Information, Price Levels and Price Volatility of Petroleum Product Futures Price

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Unexpected Information and Price Changes

• Markets form expectations about economic variables (changes in inventories, macro news, etc.) based upon existing information
• The arrival of unexpected information (surprises) alters the current information set
• If the unexpected information is relevant for pricing
  → Prices respond
The Response of Energy Futures Prices to Unexpected Information

- Empirical examinations of oil, natural gas and product futures price responses to unexpected information (surprises) have focused on:

1. Changes in energy commodity inventories
2. Reports about macroeconomic variables
3. Monetary policy news: Press releases following U.S. Federal Open Market Committee meetings
4. U.S. Strategic Petroleum Reserve News

- We briefly summarize the extant literature and present supporting empirical analyses
  - Announcements by OPEC will be the subject of a future investigation
1. Changes in energy commodity inventories

• Information about unexpected changes in inventories reveals shifts in supply and demand and expectations about future supply and demand

• Release of Weekly Petroleum Status Report (typically Wed., 10:30 AM ET)
  – Oil, gasoline, distillate

• Release of Weekly Natural Gas Storage Report (typically Thurs., 10:30 AM ET)

• Unexpected change in inventory
  – Actual change – Expected change (typically from Bloomberg survey)
    • Often standardized
Empirical Evidence on Price Responses to Unexpected Changes in Inventory

- Generally focus on log price changes (‘returns’) for front month futures contracts: Oil, Gasoline, Distillate, Natural Gas

- Immediate response that does not revert (Halova et al., 2014; this study)

- Response inversely related to unexpected change in own inventory and to inventory of companion products (Oil and Pet. Products: Chang et al., 2009; Rosa, 2014; Halova et al., 2014; Bu, 2014; Bjursell et al., 2015; Ye and Karali, 2016; Miao et al., 2017, this study; Natural Gas: Gay et al., 2008; Chiou-Wei et al., 2013, Halova et al., 2014, this study)

- Jumps in prices tied to inventory announcements (Oil: Elder et al., 2013; Bjursell et al., 2015; Natural Gas: Bjursell et al., 2015)

- Response coefficient smaller after advent of effective 24-hour trading (electronic) (this study)

- No asymmetric response to positive versus negative surprises (Elder et al., 2013; Miao et al. 2017, this study)

- Spikes in volatility tied to inventory announcements (Linn and Zhu, 2004; Bjursell et al., 2015; this study)
Empirical Analysis

• Transaction price data, front month contract
  – Log futures price changes
  – Intraday (5 mins before announcement through 10 mins after); daily
• Unexpected changes in inventory
  – EIA and Bloomberg
  – Surprise = (Actual change – Expected change)/Std.Dev. [Bloomberg median forecast]
  – Response coefficient: Log price change response to 1 standard deviation shock to Raw Surprise
• Sample period: 7/16/2003 – 6/30/2017 (observations vary depending on data availability)
Immediate Response: Oil

5 to 7 minute response relative to level at 100 minutes
Similar for Gasoline, Distillate and Natural Gas
Immediate Response of Volatility: Oil (Average Absolute Returns)

Crude Oil Futures Average Absolute Returns around EIA Inventory Announcements

- Negative Inventory Surprises
- Positive Inventory Surprises

Minutes from Announcement

Average Absolute Return (%)
# The Relation Between Intraday Futures Price Response and Unexpected Change in Inventory?

<table>
<thead>
<tr>
<th>Price Change</th>
<th>Oil Surprise</th>
<th>Gas Surprise</th>
<th>Dist. Surprise</th>
<th>NG Surprise</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil</td>
<td><strong>-0.392</strong>*</td>
<td>Negative***</td>
<td>Negative***</td>
<td><strong>-0.066</strong>*</td>
</tr>
<tr>
<td>Gasoline</td>
<td>Negative***</td>
<td><strong>-0.484</strong>*</td>
<td>Negative***</td>
<td>-0.037 (n.s.)</td>
</tr>
<tr>
<td>Distillate</td>
<td>Negative***</td>
<td>Negative***</td>
<td><strong>-0.333</strong>*</td>
<td><strong>-0.066</strong>*</td>
</tr>
<tr>
<td>Natural Gas</td>
<td><strong>-0.112</strong>*</td>
<td><strong>-0.105</strong>*</td>
<td><strong>-0.107</strong>*</td>
<td><strong>-1.005</strong>*</td>
</tr>
</tbody>
</table>

Log price change. Intraday interval 5 minutes prior to report release through 10 minutes after.

Basic model: \( r_{i,t} = \alpha_i + \beta_i S_{i,t} + \varepsilon_{i,t} \)  *** Statistically significantly different from zero at 1% level.

Red, response to own unexpected change in inventory on day of release.

Black, response of Oil, Gasoline, Distillate to companion product unexpected inv. changes.

Green: response of Natural Gas to oil, gasoline, distillate surprises on Wed.

Gold: response of Oil, Gasoline, Distillate to natural gas surprise on Thurs.
## Advent of Effective 24-hour Trading, June 6, 2006

Was the Response Closer to Zero Following Shift?

### Model:

$$ r_{i,t} = \beta_{i,0} + \beta_{i,E} E_t + \beta_{i,S} S_{i,t} + \beta_{i,SE} \left( S_{i,t} \cdot E_t \right) + \varepsilon_{i,t} $$

$E_t = 1$ if $t = June 6, 2006$ and after, else 0

(estimates of ($\beta_{i,S}; \beta_{i,S} + \beta_{i,SE}$))

<table>
<thead>
<tr>
<th>Price Change</th>
<th>Oil Surprise</th>
<th>Gas Surprise</th>
<th>Dist. Surprise</th>
<th>NG Surprise</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil</td>
<td>-0.429; -0.271***</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gasoline</td>
<td></td>
<td>-0.746; -0.470**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distillate</td>
<td></td>
<td></td>
<td>-0.664; -0.301***</td>
<td></td>
</tr>
<tr>
<td>Natural Gas</td>
<td></td>
<td></td>
<td></td>
<td>-0.708; -1.163***</td>
</tr>
</tbody>
</table>

Our results show that the response became more muted for Oil, Gasoline and Distillate but was intensified for Natural Gas.

*** Statistically significantly different from zero at 1%, ** at 5%
• Price Changes
  – Response not influenced by whether surprise was positive or negative
  – No relation between surprises and prices changes on the two days following the release

• Volatility
  – Average absolute return positively related to absolute value of surprise for Oil, Gasoline, Distillate (at Wed. release) and Natural Gas (at Thurs. release)
    • But not to abs(surprise) for other commodities (on Wed.), but all positively related to abs(natural gas surprise) on Thur.
  – Electronic trading had no differential effect on volatility
  – Response to negative surprises always smaller, but only statistically significant for Gasoline and Natural Gas
2. Reports About Macroeconomic Variables

- A variety of reports are issued on a regular basis by departments of the U.S. government as well as private organizations (example)
  - U.S. Employees on Nonfarm Payrolls Month-to-Month Change (U.S. Bureau of Labor Statistics, release time 8:30 AM ET, monthly)

- Expectations data are widely circulated, records generally obtained from surveys of professional economists (frequent source, Haver Analytics)
- Surprise = (Actual – Expected), often scaled by the standard deviation
- Price impacts have been studied using intraday price changes as well as changes at the daily frequency (generally futures prices)
General Findings, Basic Model

\[ r_{i,t} = \alpha_i + \beta_i S_{i,t} + \epsilon_{i,t} \]

<table>
<thead>
<tr>
<th>Price Change Frequency</th>
<th>Price Change Response</th>
<th>Studies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intraday</td>
<td>Yes (but limited to only a few variables, key amongst which is the non-farm payroll report)</td>
<td>Chatrath et al. (2012), Elder et al. (2013), Rosa (2013), Kurov and Stan (2016)</td>
</tr>
</tbody>
</table>
Empirical Analysis

• Focus on
  – U.S. Employees on Nonfarm Payrolls Month-to-Month Change (U.S. Bureau of Labor Statistics, release time 8:30 AM ET, monthly)
  – U.S. Retail Sales Month-to-Month % Change (U.S. Bureau of the Census, release time 8:30 AM ET, monthly)
  – U.S. Consumer Confidence Index (Conference Board, release time 10:00 AM ET, monthly)
  – U.S. ISM Manufacturing Composite Index (National Association of Purchasing Managers, release time 10:00 AM ET, monthly).

• Surprise = (Actual – Expected) scaled by standard deviation

• Sample period: Intraday price changes (July 16, 2003 to July 17, 2017; daily price changes (February 1993 through May 2017)
• Intraday price changes: 5 minutes prior to announcement through 10 minutes following
Immediate Response: Oil

Crude Oil Futures Returns around NFP Announcements

- Negative NFP Surprises
- Positive NFP Surprises

Cumulative Average Return (%) vs Minutes from Announcement
Immediate Response of Volatility: Oil (Average Absolute Returns)

Crude Oil Futures Absolute Returns around NFP Announcements

- Negative NFP Surprises
- Positive NFP Surprises

Minutes from Announcement
The Relation Between Intraday Price Responses and Macro News Surprises?

\[ r_{i,t} = \alpha_i + \beta_i S_{i,t} + \varepsilon_{i,t} \]

<table>
<thead>
<tr>
<th>Price Change</th>
<th>Non-farm Pay. Surprise</th>
<th>Retail Sales Surprise</th>
<th>ISM Prod Index Surprise</th>
<th>Con. Conf. Surprise</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil</td>
<td>0.307***</td>
<td>0.111***</td>
<td>0.088***</td>
<td>0.044**</td>
</tr>
<tr>
<td>Gasoline</td>
<td>0.288***</td>
<td>0.074*</td>
<td>0.053**</td>
<td>0.026</td>
</tr>
<tr>
<td>Distillate</td>
<td>0.239***</td>
<td>0.057*</td>
<td>0.059**</td>
<td>0.033*</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>0.124*</td>
<td>0.098***</td>
<td>0.038</td>
<td>0.014</td>
</tr>
</tbody>
</table>

Log Price Change. Intraday interval 5 minutes prior to report release through 10 minutes after release. *** Statistically significantly different from zero at 1%, ** 5%, * 10%
Price Response at Daily Frequency

• No relation was statistically significantly different from zero
  – Day of announcement
  – Announcement day + following day
  – Announcement day + 20 following days

• Referring back to the Figure we see that while the impact of a positive NFP surprise on oil reverts, the response following a negative surprise tends does not
3. Monetary Policy News

• Markets form expectations about U.S. Monetary Policy
• Surprises may occur when press releases following Federal Open Market Committee Meetings reveal changes that are of fundamental importance
• Surprises that reveal unexpected changes in policy may impact prices
  – Potential channels of influence include (Rosa, 2014; Anzuini et al, 2013; Barsky and Kilian, 2004): inventory carrying cost, supply (drilling and production), demand (economic growth), exchange rates
Issue – Measuring Surprises

• Policy Target: Federal funds rate
• Assumption: Markets form expectations about the Target rate based upon existing information and these expectations will be reflected in federal funds futures prices
• Press releases that change the information set and reveal new information about policy will be reflected in federal funds futures prices
• A measure reflecting the change in the implied federal funds rate using the change in the fed funds futures price, $T_S$ (Kuttner, 2001).

• Basic model: $r_{i,t} = \alpha_i + \beta_i T_S + \epsilon_{i,t}$
General Findings

\[ r_{i,t} = \alpha_i + \beta_i TS_t + \varepsilon_{i,t} \]

<table>
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<tr>
<th>Price Change Frequency</th>
<th>Price Change Response</th>
<th>Price Change Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intraday</td>
<td>Negative†</td>
<td>Rosa (2014), Basistha and Kurov (2015)</td>
</tr>
</tbody>
</table>

† Statistically different from zero at conventional levels
†† Except for the period 2002-2009 during which a negative relation for oil is found
Immediate Response:

Crude Oil Futures Cumulative Average Returns around FOMC Announcements

- Blue line: Negative Target Surprises
- Orange line: Positive Target Surprises
Immediate Response of Volatility: Oil (Average Absolute Returns)

Crude Oil Futures Average Absolute Returns around FOMC Announcements

- Negative Target Surprises
- Positive Target Surprises

Minutes from Announcement

Average Absolute Return (%)
Intraday Price Response and the Target Surprise?

Model 1 \[ r_{i,t} = \alpha_i + \beta_i T S_t + \varepsilon_{i,t} \]

Model 2 \[ r_{i,t} = \alpha_i + \beta_{i,c} D_{C,t} + \beta_{i,TS} T S_t + \beta_{i,DTS} \left( D_{C,t} \cdot T S_t \right) + \varepsilon_{i,t} \]

<table>
<thead>
<tr>
<th></th>
<th>Model 1</th>
<th>Model 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>TS alone</td>
<td>TS</td>
<td>Conf. Call</td>
</tr>
<tr>
<td>Oil</td>
<td>-1.21</td>
<td>-1.214</td>
</tr>
<tr>
<td>Gasoline</td>
<td>4.47</td>
<td>-1.963</td>
</tr>
<tr>
<td>Distillate</td>
<td>1.12</td>
<td>-0.878</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>-0.85</td>
<td>-6.127**</td>
</tr>
</tbody>
</table>

Intraday interval 10 minutes prior to report release through 50 minutes after.
Conf. Call = 1 if meeting involved a conference call and 0 otherwise

***Statistically significantly different from zero at 1%, ** at 5%
Response on Day of Press Release

- Oil and Gasoline: response coefficients negative but not significantly different from zero
- Distillate: coefficient is positive but not significant
- Including a measure of the path of monetary policy does not influence either the intraday or daily results
4. U.S. Strategic Petroleum Reserve News

• Increases and decreases in the amount of oil held in the U.S. Strategic Petroleum Reserve may potentially impact supply and demand conditions as well as expectations.

• As such announcements of pending changes may reveal information to the market which alters the information set participants employ in the setting of prices.
Existing Literature

• We identified only one study that examined the price impact of changes in the SPR within a reasonable recent period.

• The authors find no impact when examining price impacts over a number of days following the announcement but do not study the date of the announcement (Demirer and Kutan, 2010).
Background

• We identified 26 instances of announcements of increases or decreases of oil held in the SPR over the time period February 11, 1999 through February 21, 2017.
  — Of these 16 involved announcements of increases and 10 involved decreases
• The press/announcement releases are dated but we are unable to identify a time of day, hence our analysis is restricted to daily price changes.
Price Response to Announcements of Increases and Decreases in the SPR. Model: \( r_{i,t} = \alpha_i + \beta_{i,c} (D_{c,t}) + \varepsilon_{i,t} \)

\( D_{c,t} = 1 \) if increase and 0 otherwise (estimates: \( \alpha_i, \beta_{i,c} \))

<table>
<thead>
<tr>
<th></th>
<th>Ann. Day</th>
<th>Ann. Day + Day Following</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil</td>
<td>-1.474*, 2.486**</td>
<td>-1.933, 2.596</td>
</tr>
<tr>
<td>Gasoline</td>
<td>-1.438, 2.828*</td>
<td>-1.642, 2.87</td>
</tr>
<tr>
<td>Distillate</td>
<td>-1.294, 2.291*</td>
<td>-1.276, 1.76</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>-0.0602, 1.178</td>
<td>-0.638, 1.607</td>
</tr>
</tbody>
</table>

**Statistically significantly different from zero at 5%, * at 10%**
Conclusion

• Oil prices respond negatively to announcements of decreases in oil to be stored in the SPR and positively to announcements of increases

• Response occurs on the day of the announcement
Summary

• Futures prices of oil, gasoline, distillate and natural gas respond
  – Inversely to unexpected changes in inventories of these products (intraday response)
  – Positively to surprises for a few key macroeconomic measures of economic activity (intraday response)
    • But no relation at longer horizons
  – Inversely to target rate surprises inferred from U.S. Monetary Policy press releases (intraday response), but the effect appears to be driven by a subset following conference calls
    • No relation at longer horizons
  – Positively to announcements of planned increases in oil stored in the U.S. Strategic Petroleum Reserve and negatively to decreases (day of announcement)
• Volatility increases at the time of announcement for all four types of announcements and then dies out
Thank You