Frictional Finance
"Fricofinance"

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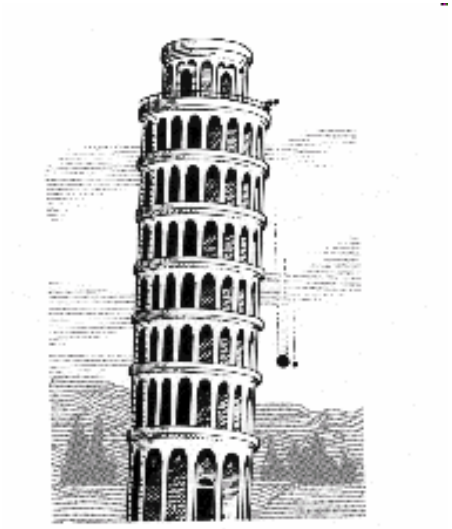
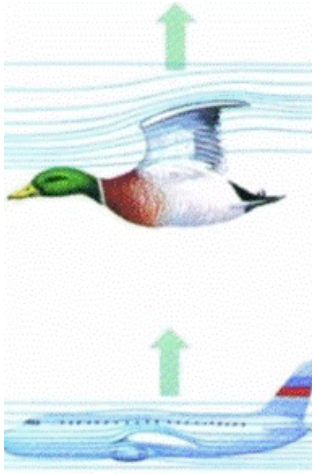
Frictional Finance: Motivation

In physics,

frictions are not important to certain phenomena: ……but frictions are central to other phenomena:

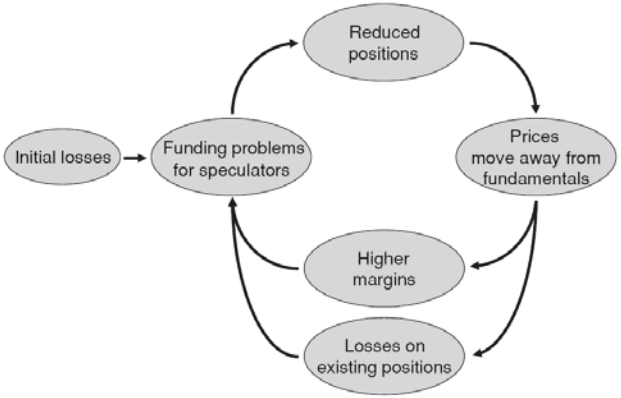




Economists used to think **financial markets** are like dropping balls

Walrasian auctioneer

However, as in aerodynamics, the frictions are central to the dynamics of the financial markets:



Frictional Finance: Implications

- Financial frictions affect
  - Asset prices
  - Macroeconomy (business cycles and allocation across sectors)
  - Monetary policy

- Parsimonious model provides unified explanation of a wide variety of phenomena

- Empirical evidence is very strong
  - Stronger than almost any other influence on the markets, including systematic risk

Frictional Finance: 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 margin constraint
  - Funding liquidity risk = risk of hitting margin constraint
    - Happens if margin requirement increases or capital decreases

Frictional Finance: Overview

- Market liquidity risk
  - Asset pricing:
    - Securities with more market liquidity risk have higher required returns
    - Limits of arbitrage
  - Evidence
    - Stocks, corporate bonds, Treasuries

- Funding liquidity risk
  - Asset pricing:
    - Securities with higher margins requirements have higher required returns, especially in crisis
  - Macro economics:
    - Financial frictions affect business cycles and allocation of capital across sectors
  - Monetary policy:
    - Interest rate tool not enough; haircuts a second monetary tool
  - Evidence:
    - Slow moving capital, limits of arbitrage
    - Deviations from the Law of One Price
    - Effect of central banks' lending facilities
    - Betting Against Beta: security market line flatter than implied by CAPM in all major markets

- Market and funding liquidity risk interactions
  - Liquidity spirals
  - Evidence
    - Drop and rebound in prices: convertible bonds, quant crisis, flash crash, currency crashes
    - Global financial crisis

Chairman Bernanke: "Crucial Lesson"

"Some more-successful firms also consistently ***embedded market liquidity premiums in their pricing models and valuations****."*

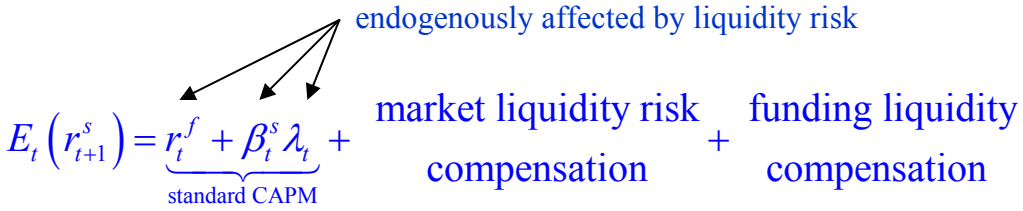
"Another crucial lesson from recent events is that ***financial institutions must understand their [funding] liquidity needs*** *at an enterprise-wide level and be prepared for the possibility that market liquidity may erode quickly and unexpectedly."*

"Consistent with its role as the nation's central bank, the Federal Reserve has responded not only with an easing of monetary policy but also with a number of steps aimed at reducing ***funding pressures*** *for depository institutions and primary securities dealers and at improving overall* ***market liquidity*** *and market functioning."*

– Chairman Ben S. Bernanke, May 13, 2008

Economic Magnitude – Frictional Finance is Big and Affects Your Life!

- Most macro models imply relatively stable required returns over time and in the cross section
  - Central banks think they can fine tune the economy by changing the risk free rate by 25 bps
- Frictional finance imply large cross-sectional and time-series variation in risk premia:



  - Empirical evidence:
    - Significant time variation in risk premia of several percent over the cycle
    - Significant cross-sectional variation in risk premia
  - This variation can lead to large variation in real investment and output
- Frictional finance affect your everyday life! Examples:
  - Lehman failure was followed by significant liquidity problems, higher *E(r)*, and a dramatic economic downturn. It affects where you will work.
  - Abundant liquidity expansion and contraction in the housing finance associated with boom-bust cycle for prices and construction: when *E(r)* goes down, price goes up, and people build houses; vice versa when *E(r)* goes up. It affects where you live.
  - Student loan market froze due to illiquidity problems in the ABS markets. It affects your studies.

Roadmap of This Talk

- **Market liquidity risk**
  - **Theory**
  - **Evidence**
- Funding liquidity risk
  - Theory
  - Evidence
- Market and funding liquidity interactions
  - Theory
  - Evidence
- Conclusion

Models of Market Liquidity

- 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)

- Survey
  - Amihud, Mendelson, and Pedersen (2005)

- **This presentation:** follows Acharya and Pedersen (JFE 2005)

A Model of Market Liquidity Risk

- OLG economy with CARA investors
- AR(1) process with normally distributed shocks for dividends D_t and trading costs C_t
- Gross return:

$$r_{t+1}^{\,i} = (P_{t+1}^{\,i} + D_{t+1}^{\,i}) / P_t^i$$

- Percentage market illiquidity:

$$c_{t+1}^{\,i} = C_{t+1}^{\,i} / P_t^i$$

- Net return:

$$r_{t+1}^{\,i} - c_{t+1}^{\,i} = (P_{t+1}^{\,i} + D_{t+1}^{\,i} - C_{t+1}^{\,i}) / P_t^i$$

Liquidity-Adjusted CAPM

Proposition

The CAPM holds for net returns $E(r^i-c^i)$

$$\mathrm{E}_t\left(r^i_{t+1}-c^i_{t+1}\right)=r^f+\lambda_t\,\frac{\mathrm{cov}_t\left(r^i_{t+1}-c^i_{t+1},r^M_{t+1}-c^M_{t+1}\right)}{\mathrm{var}_t\left(r^M_{t+1}-c^M_{t+1}\right)}$$

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

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

where

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

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

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

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

Liquidity-Adjusted CAPM: Further Implications

Proposition

If market liquidity worsens, required returns increase:

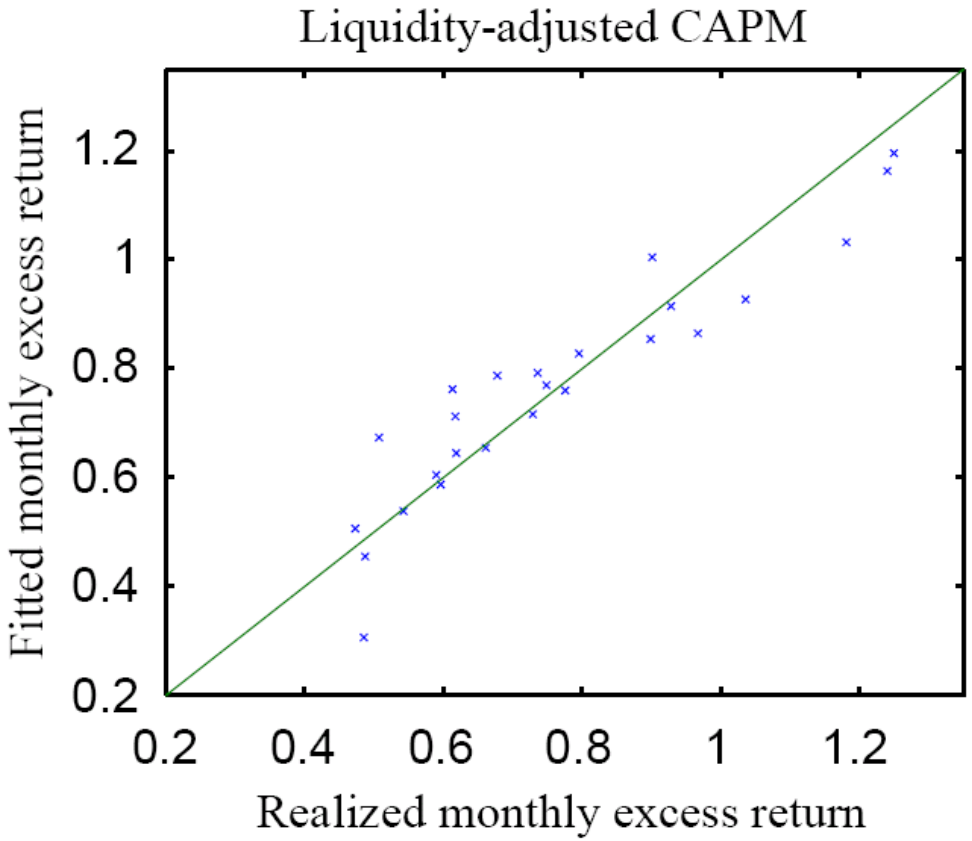
$$\frac{\partial}{\partial C_t^q} E_t(r_{t+1}^q - r^f) > 0$$

and contemporaneous prices fall:

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

Evidence on Market Liquidity Risk

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



- Cross-section of U.S. stocks, portfolios of stocks sorted by the volatility of their liquidity

Roadmap of This Talk

- Market liquidity risk
  - Theory
  - Evidence

- **Funding liquidity risk**
  - **Theory**
  - **Evidence**

- Market and funding liquidity interactions
  - Theory
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- Conclusion

Models of Funding Liquidity

- Margin requirements, asset pricing, and deviations from the Law of One Price:
  - Garleanu and Pedersen (WP 2010)

- Margin requirements and leverage constraints and the returns of stocks, bonds, credit:
  - Frazzini and Pedersen (WP 2010)

- 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)

- **This presentation:** follows Ashcraft, Garleanu, Pedersen (2010), which relies on Garleanu and Pedersen (2010) and further implications are explored in Frazzini and Pedersen (2010)

Model of Funding Liquidity

- OLG economy where agents maximize their utility:

$$\max_{\theta} \theta'(E_t\left(P_{t+1}\right)-(1+r^f)P_t)-\frac{\gamma^i}{2}\theta'\Sigma_t\theta$$

subject to a portfolio constraint:

$$\sum_s m_t^s \mid \theta^s \mid P_t^s \leq W_t^i$$

- First order condition with Lagrange multiplier ψ:

$$0=E_t\left(P_{t+1}\right)-(1+r^f)P_t-\gamma^i\Sigma_t\theta-\psi_t\mathrm{D}\left(m_t\right)P_t$$

- Solution

$$\theta^i=\frac{1}{\gamma^i}\Sigma_t{}^{-1}\left[E_t\left(P_{t+1}\right)-(1+r^f)P_t-\psi_t\mathrm{D}\left(m_t\right)P_t\right]$$

- Competitive equilibrium with $\bar{\theta}$ shares outstanding: $\sum_i \theta^i=\bar{\theta}$

- Equilibrium price with γ defined by $1/\gamma=\sum 1/\gamma^i$ and x defined by $x=\gamma/\gamma^b$

$$P_t=\mathrm{D}\left(1+r^f+\psi_t x m_t\right)^{-1}\left[E_t\left(P_{t+1}\right)-\gamma\Sigma_t\bar{\theta}\right]$$

Margin CAPM

Proposition

The equilibrium required return for any security s is:

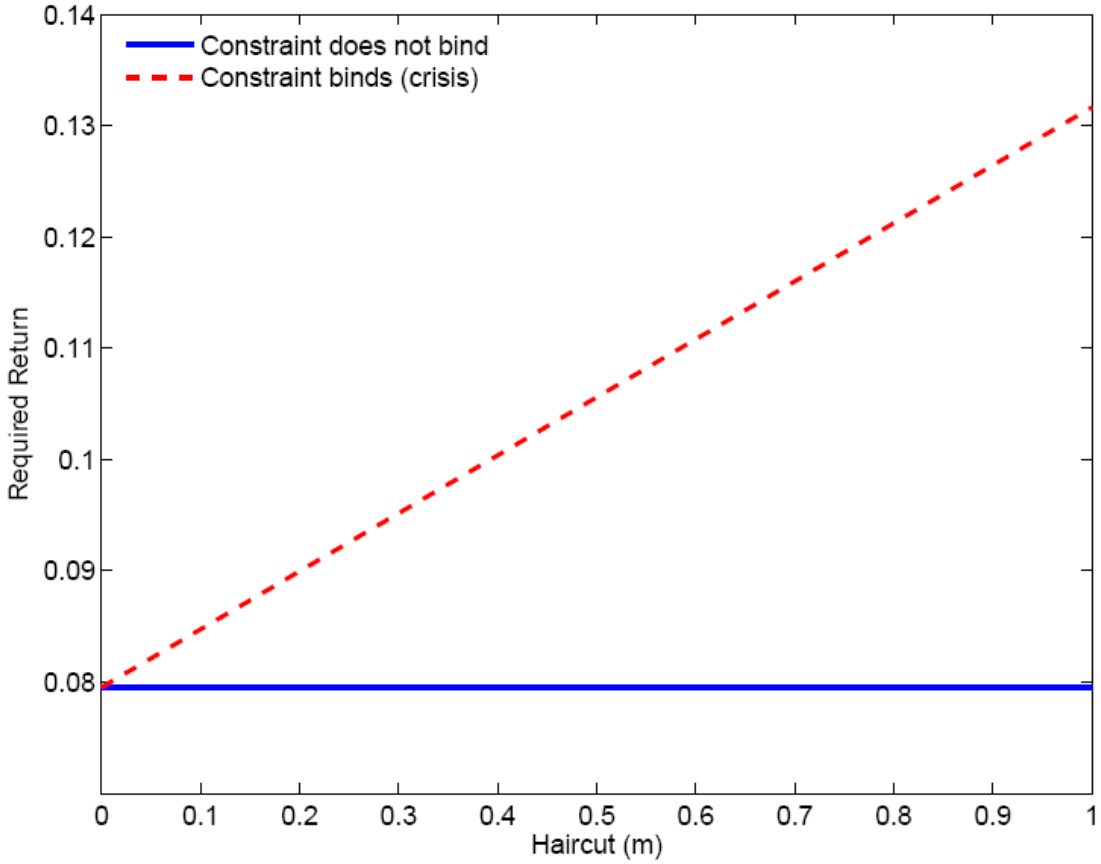
$$E_t\left(r_{t+1}^s\right) = r^f + \beta_t^s \lambda_t + \psi_t \, x_t \, m_t^s$$

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:

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

Margin CAPM

- If a security has a higher margin requirement it is more difficult to finance (i.e., it uses more balance sheet), and therefore its required return is higher when balance sheets are tight:

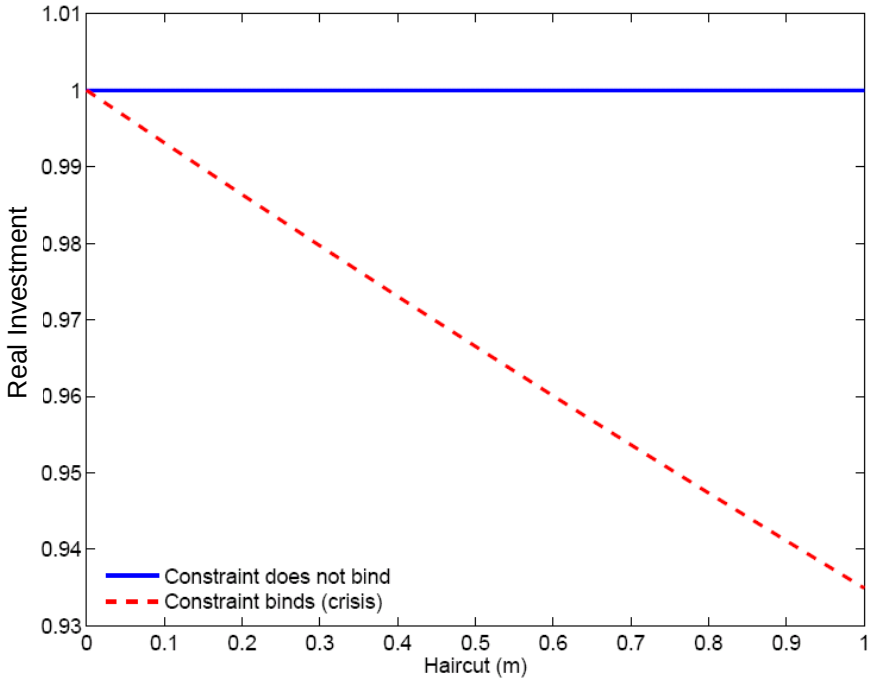


Real Investment

- Real investment, *I:*

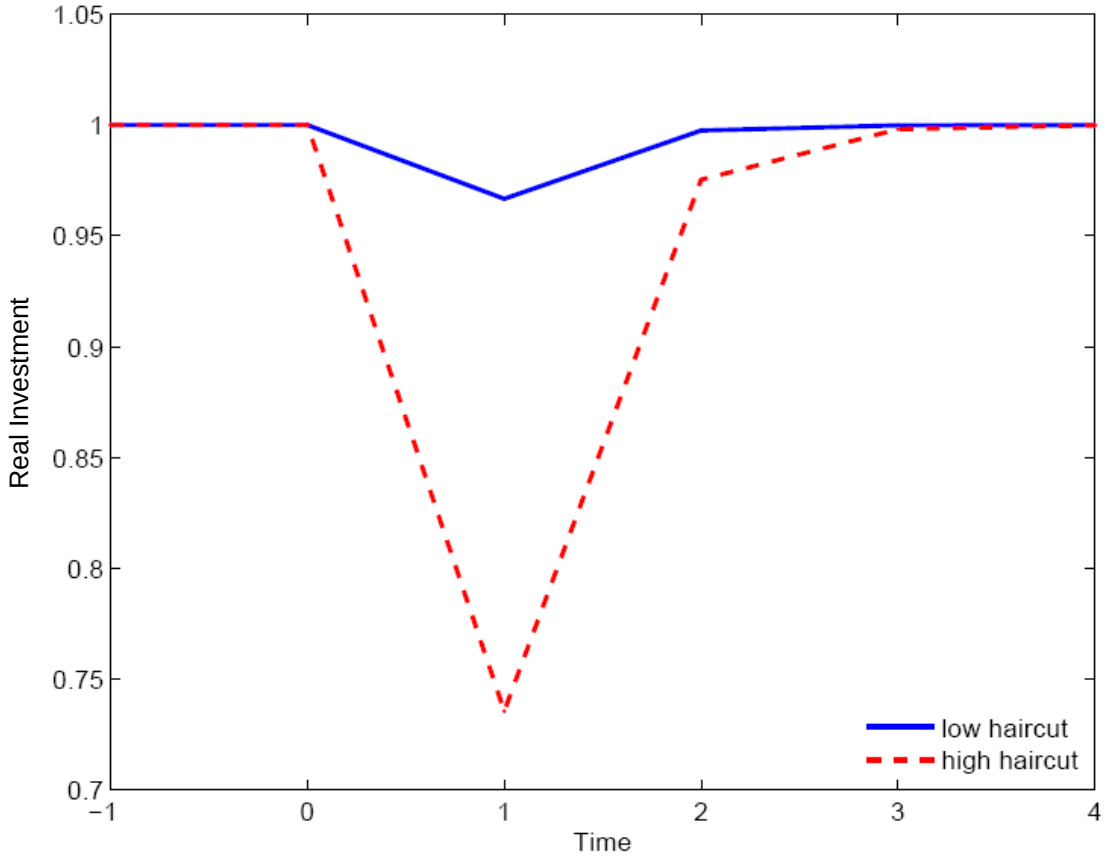
$$(I_t^j)^{1/2} = \frac{\frac{1}{2}E_t(A_{t+1}^j)}{1 + r^f + \gamma\frac{1-\beta}{2}\,\mathrm{var}_t(A_{t+1}^j) + \psi_t x m_t^j}$$

- Increases in expected productivity, $E_t(A_{t+1})$
- Decreases required return, therefore in
  - Risk free rate
  - Productivity risk, $Var_t(A_{t+1})$
  - Margin requirement, m, and shadow cost of capital, ψ



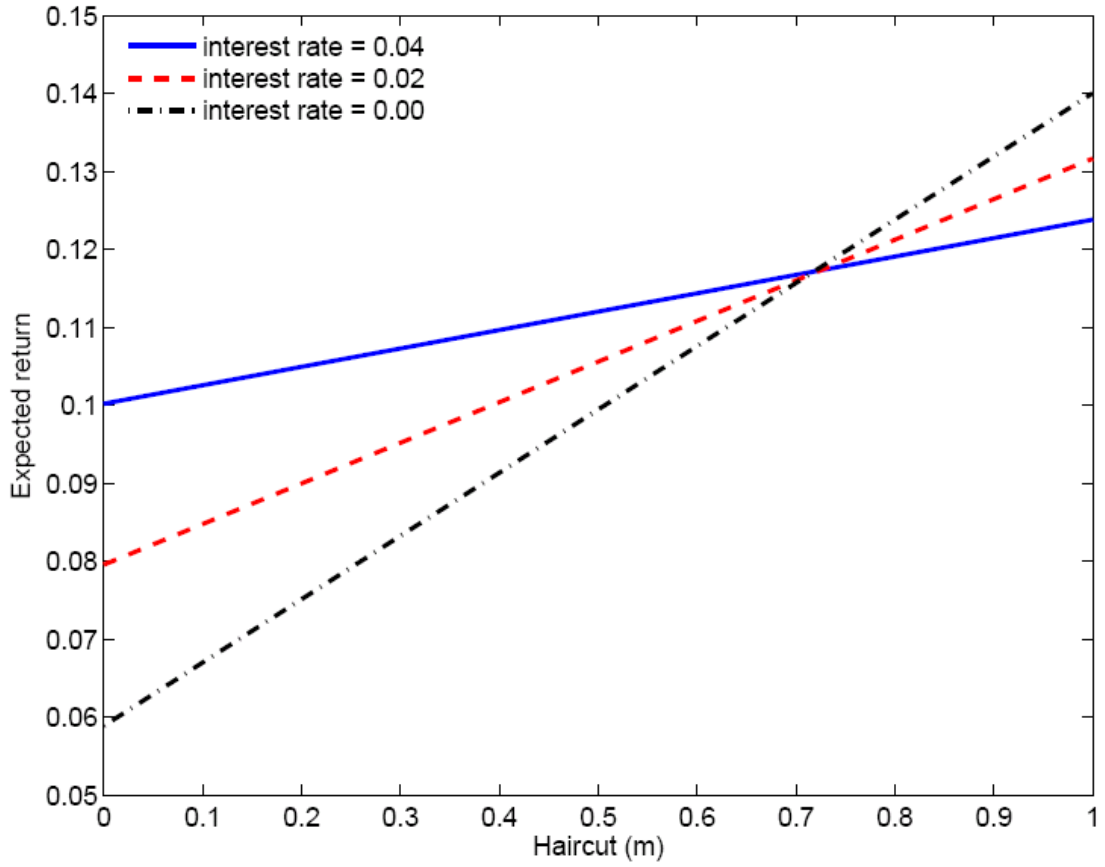
Margin-Constraint Accelerator

- Funding constraints propagates business cycles



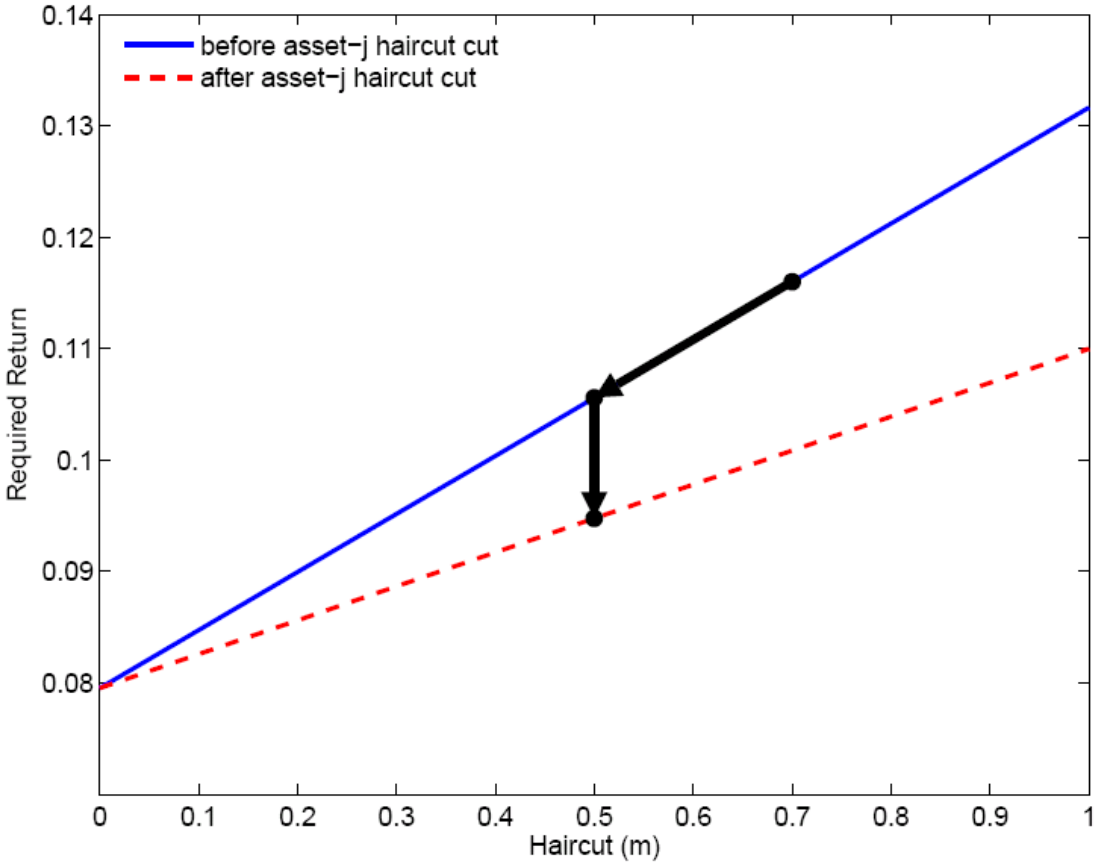
Monetary Policy: Interest-Rate Cuts Steepen Margin-Return Curve

- Surprisingly, interest-rate cuts can *increase* required return for high-margin securities



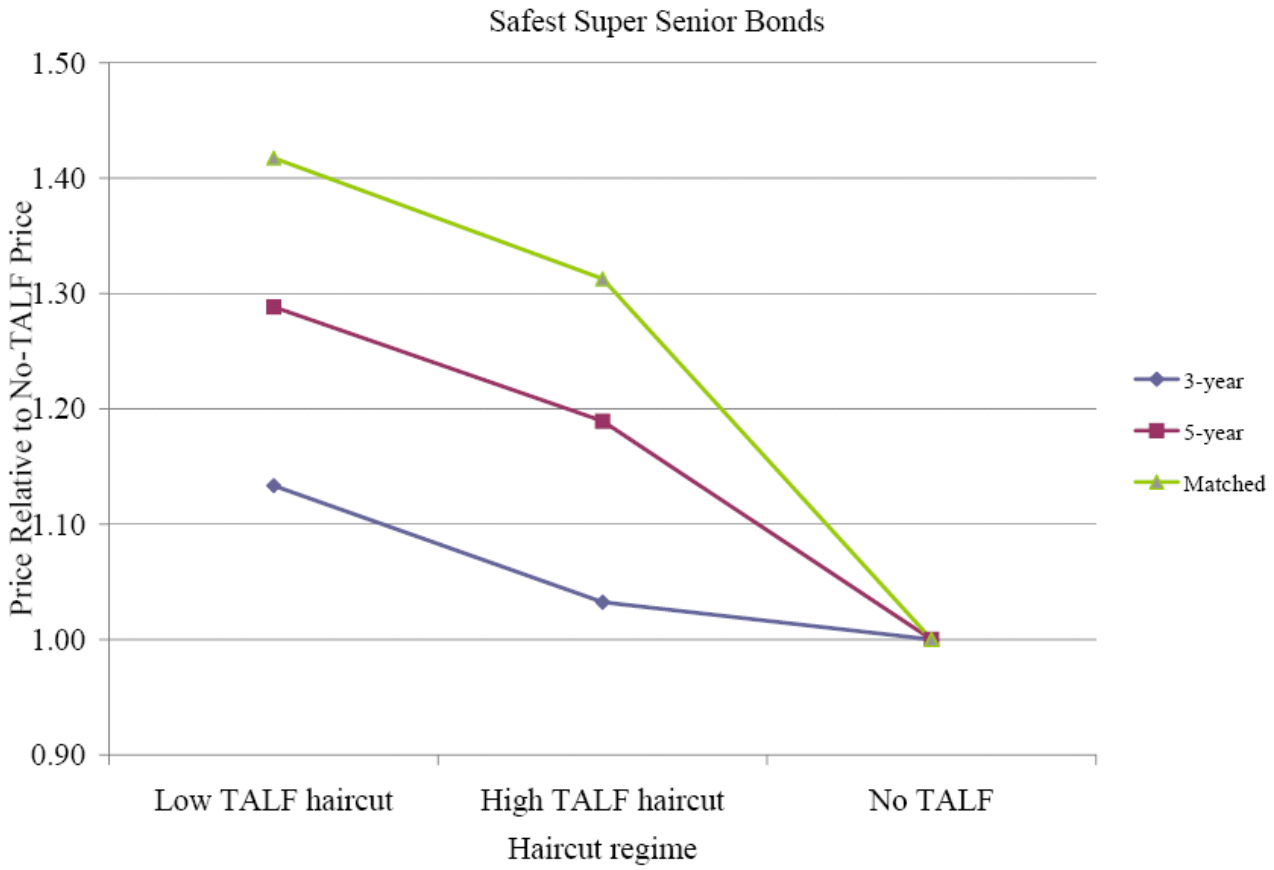
Monetary Policy: Haircut Cuts can Ease Credit Frictions

- 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



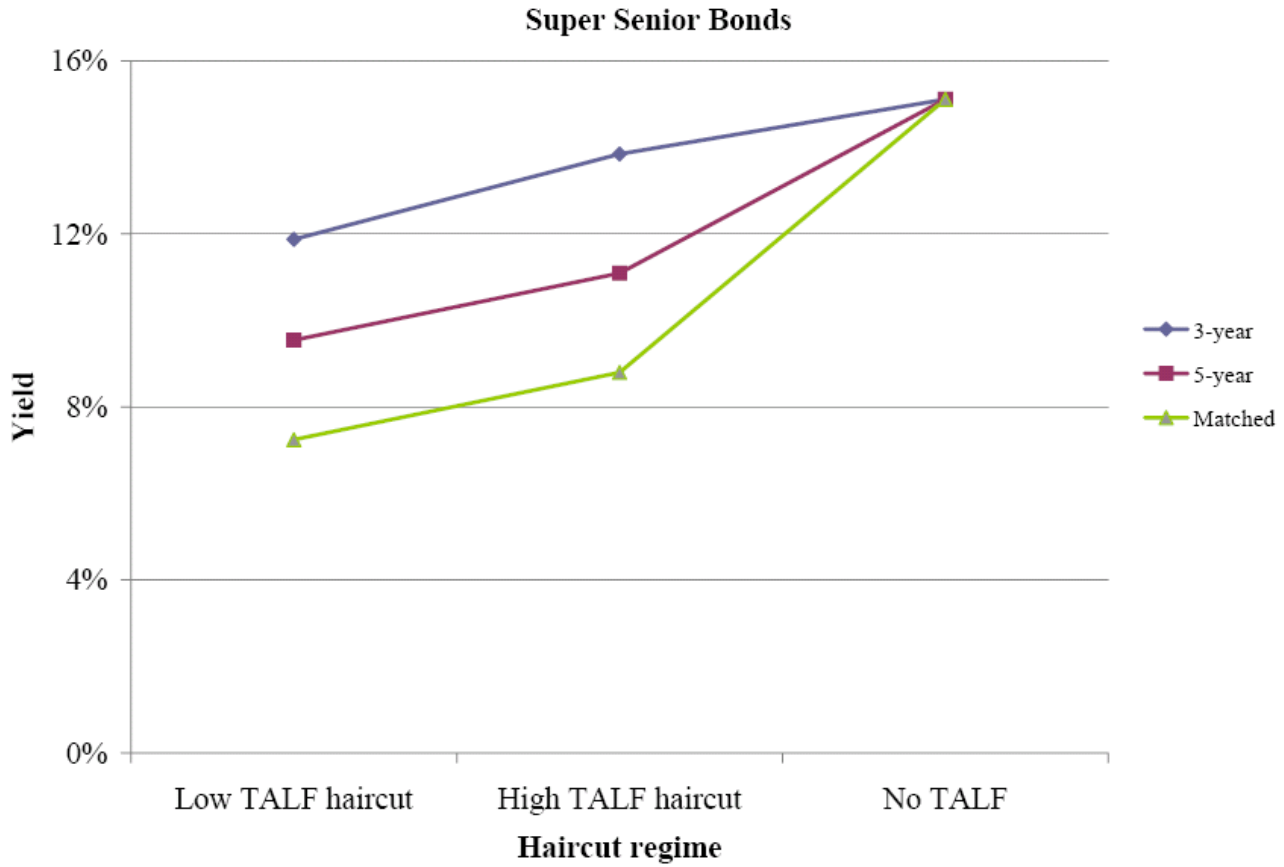
Evidence on Funding Liquidity: Effect of TALF

- Survey evidence from March 2009 on CMBS securities
- Very large demand-sensitivity to haircuts!



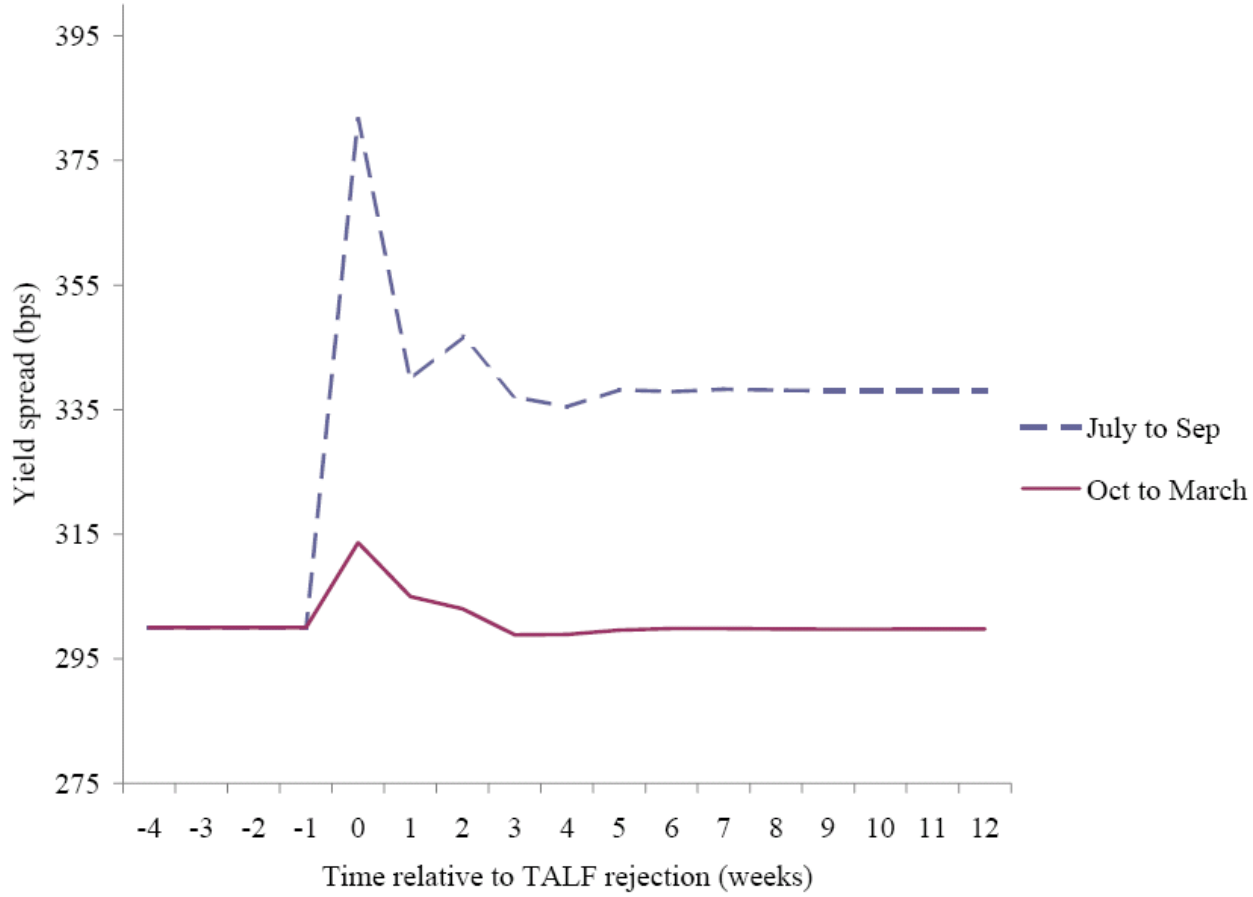
Evidence on Funding Liquidity: Effect of TALF

- 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



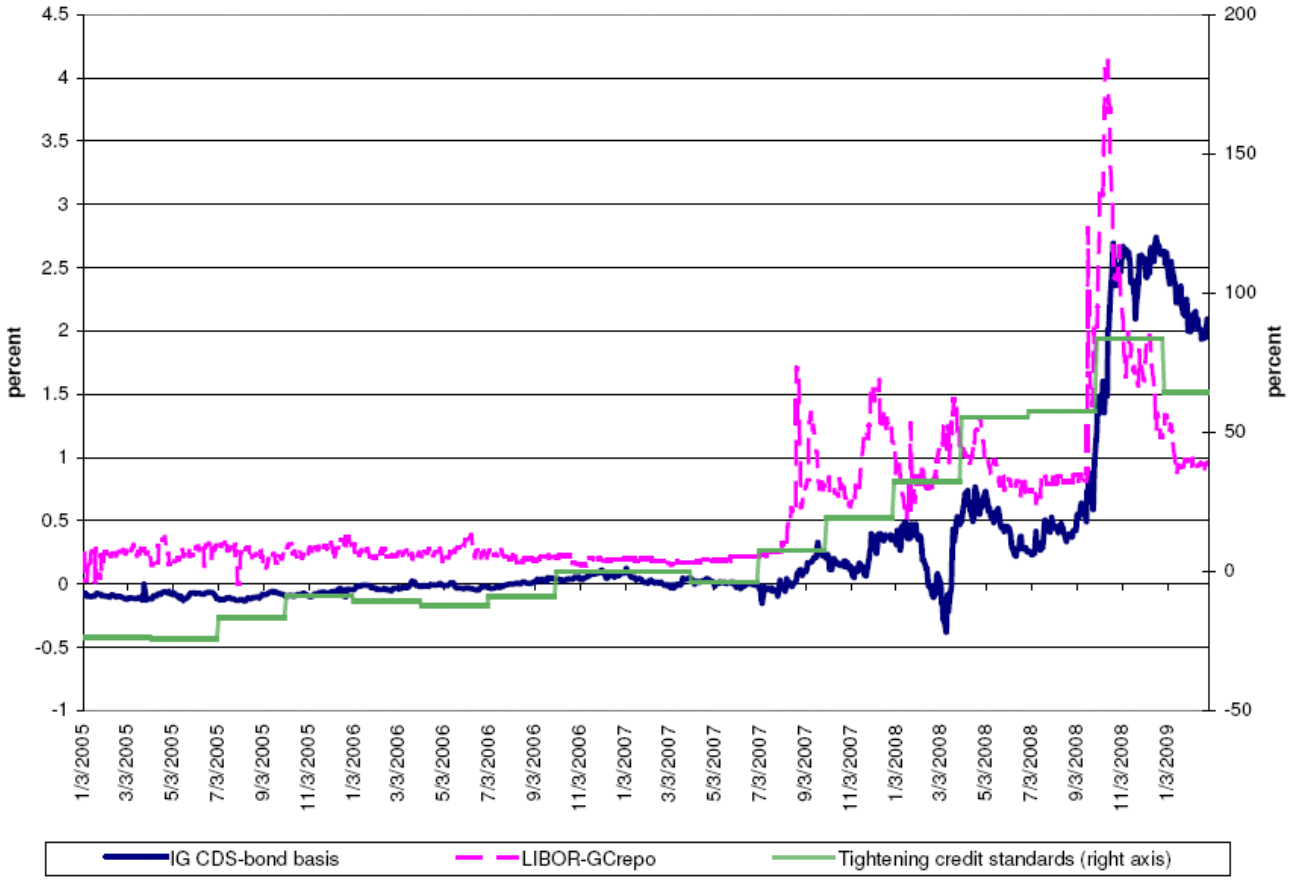
Evidence on Funding Liquidity: Effect of TALF

- 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



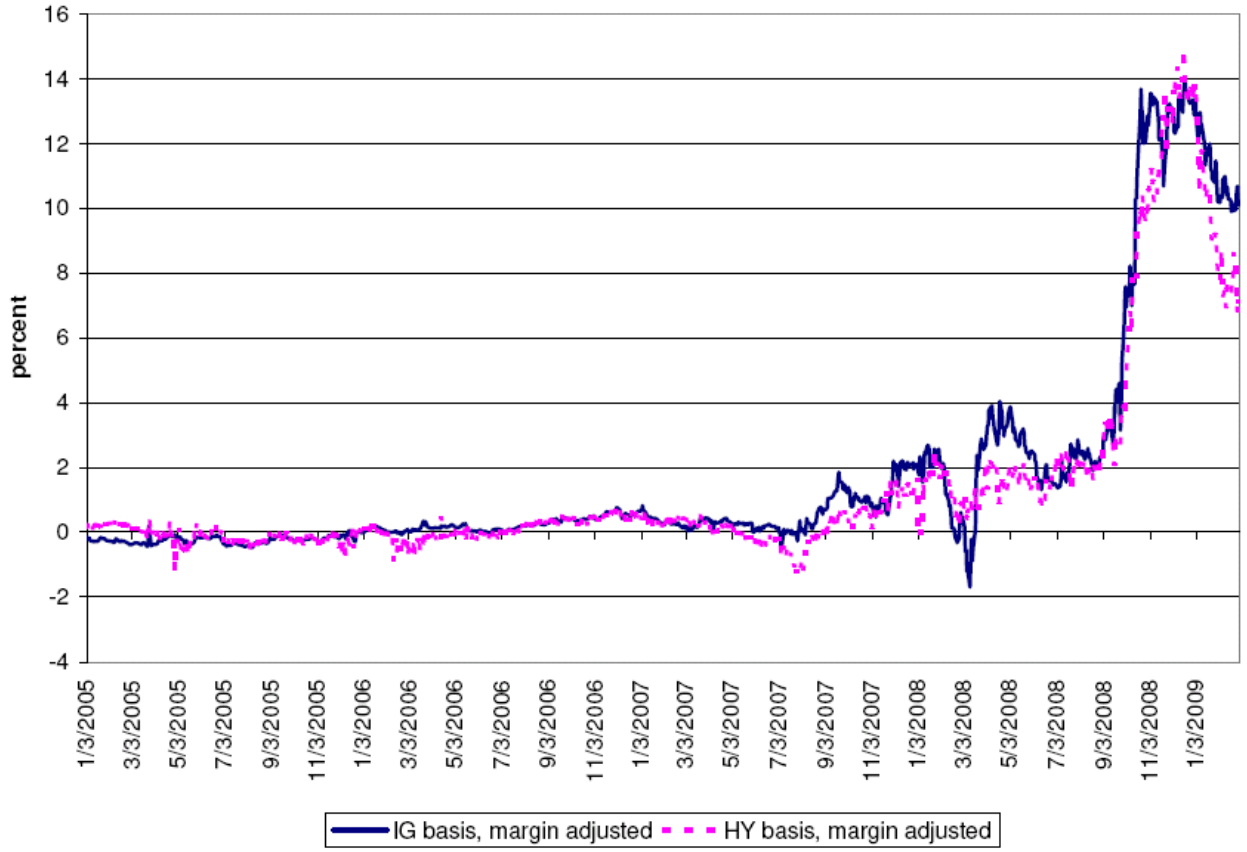
Evidence on Funding Liquidity: Deviations from LoOP

- Law of One Price (LoOP) Deviation: Spread between CDS and corporate bonds
- Time-series evidence: Deviation from LoOP lines up with funding liquidity measures:
  - credit tightness (from the Board of Governors survey)
  - LIBOR-repo spread



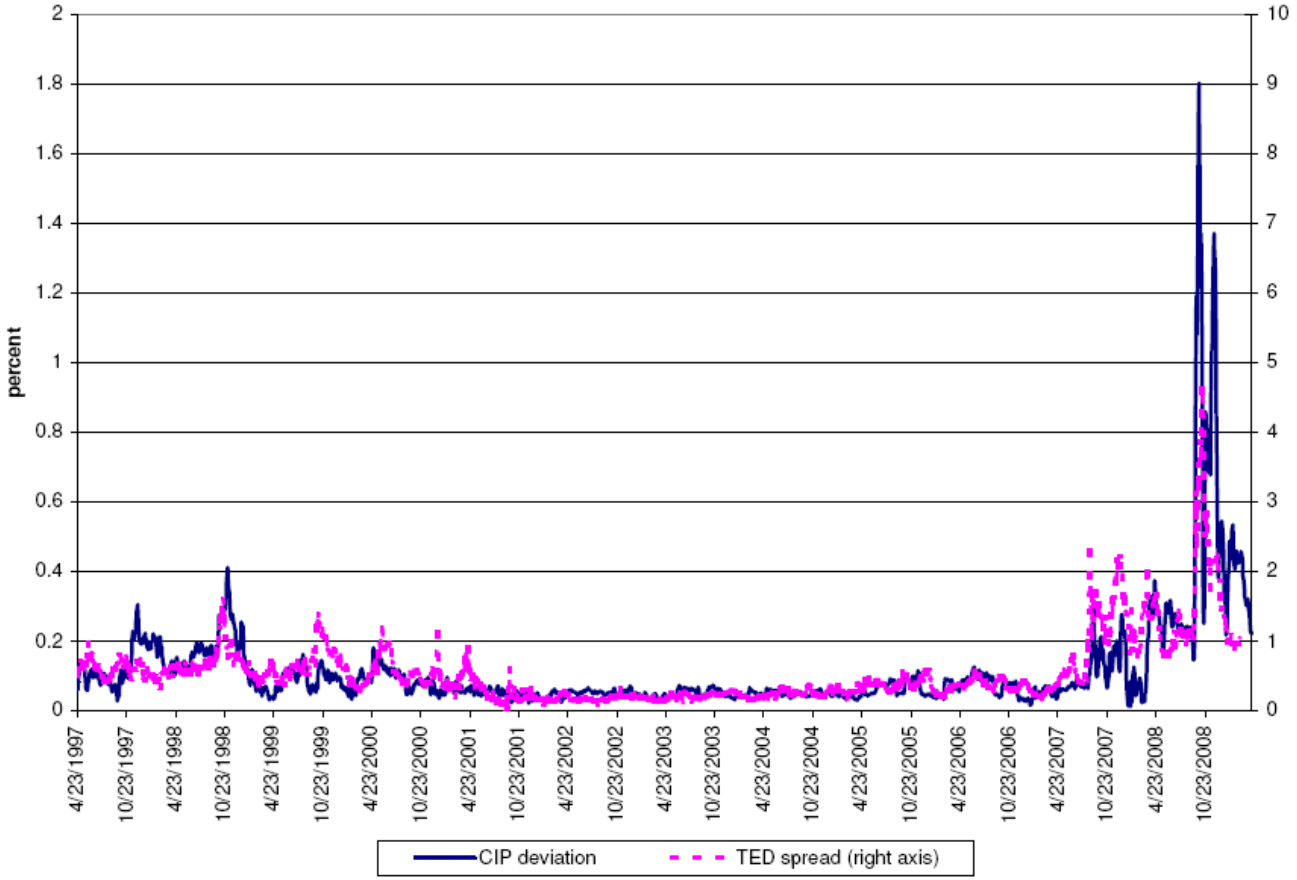
Evidence on Funding Liquidity: Deviations from LoOP

- 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:



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:



Roadmap of This Talk

- Market liquidity risk
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- **Market and funding liquidity interactions**
  - **Theory**
  - **Evidence**
- Conclusion

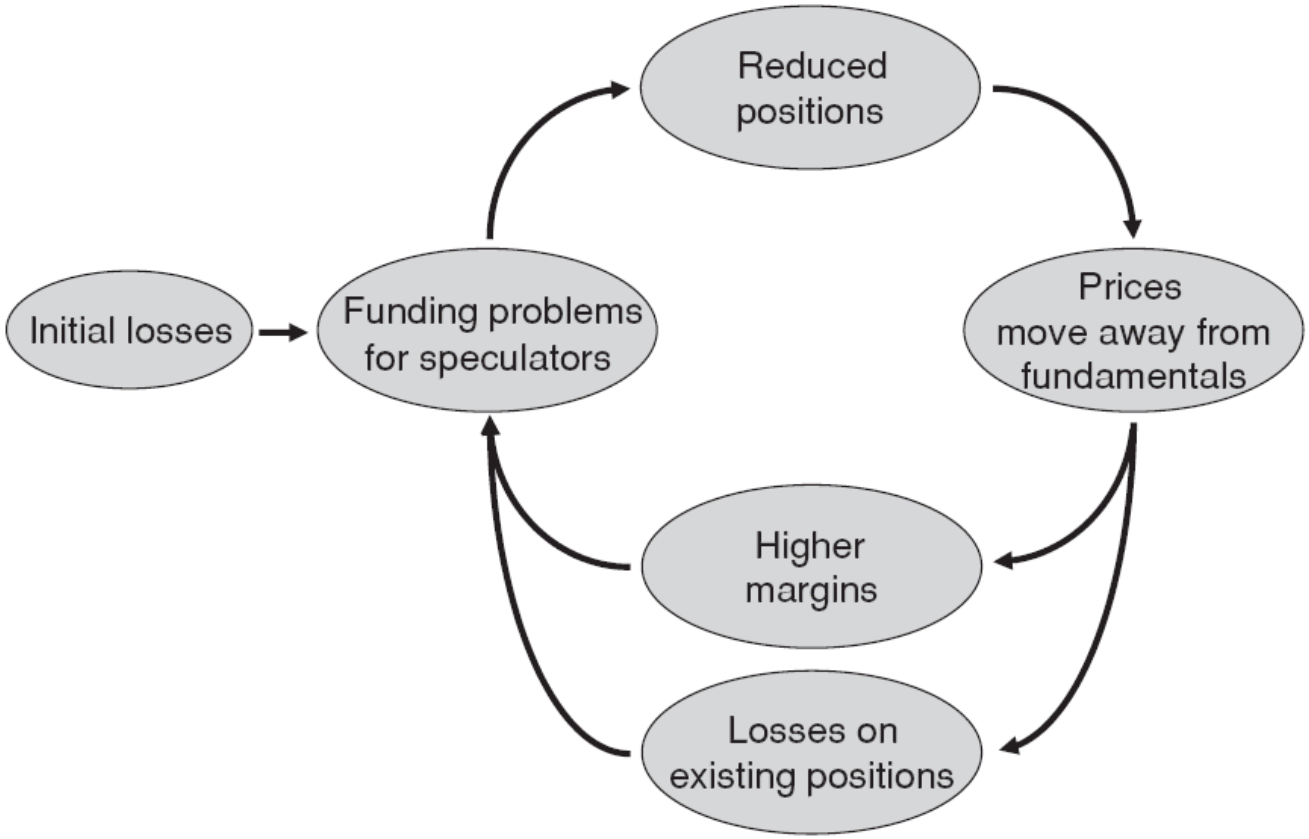
Models of Market and Funding Liquidity Interaction

- 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)

Liquidity Spirals

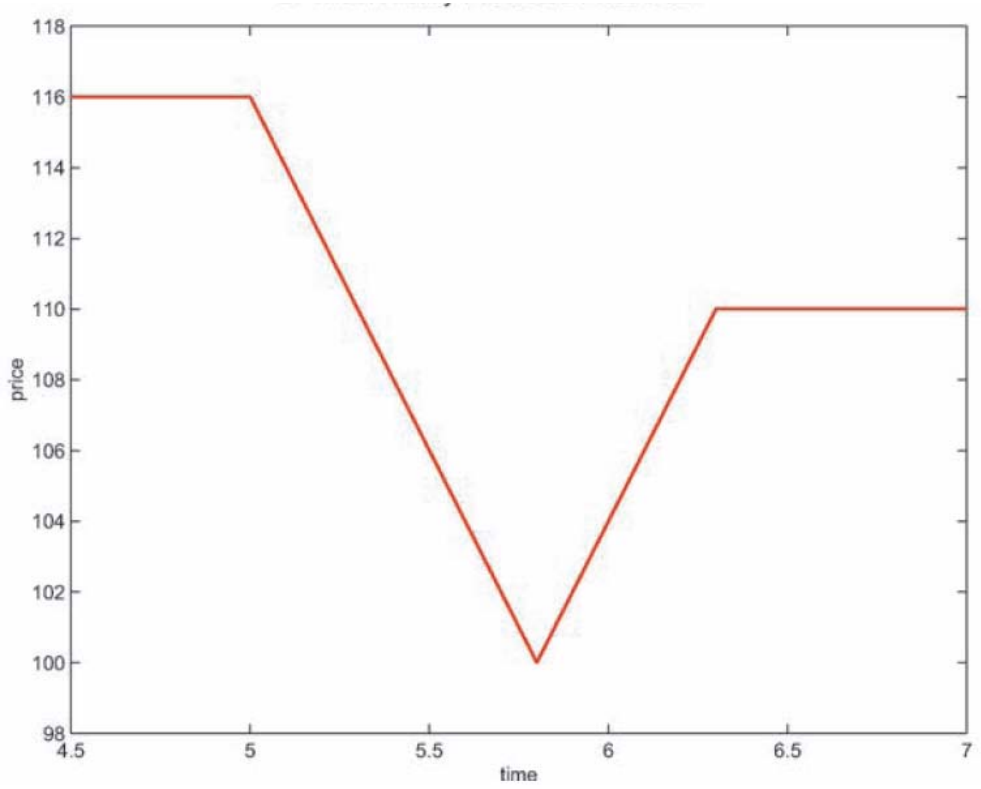


- Market and funding liquidity problems can reinforce each other, creating a systemic crisis
- Source: Brunnermeier and Pedersen (RFS 2009)

Implications of Market and Funding Liquidity Interactions

- Fragility: 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 related to 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)

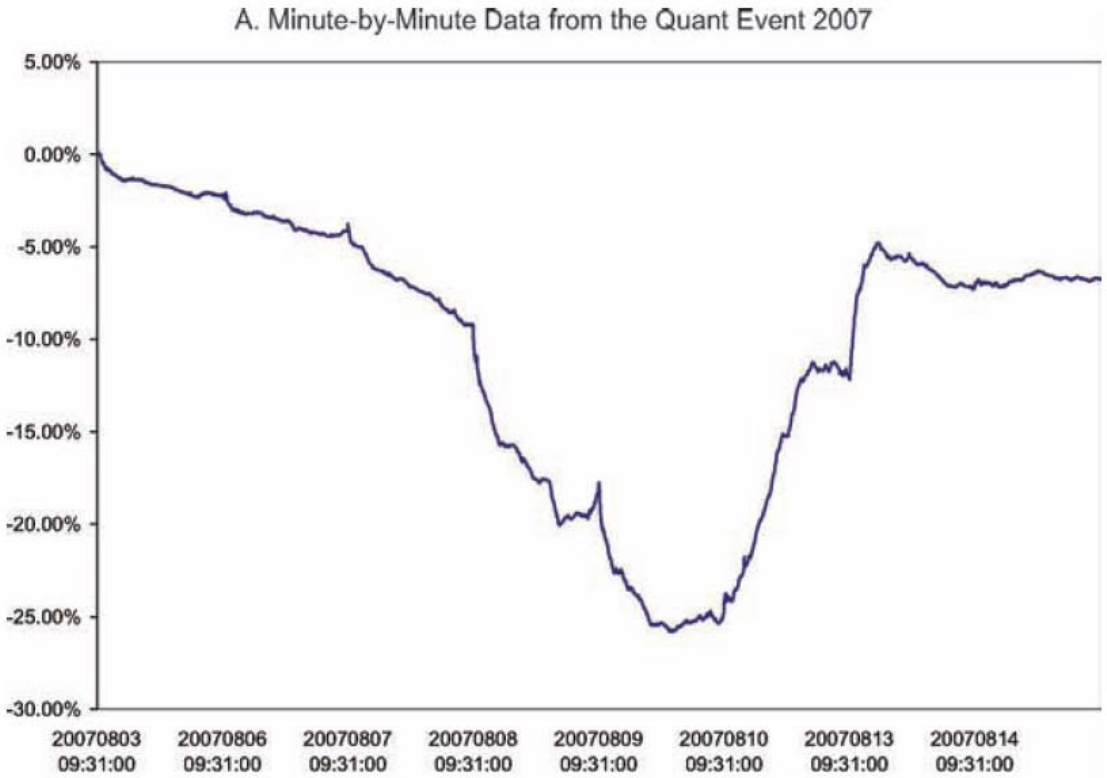
When Everyone Runs for the Exit



- 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)

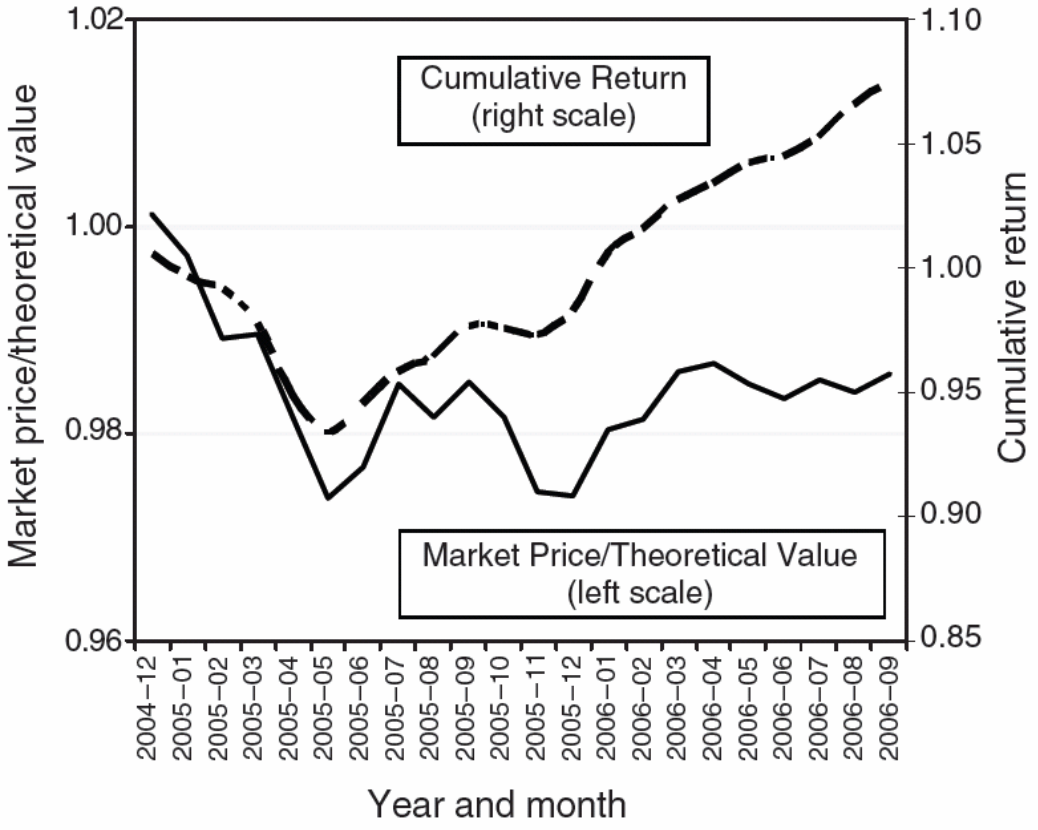
- Source: Brunnermeier and Pedersen (JF 2005)

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)

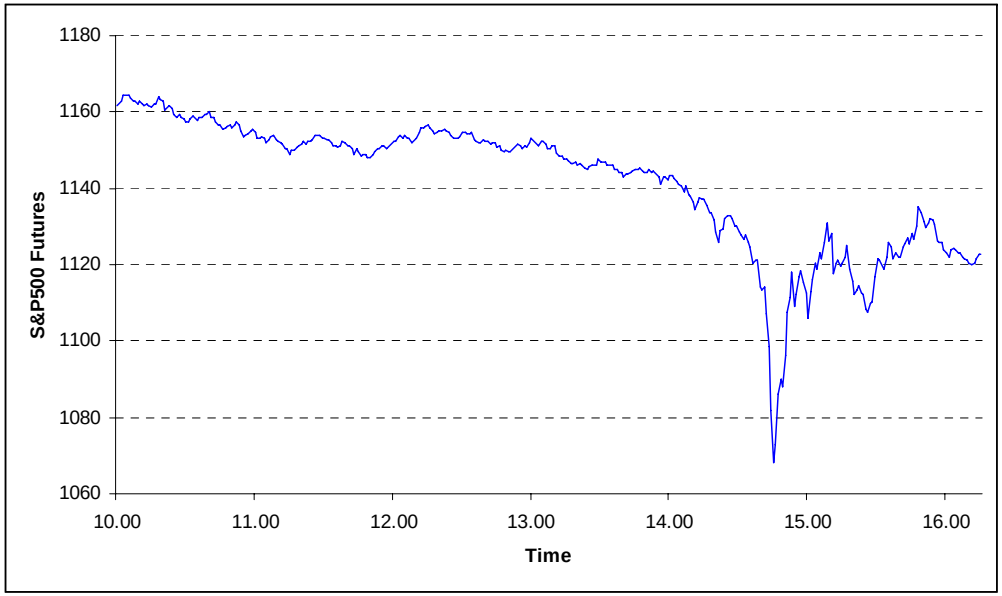
When Everyone Runs for the Exit: Convertible Bond Crisis 2005



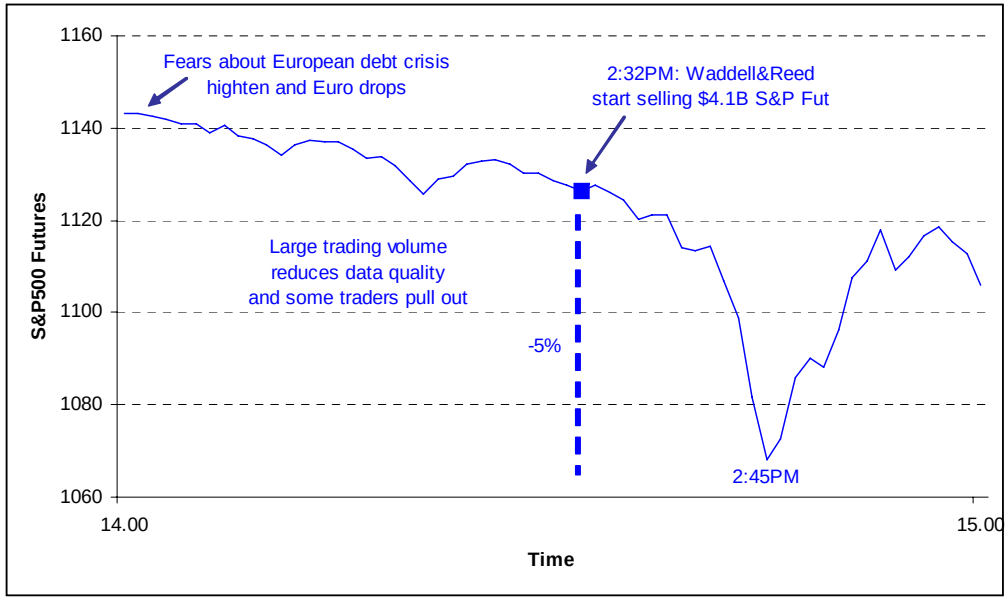
- Many convertible bond hedge funds had large redemptions
  - Forced sell off
  - Bonds cheapened relative to theoretical value implied by arbitrage relation
  - Cheapening lead to losses, further redemptions, further sell offs, firing of convert desks
  - Eventually, sell off ended and strategy became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

When Everyone Runs for the Exit: Flash Crash 2010

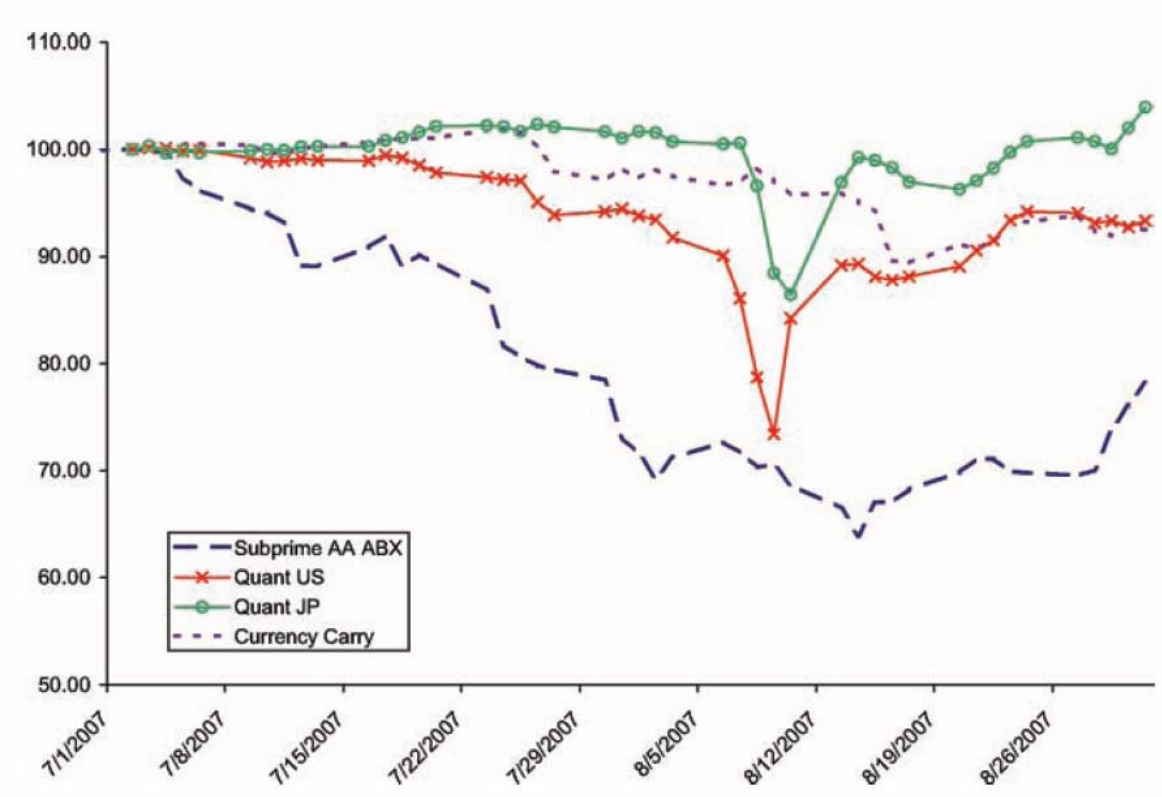
May 6, 2010



The hour 2-3PM ET



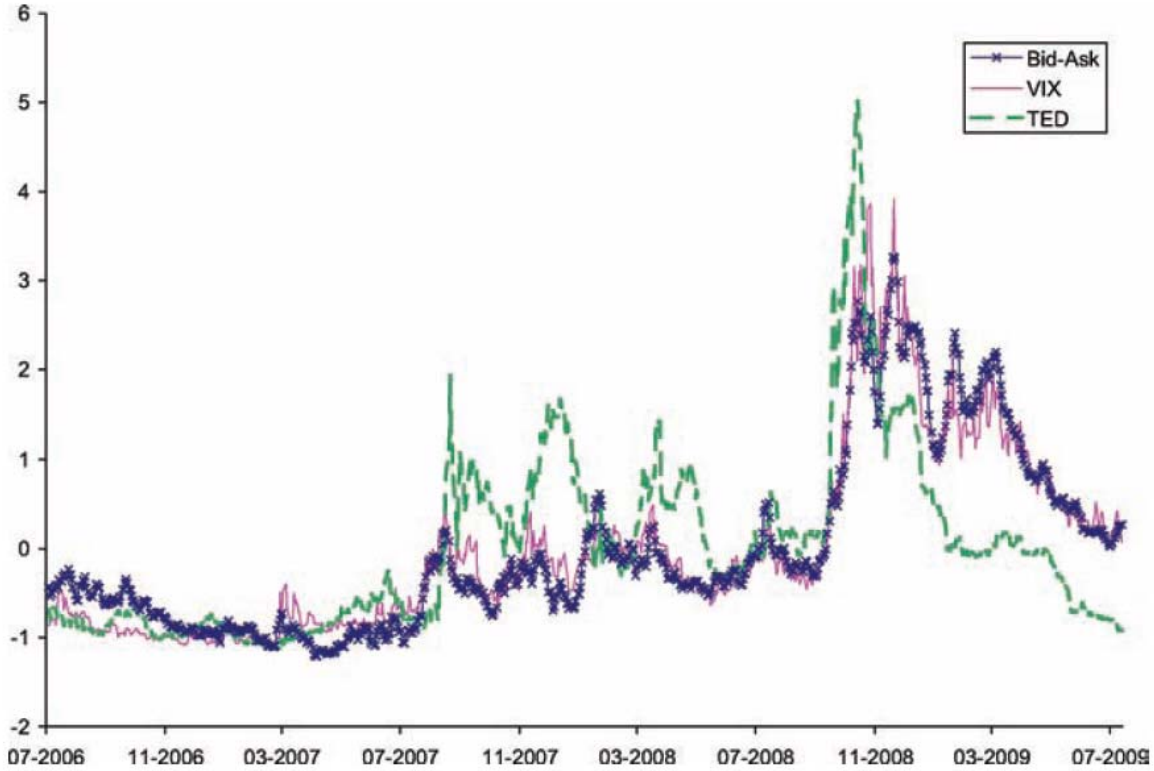
Spillover in the Beginning of the Global Financial Crisis



- 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)

Market and Funding Liquidity During the Global Financial Crisis



- Co-movement of market and funding liquidity risks:
  - TED spread: related to funding liquidity
  - Bid-ask spread: measure of market liquidity
  - VIX: measure of volatility as well as risk and liquidity premia
- Source: Pedersen (2009)

Conclusion: Summary

- Frictions are central in many parts of economics:
  - Labor economics: Search frictions (this year's Nobel Prize!)
  - Monetarists: search frictions with money as a medium of exchange
  - Macro and (New Keynesian) monetary economics: sticky prices, irreversible real investments
  - Corporate finance, insurance, health, and other: frictions due to asymmetric information and moral hazard

- Frictions are also central in financial markets: Frictional finance provides
  - parsimonious model yielding a unified explanation of a wide range of phenomena
    - Asset prices
    - Macro economy
    - Monetary policy
  - with significant empirical support
  - large economic magnitude

endogenously affected by liquidity risk

$$\mathrm{E}_t\left(r^i_{t+1}\right) = \underbrace{r^f_t + \lambda_t\,\beta^i_t}_{\text{standard CAPM}} + \underbrace{\mathrm{E}_t\left(c^i_{t+1}\right) + \lambda_t\left(\beta^{c^i,c^M}_t - \beta^{r^i,c^M}_t - \beta^{c^i,r^M}_t\right)}_{\text{compensation for expected trading costs, } c^i_{t+1} \text{ and market liquidity risks}} + \underbrace{\psi_t\, x_t\, m^i_t}_{\text{compensation for use of margin capital, } m^s_t \text{ (funding liquidity)}}$$

Frictional Finance: Some Interesting Questions for Further Research

- Macro and real consequences of financial frictions
  - Analyze how financial frictions affect allocation of capital, real investment, output, R&D, etc.
    - Over time
    - Across firms/ industries/ sectors
    - Across countries/ regions
  - Welfare implications: Why do people want/need to trade so much? Theory of trading volume? How can financial frictions be alleviated? How much would this change welfare quantitatively?
- Monetary economics
  - How do financial frictions affect the monetary transmission mechanism? What happens when bank capital is low?
  - DSGE model with margin requirements: quantify effects of financial frictions with price rigidities and Taylor rule
- Asset pricing implications of financial frictions
  - Lots more theoretical implications and empirical tests to do!
  - E.g., can the effects of market liquidity and funding liquidity be empirically distinguished?
- Market and funding liquidity as substitutes
  - As long as an investor can either sell a security or borrow against it, he can mitigate his liquidity problem (though market and funding liquidity often disappear at the same time due to liquidity spirals)
- What are the underlying determinants of margin requirements/haircuts and repo rates?
  - In theory and empirically.
  - Also, why are funding markets so opaque? What if they are made more transparent?
  - What is the best structure for the funding markets? Various forms of repo, tri-party repo, prime brokerage, leverage through derivatives, or other forms?
- What is the best market structure for trading, e.g. the structure that best prevents market breakdown?
  - E.g. what if continuous trading is replaced by having an auction every minute so that some people don't have an advantage from being faster than others?
- What is the optimal liquidity risk management for a trader?
- What other areas of economics are affected by financial frictions?

Other Related Papers (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)