Illiquidity Contagion and Liquidity Crashes

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Plan

1. Introduction: Research Question
2. Model
3. Benchmark: Segmented Markets
4. Liquidity Spillovers and Cross-asset learning
5. The role of price observability
6. The role of cross-market arbitrageurs
Co-movements in liquidity

- Co-movements ("commonalities") in liquidity between assets and market wide liquidity dry-ups are a source of risk. Important for asset management and asset pricing.

- What are the causes of co-movements in liquidity? Not well understood...

  1. **Common factors** affecting liquidity of several assets at the same time: (i) correlated liquidity demand shocks across assets (e.g., correlated institutional flows) or (ii) liquidity supply shocks (funding liquidity risk for dealers).

  2. **Liquidity spillovers**: shocks specific to one asset class propagate to other classes: asset X becomes less liquid \(\implies\) asset Y becomes less liquid as well.

- Extant research on liquidity risk relies extensively on channel #1 What about channel #2?
Are common factors sufficient to explain liquidity risk and liquidity dry-ups?

- The Flash-Crash: a transient market wide evaporation of liquidity in hundredths of securities at almost the same time.
• **Consolidated depth** (green: sell side of the limit order book, blue: buy side of the book) for **Procter and Gamble from 9:00 a.m to 4:00 p.m. on May 6, 2010.**
Possible explanations

- **Funding liquidity channel:** Funding constraints tightened at 2:30 p.m. for dealers in hundredth of assets and then relaxed at 3:00 p.m. Unlikely.

- **Correlated demand shocks channel:** Institutions were massively on the sell side at 2:30 p.m. in hundredth of securities...Unlikely (in fact for some assets prices were ridiculously high because of large buy orders).

- Common factors cannot explain all commonalities in liquidity...
Our Hypothesis

- **Important change in market structure in recent years:** information on prices is more widely and quickly disseminated than ever.

- **Example:**

<table>
<thead>
<tr>
<th>Date</th>
<th>Markets</th>
<th>Technology</th>
<th>Reduction in delay</th>
</tr>
</thead>
<tbody>
<tr>
<td>1846</td>
<td>NYSE-Philadelphia</td>
<td>Telegraph</td>
<td>One day to a few hours</td>
</tr>
<tr>
<td>1975</td>
<td>NYSE-Regionals</td>
<td>Consolidated Tape</td>
<td>5-10 mns to 1-2 mns</td>
</tr>
<tr>
<td>1980</td>
<td>NYSE</td>
<td>Upgrades on floor</td>
<td>2mns to 20 sds</td>
</tr>
<tr>
<td>Circa 2005</td>
<td>Electronic.</td>
<td>Co-location</td>
<td>sd to nano sds</td>
</tr>
</tbody>
</table>
Liquidity spillovers

- Liquidity providers in one asset class increasingly rely on the information contained in prices of other assets.
  - In part because price information is more widely and more quickly disseminated.
- Interconnected liquidity

Why?

1. Prices = signals
2. "Signal-to-noise" ratio is low when markets are liquid: Prices are more informative when liquidity is higher and vice versa:
3. Self-reinforcing loop between price informativeness and liquidity generates liquidity spillovers.
Contagion and Illiquidity Multiplier

Figure 2: Cross-asset learning and liquidity spillovers.
Main properties of the model

- **Spillovers and fragility**
  1. **Interconnected liquidity**: liquidity measures of each asset are **positively** inter-connected → an increase in illiquidity for one asset worsens the liquidity for **all** other assets.
  2. **Illiquidity multiplier**: Small shocks to the liquidity of one asset are amplified through feedback effects → can have disproportionately large effects on the liquidity of all assets.
  3. **Liquidity crashes**: Parameter values for which a small shock to one asset can lead to a market wide liquidity dry-ups (“liquidity crash”).
  4. **Multiple rational expectations equilibria with high or low levels of illiquidity in all securities** → another source of fragility.
Implications

- "Liquidity externality:" A change in market structure or regulation directly affecting the liquidity of one asset class should affect liquidity of other classes.
  
  1. Important for the design of new rules affecting liquidity (e.g., a short sale ban for stocks, greater transparency for a subset of bonds etc.)

- Co-movements in liquidity:
  
  1. Bigger when information on prices for two assets is more widely disseminated
  2. Smaller when there is more capital devoted to arbitrage between two assets.

- Measuring the strength of liquidity spillovers from one asset to another can be used to assess the illiquidity multiplier $\rightarrow$ Early warning indicators for liquidity crashes.
Introduction: Research Question

Model
The Model

- **Two assets** $D$ ("Derivative") and $F$ ("Stock")

- **Securities Payoffs at date $t=2$:**
  
  \[
  v_D = \underbrace{\delta_D}_{\text{Risk factor } D} + d_D \times \underbrace{\delta_F}_{\text{Risk factor } F} + \underbrace{\eta_D}_{\text{Idiosyncratic Risk } D},
  \]
  
  \[
  v_F = \underbrace{\delta_F}_{\text{Risk factor } F} + d_F \times \underbrace{\delta_D}_{\text{Risk factor } D} + \underbrace{\eta_F}_{\text{Idiosyncratic Risk } F},
  \]

- **$v_j$: Cash-Flow Asset $j \in \{D, F\}$**
Market Participants

- **Trades at date $t=1$. In each market:**
  1. Risk averse dealers;
  2. Risk averse “cross-market arbitrageurs”;
  3. Liquidity traders’ "Demand shocks". (Dealers’ clients). They want to trade $u_j$ units of asset $j$.

- **Both arbitrageurs and dealers supply liquidity to liquidity traders**

- **Dealers and arbitrageurs have different "business models"**
  1. Dealers have expertise in assessing one risk factor and they specialize on the asset in which they have expertise $\Rightarrow$ Dealers specialized in different assets have different information.
  2. Arbitrageurs have no information on risk factors but engage in cross-market hedging to reduce the risk of their portfolios.
Market Participants

- **Dealers in security $j$:**
  1. Observe ("monitors") the price in the other market
  2. Choose their position to maximize their expected profit
  3. **Information for dealers in asset $j = \{\text{price}_F, \text{price}_D, \text{risk factor}_j\}$.**

- **Cross-market arbitrageurs:**
  1. Have no private information
  2. Choose their arbitrage portfolio to maximize the expected profit of their arbitrage portfolio.
Equilibrium

In each asset, equilibrium at date $t=1$: prices adjust so that:

Dealers + Arbitrageurs' position

=

Liquidity traders’ Net Order Imbalance.
Plan

1. **Introduction: Research Question**
2. **Model**
3. **Benchmark: Segmented Markets**
Benchmark

- **Segmented markets:** No price monitoring/No arbitrageurs
- **The equilibrium is unique.**
- **Prices:**

\[
\text{Price Asset } j = \delta_j + \text{Illiq}^\text{bench}_j \times u_j
\]

- \(\text{Illiq}^\text{bench}_j\) = Sensitivity of price to liquidity demand = "Illiquidity of security \(j\)." Equilibrium:

\[
\text{Illiq}^\text{bench}_j = \frac{\text{Risk Asset } j \text{ as perceived by Dealers in Asset } j}{\text{Risk Appetite Dealers in Asset } j}
\]

- Shocks to "liquidity fundamentals" in one market do not affect the other market → **No liquidity spillovers if no cross-asset learning.**
Price informativeness and liquidity

- The price of security $j$ is a noisy signal about risk factor $\delta_j$:

  $\text{Price Asset } j = \delta_j + \text{Illicj}_{\text{benc}} \times u_j$

- The informativeness of security $D$ for dealers in security $F$ depends on the liquidity of security $D$ and vice versa.
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No arbitrageurs, All Dealers Monitor Prices

- In equilibrium:

\[
\text{Price Asset } j = \mathbb{E}(v_j|\delta_j, \text{Price Information}) + \text{Illiq}_j \times u_j
\]

with

\[
\text{Illiq}_j = \text{Illiq}_{j\text{bench}}(1 - \text{Info}_j)
\]

Illiquidity with wide dissemination of price info

- Variable $\text{Info}_j$ measures the informativeness of the price of security $-j$ about the payoff of security $j$ for dealers in security $j$. It is inversely related to the illiquidity of asset $-j$. 
Self-reinforcing illiquidity

- **Illiquidity of security** $F \rightarrow \nabla$ **Informativeness of the price of security** $F \rightarrow \nabla$ **Illiquidity of security** $D$ and vice versa

- **Solving for the equilibrium** $\iff$ Find solutions to:

$$Illiq_D = f_D(Illiq_F; \text{parameters})$$
$$Illiq_F = f_F(Illiq_D; \text{parameters})$$

- **Interconnected liquidity/Positive Liquidity spillovers**
Self-reinforcing illiquidity

- **X-axis**: Illiquidity asset F; **Y-axis**: Illiquidity asset D.
Self-reinforcing illiquidity

- Suppose that the risk appetite of dealers in security $D$ decreases:

  1. Security $D$ becomes less liquid: $B_{D1} \uparrow$
  2. Hence the price of security $D$ is less informative for dealers in security $F$.
  3. Thus, inventory risk is higher for dealers in security $F$ and security $F$ becomes less liquid: $B_{F1} \uparrow$.

- More generally, a shock to the liquidity fundamental of one security induces a change in the same direction for the liquidity of securities $D$ and $F \implies$ positive co-movements in liquidity.
Figure 2: Cross-asset learning and liquidity spillovers.
The illiquidity multiplier

- **Liquidity is fragile**: A small shock to the illiquidity of one market can trigger large changes in the liquidity of both markets.

- **Example**: Effect of a 1% decrease in risk appetite on illiquidities

<table>
<thead>
<tr>
<th>Risk Appetite</th>
<th>Dealer D</th>
<th>w/feedback</th>
<th>w/o feedback</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>D</td>
<td>F</td>
<td>D</td>
</tr>
<tr>
<td>+2%</td>
<td>6.11%</td>
<td>18.9%</td>
<td>1%</td>
</tr>
<tr>
<td>+1%</td>
<td>9.42%</td>
<td>27%</td>
<td>1%</td>
</tr>
<tr>
<td>Base</td>
<td>1779%</td>
<td>3829%</td>
<td>1%</td>
</tr>
<tr>
<td>-1%</td>
<td>9.37%</td>
<td>16%</td>
<td>1%</td>
</tr>
<tr>
<td>-2%</td>
<td>6.05%</td>
<td>9%</td>
<td>1%</td>
</tr>
</tbody>
</table>
Cross-Asset Learning and Interconnected liquidity

Liquidity Crashes

- **High illiquidity multiplier** → a small change in the economic environment of one asset (e.g., a small decrease in risk appetite of dealers in asset D) can trigger a very large increase in illiquidity for all assets
- **→ the illiquidity multiplier is a source of "liquidity dry-ups"/"liquidity crashes".**
- **Consequence:** a small decrease in risk appetite can generate a large increase in price impacts and volatility across all stocks → Liquidity dry-ups are a source of risk.
Liquidity Crashes and Price Volatility

- **X Axis:** Dealers’ Risk Appetite in Asset D; **Y-Axis:** Price volatilities for Asset D (Left panel) and Asset F (Right panel)
Early warning indicators

- How to detect whether markets are exposed to liquidity dry-ups? whether the illiquidity multiplier is high?
- Consider a regression of the illiquidity of market $j$ on the illiquidity of market $-j$:

$$\text{Liquidity}_j = a_0 + \beta_j \times \text{Liquidity}_{-j} + \text{Ctrl Variables} + \eta_j$$

**Note:** Identifying $\beta_j$ is not straightforward (endogeneity)....

- The illiquidity multiplier in our model is:

$$\text{Illiquidity Multiplier} = \text{Inverse of (1-Product of } \beta_{js})$$

- $\implies$ High $\beta_{js}$ signals fragility...
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The role of cross-price observability

- Observing the price of some assets is sometimes difficult (e.g., assets that trade OTC, such as bonds, CDS etc.)

- What is the effect of varying the number of dealers in one asset who can observe the price of the other asset?
Equilibrium with inattentive dealers

- Two types of dealers in each security:
  1. "Pricewatchers"
  2. "Inattentive dealers:" Dealers with no price information

- Inattentive dealers are less informed than pricewatchers

1. Differential access to price information by a fraction of dealers is a source of adverse selection.
2. Analysis is similar but more complex.

# Pricewatchers is higher if wider dissemination of price information.
Implications

- **Co-movements:**
  1. The size of co-movements in liquidity increases in the fraction of pricewatchers in either assets: broader dissemination of prices is a source of commonalities in liquidity.
  2. Could be one force behind the secular increase in commonalities over the last 30 years (see Kamara et al. (2008)).

- **A wider dissemination of prices (greater market transparency) for, say, asset $F$ makes asset $D$ more liquid.**
  1. Consistent with evidence regarding the effects of greater bond market transparency in the U.S. (implementation of the TRACE price reporting system in 2002).
  2. Liquidity of bonds ineligible for TRACE improved even though nothing changed for these bonds (see Bessembinder et al. (2006)).
Co-movements in liquidity and price information

- **X Axis:** Fraction of pricewatchers in Asset F; **Y-Axis:** Size of co-movements between assets $D$ and $F$.

- **Testable prediction:** co-movements in liquidity become stronger when price information is more widely disseminated.
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Cross-market arbitrageurs

- **Cross-market arbitrageurs** = cross-market dealers.

"Cross-market strategies primarily focus on the contemporaneous trading of securities-related products [...] to capture temporary price differences between any two related products, but with limited or no exposure to subsequent price moves in those products [...] Some firms focus on “one-way” strategies by acting as a liquidity provider (i.e., trading passively by submitting non-marketable resting orders) primarily in one product, and then hedging by trading another product." (CFTC-SEC(2010)).
Cross-market arbitrageurs and market integration

- **Cross-market arbitrageurs do exactly this in our model:** if liquidity traders sell one asset, they will provide liquidity by buying the asset and hedge their positions by selling the other asset.

- **Results are qualitatively unchanged with arbitrageurs. In particular:**
  1. The informativeness of prices is not affected (arbitrageurs have no information and their flows are known once prices are known).
  2. The parameters for which multiple equilibria are obtained are exactly the same with and without cross-market arbitrageurs.
  3. The presence of arbitrageurs dampens the illiquidity multiplier and the size of illiquidity co-movements but do not suppress it.
Co-movement and Arbitrage Capital

**Example:** The covariance in the illiquidity in both markets as a function of arbitrage capital ($\lambda$) devoted to arbitrage between $F$ and $D$. 

![Graph showing Covariance between $B_D$ and $B_F$]
Conclusions

Thanks!

(latest version of the paper is available at: http://www.hec.fr/foucault)