

# Trading Agents and Liquidity Risk

---

**Joseph Cherian**  
**May 08, 2009**



## Few opening claims

---

- Liquidity risk is well-studied but still an “elusive concept”
- Recent experience suggests that it is central to asset pricing and risk management
  - Liquidity risk drives security prices away from fundamentals
- In other words, markets are not efficient in pricing liquidity risk and hence it presents trading opportunities if exploited properly



## What we wish to achieve today

---

- Establish a practical understanding of liquidity risk
- Introduce (well-established) empirical metrics to estimate liquidity risk using **intraday** data
- Introduce simple trading strategies to exploit liquidity risk
- Present an information-based trading model where agents have superior information, liquidity needs, or hedging requirements
- By conjoining the empirical model with the theoretical one, establish a framework to forecast future liquidity



# Understanding Liquidity and Liquidity Risk

---

## □ Definitions

- **Liquidity** is the ease of trading a security
- **Liquidity Risk** is the uncertainty associated with liquidity

## □ Few observations

- Liquidity is not a fixed property
- Liquidity can suddenly dry up
- Liquidity influences asset returns
- Liquidity is a significant source of risk
- Size and trading volume are insufficient proxies of liquidity



## Literature review

---

- Liquidity and the real economy
  - Bernanke and Gertler (1995)
- Liquidity and long-term performance
  - Amihud and Mendelson (1986)
- Market impact of liquidity
  - Amihud (2002)
- Equilibrium, liquidity and spirals
  - Acharya and Pedersen (2005)
  - Brunnermeier and Pedersen (2007)



## What causes illiquidity (i.e. lack of liquidity)?

---

- Demand / supply pressure and inventory risk
  - Extreme events cause order imbalances and inventory overload
- Agents may lack propensity to trade
  - Natural counterparty may not be immediately available
  - Latent Liquidity - Mahanti, Nashikkar, Subrahmanyam, Chacko and Mallik, (2008)
- Private information
- Short sale constraints
- Funding liquidity or cost of margin trading
  - Cherian, Jacquier and Jarrow (2004)
- **Flight-to-liquidity** (LTCM / quality trade) versus **Fight-for-liquidity** (Aug 2007 / deleveraging spiral)



## How to measure Liquidity?

---

- Ease of availability of financing for very short term maturities
- Ease of liquidating positions
  - Ability to liquidate positions without significantly affecting prices
  - This measure is most commonly used by market participants and the measure we adopt
- Uncertainty of not being able to buy or sell something for the value we expect (and at the time we expect)

# How to measure Liquidity?

## Ease of liquidating positions

---

- First Step: Estimate the ease of liquidating positions
  - Measured as the magnitude of price movements resulting from order size – Amihud (2002)
  - Modeled using **intraday trading data**

$$ILLIQ_t = \frac{|r_t|}{V_t}$$

- Measure is computed on a weekly basis and normalized to allow comparisons across time
- Second Step: Estimate the uncertainty in the cost
  - Formulate a time-series model of illiquidity
  - Estimate liquidity risk as the illiquidity shock – Amihud (2002)

$$ILLIQ_t = a + b * ILLIQ_{t-1} + \varepsilon_t$$



## Some associated liquidity jargon

---

### □ **Illiquidity Level**

- Stock Illiquidity Level (SIL): Normalized  $ILLIQ_t$
- Market Illiquidity Level (MIL): Median SIL

### □ **Liquidity Risk**

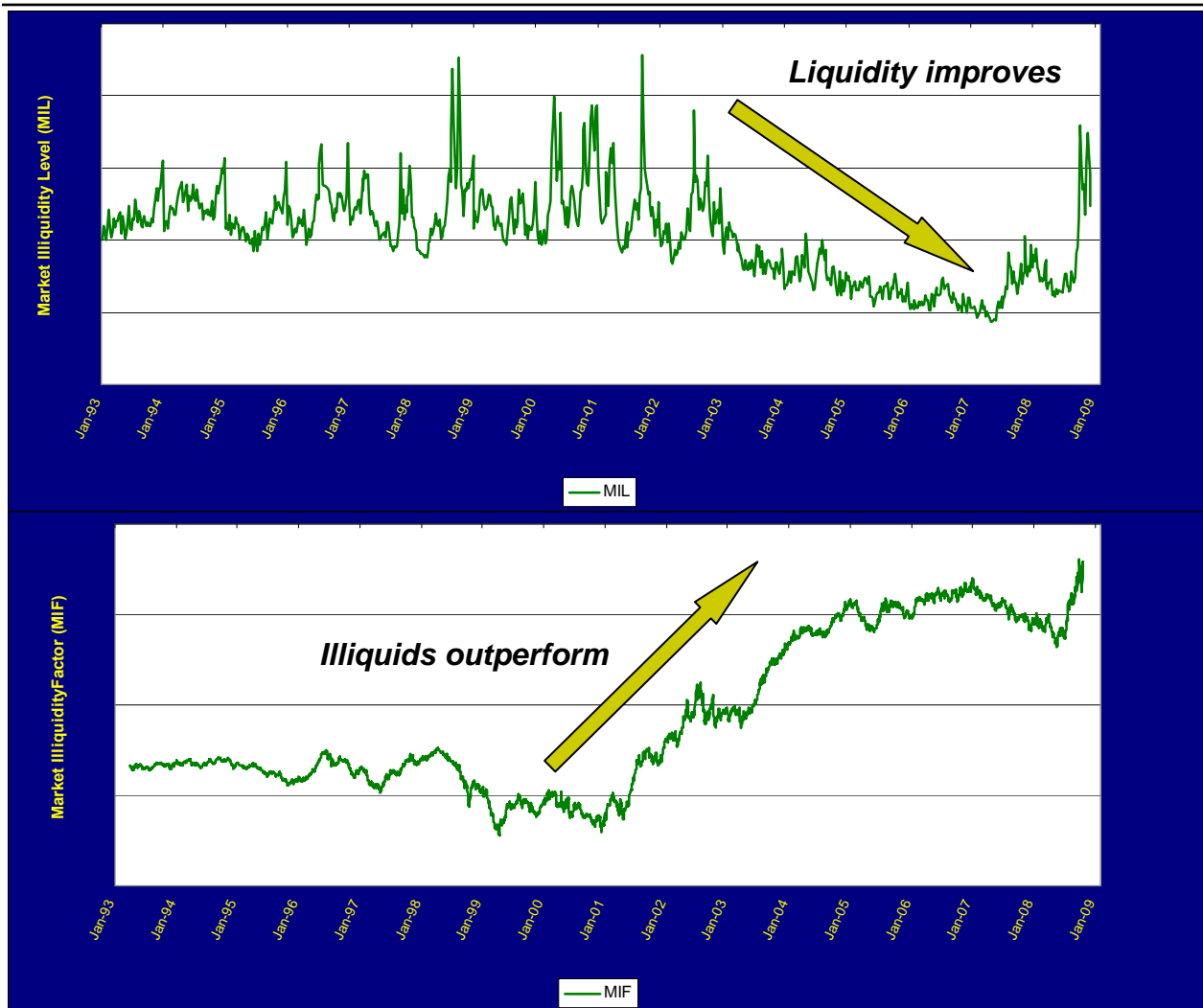
- Stock Liquidity Rating (SLR):  $\varepsilon_t$ , i.e. the illiquidity shock

### □ **Returns to Liquidity Risk**

- Market Illiquidity Factor (MIF): Illiquids *minus* Liquids

(See Appendix at the end for full definitions)

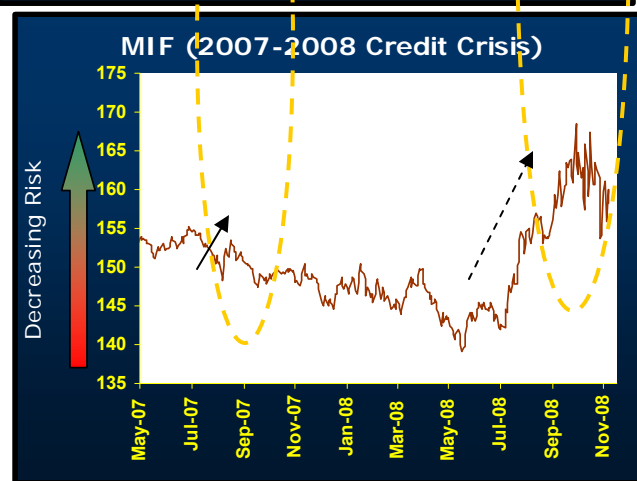
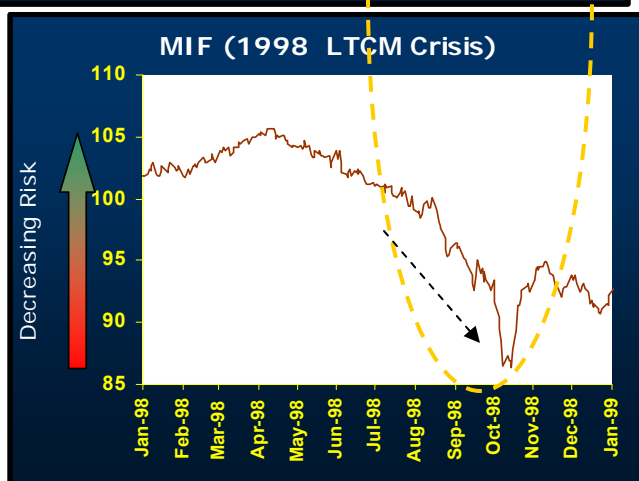
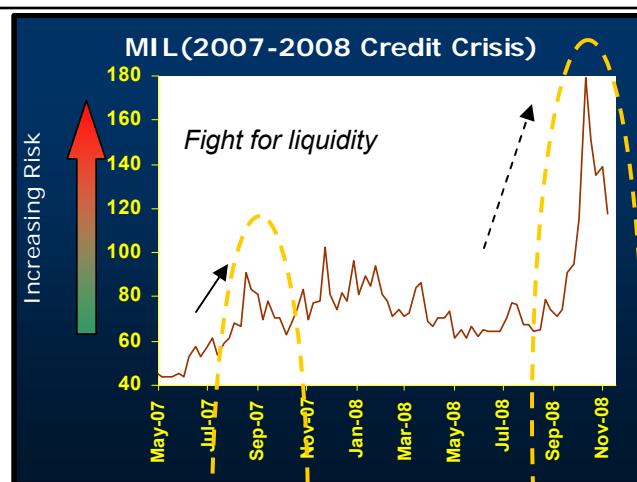
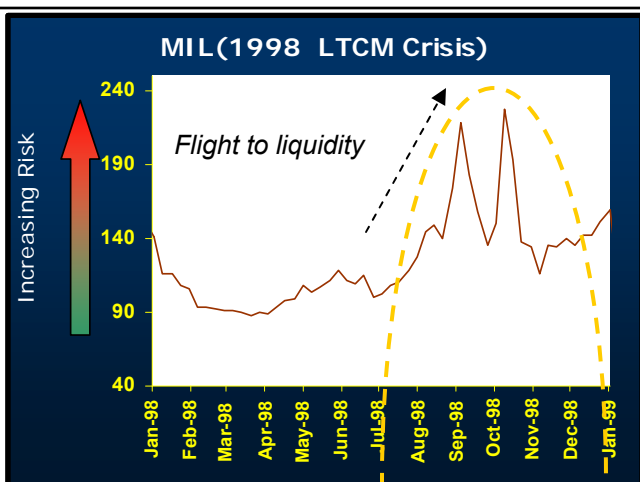
# MIL and MIF over time (Jan 1993 – Dec 2008)



MIL, which is the median illiquidity level for stocks in the market, captures the time-variation in market liquidity

MIF, which calculates the relative performance between illiquid and liquid securities, measures how liquidity risk is priced by the market

# Using MIL and MIF to detect liquidity crisis

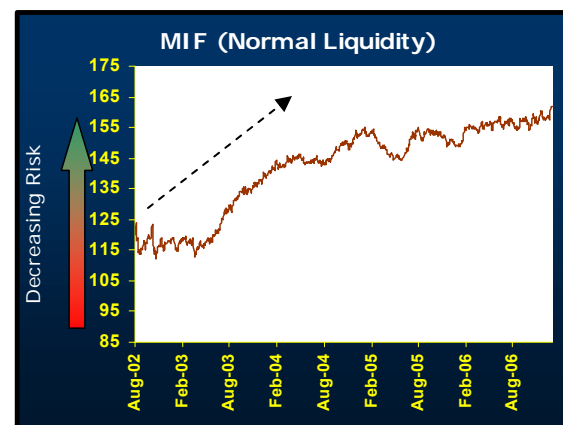
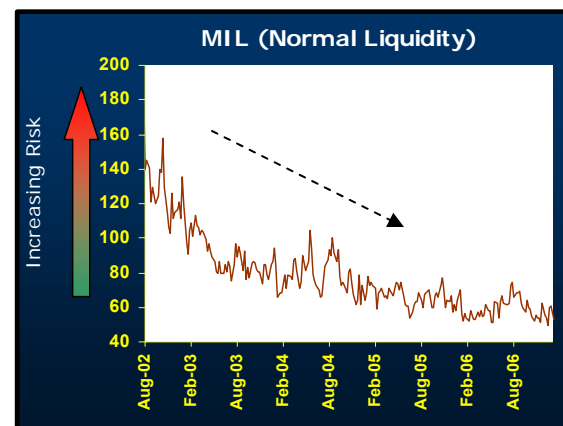


Liquidity is a significant source of risk in U.S. equity markets, especially during periods of market stress

See Appendix for definitions. The MIL is based on an initial value of 100 registered on Jan 8, 1993. MIF is based on an initial value of 100 registered on April 1, 1993.

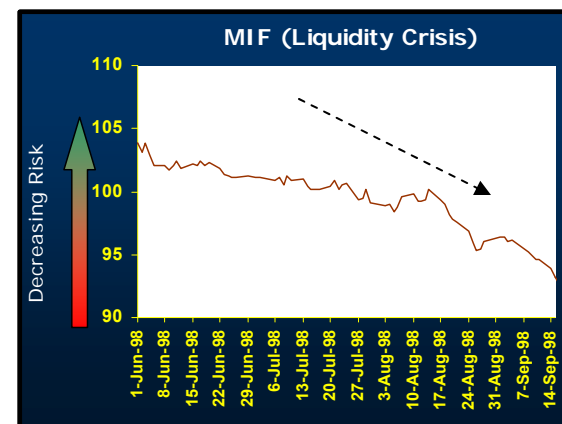
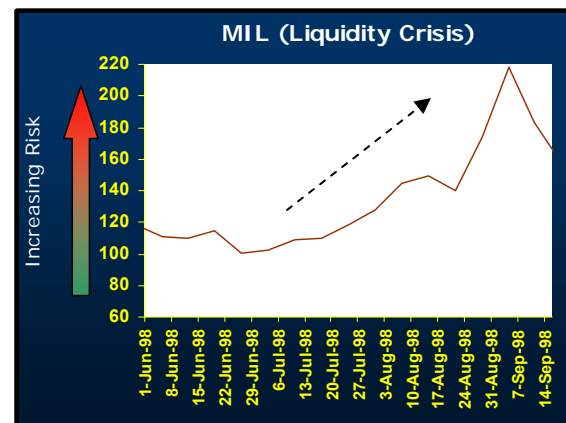
# Liquidity Regimes – Normal Markets

- Benign Liquidity Regime
  - Illiquid securities out-perform accompanied with improvement in liquidity fundamentals
  - See Amihud and Mendelson (1986)



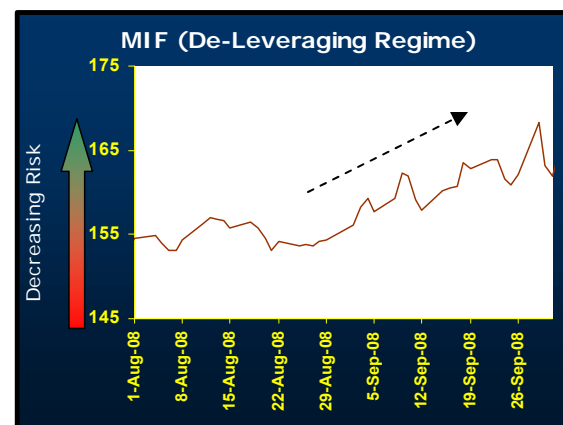
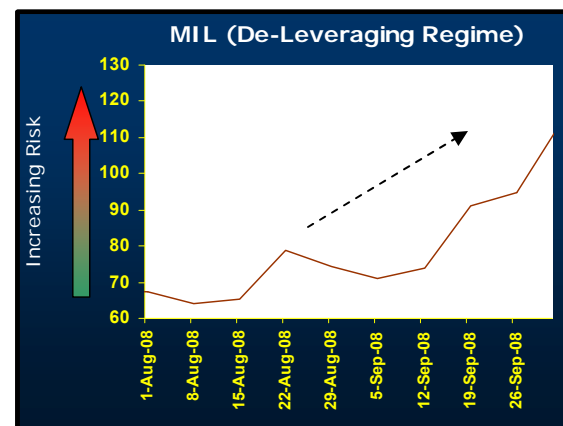
# Liquidity Regimes – Flight-to-liquidity

- Liquidity Crisis Regime (“Flight-to-liquidity”)
  - Illiquid securities underperform accompanied with deterioration in liquidity fundamentals
  - August 98 (LTCM crisis)

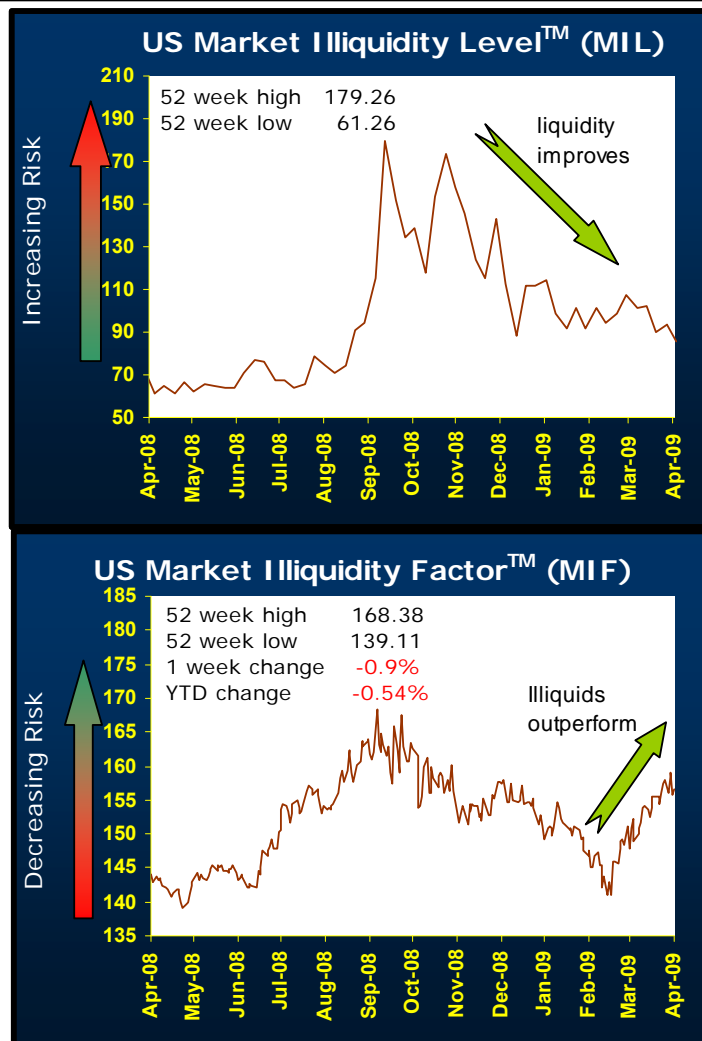


# Liquidity Regimes – Fight-for-liquidity

- De-leveraging Regime (“Fight-for-liquidity”)
  - Illiquid securities out-perform despite deterioration in liquidity fundamentals
  - Reason: During extreme deleveraging situations, investors offload the most liquid, highest quality securities to meet redemptions/margin calls, given these are easiest to sell
  - August 07 (Quant crisis) and August 08 (Credit crisis)



# MIL and MIF behavior more recently (April 2008 – April 2009)



- Market Illiquidity Level (MIL) reached a 6-year high during week of Oct 10, 2008
- Illiquid securities underperformed liquid securities by 13% between Oct 1 2008 and Mar 11 2009, as measured by the Market Illiquidity Factor (MIF)
- Since mid-March 2009, the liquidity premium has been catching up with the liquidity fundamentals, with the illiquid securities outperforming substantially
- Albeit during the last 2 weeks of April, illiquid stocks underperformed the liquid stocks in Financials (i.e., negative illiquidity premium)

# Stock Liquidity Rating (SLR) – April 27, 2009

## LARGE CAP

Highest Liquidity Risk	Lowest Liquidity Risk
LEVEL 3 COMMUNICATIONS INC	EXXON MOBIL CORP
AEGON NV	APPLE INC
WARNER CHILCOTT LTD	GOOGLE INC
CNX GAS CORP	GOLDMAN SACHS GROUP INC
CNH GLOBAL NV	WYETH
WHITE MTNS INS GROUP LTD	WAL-MART STORES INC
RELIANT ENERGY INC	JOHNSON & JOHNSON
CNA FINANCIAL CORP	GENERAL ELECTRIC CO
QUICKSILVER RESOURCES INC	JPMORGAN CHASE & CO
AES CORP. (THE)	PFIZER INC

## MID CAP

Highest Liquidity Risk	Lowest Liquidity Risk
EXXON MOBIL CORP	PUGET ENERGY INC
APPLE INC	ITT EDUCATIONAL SERVICES INC
GOOGLE INC	SMUCKER (JM) CO
GOLDMAN SACHS GROUP INC	DEAN FOODS CO
WYETH	DEVRY INC
WAL-MART STORES INC	AECOM TECHNOLOGY CORP
JOHNSON & JOHNSON	NETFLIX INC
GENERAL ELECTRIC CO	DRYSHIPS INC
JPMORGAN CHASE & CO	TESORO CORP
PFIZER INC	HEALTH CARE REIT INC

## SMALL CAP

Highest Liquidity Risk	Lowest Liquidity Risk
SEMICONDUCTOR MFG INTL CORP	ADVANCED MEDICAL OPTICS INC
XYRATEX LTD	CV THERAPEUTICS INC
VIEWPOINT FINANCIAL GROUP	BARNES & NOBLE INC
NATIONAL INTERSTATE CORP	MFA MORTGAGE INVESTMENTS INC
LIFE SCIENCES RESEARCH INC	CONTINENTAL AIRLINES INC -CL B
IGATE CORP	PALM INC
APCO ARGENTINA INC	AMR CORP/DE
CREDIT ACCEPTANCE CORP	CHICOS FAS INC
ASPEN TECHNOLOGY INC	SYNAPTICS INC
UTSTARCOM INC	DICKS SPORTING GOODS INC

## ADR

Highest Liquidity Risk	Lowest Liquidity Risk
WOORI FINANCE HLDGS CO	TEVA PHARM INDS
INDUSTRIAS BACHOCO SAB	BAIDU.COM INC
WNS (HOLDINGS) LTD	TOTAL SA
KONAMI CORP	ANGLOGOLD ASHANTI LTD
AIR FRANCE-KLM	NOKIA CORP
NORSK HYDRO ASA	CHINA LIFE INS CO
AIXTRON AG	NOVARTIS AG
TONGJITANG CHINESE MEDS	INFOSYS TECHNOLOGIES
BANCO DE CHILE	HARMONY GOLD MINING LTD
ACTIONS SEMICONDCTR LTD	CEMEX SAB DE CV

Liquidity Risk is estimated using trailing one month intra-day trading data

Stocks are grouped into Large Cap, Mid Cap and Small Cap using market capitalization as of 6/30/2008

Large Cap: Largest 500 U.S. Securities

Mid Cap: Largest 500 to 1000 U.S. Securities

Small Cap: Largest 1000 to 2000 U.S. Securities

# Liquidity Analysis presents alpha generation opportunities

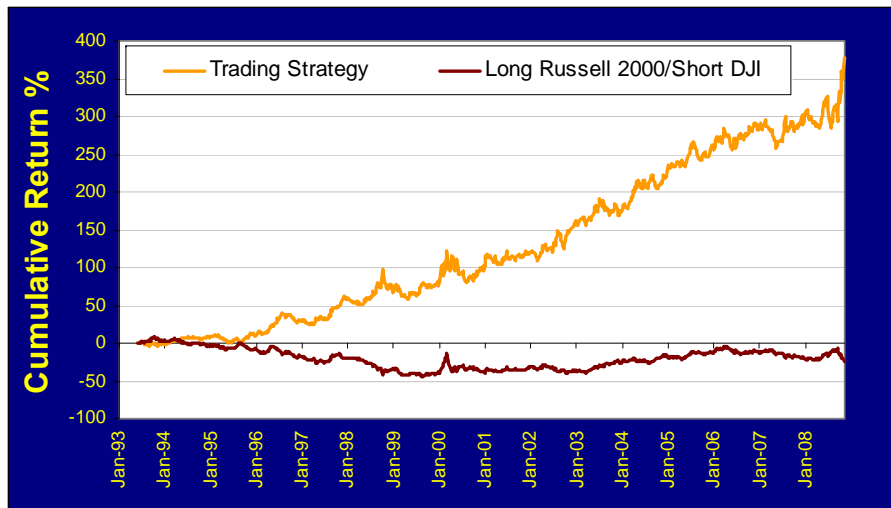
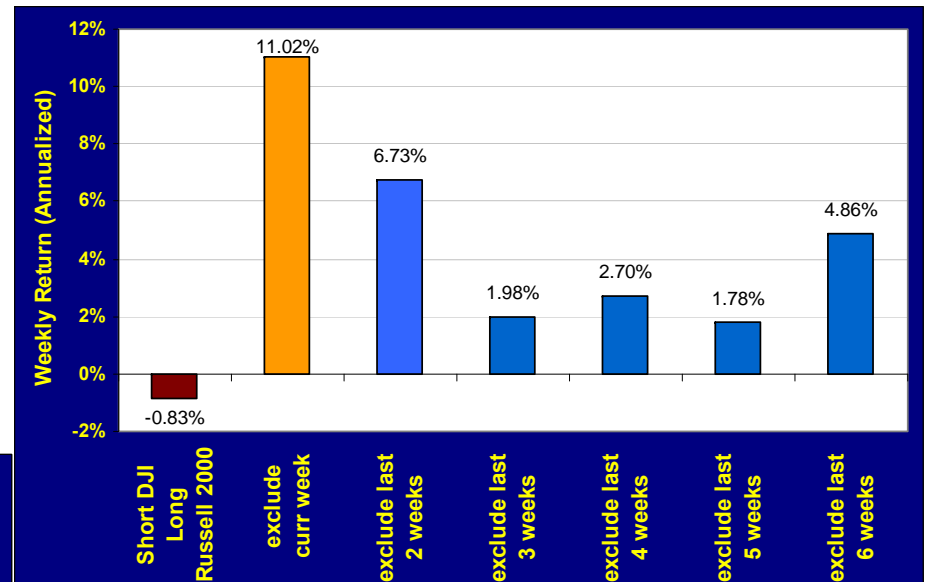
		Russell		Russell	
	# of	2000	DJI	2000	DJI
Trailing Liquidity	weeks	Return	Return	Std Deviation	Std Deviation
Deteriorating	371	-5.3%	6.8%	24.0%	19.4%
Improving	442	18.4%	9.0%	15.4%	14.0%

Annualized numbers based on weekly data for the period April 1993 - October 2008

- When **prior** Market Illiquidity Level (MIL) **increases** (i.e., as liquidity deteriorates)
  - Investors favor liquid securities over illiquid securities
  - Russell 2000 (proxy for illiquid securities) **underperforms** DJ Industrial Average (proxy for liquid securities)
  
- When **prior** Market Illiquidity Level (MIL) **decreases** (i.e., as liquidity improves)
  - Market participants favor illiquid securities over liquid securities
  - Russell 2000 **outperforms** DJ Industrial Average

# Liquidity Analysis presents alpha generation opportunities

- When MIL increases
  - **Short** Russell 2000 (RUT)
  - **Long** Dow Jones Industrial Average (DJI)
- When MIL decreases
  - **Long** Russell 2000 (RUT)
  - **Short** Dow Jones Industrial Average (DJI)
- Weekly rebalancing



- Outperforms
  - Naïve Short DJI / Long RUT strategy
  - HFR Equity Market Neutral strategy
- The MIL based trading signal is persistent
- Results do not consider transaction costs

# Liquidity Analysis presents alpha generation opportunities

- Panel regression (with fixed effect) of security's future quarter return against various explanatory variables using quarterly time series data across public U.S. equities from 1993-2007
- The explanatory variables include the current quarter's Stock Illiquidity Level (SIL), Stock Liquidity Rank (SLR), market capitalization, turnover, book value/price (using trailing 1 year data) and eps/price (using trailing 1 year data).
- The various variables enter the regression as a percentile number (0-1), where the percentile value is recomputed every quarter. The t-stats are shown in parenthesis.

Explanatory variable (previous quarter value)	Coefficient
previous_quarter_return	<b>-0.04</b> (-18.25)
illiquidity	<b>-0.23</b> (-43.93)
liquidity_risk	<b>-0.01</b> (-2.51)
market_cap	-0.04 (-0.95)
turnover	0.00 (-0.09)
bookvalue_by_price	<b>-0.08</b> (-20.69)
eps_by_price	-0.01 (-1.53)



# Liquidity is important in explaining asset returns

---

- Traditional asset pricing models are based on frictionless markets.
- However markets are plagued by some form of illiquidity
  - Prices are not always at fundamentals and are affected by trading activity
- Hence asset pricing models should incorporate liquidity
  - Macroeconomic factors (e.g., Risk free rate, LIBOR OAS)
  - Market factors
  - Size factor
  - Value factor
  - Market sentiment (e.g., VIX)
  - **Liquidity** (MIL)

# U.S. market liquidity is important in explaining asset returns across world equity indices

- Market Illiquidity Level (MIL) measures the illiquidity level aggregated for the entire market (run at the index level)

	Intercept	Size	Value	T-Bill	T-Bill LIBOR OAS	VIX	MIL	Adjusted R <sup>2</sup> without MIL	Adjusted R <sup>2</sup> with MIL
Russell 2000	<b>0.84</b>	<b>0.56</b>	<b>-0.71</b>	-0.34	-0.02	<b>-0.03</b>	<b>-0.07</b>	0.40	0.48
S&P 500	<b>0.89</b>	<b>-0.52</b>	<b>-0.86</b>	-0.79	-0.01	<b>-0.03</b>	<b>-0.07</b>	0.31	0.42
DJI	<b>0.84</b>	<b>-0.58</b>	<b>-0.62</b>	-0.94	-0.01	<b>-0.03</b>	<b>-0.08</b>	0.20	0.32
Hang Seng	0.76	-0.14	<b>-0.52</b>	-0.93	0.04	-0.03	<b>-0.08</b>	0.06	0.11
DAX	<b>1.25</b>	<b>-0.29</b>	<b>-0.69</b>	-0.16	-0.02	<b>-0.05</b>	<b>-0.09</b>	0.13	0.22
FTSE	<b>0.79</b>	<b>-0.28</b>	<b>-0.45</b>	0.19	-0.01	<b>-0.04</b>	<b>-0.06</b>	0.11	0.18

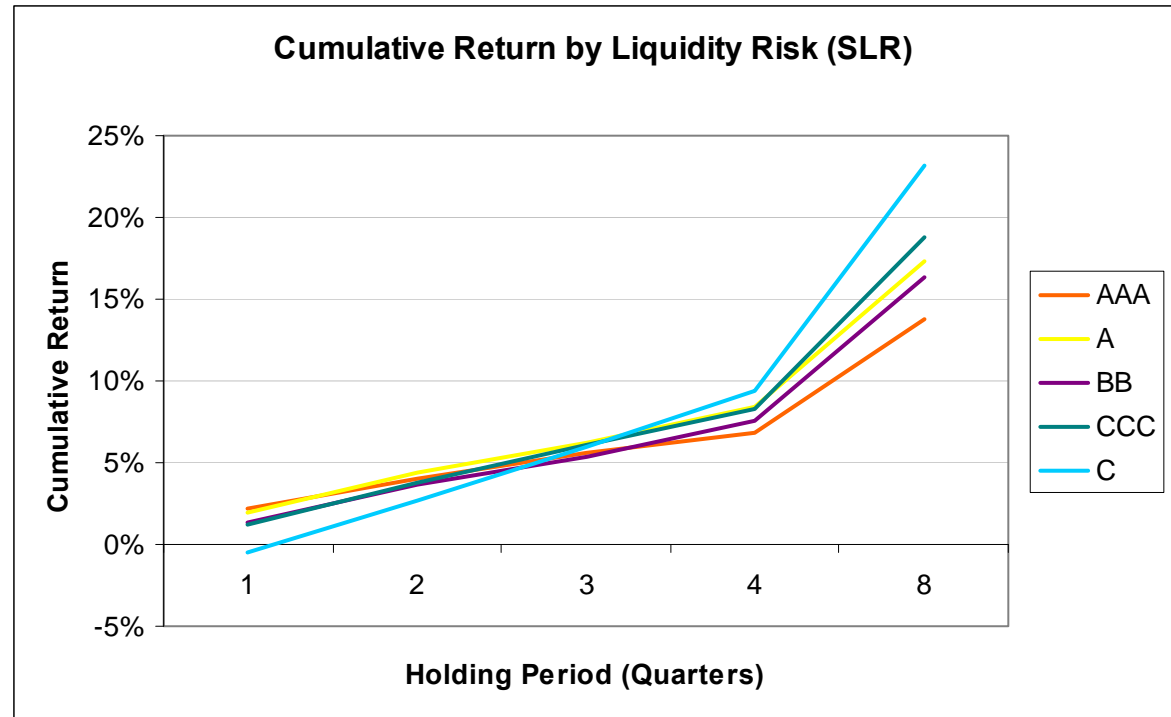
Coefficients in **bold** indicate significance level greater than 99%

The regression is carried out using data from Jan 1994 through Dec 2007

# Applications in portfolio management: The evidence

The U.S. evidence suggests

- for shorter holding periods (less than 3 quarters) **liquid securities** provide a higher return on investments
- for longer holding periods (more than 3 quarters) **illiquid securities** provide a higher return on investments



## Notes

1. Liquidity Risk is expressed using the Stock Liquidity Rating (SLR) scheme: (AAA, AA, A, BBB, BB, B, CCC, CC, C and D) with AAA having lowest risk and D having highest risk
2. Cumulative Return is the equally weighted return for given SLR portfolio, adjusted for round trip market impact cost. A SLR portfolio is defined as all stocks with a given SLR selected from the universe of largest 3000 U.S. stocks. The average size of a portfolio is \$300 million. The portfolio is held constant throughout the holding period.
3. Period analyzed: Jan 1993 – Jun 2008

## Liquidity Risk: Model Stability

---

original rating	Probability of migrating to rating by quarter end		
	Low Liquidity Risk	Medium Liquidity Risk	High Liquidity Risk
Low Liquidity Risk	77%	17%	5%
Medium Liquidity Risk	23%	49%	28%
High Liquidity Risk	5%	23%	72%

- Liquidity Risk Model has a reasonable turnover
- Probability of low liquidity risk stock moving to high liquidity risk during the next quarter is 5 %
- Probability of high liquidity risk stock moving to low liquidity risk is 5 %

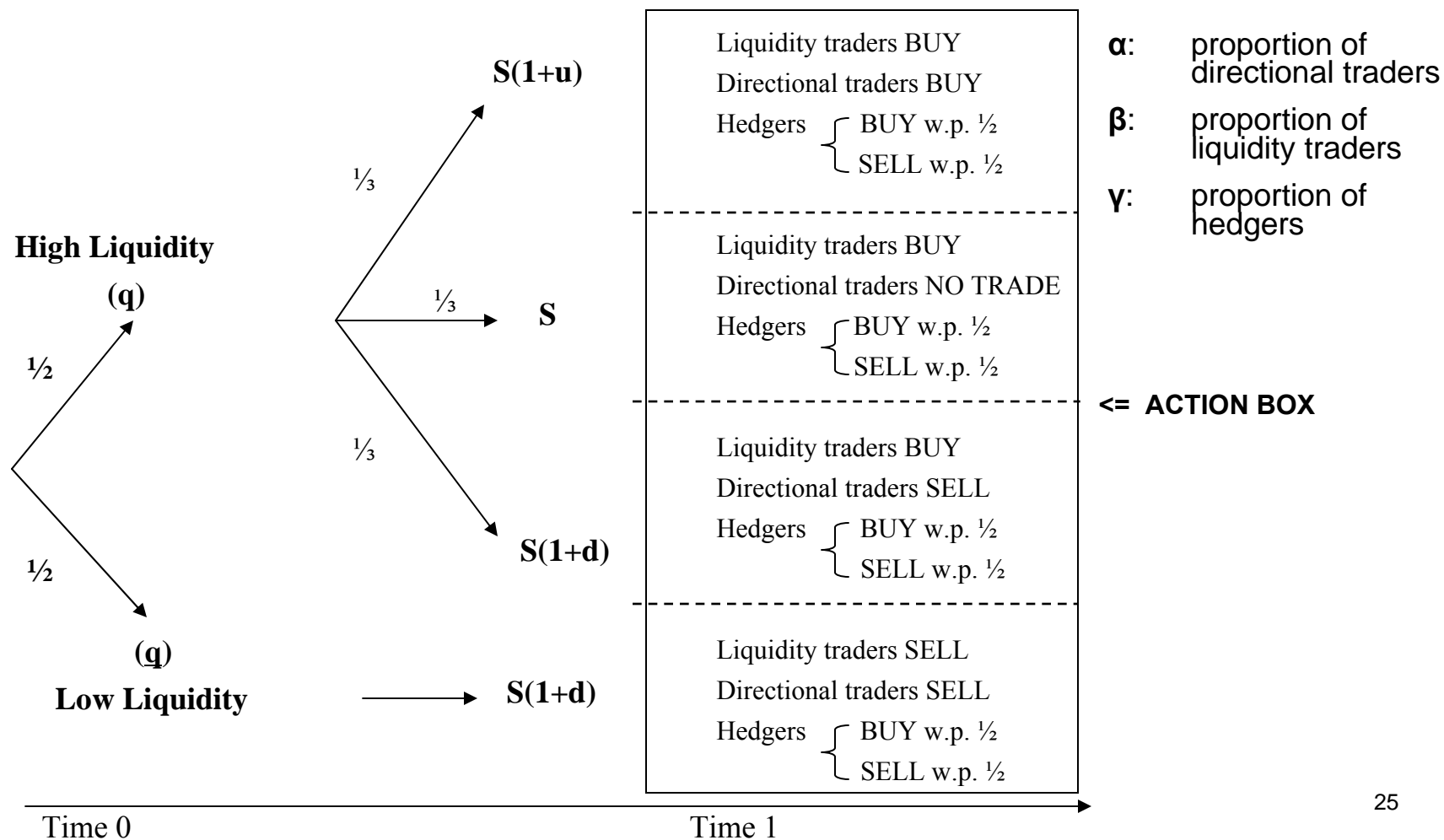


## Trading Agents and Liquidity Risk

---

- Trading agents
  - Directional Traders: Informed about stock market's direction (insiders, momentum traders)
  - Liquidity Traders: Informed about liquidity conditions. Trading is strategic and influenced by liquidity or other needs
  - Hedgers: Trading is influenced by hedging requirements (uninformed)
  
- Provides a theoretical framework for forecasting future liquidity given there is persistence in agents' behavior

# Model of Informed Liquidity Trading



# Main Results

---

## Result 1 (BID / ASK Prices)

a) *The equilibrium ASK Price is given by:*

$$S(1+u)(1+q)(\alpha + \beta + 1)/(6 - 4\alpha) + S(1+q)(1 + \beta - \alpha)/(6 - 4\alpha) \\ + S(1+d)(1+q)(1 + \beta - \alpha)/(6 - 4\alpha) + S(1+d)(1+q)(3(1 - \alpha - \beta))/(6 - 4\alpha)$$

b) *The equilibrium BID Price is given by:*

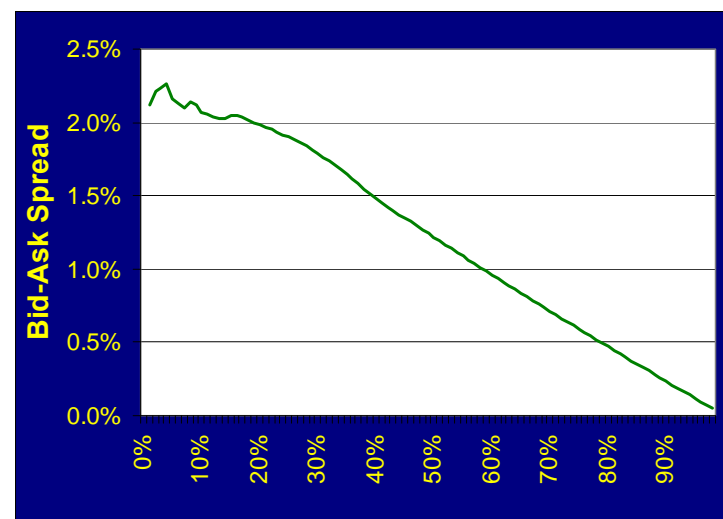
$$S(1+u)(1+q)(1 - \alpha - \beta)/(6 + 2\alpha) + S(1+q)(1 - \alpha - \beta)/(6 + 2\alpha) \\ + S(1+d)(1+q)(1 + \alpha - \beta)/(6 + 2\alpha) + S(1+d)(1+q)(3 + 3\alpha + 3\beta)/(6 + 2\alpha)$$

## Result 2 (BID / ASK Spread)

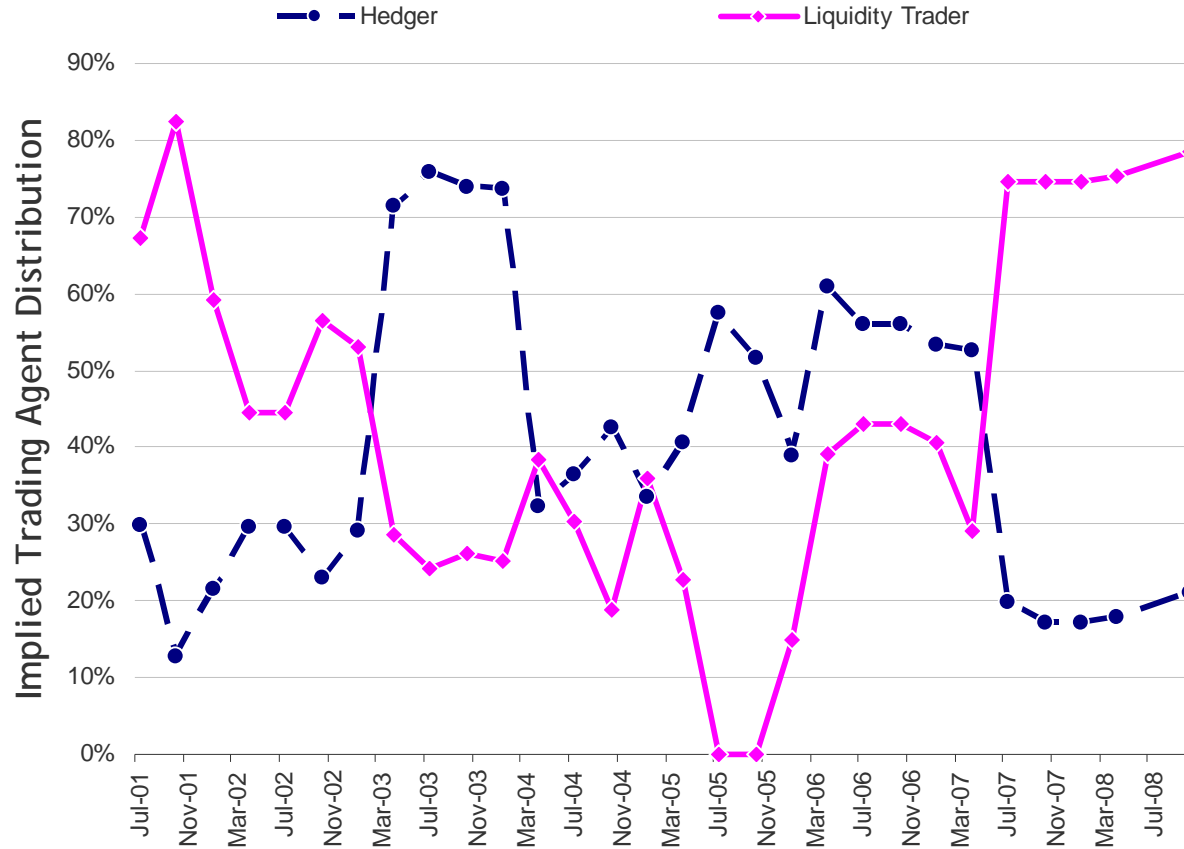
$$\frac{1}{2} \{ S(1+u)(1+q) [ (6-\alpha)(\alpha+\beta) + 3\alpha ] + S(1+q) [ (6-\alpha)(3\alpha+\beta) - 15\alpha ] \\ + S(1+d)(1+q) [ (6-\alpha)(\beta-\alpha) + 3\alpha ] + 3 \cdot S(1+d)(1+q) [ \uparrow (6-\alpha)(\alpha+\beta) + 3\alpha ] \} / \\ [(3+\alpha)(3-2\alpha)]$$

## Trading Agents and Liquidity Risk

- The presence of hedgers increases liquidity (decreases bid-ask spread) as they represent both sides of the (no-information) trade equally



# Liquidity Traders dominant during the current Liquidity Crisis

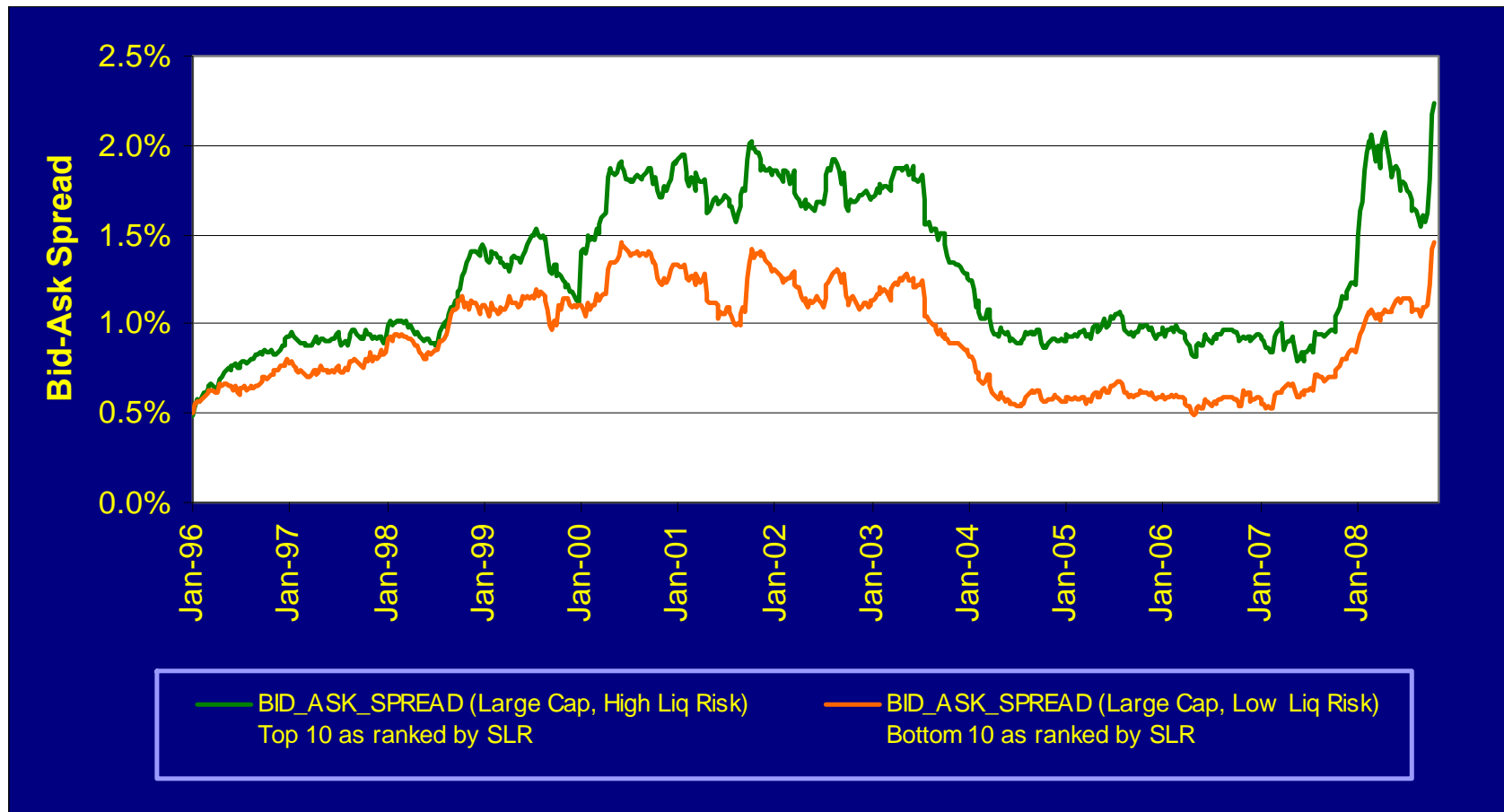


# Application: Model for Forecasting Future Liquidity 1



Universe: Largest 3000 U.S. Equities

# Application: Model for Forecasting Future Liquidity 2



Universe: 500 largest U.S. equities



## Summary

---

- Liquidity Risk an important source of risk and still being understood
- We introduced empirical metrics to estimate liquidity risk using **intraday** data that have predictive ability
- By conjoining the empirical model with the theoretical one, we established a framework to:
  - rank stocks by their liquidity risk
  - identify liquidity regimes
  - forecast future liquidity
- Introduced portfolio management applications and simple trading strategies to exploit liquidity risk



## Appendix: Definitions

---

- **Market Illiquidity Level (MIL)** is the median illiquidity level for stocks, as captured by the Stock Illiquidity Level (SIL), for the entire market of stocks selected from a universe of 3000 largest public U.S. equities by market capitalization, as determined at the beginning of the quarter. The weekly SIL for each stock is determined using intra-day trading data ( $ILLIQ_t$ ). The median SIL across the universe is denoted as MIL. The MIL is based on an initial value of 100 registered on Jan 8, 1993. An increase in MIL indicates deteriorating liquidity conditions. When MIL declines, illiquid securities can be expected to outperform liquid securities. When MIL increases, illiquid securities can be expected to underperform liquid securities.
- **Stock Liquidity Rating (SLR)** measures a stock's liquidity risk, given by the uncertainty associated with the cost of liquidating a position ( $\varepsilon_t$ ). SLR categorizes a stock into one of ten liquidity risk buckets (AAA, AA, A, BBB, BB, B, CCC, CC, C, D), with AAA having the least risk and D the greatest risk
- **Market Illiquidity Factor (MIF)** measures how liquidity risk is priced by market participants. It measures the cumulative return of illiquid securities relative to liquid securities as ranked by the stock-level liquidity rating system (SLR). The MIF for the U.S Equities Market is created through analysis of the 3,000 largest U.S. stocks. The MIF is based on an initial value of 100 registered on April 1, 1993.