Information Propagation in Financial Markets: The Importance of Attention

Anastassia Fedyk (Harvard Business School)

FDSA Keynote Address

June 20, 2016
Importance of News in Financial Markets

- **Canonical case:** cancer breakthrough in 1997
  - Huberman and Regev (2001)
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  - November 27, 1997: article in Nature, mentioned in popular press (incl. NYT)
  - May 3, 1998: front page article in NYT
    - Content: very similar to that on November 27, 1997
  - No other news on May 3
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A Cure for Cancer: Market Reaction

ENMD stock price reaction on November 27, 1997

ENMD stock price reaction on May 3, 1998
Importance of News in Financial Markets

A Cure for Cancer: Market Reaction

ENMD stock price reaction on November 27, 1997

+28.5%

ENMD stock price reaction on May 3, 1998

+330%
Importance of News in Financial Markets

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Importance of News in Financial Markets
Lessons from “A Cure for Cancer”

1. New information may not receive sufficient attention immediately
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3. Investors’ attention to news is of great import to asset prices
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- **Financial data science**: large datasets of news publication and consumption
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- Financial data science: large datasets of news publication and consumption
  - Understand how information and attention affect markets
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Financial data science: large datasets of news publication and consumption

- Understand how information and attention affect markets
- Inform policies on information dissemination
News Publication and Consumption

- Millions of news stories published per day
- Read by hundreds of thousands of finance professionals, millions of other individuals
News Publication and Consumption

Delay from Publication to Read
Inattention and Gradual Information Diffusion

- Fedyk (2016): understand consequences of new information not receiving attention immediately
Inattention and Gradual Information Diffusion

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1. Slow price adjustment around individual news articles
Inattention and Gradual Information Diffusion

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  2. Post-earnings-announcement drift
Inattention and Gradual Information Diffusion

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  1. Slow price adjustment around individual news articles
  2. Post-earnings-announcement drift
  3. Log-term return momentum
Inattention and Gradual Information Diffusion

Question

Does immediacy of attention predict immediacy of the price response?
Inattention and Gradual Information Diffusion

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Publication timestamp

- $t$
- $t+1\text{ min}$
- $t+5\text{ min}$

Immediate attention

5-minute window
Inattention and Gradual Information Diffusion

Question

Does immediacy of attention predict immediacy of the price response?
Inattention and Gradual Information Diffusion

- Share of immediate attention: \( \frac{Attention_{[t,t+1\text{min}]} \times \text{Attention}_{[t,t+5\text{min}]} }{1} \)
- Share of immediate price change: \( \frac{Price\text{Var}_{[t,t+2\text{min}]} \times Price\text{Var}_{[t,t+5\text{min}]} }{1} \)
Inattention and Gradual Information Diffusion

- Share of immediate attention: \( \frac{Attention_{[t,t+1\,min]}}{Attention_{[t,t+5\,min]}} \)
- Share of immediate price change: \( \frac{PriceVar_{[t,t+2\,min]}}{PriceVar_{[t,t+5\,min]}} \)

<table>
<thead>
<tr>
<th>Click window</th>
<th>Immediate price variance window</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 minute</td>
<td>2 minutes</td>
</tr>
<tr>
<td>1 minute</td>
<td>0.31†</td>
</tr>
<tr>
<td>Standard error</td>
<td>(0.17)</td>
</tr>
<tr>
<td>2 minutes</td>
<td>0.28†</td>
</tr>
<tr>
<td>Standard error</td>
<td>(0.17)</td>
</tr>
</tbody>
</table>

- 10% more immediate attention corresponds to 3% more immediate price variance
Inattention and Gradual Information Diffusion

Post-Earnings-Announcement Drift

- Earnings surprise: difference in actual earnings and expected earnings
  - Expected earnings measured as earnings from same quarter a year ago
  - Normalized by the standard deviation of this measure over 20 quarters

\[
SUE_{i,t} = \frac{Earnings_{i,t} - Earnings_{i,t-4}}{\sigma_{i,[t-20,t-1]}}
\]

Post-earnings-announcement drift phenomenon:
- After positive earnings surprises, price continues to rise for 20-40 days
- After negative earnings surprises, price continues to fall for 20-40 days

[Ball and Brown (1968), Foster, Olsen, and Shevlin (1984), Bernard and Thomas (1989)]
Inattention and Gradual Information Diffusion

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Question

Is the post-earnings-announcement drift driven by delayed attention?
Inattention and Gradual Information Diffusion

Post-Earnings-Announcement Drift

Sort announcing firms based on:

- **Earnings surprise**: $SUE_{i,t}$ for firm $i$ at announcement $t$
- **Attention**: $ImmClicks_{i,t} = \text{percentage of reads on earnings news that occur on the first day}$
Inattention and Gradual Information Diffusion

Post-Earnings-Announcement Drift

- Sort announcing firms based on:
  - Earnings surprise: \( SUE_{i,t} \) for firm \( i \) at announcement \( t \)
  - Attention: \( ImmClicks_{i,t} \) = percentage of reads on earnings news that occur on the first day

- For each portfolio: compute \( Drift_{i,t} \), abnormal returns over 20 days after the announcement
Inattention and Gradual Information Diffusion

Post-Earnings-Announcement Drift

- Sort announcing firms based on:
  - Earnings surprise: \( SUE_{i,t} \) for firm \( i \) at announcement \( t \)
  - Attention: \( ImmClicks_{i,t} = \) percentage of reads on earnings news that occur on the first day

- For each portfolio: compute \( Drift_{i,t} \), abnormal returns over 20 days after the announcement

- Conjecture: positive relationship between \( SUE_{i,t} \) and \( Drift_{i,t} \) is higher when \( ImmClicks_{i,t} \) is lower
### Inattention and Gradual Information Diffusion

#### Post-Earnings-Announcement Drift

<table>
<thead>
<tr>
<th>SUE quintile</th>
<th>1 (bottom)</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5(top)</th>
<th>Diff (5-1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (bottom)</td>
<td>-1.24%</td>
<td>-1.31%†</td>
<td>-1.04%</td>
<td>0.00%</td>
<td>0.55%*</td>
<td>1.79%*</td>
</tr>
<tr>
<td>2</td>
<td>-1.30%†</td>
<td>-0.06%</td>
<td>-0.89%</td>
<td>0.09%</td>
<td>0.64%†</td>
<td>1.94%*</td>
</tr>
<tr>
<td>3</td>
<td>-1.28%</td>
<td>-0.39%</td>
<td>-0.59%</td>
<td>0.16%</td>
<td>-0.98%</td>
<td>0.30%</td>
</tr>
<tr>
<td>4</td>
<td>-0.49%</td>
<td>-0.48%</td>
<td>0.10%</td>
<td>-0.30%</td>
<td>-0.44%</td>
<td>0.05%</td>
</tr>
<tr>
<td>5</td>
<td>0.25%</td>
<td>0.39%</td>
<td>0.32%</td>
<td>0.04%</td>
<td>-0.17%</td>
<td>-0.42%</td>
</tr>
</tbody>
</table>

* and † denote significance at the 5% and 10% levels, respectively.

- **PEAD** stronger when attention is less immediate
Momentum phenomenon:
- Stocks that performed well over the past 3-12 months continue to do well in the next 3-12 months
- Stocks that underperformed in the past 3-12 months continue to do so in the next 3-12 months
Inattention and Gradual Information Diffusion

Return Momentum

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**Question**

*Is delayed attention related to return momentum?*
Inattention and Gradual Information Diffusion

Return Momentum

- **Momentum proxy**: for each firm $i$, $MOM_i = \text{correlation between } Ret_t$ and $Ret_{[t-12,t-2]}$
Inattention and Gradual Information Diffusion

Return Momentum

- **Momentum proxy**: for each firm $i$, $MOM_i = \text{correlation between } Ret_t$ and $Ret_{[t-12, t-2]}$

- **Attention speed**: for each firm compute measures of speed of clicks on their news
  - **Proxies**: mean / median lag from publication to click, percentage of clicks within first day / week
  - **Adjusted proxies**: take residuals from regression on size, industry FE; normalize to mean zero, standard deviation one
Inattention and Gradual Information Diffusion

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- Cross-sectional regression of $MOM_i$ on each attention proxy $Attention_i$:

  $$MOM_i = \alpha + \beta Attention_i + \epsilon_i$$
## Inattention and Gradual Information Diffusion

**Return Momentum**

<table>
<thead>
<tr>
<th></th>
<th>Lag to read</th>
<th>Percentage of quick reads</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MeanTimeLag</td>
<td>MedTimeLag</td>
</tr>
<tr>
<td><strong>Raw</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coefficient</td>
<td>0.07**</td>
<td>0.17*</td>
</tr>
<tr>
<td>Standard error</td>
<td>(0.01)</td>
<td>(0.08)</td>
</tr>
<tr>
<td><strong>Adj.</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coefficient</td>
<td>0.01**</td>
<td>0.003</td>
</tr>
<tr>
<td>Standard error</td>
<td>(0.004)</td>
<td>(0.005)</td>
</tr>
</tbody>
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- Higher momentum for firms whose news receives slower attention
Attention to Stale News

- Inattention to news is important for prices
Attention to Stale News

- Inattention to news is important for prices
- What about too much attention to unimportant news?
Attention to Stale News

- Inattention to news is important for prices
- What about too much attention to unimportant news?
- Enke and Zimmermann (2014): humans have trouble accounting for complex correlation structures in information signals
Attention to Stale News

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Question

*When do investors continue paying attention to stale information?*
Fedyk and Hodson (2014): understand how old information makes its way into prices
Attention to Stale News

- Fedyk and Hodson (2014): understand how old information makes its way into prices

- Differentiate between types of stale news
  - Duplicate: news story with content copied from single previous story
  - Aggregate: news story with stale content spanned by multiple previous stories
  - Information processing: easier to identify duplicate stale news than aggregate
  - Do investors react more to aggregation of stale information?
Attention to Stale News

Duplicate News: Example (November 2013)

- *Bloomberg News* on November 10, 2013:
  “Apple Said Developing Curved iPhone Screens”
Attention to Stale News

Duplicate News: Example (November 2013)

- *Bloomberg News* on November 10, 2013:  
  “Apple Said Developing Curved iPhone Screens”

- *New York Post* on November 11, 2013:  
  “Apple developing larger, curved-screen iPhones”
Attention to Stale News

Aggregate News: Example (October 3, 2012)

- *The Fly On The Wall*: “CELG: VentiRx announces collaboration with Celgene for VTX-233”
Attention to Stale News

Aggregate News: Example (October 3, 2012)

- *The Fly On The Wall*: “CELG: VentiRx announces collaboration with Celgene for VTX-233”

- *Bloomberg News*: “Celgene to retain exclusive option to acquire VentiRx”
Attention to Stale News

Aggregate News: Example (October 3, 2012)

- *The Fly On The Wall*: “CELG: VentiRx announces collaboration with Celgene for VTX-233”

- *Bloomberg News*: “Celgene to retain exclusive option to acquire VentiRx”

- Briefing.com: “VentiRx Pharmaceuticals announced the formation of an exclusive, world-wide collaboration with Celgene (CELG) for the development of VTX-2337 [...]. Celgene will retain the exclusive option to acquire VentiRx”
Attention to Stale News

Data Processing

**Information:** extract unique words from each article

- Exclude common stop words ("a", "the", "in", "when", etc) and numbers
- Standard stemming algorithm [Porter (1980)]: e.g., "earned" and "earning" become "earn-"
Information: extract unique words from each article
  ▶ Exclude common stop words ("a", "the", "in", "when", etc) and numbers
  ▶ Standard stemming algorithm [Porter (1980)]: e.g., "earned" and "earning" become "earn-"

Norm \| \cdot \|: number of unique words
  ▶ E.g., \|s_1 \cap s_2\| = \# unique words appearing in both stories, s_1 and s_2
Attention to Stale News

Article Staleness

- Unigram similarity of article $s'$ to article $s$:

$$\text{Sim}(s, s') = \frac{||s \cap s'||}{||s||}$$

Example:

$\triangleright$ $s = \text{“Here comes latest article.”}$

$\triangleright$ $s' = \text{“Previously seen article.”}$

$\triangleright$ $||s|| = 4$

$\triangleright$ $||s \cap s'|| = 1$

$\triangleright$ $\text{Sim}(s, s') = 0.25$
Attention to Stale News

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  - $s = \text{“Here comes latest article.”}$
  - $s' = \text{“Previously seen article.”}$
  - $|s| = \# \text{ words in } s = 4$
  - $|s \cap s'| = \# \text{ words in both } s \text{ and } s' (\text{“article”}) = 1$
  - $\implies Sim(s, s') = 0.25$
Attention to Stale News

Article Staleness

- **Staleness**: amount of information captured by previous articles for same firm
  - For each article $s$, look at stories tagged with same firm within last 3 days
  - Select textually closest 5 stories: $s_1, ..., s_5$ with maximal $Sim(s, s_i)$
  - Staleness = percentage of $s$'s content covered by $s_1, ..., s_5$:
    \[
    Stale(s) = \frac{||s \cap (\bigcup_{i=1}^{5} s'_i(s))||}{||s||}
    \]
Attention to Stale News

Duplicates vs. Aggregates

Panel 1

Panel 2
Attention to Stale News

Duplicates vs. Aggregates

- **Duplicate measure**: similarity to closest preceding article:

\[
Duplicate(s) = \frac{\max_{s'} ||s \cap s'||}{||s||}
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Attention to Stale News

Duplicates vs. Aggregates

- **Duplicate measure**: similarity to closest preceding article:

  \[
  \text{Duplicate}(s) = \frac{\max_{s'} \|s \cap s'\|}{\|s\|}
  \]

- **Aggregate measure**: difference between measures of staleness and duplicate:

  \[
  \text{Aggregate}(s) = \text{Stale}(s) - \text{Duplicate}(s)
  \]

  - Info that is not novel, but also not covered by single closest neighbor
Attention to Stale News

Article Classification

- Classify each article as novel / duplicate / aggregate

Article s
Attention to Stale News

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\[ Stale(s) \geq 0.6? \]
Attention to Stale News

Article Classification

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\[
\text{Article } s \\
\text{Stale}(s) \geq 0.6? \\
\text{No} \\
\text{Novel}
\]
Attention to Stale News

Article Classification

- Classify each article as novel / duplicate / aggregate

\[ Stale(s) \geq 0.6? \]

- No → Novel
- Yes →
  \[ Duplicate(s)/Stale(s) \geq 0.8? \]
  - No
  - Yes
Attention to Stale News

Article Classification

- Classify each article as novel / duplicate / aggregate

\[ \text{Stale}(s) \geq 0.6? \]

- No → Novel
- Yes →
  - \[ \frac{\text{Duplicate}(s)}{\text{Stale}(s)} \geq 0.8? \]
    - Yes → Duplicate
    - No → Novel
Attention to Stale News

Article Classification

- Classify each article as novel / duplicate / aggregate

![Decision Tree Diagram]

- $Stale(s) \geq 0.6$?
  - No: Novel
  - Yes: $Duplicate(s)/Stale(s) \geq 0.8$?
    - No: Aggregate
    - Yes: Duplicate
Attention to Stale News

Effect of Aggregation in Stale News

- Firm-level proxies: percentages of articles about firm $i$ on date $t$ that are stale and aggregate:

  \[
PrcStale_{it} = \frac{\sum_{s \in S_{it}} StaleDummy(s)}{|S_{it}|}
  \]

  \[
PrcAggregate_{it} = \frac{\sum_{s \in S_{it}} AggregateDummy(s)}{|S_{it}|}
  \]

- Effect of $PrcStale_{it}$ and $PrcAggregate_{it}$ on the size of returns:

| Explanatory variable | Dependent variable: $|AbnRet|_{i,t+1}$ |
|----------------------|--------------------------------------|
| $PrcStale_{it}$      | -0.045** (0.003)                     |
| $PrcAggregate_{it}$  | 0.016** (0.003)                      |

** = significant at the 1% level
Attention to Stale News

Results: Time Series

Panel 1: Staleness

Panel 2: Aggregation
Attention to news is not allocated efficiently
  ▶ Insufficient attention to important news
  ▶ Too much attention to complex stale news

Question: How do market participants choose which news to read?
Front page positioning likely had a large effect in “Cure for Cancer”
Other potential determinants of whether a news gets read:
  ▶ Timing: different days of the week
  ▶ Firm characteristics: large vs. small firms
  ▶ Article characteristics: good vs. bad news
Understanding Consumption of News

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Understanding Consumption of News

Effect of Front Page Positioning

- News placed on the front page of a newspaper or pinned to the top of a news website receive more attention
Understanding Consumption of News

Distribution of Reads by Day of the Week

- Average # of reads by day of the week (in millions)

![Bar chart showing average number of reads by day of the week.](image)
Understanding Consumption of News

Attention by Firm Size

- For each firm, record the time lag between publication and click
- Sort firms into deciles based on size
- Within each size decile, compute median time lag
Understanding Consumption of News

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- Within each size decile, compute median time lag
Understanding Consumption of News

Article Characteristics: Sentiment

- Fedyk (2015): Differential consumption of positive and negative news
Understanding Consumption of News

Article Characteristics: Sentiment

- Fedyk (2015): Differential consumption of positive and negative news

- Preference against bad news:
  - Karlsson, Loewenstein, and Seppi (2009)
  - “Ostrich effect”: less portfolio-monitoring during falling markets
Understanding Consumption of News

Article Characteristics: Sentiment

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- Preference against bad news:
  - Karlsson, Loewenstein, and Seppi (2009)
  - “Ostrich effect”: less portfolio-monitoring during falling markets

- Preference in favor of bad news:
  - Falk and Zimmermann (2014)
  - Subjects prefer to receive information about upcoming discomfort sooner, averse to piecemeal information
Understanding Consumption of News

Sentiment: Examples

- **Positive**: “Apple on pace to beat Sept. Qtr. iPhone unit estimate of 4.1M” (*TheFlyOnTheWall.com*, 8/13/2008)

- **Negative**: “Goldman Sachs Downgrades Apple (AAPL) to Neutral” (*StreetInsider.com*, 12/15/2008)

- **Neutral**: “Apple to unveil new laptop, but not tablet computer” (*CNBC*, 6/5/2009)
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Distribution of News Sentiment

- Positive: 33%
- Neutral: 56%
- Negative: 11%
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Sentiment: Univariate Analysis

- Average reads for positive / neutral / negative stories:

![Bar chart showing average reads](chart.png)

- Average reads:
  - Positive: 30
  - Neutral: 24
  - Negative: 38

- Univariate regression:
  - Intercept: 24.28
  - Positive Dummy: 5.49
  - Negative Dummy: 13.99

- t-statistics on the differences:
  - Positive - Neutral: 20.55
  - Negative - Neutral: 30.48
  - Positive - Negative: 35.51

Anastassia Fedyk (HBS)
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![Bar chart showing average reads for positive, neutral, and negative stories.]

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<table>
<thead>
<tr>
<th></th>
<th>Positive - Neutral</th>
<th>Negative - Neutral</th>
<th>Positive - Negative</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>20.55</td>
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</tr>
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<table>
<thead>
<tr>
<th>Difference</th>
<th>( t )-statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive - Neutral</td>
<td>20.55</td>
</tr>
<tr>
<td>Negative - Neutral</td>
<td>30.48</td>
</tr>
<tr>
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<td>35.51</td>
</tr>
</tbody>
</table>

- Univariate regression:

<table>
<thead>
<tr>
<th>Intercept</th>
<th>Positive Dummy</th>
<th>Negative Dummy</th>
</tr>
</thead>
<tbody>
<tr>
<td>24.28</td>
<td>5.49</td>
<td>13.99</td>
</tr>
<tr>
<td>( (0.16))</td>
<td>( (0.26))</td>
<td>( (0.40))</td>
</tr>
</tbody>
</table>
# Understanding Consumption of News

## Sentiment: Multivariate Analysis

<table>
<thead>
<tr>
<th></th>
<th>Dependent var: $\text{Reads}_s$</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No Controls</td>
<td>Baseline Controls</td>
<td>Source Effects</td>
<td>Date FE</td>
<td>Firm FE</td>
</tr>
<tr>
<td>$\text{Positive}_s$</td>
<td>5.49**</td>
<td>2.17**</td>
<td>11.66**</td>
<td>12.02**</td>
<td>12.34**</td>
</tr>
<tr>
<td></td>
<td>(0.26)</td>
<td>(0.27)</td>
<td>(0.27)</td>
<td>(0.27)</td>
<td>(0.27)</td>
</tr>
<tr>
<td>$\text{Negative}_s$</td>
<td>13.99**</td>
<td>12.03**</td>
<td>17.49**</td>
<td>17.57**</td>
<td>14.76**</td>
</tr>
<tr>
<td></td>
<td>(0.40)</td>
<td>(0.40)</td>
<td>(0.39)</td>
<td>(0.39)</td>
<td>(0.40)</td>
</tr>
<tr>
<td>$\text{Length}_s$</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>$\text{Staleness}_s$</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>$\text{Source}_s$</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Date FE</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
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<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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</tbody>
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** = significant at the 1% level
Information Propagation in Financial Markets

Takeaways

- What we learn from the data:
  - Delayed attention to new information
  - Continued attention to stale information, especially aggregate news
  - Attention allocated towards bad news, news about large firms
Information Propagation in Financial Markets

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