Market Quality Breakdowns in Equities

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How frequently do breakdowns in market quality occur?

- We analyze every change in the listing exchanges’ best bid and offer for 1993 – 2011.

What causes market quality breakdowns?

- We explore explanations with regard to changes in market structure and correlation.
Regulatory Changes:

- The biggest change was the adoption of Reg. NMS in April 2005. The new regulations were extended in stages and were fully in place by October 15, 2007.
- Market quality breakdowns are 41.78% less frequent after Reg. NMS.

Market Fragmentation:

- Madhavan (2012) emphasizes the fragmentation and claims fragmented markets are more fragile.
- Jiang, McInish and Upson (2011) take the contrary view.
- Madhavan’s Herfindahl index measure does not explain the breakdown frequency over a longer historical period.
Exchange Effects:

- Controlling for market capitalization, price, volume and volatility, exchanges still matter.
- NYSE stocks break down 20.03% less frequently than Nasdaq stocks, 43.91% less frequently than AMEX listings, and 69.04% less frequently than ARCA listings.

Market Correlation:

- The average correlation among the Fama-French industry portfolios rises from 37.16% in 1993 to 76.32% in 2011.
- Correlation does spike during market quality breakdowns, raising the frequency of breakdowns by 25.62%.
Exchange Traded Funds:

- Ben-David, Franzoni, and Moussawi (2014) note that ETFs exacerbate the volatility of the underlying stocks through the propagation of liquidity shocks.
- ETFs break down 90.33% more frequently than non-ETFs.

High Frequency Trading:

- Some papers suggest that HFT firms generally enhance market quality, e.g. Hasbrouck and Saar (2013), Brogaard, Hendershott and Riordan (2014).
- Other papers show that HFT activity might be more harmful, e.g. Brogaard, Hendershott and Riordan (2013), Gao and Mizrach (2013).
- We find that HFT raises the breakdown frequency by 18.33%.
Our analysis relies on quotes rather than trades.

Our focus is on the best bid and offer from the listing exchange, but we examine the robustness of our findings by looking at alternative definitions.

We analyze stocks that are in both the CRSP and the NYSE TAQ databases.

We exclude quotes with bids greater than or equal to offers. Quotes with non-positive prices or depths are also omitted.
We look at movements in the time frame 09:35-15:55, because opening and closing procedures vary across exchanges and may not be comparable. A stock is identified as having a market quality breakdown if

1. **Breakdown**: the best bid prices fall 10% or more below the 09:35 price;
2. **Recovery**: the price must rebound to at least 2.5% below the 09:35 price at 15:55;
3. **Not fleeting**: the low tick must be repeated at least once in a subsequent calendar second.
Market Quality Metrics for the Flash Crash

Introduction

Data and Definitions

Breakdown

Frequency

Market Structure

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Robustness Checks

Conclusions
Timing of Lows on May 6, 2010 14:00-15:00

[Graph showing market data]

Source: CFTC-SEC (2010)
Breakdown Frequency

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Number of Breakdowns

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The daily average breakdown frequency is 0.64% throughout our sample period, an average of 44 stocks per day.

Despite the Flash Crash, 2010 has the fewest breakdowns of any year since 2007. The breakdown frequency is 0.39% in 2011, half the rate of 1998 when humans provided the majority of quotes. Breakdowns in 2010-2011 occur less than once per year in a typical stock.
We model the aggregate frequency of breakdown events conditional on market volatility and volume.

We measure market volatility using the opening value of the VIX.

The daily volume is the sum of trading activity on each exchange in its own listings.

We use a dummy variable, $\tilde{v}_t$, to represent volume spikes

$$
\tilde{v}_t = I_{\alpha=0.05} \left( \frac{v_t - \sum_{j=1}^{20} v_{t-j}/20}{\sigma_t^v} \right)
$$
Baseline Model

- We use a generalized linear model with gamma probability distribution, and it is estimated by quasi-maximum likelihood method using robust standard errors.

\[
\log(\mathbb{E}[\pi_t]) = \alpha + \beta_1 \sigma_t^{VIX_{open}} + \beta_2 \tilde{\nu}_t
\]

<table>
<thead>
<tr>
<th>Variable</th>
<th>(\alpha)</th>
<th>(\beta_1)</th>
<th>(\beta_2)</th>
<th>(R^2_M)</th>
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<td>(t-stat)</td>
<td>(70.07)</td>
<td>(47.66)</td>
<td>(4.44)</td>
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</tbody>
</table>

- We measure goodness-of-fit using McFadden’s measure, \(R^2_M\), which is defined as

\[
R^2_M = 1 - \frac{\log L(M_f)}{\log L(M_i)}
\]
Effect of Reg. NMS on Breakdown Frequency

- We model whether crashes increased after the rules were fully adopted on October 15, 2007, by including a dummy variable $d^{NMS}$.

$$\log(E[\pi_t]) = \alpha + \beta_1 \sigma_t^{VIX_{open}} + \beta_2 \tilde{V}_t + \theta_1 d^{NMS}$$

<table>
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<tr>
<th>Variable</th>
<th>$\alpha$</th>
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<th>$\beta_2$</th>
<th>$\theta_1$</th>
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<td>($t$-stat)</td>
<td>(71.74)</td>
<td>(49.97)</td>
<td>(4.23)</td>
<td>(13.27)</td>
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</table>

- Quantitatively, Reg. NMS has reduced breakdowns by $e^{-0.5410} - 1 = -41.78\%$.

- With approximately 7,000 U.S. equity listings, this implies that 16 fewer stocks each day are experiencing breakdowns or approximately 4,000 fewer breakdown events each year.
### Impact of Market Fragmentation

- **The Herfindahl index 1993-2011**

\[
\log (E[\pi_t]) = \alpha + \beta_1 \sigma_t^{VIX_{open}} + \beta_2 \tilde{v}_t + \theta_1 d^{NMS} + \theta_2 \tilde{H}_t
\]

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<tr>
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<td>(t-stat)</td>
<td>(71.37)</td>
<td>(50.19)</td>
<td>(4.23)</td>
<td>(13.37)</td>
<td>(0.27)</td>
<td></td>
</tr>
</tbody>
</table>

- **The % of volume executed in TRFs 2007-2011**

\[
\log (E[\pi_t]) = \alpha + \beta_1 \sigma_t^{VIX_{open}} + \beta_2 \tilde{v}_t + \theta_2 \tilde{TRF}_t
\]

<table>
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<td>(36.58)</td>
<td>(27.35)</td>
<td>(3.32)</td>
<td>(1.61)</td>
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Breakdown Frequency by Exchange
We model breakdown occurrences of individual stocks in pooled panel regression.

We include the covariates from the baseline model and add the log opening price of the stock, $p_{i,t}^{open}$, and its log market capitalization, $\kappa_{i,t}$.

$$\log(\mathbb{E}[n_{i,t}]) = \alpha + \beta_1 p_{i,t}^{open} + \beta_2 \kappa_{i,t} + \beta_3 \sigma_{i,t} + \beta_4 \tilde{V}_{i,t} + \theta_1 d^{NYSE}_{i,t} + \theta_2 d^{NASDAQ}_{i,t} + \theta_3 d^{ARCA}_{i,t}$$

<table>
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<tr>
<th>Variable</th>
<th>$\theta_1$</th>
<th>$\theta_2$</th>
<th>$\theta_3$</th>
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<td>(44.47)</td>
<td>(34.71)</td>
<td>(18.02)</td>
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NYSE listed stocks break down approximately 20.03% less frequently than Nasdaq stocks, 43.91% less frequently than AMEX listings, and 69.04% less frequently than ARCA listings.
We construct a theoretical model with correlated liquidity shocks based on Sandås (2001).

- Two risky assets, A and B.
- Two types of agents, market makers and traders.
- The bid prices in the book of asset $i$ are denoted by $\{p_1^i, p_2^i, \ldots, p_k^i\}$, where $p_1^i$ is the best bid price.
- Let $\{Q_1^i, Q_2^i, \ldots, Q_k^i\}$ denote the order quantities associated with each price.
- The market order quantity for asset $i$ is denoted by $m^i$. It is positive for buy orders, and negative for sell orders.

$$f\left(m^A, m^B\right) = \frac{1}{\lambda^A \lambda^B} e^{\frac{m^A}{\lambda^A} + \frac{m^B}{\lambda^B}} \left[1 + 4\rho \left(1 - 2e^{\frac{m^A}{\lambda^A}}\right) \left(1 - 2e^{\frac{m^B}{\lambda^B}}\right)\right],$$

$s^A \leq 0$, $m^B \leq 0$ and $-1 \leq \rho \leq 1$. 
Cross-asset Effects of Market Orders

We are more interested in the cross-asset effect of market orders on the limit order book. To analyze it we take the derivative of $Q^A_1$ with respect to $m^B$,

$$\frac{\partial Q^A_1}{\partial m^B} = \frac{\beta + 4\rho C}{\alpha + 4\rho D},$$

where

$$C = \beta \left(1 - 2e^{m^B/\lambda^B}\right) \left(1 - e^{-Q^A_1/\lambda^A}\right) + \alpha \frac{\lambda^A}{\lambda^B} e^{m^B/\lambda^B}$$

$$+ \frac{2}{\lambda^B} e^{m^B/\lambda^B} \left(1 - e^{-Q^A_1/\lambda^A}\right) \left(p^A_1 - c - X^A_t + \alpha \left(Q^A_1 + \lambda^A/2\right) - \beta m^B\right)$$

$$D = \alpha \left(1 - 2e^{m^B/\lambda^B}\right) \left(1 - e^{-Q^A_1/\lambda^A}\right)$$

$$+ \frac{1}{\lambda^A} e^{-Q^A_1/\lambda^A} \left(1 - 2e^{m^B/\lambda^B}\right) \left(p^A_1 - c - X^A_t + \alpha \left(Q^A_1 + \lambda^A/2\right) - \beta m^B\right).$$

If $1 - 2e^{m^B/\lambda^B} > 0$ and $p^A_1 - c - X^A_t + \alpha \left(Q^A_1 + \lambda^A/2\right) - \beta m^B > 0$, then both $C > 0$ and $D > 0$. 
For a market sell order on Asset $B$, $m^B \leq 0$, this trade will also reduce the depth at the best bid price level of Asset $A$.

Generally, a market buy order in security $B$ will increase the bid depth in security $A$.

When $\rho$ increases, the cross-asset effect of a market sell or buy order is even stronger.
We construct the correlation measure using daily returns of 30 Fama-French industry portfolios.
- We find correlation spikes are driving market quality breakdowns.
- Spikes in market correlation raise the breakdown frequency by 25.62%.

\[
\log(E[\pi_t]) = \alpha + \beta_1 \sigma_t^{\text{VIXopen}} + \beta_2 \tilde{v}_t + \beta_3 d^{\text{NMS}} + \beta_4 \tilde{\rho}_t
\]

<table>
<thead>
<tr>
<th>Variable</th>
<th>$\alpha$</th>
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<td>(4.48)</td>
<td>(14.36)</td>
<td>(3.21)</td>
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</table>
Causes of Market Correlation

Panel A: Exchange Traded Funds

\( H_0: \) ETF volume does not Granger cause market correlation.
\[
F\text{-stat} \quad 7.20 \quad p\text{-value} \quad 0.0000
\]

\( H_0: \) market correlation does not Granger cause ETF volume.
\[
F\text{-stat} \quad 1.36 \quad p\text{-value} \quad 0.2446
\]

Panel B: High Frequency Trading 2008-2009

\( H_0: \) HFT\% does not Granger cause market correlation.
\[
F\text{-stat} \quad 3.65 \quad p\text{-value} \quad 0.0058
\]

\( H_0: \) market correlation does not Granger cause HFT\%.
\[
F\text{-stat} \quad 2.07 \quad p\text{-value} \quad 0.0833
\]
We investigate whether ETFs are unstable by including a dummy variable for ETFs into the individual stock model.

ETFs exhibit significantly higher likelihood of breakdowns than non-ETFs after controls. ETFs break down 90.33% more frequently.

If the market is consisted exclusively of ETFs, there would be greater than 9,000 more breakdowns per year.
We use an HFT dataset that includes all trades on the Nasdaq exchange for 120 stocks on each trading date in 2008 and 2009.

We measure HFT activity as the share of volume executed by HFT firms in a trading day.

The marginal effect of correlation spikes is 31.31% from 2008-2009, and spikes in HFT activity raise the breakdown frequency an additional 18.33%.

\[
\log(\mathbb{E}[\pi_t]) = \alpha + \beta_1 \sigma_t^{\text{VIXopen}} + \beta_2 \tilde{v}_t + \beta_3 \tilde{HFT}_t + \beta_4 \tilde{\rho}_t
\]

<table>
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<tr>
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<td>0.1683</td>
<td>0.2427</td>
<td>0.2340</td>
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<tr>
<td>(t-stat)</td>
<td>(18.24)</td>
<td>(19.26)</td>
<td>(3.80)</td>
<td>(2.15)</td>
<td>(2.65)</td>
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Breakdowns are Predictable

We take the 09:30 opening value of the VIX, and add the two prior days’ probabilities.

\[ \log(E[\pi_t]) = \alpha + \beta_1 \sigma_t^{VIX_{open}} + \sum_{j=1}^{2} \eta_j \pi_{t-j} \]

<table>
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<tr>
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<th>(R_M^2)</th>
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<td>0.3059</td>
<td>0.4936</td>
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<tr>
<td>(t\text{-stat})</td>
<td>(48.12)</td>
<td>(10.64)</td>
<td>(3.74)</td>
<td>(3.33)</td>
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Robustness Checks

Our results are quite robust to perturbations in metric values.
- e.g. 15% decline rather than 10%, close flat rather than down 2.5%, and etc.

"Breakups":
- breakdowns on the offer side of the limit order book.

Our results are not being driven solely by low-liquidity securities.
  - a purely large market capitalization sample.

We also consider alternative microstructure definition:
  - the national best bid or offer (NBBO);
  - trading breakdowns.
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Unconditional Frequency Comparison
## Models for Robustness Checks

<table>
<thead>
<tr>
<th>Filter</th>
<th>Since Reg. NMS</th>
<th>$\rho$ Spikes</th>
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<tr>
<td>Primary Listing</td>
<td>-41.78%</td>
<td>25.62%</td>
</tr>
<tr>
<td>Breakups</td>
<td>1.00%</td>
<td>8.915%</td>
</tr>
<tr>
<td>Large Caps</td>
<td>-91.81%</td>
<td>121.90%</td>
</tr>
<tr>
<td>NBBO</td>
<td>-60.61%</td>
<td>17.62%</td>
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<tr>
<td>Trades</td>
<td>-79.91%</td>
<td>31.19%</td>
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Market quality breakdowns have a daily average frequency of 0.64%, approximately 44 stocks per day.

Volume and volatility are still the prime causes of market quality breakdowns, improving the likelihood by more than 40% over a model with just a constant term.

The daily probability of breakdowns has fallen 41.78% since Reg NMS.

Market fragmentation does not have a statistically significant impact on the breakdown frequency.

Spikes in market correlation make breakdowns 25.62% more likely.

Both ETFs and HFT activity Granger cause the market correlation.

ETFs break down more often than non-ETFs.

Breakdowns are predictable.