Market Liquidity and Funding Liquidity: An Overview

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Lasse H. Pedersen

New York University, Copenhagen Business School, CEPR, NBER, and AQR Capital Management
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**

\[
E_t(r_{t+1}^s) = r_t^f + \beta_t^s \lambda_t + \text{market liquidity risk compensation} + \text{funding liquidity risk compensation}
\]

- 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 $E(r^i - c^i)$

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

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

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

where

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

market beta

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

commonality in liquidity

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

return sensitivity to aggregate liquidity

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

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))

  - 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
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Funding Liquidity: Margin CAPM

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 $\psi_t$ 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 $\lambda_t$ 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 $\beta$ and different margin requirement $m$.

2. Find securities with the different fundamental risk $\beta$ 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:

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:

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 \( \lambda_t = E_t \left( r^M_t \right) - r^f - \psi_t \), and \( \psi \) 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)
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,” 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

<table>
<thead>
<tr>
<th>Embedded Leverage (t-1)</th>
<th>Equity Options</th>
<th>Index Options</th>
<th>ETFs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Log(open interest) (t-1)</td>
<td>-0.72 (5.40)</td>
<td>-1.53 (9.37)</td>
<td>-1.90 (10.39)</td>
</tr>
<tr>
<td>Log(total open interest) (t-1)</td>
<td>0.25 (3.67)</td>
<td>-0.92 (1.34)</td>
<td>-1.13 (1.46)</td>
</tr>
<tr>
<td>Months to expiration (t-1)</td>
<td>-1.27 (2.02)</td>
<td>-1.14 (2.48)</td>
<td>-1.07 (2.29)</td>
</tr>
<tr>
<td>Moneyness (t-1)</td>
<td>-0.24 (2.31)</td>
<td>-0.08 (0.60)</td>
<td>-0.09 (1.14)</td>
</tr>
<tr>
<td>Implied volatility (t-1)</td>
<td>-36.28 (7.36)</td>
<td>-45.13 (10.25)</td>
<td>-44.22 (6.25)</td>
</tr>
<tr>
<td>1-Month spot volatility (t-1)</td>
<td>3.77 (0.69)</td>
<td>2.48 (0.58)</td>
<td>-2.49 (0.65)</td>
</tr>
<tr>
<td>12-Month spot volatility (t-1)</td>
<td>10.48 (2.22)</td>
<td>6.77 (1.56)</td>
<td>7.30 (2.67)</td>
</tr>
<tr>
<td>Option Vega (t-1)</td>
<td>-0.03 (3.23)</td>
<td>-0.03 (2.56)</td>
<td>-0.05 (2.29)</td>
</tr>
<tr>
<td>Option Gamma (t-1) *100</td>
<td>-0.35 (1.32)</td>
<td>-0.20 (1.86)</td>
<td>-0.24 (2.18)</td>
</tr>
<tr>
<td>Stock return (t)</td>
<td>-10.66 (1.90)</td>
<td>-11.51 (2.18)</td>
<td>-13.77 (2.98)</td>
</tr>
<tr>
<td>Option turnover (t)</td>
<td>8.73 (12.42)</td>
<td>8.62 (12.39)</td>
<td>10.08 (12.87)</td>
</tr>
<tr>
<td>Total option turnover (t)</td>
<td>9.60 (3.30)</td>
<td>11.73 (4.56)</td>
<td>12.01 (5.13)</td>
</tr>
<tr>
<td>Option B/A Spread (t-1)</td>
<td>14.37 (4.73)</td>
<td>14.62 (4.69)</td>
<td>17.16 (4.54)</td>
</tr>
<tr>
<td>Total option B/A Spread (t-1)</td>
<td>4.56 (0.44)</td>
<td>4.40 (0.54)</td>
<td>-8.33 (-1.94)</td>
</tr>
</tbody>
</table>
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
Buffer'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
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 Risk and Monetary Policy

required return

\( \beta \)

market liquidity risk
funding liquidity risk

\[ \beta \]

In the diagram, the relationship between required return and liquidity risk is depicted. The graph illustrates how market liquidity risk and funding liquidity risk affect each other, with a line showing the positive correlation between required return and \( \beta \).
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

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

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, $\psi_t$ 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)
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)
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

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)
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

May 6, 2010

The hour 2-3PM ET

Fears about European debt crisis heighten and Euro drops

2:32PM: Waddell&Reed start selling $4.1B S&P Fut

Large trading volume reduces data quality and some traders pull out

-5%

2:45PM
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 and risk: Acharya and Pedersen (JFE 2005)

➢ Market liquidity as search:

➢ Asset pricing with market liquidity as asymmetric information
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:

- 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:

- Monetary models with frictions:
  - Curdia and Woodford (2009), Gertler and Karadi (2009)

- Asset pricing and constraints:

- 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:

- Dynamic trading with predictable returns and transaction costs:
  - Garleanu and Pedersen (2008)

- Informational frictions in asset markets
  - Grossman and Stiglitz (1980)
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

![Liquidity-adjusted CAPM graph]

- 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)

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

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

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