Quantitative law describing market dynamics before and after interest-rate change.


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before and after interest-rate change
(can we better understand market crashes by studying market dynamics?)
1. What kind of perturbations occur in the stock market?
2. Case study: Federal Interest Rate change announcements
3. Response dynamics before in addition to after market shocks

Outline

Motivation: A better understanding of response dynamics in financial markets can help prepare emergency plans for financial crises
Part 1)

Typical perturbations in the Stock Market

- Earnings forecast & report (quarterly)
- Upgrades, Downgrades
- Stock split announcement, Dividends announcement
- Generic News: unemployment reports, consumer confidence reports
- Political events, national catastrophe


Company specific or global:

- Earnings forecast & report (quarterly)
Part 2: Probing market response dynamics using common Fed interest-rate changes
Federal Interest Rates (set benchmarks for banks)

- The Federal Interest Target rate \( R(t) \) is set by the U.S. Federal Reserve (Fed) at Federal Open Market Committee (FOMC) meetings (denoted by \( \bullet \)). These meetings are scheduled in advance and announced publicly.

- Interest rates change by "step function" at FOMC meetings.

The Federal Interest Target Rate \( R(t) \) is set by the U.S. Federal Reserve (Fed) at Federal Open Market Committee (FOMC) meetings (denoted by \( \bullet \)). These meetings are scheduled in advance and announced publicly.
The Effective rate fluctuates around the Target rate

The Federal Interest Target rate $R(t)$, is set by the U.S. Federal Reserve (Fed) at Federal Open Market Committee (FOMC) meetings (denoted by •).

The Federal Interest Effective rate $F(t)$, ("overnight rate") is an open market realization of the Target rate.

(2) Federal Interest Rates (set benchmarks for banks)
The T-Bill anticipates movement in the Target rate

Federal Interest Rates (set benchmarks for banks)

- The Federal Interest Target rate \( R(t) \), is set by the U.S. Federal Reserve (Fed) at Federal Open Market Committee (FOMC) meetings (denoted by \( \bullet \)).
- The Federal Interest Effective rate \( F(t) \), is set by the U.S. Federal Reserve (Fed) and is an open market realization of the Target rate.
- U.S. Treasury Bills \( B(t) \), are a "riskless" security issued by the U.S. Treasury.
- The T-Bill anticipates movement in the Target rate.

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- U.S. Treasury Bills $B(t)$, are a type of security issued by the U.S. Treasury.

A large set of frequent events to study!

12/14/2004
Using \( F(t) \) and \( B(t) \) we can quantify market speculation:

\[
\Theta \equiv \Theta^i(t) = \ln F(t) - \ln B(t)
\]

Relative "Spread" \( \delta(t) \):

1) \( \Theta^i(t) = \Phi(t) \in F(t) \)
2) \( \Phi(t) \in B(t) \)

Market speculation, concerned with whether or not the rate will be increased and by how much, causes anticipation (stress) in the markets prior to the scheduled meeting announcements. The value of the T-Bill \( B(t) \) is closely linked to the value of the Federal Target Rate \( R(t) \) and Effective Rate \( F(t) \).
Part 3(a):

- How important are Fed announcements?
- Can we quantify the speculation related to the financial shock?
Daily market volatility $v(t) = \ln[p_{hi}(t)/p_{low}(t)]$ is the high-low price range within one trading day calculated using daily price data for the top 100 companies in the S&P500 for the 8-year period 2000-2008. We define FOMC meeting volatility $V_i = v_i(\Delta t = 0)$ as the average market volatility $\langle v(\Delta t) \rangle = \frac{1}{66} \sum_{i=1}^{66} v_i(\Delta t)$ over 66 meetings before and after a FOMC announcement. $\langle v(\Delta t) \rangle$ indicates a significant increase in market volatility on FOMC announcement days, with an average increase of ~15-20%.
- Response dynamics both before and after the time of the Fed announcement
Market volatility: intraday time scale

\[ v(t) = \ln p(t) - \ln p(t - dt) \]

\[ \left\{ \begin{array}{l}
    b \leq (1)^\lambda \\
    b > (1)^\lambda
\end{array} \right\} \times \frac{1p}{1} = (1p|1)^b\lambda \]

\[ |(1p - 1)d\ln - (1)d\ln| = (1p|1)^\lambda \]

Data analyzed: TAQ (trades and quotes) for the top 100 companies in the S&P500. We refined data for each transaction into 1-minute time resolution time series for each company, together comprising ~ 20 x 10^6 data values.

For each company, we calculate the intraday market volatility in units of the standard deviation of the given company, allowing for cross-comparison.

We next study how the rate of events above a volatility threshold evolves with time, before and after the announcement of the interest-rate change occurring at time T_{FOMC}.

\[ T_{FOMC} = 90 \text{ min.} \]

\[ \lambda = 4 \text{, } b = 10 \]

\[ April 18, 2001 \]

Cascading aftershocks immediately after T_{FOMC}
Market volatility: intraday time scale

\( N(t) = \int_0^T \sigma(t) dt \)

- Data analyzed: TAQ (trades and quotes) for the top 100 companies in the S&P500. We refined data for each transaction into 1-minute time resolution time series for each company, together comprising ~20 x 10^6 data values.

- For each company, we calculate the intraday market volatility \( \sigma(t) \) in units of the standard deviation of the given company, allowing for cross-comparison.

- We next study how the rate of events above a volatility threshold \( q \) evolves with time, before and after the announcement of the interest-rate change occurring at time \( T \) 

We cascade aftershocks immediately after \( T \) 

\( \text{FOMC} \)

\( T = 90 \text{ min.} \)

\( q = 3 \)

\( \sigma = b \)

\( 04/18/2001 \)

\( 04/18/2001 \)
3) The Omori aftershock law predicts the volatility decay pattern after a market crash.

- The Omori law quantifies the rate \( n(t) \) of earthquake aftershocks.
- Econophysicists use the Omori law to quantify the decay of volatility after market crashes (Lillo & Mantegna, 2003; Weber et al., 2007; Petersen et al., 2010).

\[
I(t) = b \\
\text{min} \quad 0 = T \\
\gamma = 0.28
\]

\[
N(t) \sim \alpha |t - T|^{-\Omega}
\]

\[
S & P 100 \]

\[
\text{Average market volatility}
\]

\[
\text{Omori-law aftershocks occur on all scales}
\]

\[
\int_{-\infty}^{\infty} |L - t| P(|L - t|) d|L - t| = (|L - t|)N
\]

\[
\gamma |L - t|^{\omega} \sim (|L - t|)^{\alpha}
\]
We find that the Omori law describes the decay of aftershocks in financial markets following FOMC news on the 1-min time resolution for 19 FOMC meetings in the 2-year period 2001-2002.

Market response is the same for both financial news and financial crises, reminiscent of scale-free behavior found in many complex systems.

The regularity in the FOMC meeting conditions allows us to aggregate and analyze many FOMC events.

- For scheduled meetings, T is typically 2:15 pm ET (285 minutes).
- Following FOMC news on the 1-min time resolution for 19 FOMC meetings in the 2-year period 2001-2002.

We find that the Omori law describes the decay of aftershocks in financial markets.
We identify significant precursors that are also described by an "inverse" Omori-law.

For each FOMC meeting we quantify the market response calculating the Omori amplitude \( \alpha \) and the Omori decay exponent \( \beta \).

We analyze both before and after a FOMC event using the displaced time \( t' \), and the Omori amplitude \( \sigma \).

For each FOMC meeting we quantify the market response calculating:

- \( 19 \) FOMC events
- \( 285 \) min before the FOMC event
- \( 105 \) min after the FOMC event

\[ |t - t'| = t' \]
triggers cascade; recovery of US economy also
Chairman Greenspan about
Public statement by Fed.
Non-FOMC market shock:
Omori-law can extend for several days

Other examples
the Sign Effect are also consistent with Omori parameter values.

The Speculation quantifies the market sentiment before the announcement. In the case of \( \Delta t > 0 \), corresponding to bad market sentiment and a possible rate decrease, the dynamics before and after the announcement have large amplitude. A smaller decay exponent \( \theta \) represents a longer aftershock.

Bank Sector: 18 financial companies

\( \Delta t \) response-time

Amplitude. A smaller decay exponent \( \theta \) represents a longer aftershock. In the case of \( \Delta t > 0 \), corresponding to bad market sentiment and a possible rate decrease, the dynamics before and after the announcement have large amplitude. The Speculation quantifies the market sentiment before the announcement. In the case of \( \Delta t > 0 \), corresponding to bad market sentiment and a possible rate decrease, the dynamics before and after the announcement have large amplitude.

3) Omori response parameters \( \Theta \) and \( \beta \).
The Omori exponent $\langle q \rangle$ is related to the amount of market "surprise":

- Bigger surprise $\rightarrow$ longer time for market to adjust
- The Omori exponent $\langle q \rangle$ is related to the amount of market "surprise"

- Systems
  - Financial crises, reminiscent of scale-free behavior found in many complex systems.
  - The response of the stock market is the same for both financial news and financial crises, reminiscent of scale-free behavior found in many complex systems.


- Possibility that there is a universal underlying mechanism (e.g., non-linear shot noise) which governs cascading dynamics in financial markets for a large range of market shock size $A$, M. Petersen, F. Wang, S. Havlin, and H. E. Stanley, Market dynamics immediately before and after financial shocks: quantifying the Omori, productivity, and bath laws. Phys. Rev. E 81, 066121 (2010).

- For up to 3 days after for banking companies following FOMC news (global perturbation) market cascades that can last $L$.

Summary & Take Home Message

- A better understanding of response dynamics in financial markets can help prepare emergency plans for financial crises.

- Omori law (power-law) describes the decay of aftershocks in financial markets.
Thank You!

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ICE 2011, Shanghai!

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Thank You!
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Abstract

Significant volatility after shocks, confirming a "market underreaction" that lasts at least 1 trading day. Results are consistent with the "sign effect," in which "bad news" has a larger impact than "good news." Furthermore, we observe a significant news effect, which we attribute to the relative difference between the U.S. Treasury Bill and the Federal Funds Effective Rate. Our findings are consistent with the Omori earthquake law. We demonstrate that the news associated with interest rate change causes a financial shock, and its magnitude is determined by the relative difference between the U.S. Treasury Bill and the Federal Funds Effective Rate. As a first case study, we present the market response to U.S. Federal Reserve announcements, showing that the dynamics after the announcement is described by a simpler version of the Omori earthquake law. Our results are consistent with the "sign effect," in which "bad news" has a larger impact than "good news." Furthermore, we observe significant volatility after shocks, confirming a "market underreaction" that lasts at least 1 trading day.
Markets are more volatile when anticipating rate decrease ($R > 0$)

\[ q(i) \equiv \Theta \]

"Speculation":

\[ g(i) \equiv \ln B(i) - \ln F(i) \]

Relative "Spread" $g(t)$:

- **Sign Effect**: Asymmetric response to "bad" and "good" news
  - Sign Effect = market volatility is larger in response to "bad news" as compared to "good news".
  - Rate decreases ($R < 0$), which encourage borrowing and increase money liquidity, typically correspond to "bad news".
  - $q(i)$ quantifies the "speculation" over a rate change in the week before the FOMC meeting.
  - Volatility $V_i$:
    - FOMC meeting volatility $V_i$:
      - $\Theta$: quantifies the "speculation" over a rate change in the week before the FOMC meeting.
      - Liquidity, typically correspond to bad news.
    - Sign Effect = market volatility is larger in response to "bad news" as compared to "good news".

\[ (0 = RV) \quad \forall i \quad \forall V \]

\[ N = 66 \quad F = 6.125 \quad p = 0.016 \]
Federal Interest Rates

- The U.S. Treasury Bill \( B(t) \), is a type of security issued by the U.S. government. These securities are very risk-free, as they are backed by the U.S. government. The "T-Bill" comes in several versions, distinguished by their maturity length (here we consider only the 6-Month T-Bill). These Treasury Bills are very risk-free, as they are backed by the U.S. government.

- Federal interest rates set a benchmark for banks in their day-to-day borrowing and lending activities. The Fed rates serve as both a benchmark and a barometer for the U.S. and global economies. The Federal Reserve sets a benchmark for banks in their day-to-day borrowing and lending activities.

- The Federal Target interest-rate \( R(t) \), is set by the U.S. Federal Reserve (Fed) at Federal Open Market Committee (FOMC) meetings. These meetings are scheduled in advance and announced publicly. Historically, there have been around 8 scheduled FOMC meetings per year.

- The Federal Effective interest-rate \( F(t) \), ("overnight rate") is a weighted average over all lending transactions each day, and oscillates around the \( R(t) \). It is the market realization of the Target rate. \( F(t) \) is a weighted average over all open market transactions each day, and oscillates around the \( R(t) \).