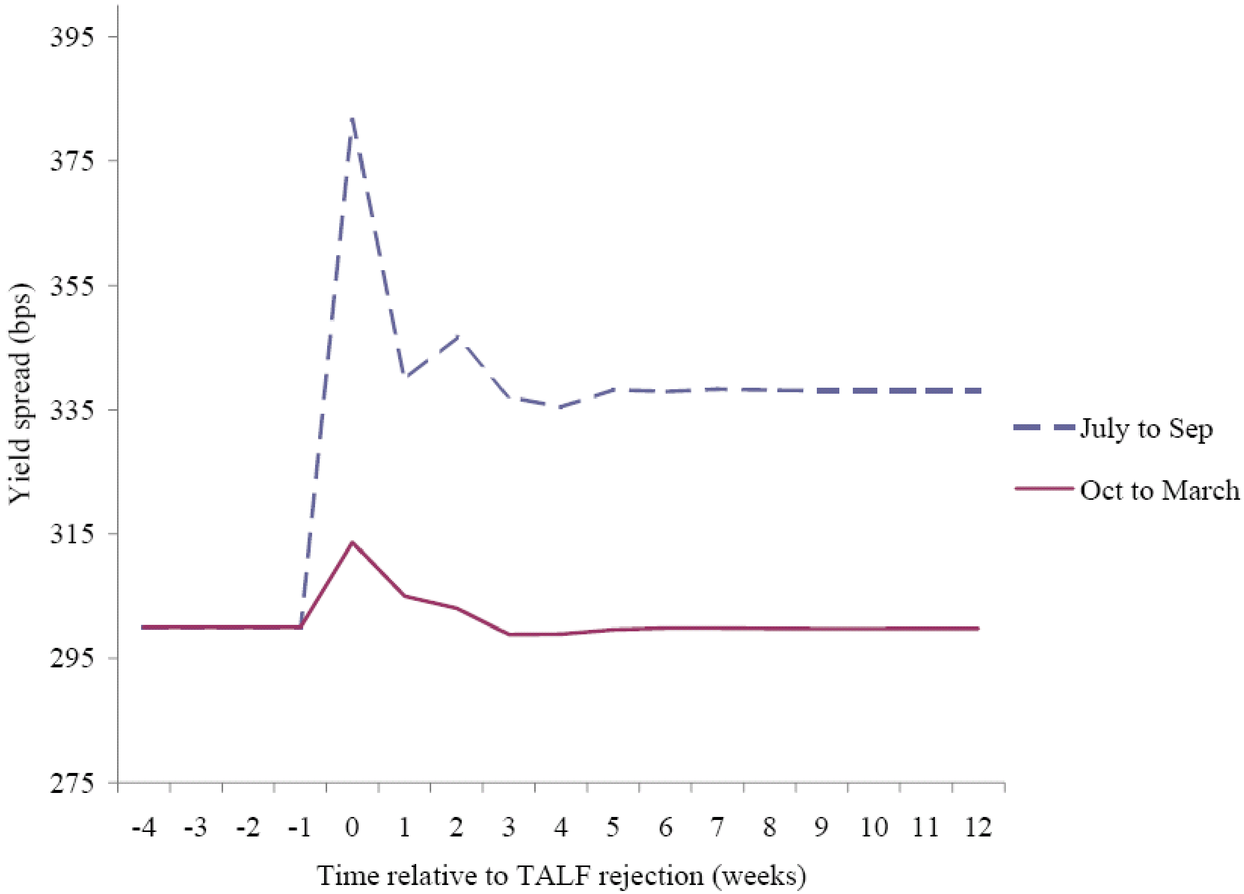
- Survey evidence from March 2009 on CMBS securities
- Demand sensitivity measured in terms of yields
  - Improving funding conditions can lower required returns by several percentage points
  - Note that the Fed had lowered the short rate from 5% to zero and hit the zero lower bound



Source: Ashcraft, Garleanu, and Pedersen (2010), "Two Monetary Tools: Interest Rates and Haircuts"

Evidence on Funding Liquidity: Effect of Monetary Policy

- Effect on market prices of CMBS securities of rejection from the TALF lending facility
  - Significant effect of the lending facility on market prices
  - The effect was larger in the earlier sample than in the later sample when the banking crisis had ended
    In the language of the model, ψ_t was larger in the early sample



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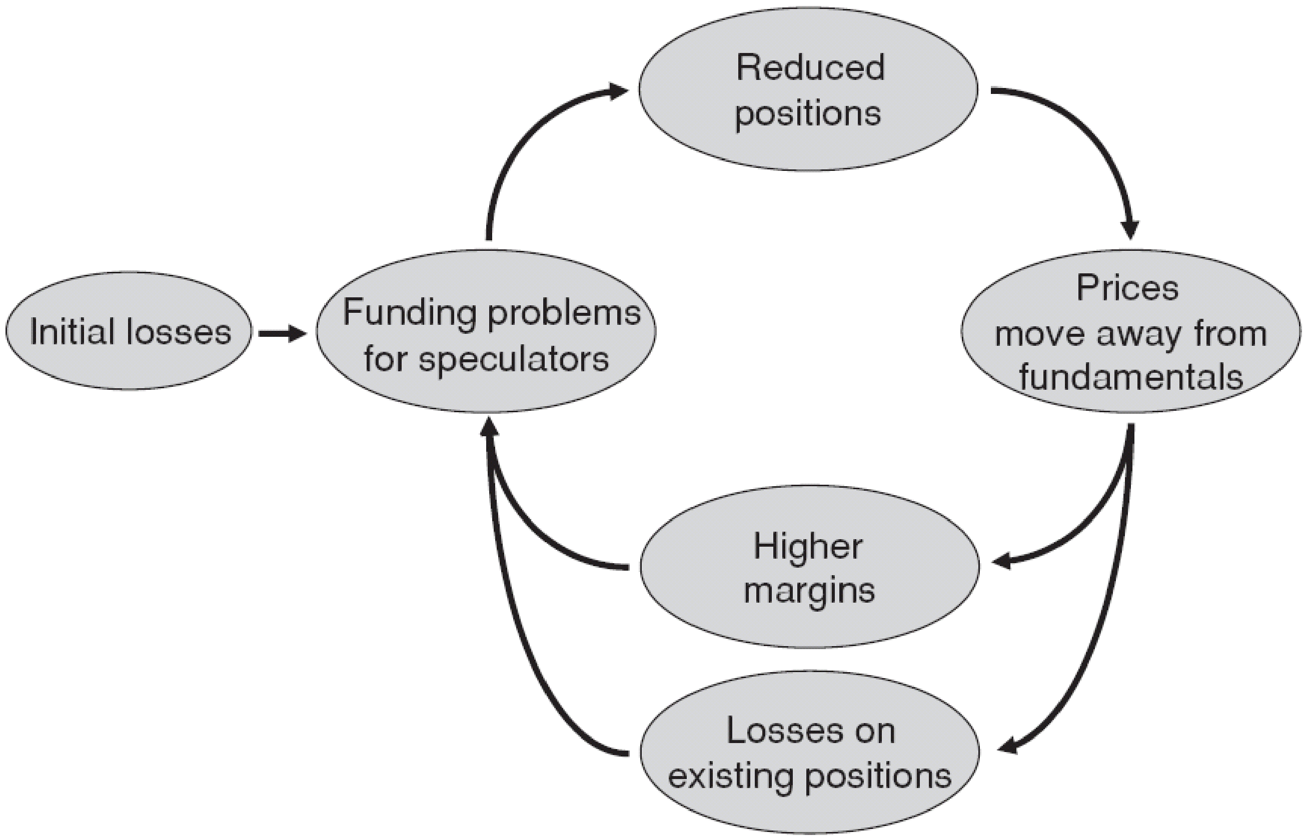
Liquidity Spirals

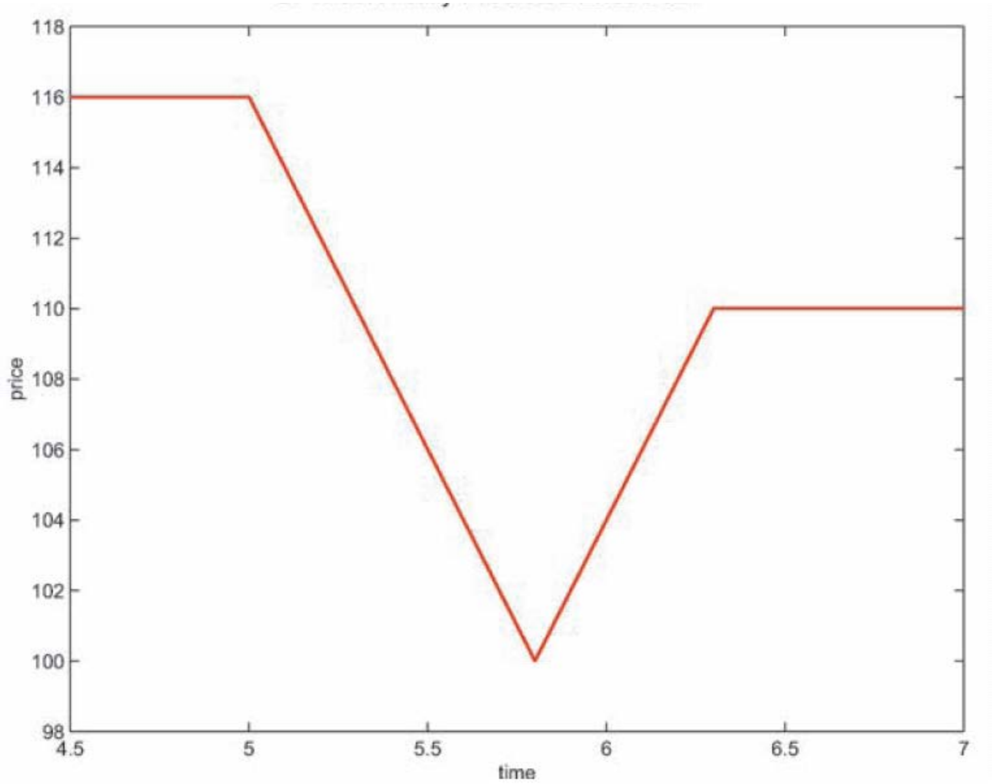


- Market and funding liquidity problems can reinforce each other, creating a systemic crisis
- Source: Brunnermeier and Pedersen (RFS 2009), “Market Liquidity and Funding Liquidity”

Implications of Liquidity Spirals

- Fragility and the risk of a “collateral run”:
  - A small shock can lead to large changes in liquidity and prices
  - Because of liquidity spirals and discontinuous switch from liquid equilibrium to illiquid equilibrium
- Commonality in market liquidity:
  - Different securities’ market liquidity co-move since they are driven by common funding shocks
- Spillover effects:
  - A shock to one market spills over to the markets when it significantly impairs to capital of financial institutions
- Market liquidity risk related to market risk
  - Because funding terms are
- Flight to quality
- Negative skewness of assets held by leveraged investors and leveraged investors’ portfolio returns
  - Since losses are amplified by liquidity spirals, while gains are not
- Source: Brunnermeier and Pedersen (RFS 2009)

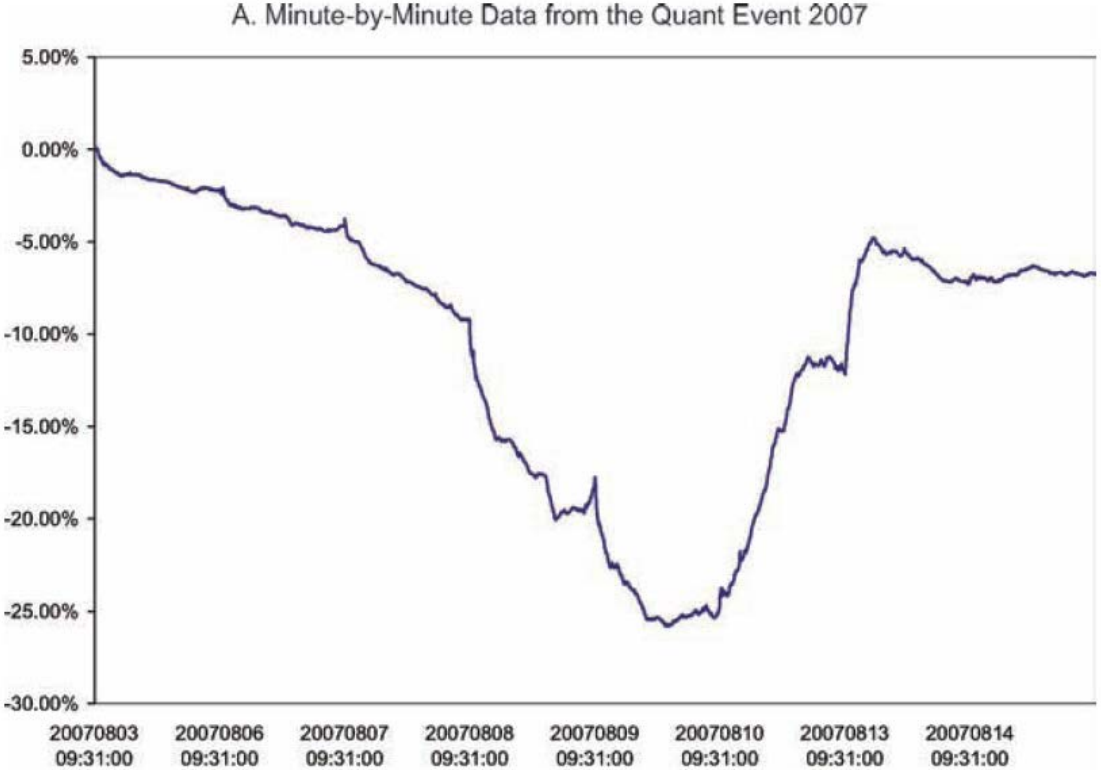
When Everyone Runs for the Exit



- Theoretically predicted price path when everyone runs for the exit
  - Prices decline more smoothly than random walk (because of the run for the exit)
  - Prices suddenly rebound (this distinguishes a run from a fundamental shock)
  - Prices end up lower than they started (because some investors left the market)

- Source: Brunnermeier and Pedersen (JF 2005)

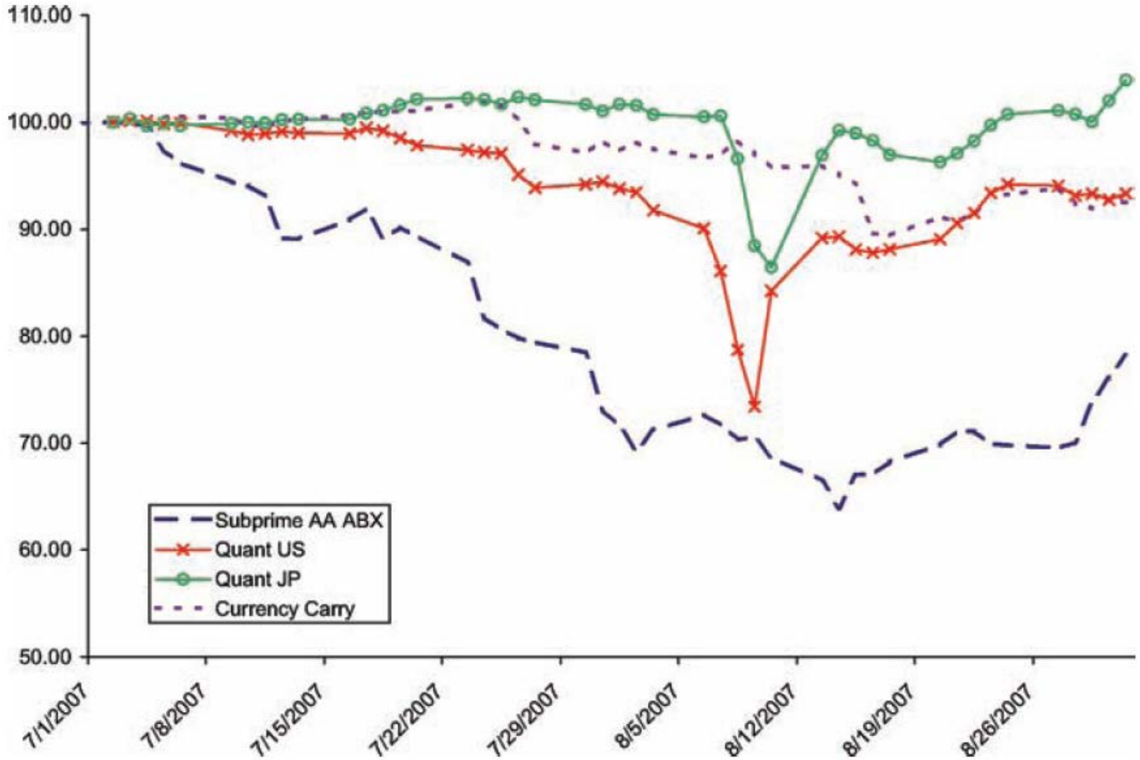
When Everyone Runs for the Exit: Quant Event 2007



- August 2007:
  - certain quantitative equity investors had funding liquidity problems
  - others ran for the exit as well
  - a value-momentum portfolio was severely affected in for U.S. large cap equities – normally one of the world's most liquid markets
  - the episode was almost invisible to non-quants: must be seen through the lens of a long/short portfolio

- Source: Pedersen (2009), "When Everyone Runs for the Exit"

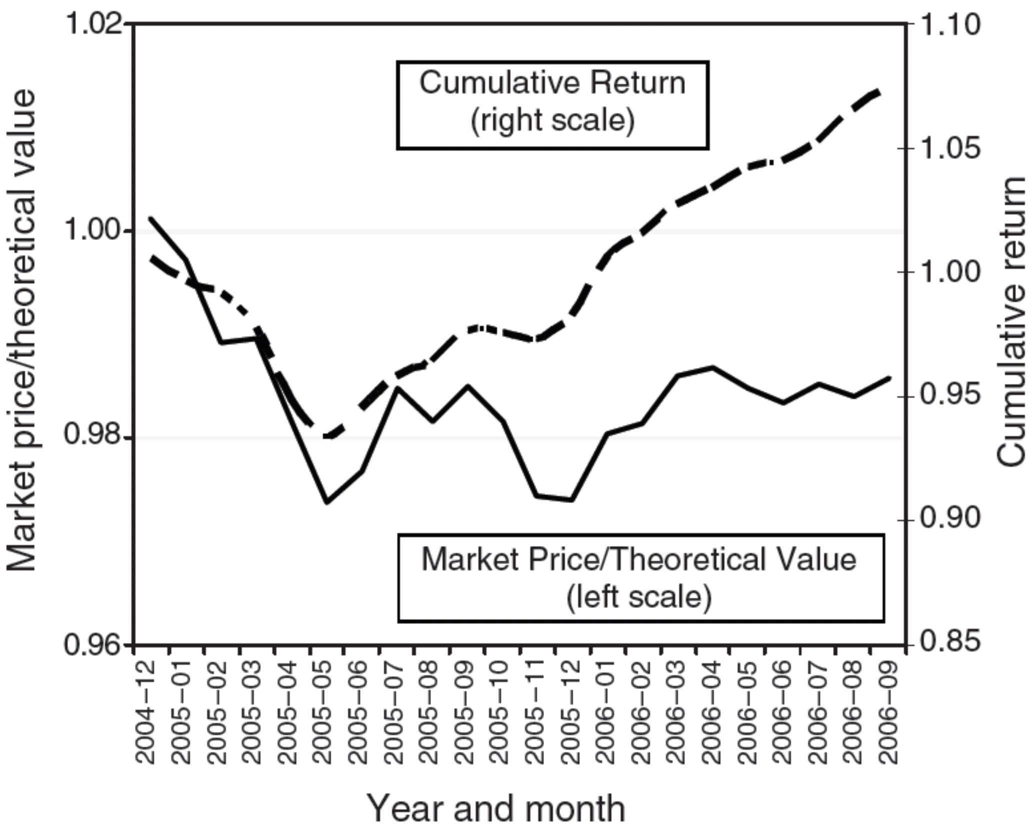
Spillover in the Beginning of the Global Financial Crisis



- Spillover from
  - subprime credit, to
  - quant equity strategies in the U.S., to
  - quant equity strategies in certain global markets such as Japan, to
  - currency markets

- Source: Pedersen (2009)

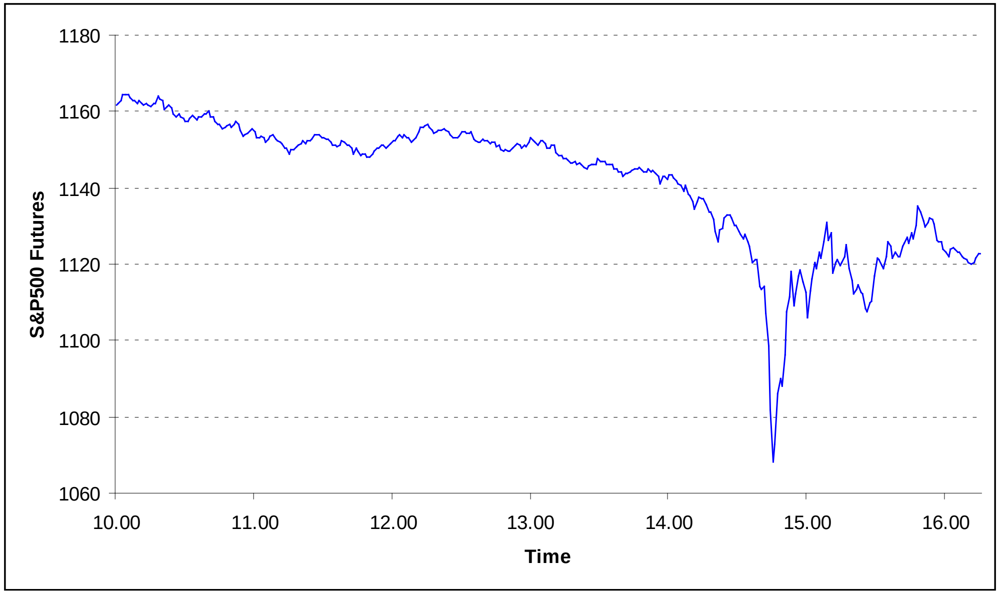
When Everyone Runs for the Exit: Convertible Bond Crisis 2005



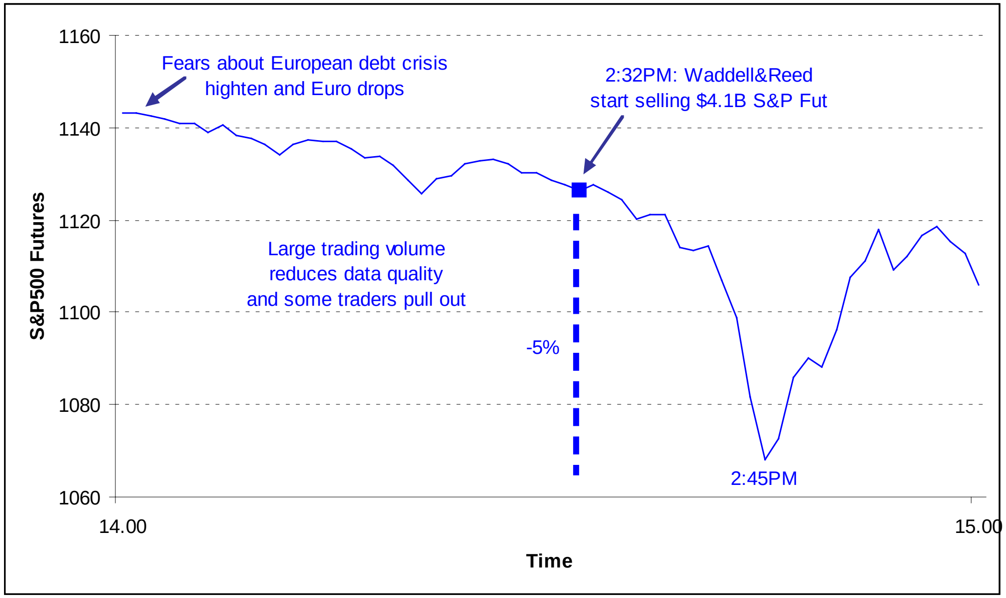
- Many convertible bond hedge funds had large redemptions
  - Forced sell off
  - Bonds cheapened relative to theoretical value implied by arbitrage relation
  - Cheapening lead to losses, further redemptions, further sell offs, firing of convert desks
  - Eventually, sell off ended and strategy became very profitable
- Source: Mitchell, Pedersen, and Pulvino (2007), “Slow Moving Capital”

When Everyone Runs for the Exit: Flash Crash 2010

May 6, 2010



The hour 2-3PM ET



Conclusion: Some Practical Implications of Liquidity Risk

1. **Higher required returns from assets with market liquidity risk**
   - If you can hold for the long term (low transaction costs, low risk of fire sales)
   - Examples: small stocks, convertible bonds, (re)insurance, alternative risk premia, and private equity
   - Market liquidity risk premium various over time: provide liquidity during crises
     - Understanding whether prices drop due to fundamentals vs. liquidity is important
     - Liquidity-driven drops are often followed by a rebound

2. **High risk-adjusted return from assets with high margin requirements or low risk**
   - Betting against beta: risk parity, safe stocks, short maturity bonds, high-grade bonds, etc.

3. **Portfolio choice and exercise behavior**
   - **Risk management**: worry about market and funding liquidity risk
     - Don’t be forced into large and sudden fire sale
   - Consider the financial *system*: are other institutions taking similar risks and are they highly leveraged?

4. **Performance measurement**: do returns arise from taking liquidity risk?

5. **Monetary policy and the macro economy**:
   - Managing liquidity risk is central

Appendix: References for Models of Market Liquidity

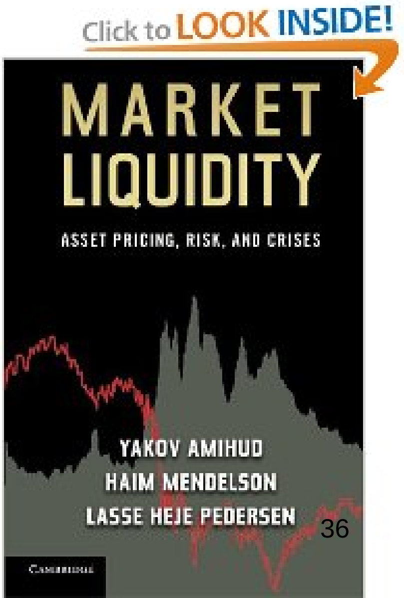
Papers can be downloaded at http://www.lhpedersen.com/

- Overview
  - Amihud, Mendelson, and Pedersen (2013)

- Market liquidity as trading costs
  - Liquidity level: Amihud and Mendelson (JFE 1986), Constantinides (1986), Vayanos (1998)
  - Liquidity level and risk: Acharya and Pedersen (JFE 2005)

- Market liquidity as search:
  - Duffie, Garleanu, and Pedersen (Econometrica 2005, RFS 2007), Garleanu and Pedersen (AER 2007), Weill (2007), Vayanos and Weill (JF 2008), Duffie and Strulovici (2009)

- Asset pricing with market liquidity as asymmetric information
  - Wang (1993), Garleanu and Pedersen (RFS 2004)



Appendix: References for Models of Funding Liquidity

- Margin requirements, asset pricing, and deviations from the Law of One Price:
  - Garleanu and Pedersen (2011)

- Margin requirements and leverage constraints and the returns of stocks, bonds, credit:
  - Frazzini and Pedersen (WP 2011, JFE 2014), Asness, Frazzini, and Pedersen (2011, FAJ forthcoming)

- Margin requirements, macro economics, and monetary policy:
  - Ashcraft, Garleanu, Pedersen (NBER Macroannual 2010)

- Funding liquidity and systemic risk
  - Acharya, Pedersen, Philippon, and Richardson (WP 2010)

Appendix: References for Models of Market and Funding Liquidity Interaction

- Liquidity spirals, fragility, and bank balance sheets as drivers of crises:
  - Brunnermeier and Pedersen (JF 2005, RFS 2009)
- Amplification when everyone tries to manage risk:
  - Garleanu and Pedersen (AER 2007)
- When everyone runs for the exit:
  - Pedersen (IJCB 2009)

Appendix: Other Related References (Incomplete List)

- Macro and general equilibrium models:
  - Bernanke and Gertler (1989), Constantinides and Duffie (1996), Geanakoplos (1997), Kiyotaki and Moore (1997,2008), Aiyagari and Gertler (1999), Lorenzoni (2008), Brunnermeier and Sannikov (2010), He and Krishnamurthy (2010)
- Monetary models with frictions:
  - Curdia and Woodford (2009), Gertler and Karadi (2009)
- Asset pricing and constraints:
  - Hindy (1995), Cuoco (1997), Detemple and Murthy (1997), Basak and Croitoru (2000), Coen-Pirani (2005), Gorton and Metrick (2009), Adrian and Shin (2010), Greenwood and Vayanos (2010)
- Limits of arbitrage:
  - Shleifer and Vishny (1997)
- Liquidity and welfare when arbitrageurs have margin constraints
  - Gromb and Vayanos (2002)
- Limited attention and slow moving capital:
  - Duffie (2010, AFA Presidential address)
- Corporate finance and banking:
  - Diamond and Dybvig (1983), Shleifer and Vishny (1992), Holmstrom and Tirole (1997, 2001), Acharya and Viswanathan (2010)
- Dynamic trading with predictable returns and transaction costs:
  - Garleanu and Pedersen (2008)
- Informational frictions in asset markets
  - Grossman and Stiglitz (1980)

Extra Slides

Liquidity Crises and Liquidity Risk: Definitions

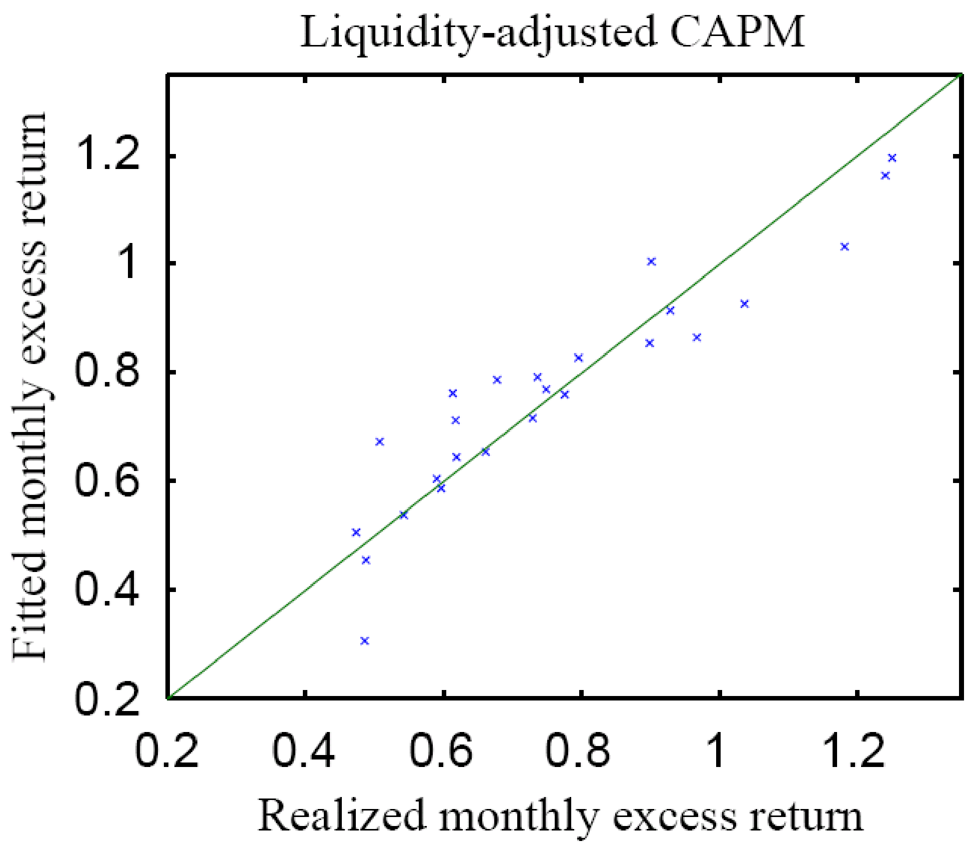
- **Market liquidity risk**:
  - Market liquidity = ability to trade at low cost (conversely, market illiquidity = trading cost)
    - Measured as bid-ask spread or as market impact
  - Market liquidity risk = risk that trading costs will rise
    - We will see there are 3 relevant liquidity betas

- **Funding liquidity risk**:
  - Funding liquidity for a security = ability to borrow against that security
    - Measured as the security's margin requirement or haircut
  - Funding liquidity for an investor = investor's availability of capital relative to his need
    - "Measured" as Lagrange multiplier of funding constraint
  - Funding liquidity risk = risk of hitting margin constraint
    - Happens if margin requirement increases or capital decreases

- **Liquidity crisis**:
  - Liquidity spiral: market and funding liquidity deteriorate in a mutually reinforcing process
  - Crisis are distinct from normal times: Funding constraints are binding (vs. slack) for large institutions

Evidence on Market Liquidity Risk

- The cross-section of stocks better explained by the liquidity-adjusted CAPM than the standard CAPM



Source:

Acharya and Pedersen (JFE 2005), *Asset Pricing with Liquidity Risk*

- Cross-section of U.S. stocks, portfolios of stocks sorted by the volatility of their liquidity
- Consistent evidence in other asset classes, e.g.
  - corporate bonds, Dick-Nielsen, Feldhutter, and Lando (JFE 2012)

Liquidity-Adjusted CAPM: Crises

Proposition. [Acharya and Pedersen (2005), Prop. 2-3]

If market liquidity worsens, required returns increase:

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

and contemporaneous prices fall:

$$\mathrm{cov}_t(c_{t+1}^q, r_{t+1}^q) < 0$$

- Market liquidity crisis:
  - Higher illiquidity leads to price drops
  - Amihud (2002)