Manipulation of day-ahead electricity prices through virtual bidding in the U.S.

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New York City, USA
“FERC amps up market enforcement”

Some electricity market manipulation cases brought by the Federal Energy Regulatory Commission, 2012-2014

<table>
<thead>
<tr>
<th>Company</th>
<th>Civil penalties (‘000 $)</th>
<th>Disgorgement (‘000 $)</th>
<th>Settled?</th>
</tr>
</thead>
<tbody>
<tr>
<td>JP Morgan Ventures Energy Corporation</td>
<td>285,000</td>
<td>125,000</td>
<td>Yes</td>
</tr>
<tr>
<td>Constellation Energy Commodities Group</td>
<td>135,000</td>
<td>110,000</td>
<td>Yes</td>
</tr>
<tr>
<td>Deutsche Bank Energy Trading</td>
<td>1,500</td>
<td>172</td>
<td>Yes</td>
</tr>
<tr>
<td>Louis Dreyfus Energy Services</td>
<td>4,072</td>
<td>3,334</td>
<td>Yes</td>
</tr>
<tr>
<td>Barclays Bank</td>
<td>435,000 (proposed)</td>
<td>35,000 (proposed)</td>
<td>No</td>
</tr>
</tbody>
</table>
Research question

- One type of market manipulation strategy considered by FERC:
  - Virtual bids (Unprofitable) → INTENDED TO → Change the DA market price ➔ TO ENHANCE THE VALUE OF Financial Transmission Rights (Profitable)

- Ledgerwood and Pfeifenberger (2013) → not an equilibrium

- Absent control over real-time energy markets, how can one energy trader manipulate day-ahead electricity prices through virtual bidding over a sustained period of time?
Methodology

- Equilibrium model of day-ahead electricity market manipulation

- Assumptions:
  - No real-time market manipulation
  - No collusion among market participants
  - Risk neutrality
  - Choice of quantities, not supply/demand functions

- Kumar and Seppi (1992)

1. Futures delivery
2. Futures market
3. Spot market
4. Dividend announced and paid

- Futures market:
  - Noise traders
  - Uninformed trader

- Spot market:
  - Noise traders
  - Uninformed trader
  - Informed trader
Application of Kumar and Seppi (1992)

Consider a single electricity node

<table>
<thead>
<tr>
<th>Time 1</th>
<th>FTR market</th>
<th>Participants</th>
<th>Positions</th>
<th>MCQ</th>
<th>MCP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Noise traders</td>
<td>$e \sim N(0,\sigma^2_e)$</td>
<td>$e + \Delta = y_{1f}$</td>
<td>$F(y_{1f})$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Uninformed trader</td>
<td>$\Delta \sim N(0,\sigma^2_{\Delta})$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time 2</td>
<td>DA energy market</td>
<td>Noise traders</td>
<td>$u \sim N(0,\sigma^2_u)$</td>
<td>$S(y_{1f}, y_{2s})$</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Uninformed trader</td>
<td>$z$</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Informed trader</td>
<td>$x$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time 3</td>
<td>RT energy market</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Manipulator’s problem:

$$\max_{\Delta} E_c \left\{ \max_{z} E_{v,u,x} \left\{ \Delta[S - F] + z[v-S] \mid y_{1f} \right\} \right\}$$

s.t. $|\Delta| \leq |W|$
Assume linear pricing rules and trading strategies

There exists a unique equilibrium in which the uninformed trader:

- Randomizes its trading strategy in the FTR auction with equal probability (i.e., goes long $|W|$ or short $-|W|$ FTR positions at date 1), and then trades in the DA market
- Loses (on average) on its DA position
- Gains on its FTR position

If the FTR position is larger than the expected DA position, this strategy is profitable

Application of Kumar and Seppi (1992)
Numerical illustration of the impacts of manipulation

- Assumed distributional parameters

<table>
<thead>
<tr>
<th>Participants</th>
<th>Noise traders</th>
<th>Noise traders, Informed trader</th>
<th>Noise traders, Informed trader, Uninformed trader</th>
</tr>
</thead>
<tbody>
<tr>
<td>Market setting</td>
<td>DA, RT</td>
<td>DA, RT</td>
<td>FTR, DA, RT</td>
</tr>
<tr>
<td>$\sigma_e$</td>
<td>-</td>
<td>-</td>
<td>10</td>
</tr>
<tr>
<td>$\sigma_\Delta$</td>
<td>-</td>
<td>-</td>
<td>5</td>
</tr>
<tr>
<td>$\sigma_u$</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>$\sigma_v$</td>
<td>16</td>
<td>16</td>
<td>16</td>
</tr>
<tr>
<td>$\mu$</td>
<td>50</td>
<td>50</td>
<td>50</td>
</tr>
</tbody>
</table>

- Case realized: $v=62 \$/MWh
Numerical illustration of the impacts of manipulation

- Assumed parameters: $\sigma_e = 10; \sigma_{\Delta} = 5; \sigma_u = 10; \sigma_v = 16; \mu = 50$
- Case realized: $v = 62$

<table>
<thead>
<tr>
<th>Participants</th>
<th>Noise traders</th>
<th>Noise traders, Informed trader</th>
<th>Noise traders, Informed trader, Uninformed trader</th>
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</thead>
<tbody>
<tr>
<td>Market setting</td>
<td>DA, RT</td>
<td>DA, RT</td>
<td>FTR, DA, RT</td>
</tr>
<tr>
<td>$E(S)$</td>
<td>50</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>$\lambda$</td>
<td>0</td>
<td>0.80</td>
<td>0.78</td>
</tr>
<tr>
<td>St. Dev.(y2s)</td>
<td>10</td>
<td>14.14</td>
<td>14.66</td>
</tr>
<tr>
<td>St. Dev.(S)</td>
<td>0</td>
<td>11.31</td>
<td>11.31</td>
</tr>
</tbody>
</table>
Numerical illustration of the impacts of manipulation

- Assumed parameters: $\sigma_e = 10; \sigma_\Delta = 5; \sigma_u = 10; \sigma_v = 16; \mu = 50$
- Case realized: $v = 62$

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<tr>
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<th>Noise traders, Informed trader</th>
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</thead>
<tbody>
<tr>
<td><strong>Market setting</strong></td>
<td>DA, RT</td>
<td>DA, RT</td>
<td>FTR, DA, RT</td>
</tr>
<tr>
<td><strong>Ex ante profits ($/h)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Informed trader, DA</td>
<td>-</td>
<td>80</td>
<td>81.98</td>
</tr>
<tr>
<td>Uninformed trader, FTR</td>
<td>-</td>
<td>-</td>
<td>7.81</td>
</tr>
<tr>
<td>Uninformed trader, DA</td>
<td>-</td>
<td>-</td>
<td>-3.90</td>
</tr>
<tr>
<td>Noise traders, FTR</td>
<td>-</td>
<td>-</td>
<td>-7.81</td>
</tr>
<tr>
<td>Noise traders, DA</td>
<td>0</td>
<td>-80</td>
<td>-78.07</td>
</tr>
</tbody>
</table>
Preliminary conclusions and next steps

- We are developing a theoretical framework of day-ahead electricity price manipulation by financial participants, absent control over the real-time market.

- Manipulation would imply randomization of FTR positions with equal probability.

- It would not create a persistent divergence between the expected day-ahead and real-time prices, nor increase the volatility of the day-ahead price.

- We are currently working to include:
  - Sequential rounds of trading in the DA market
  - Two-node network (FTR source and sink)
Thanks for your attention
Back-up
Outline

- Virtual bids in U.S. two-settlement markets for electric energy

- Electricity market manipulation cases recently brought by the FERC
  - The Louis Dreyfus case

- Research question: how can manipulation of day-ahead electricity prices through virtual bidding be sustained over time?

- Methodology: equilibrium model of market manipulation

- Preliminary findings and ongoing work
Basic formulation of the auction models

Max $\sum_{m,i} (\text{Bid}_{mi} d_{mi}) - \sum_{m,i,h} (\text{Start}_{mih} z_{mih} + \text{Offer}_{mih} g_{mih})$

s.t. Energy balance constraint, for each $i$ ($\lambda_i$)

Generator constraints

Transmission constraints

$I$ : set of nodes
$M$ : set of market participants
$H$ : set of generators

$\lambda_i = \text{LMP}_i = \lambda_{\text{REF}} + \lambda_{\text{LOSS}_i} + \lambda_{\text{CONGESTION}_i}$

Energy component  Loss component  Congestion component
Financial transmission rights (1)

Initial system (no losses)

Gen 1:  
110 MW max @40$/MWh

Load 1:  
95 MW

95 MW

A

95 MW

B

100 MW max

110 MW max @40$/MWh

LMP_A: 40 $/MWh

LMP_B: 40 $/MWh

Generator 1 gets: 40$/MWh * 95 MW = 3,800 $/h
Load 1 pays: 40$/MWh * 95 MW = 3,800 $/h
1. INTRO ON WHOLESALE ELECTRICITY MARKETS IN THE U.S.

Financial transmission rights (2)

Expanded system (no losses)

Gen 1:
110 MW max @ 40$/MWh

Load 1: 95 MW
Load 2: 10 MW

Gen 2:
10 MW max @ 80$/MWh

100 MW

Load 1: 95 MW
Load 2: 10 MW

Generators get: 40$/MWh * 100 MW + 80$/MWh * 5 MW = 4,400 $/h
Loads pay: 80$/MWh * 95 MW + 80$/MWh * 10 MW = 8,400 $/h
ISO collects congestion revenue = (8,400 - 4,400) $/h = 4,000 $/h

LMP_A: 40 $/MWh

LMP_B: 80 $/MWh
Financial transmission rights (3)

Suppose Load 1 gets an A-to-B FTR for 95 MW, which pays:

\( (\lambda_{\text{CONGESTION_B}} - \lambda_{\text{CONGESTION_A}}) \times \text{FTR size} = 40\$/\text{MWh} \times 95\text{MW} = 3,800\$/h \)

Then, Load 1’s net payment is 7,600\$/h (energy) – 3,800\$/h (share of congestion rent) = 3,800 $/h

Load 1 is hedged against DA transmission congestion costs
A FTR is a financial instrument that entitles the holder the right to collect a payment—or the obligation to pay a charge—when DA congestion arises between two locations on the transmission network.

The value of an FTR of size $F$ is equal to:

$$\left(\lambda_{\text{CONGESTION\_SINK}} - \lambda_{\text{CONGESTION\_SOURCE}}\right) \times F$$

Participants acquire FTRs by auction, on the secondary market or through unregistered bilateral trades.
### Example *

- Consider one hour of market operation
- A trader holds a FTR position (F) of 60 MW from A to B
- Given an existing expected price differential ($P_{RT} - P_{DA}$) of 40$, the trader should choose the optimal quantity of DECs (X MW) to bid at node B

![Diagram of FTR Source and Sink with 60 MW connection]

Trader’s objective: Max \((P_{RT} - P_{DA}) \times X + (\lambda_{CONGESTION\_SINK} - \lambda_{CONGESTION\_SOURCE}) \times F\)

<table>
<thead>
<tr>
<th></th>
<th>Expected price spread</th>
<th>Quantity of DECs cleared</th>
<th>Total revenues of virtuals</th>
<th>Enhanced value of FTR position</th>
<th>Total revenues</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Max profit</strong></td>
<td><strong>20</strong></td>
<td><strong>20</strong></td>
<td><strong>400</strong></td>
<td><strong>1,200</strong></td>
<td><strong>1,600</strong></td>
</tr>
<tr>
<td><strong>virtuals only</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Max revenues</strong></td>
<td><strong>-10</strong></td>
<td><strong>50</strong></td>
<td><strong>-500</strong></td>
<td><strong>3,000</strong></td>
<td><strong>2,500</strong></td>
</tr>
</tbody>
</table>

* Source: Ledgerwood and Pfeifenberger (2013)
Manipulation of DA electricity markets through virtual bidding

VB Position (Unprofitable) \( \rightarrow \) Change the DA market price \( \rightarrow \) FTR Position (Profitable)

**INTENDED TO**

**TO ENHANCE THE VALUE OF**

**MANIPULATION PROFITS**

\[ \text{if gains on FTR Position} > \text{losses on VB Position} \]
Market manipulation:
“to act against its economic interest in one market in order to benefit its position in another market by artificially moving the market price.” (124 FERC 61, 295; p. 22)
Manipulation of energy markets in the U.S. 
FERC’s anti-manipulation rule

“The Commission will act in cases where an entity: (1) uses a fraudulent device, scheme or artifice, or makes a material misrepresentation or a material omission as to which there is a duty to speak under a Commission-filed tariff, Commission order, rule or regulation, or engages in any act, practice, or course of business that operates or would operate as a fraud or deceit upon any entity; (2) with the requisite scienter; (3) in connection with the purchase or sale of … electric energy or … transmission of electric energy subject to the jurisdiction of the Commission.” (FERC Order No. 670, Par. 49)

- Fraud: “any action, transaction, or conspiracy for the purpose of impairing, obstructing or defeating a well-functioning market” (Order No. 670, Par. 50).
- Scienter: “knowing or intentional misconduct”; “conduct designed to deceive or defraud by controlling or artificially affecting the price”; “recklessness” (Order No. 670, Par. 52 and 53).
- Recklessness: “extreme departure from the standards of ordinary care…which presents a danger that is either known or so obvious the actor must have been aware of it” (128 FERC 61,049, p. 26).
Enforcement staff investigations in the electricity sector

1. Preliminary examination
2. Initiation of an investigation
3. Discovery
4. No violation: Investigation is closed
5. Violation: Additional communication with the subject of the investigation
6. Investigation is closed
7. Violation
Violation

- Settlement
  - Investigation is closed

Order to Show Cause and Notice of Proposed Penalty

- Settlement
  - Investigation is closed
- Initiation of enforcement proceedings

The subject responds to the Order to Show Cause and chooses between:

- Administrative Law Judge path, prior to the assessment of penalties [Section 31(d)(2) of FPA]
- Federal district court path, after the assessment of penalties [Section 31(d)(3) of FPA]
Manipulation of energy markets in the U.S.
FERC’s anti-manipulation rule (Title 18 C.F.R. § 1c)

➢ It is unlawful for any entity, directly or indirectly, in connection with the purchase or sale of products subject to FERC jurisdiction,

(1) To use or employ any device, scheme, or artifice to defraud*;

(2) To make any untrue statement of a material fact or to omit to state a material fact necessary in order to make the statements made, in the light of the circumstances, not misleading; or

(3) To engage in any act, practice, or course of business that operates or would operate as a fraud or deceit upon any entity.

* FERC defines fraud as “any action, transaction, or conspiracy for the purpose of impairing, obstructing or defeating a well-functioning market” (Order No. 670, Par. 50).
Research question
How can energy traders manipulate day-ahead electricity prices through virtual bidding for a sustained period of time?

➢ In well-functioning electricity markets, a divergence between day-ahead and real-time prices should encourage entry and competition for arbitrage rents → price convergence

➢ If price convergence is not restored, there may be market design problems that implicate day-ahead market manipulation

➢ Market manipulation through virtual bidding could exploit:
  • asymmetric information;
  • risk aversion;
  • restrictions to entry, due to:
    ✓ liquidity constraints
    ✓ asymmetric charges allocated to virtual positions
The Louis Dreyfus case

<table>
<thead>
<tr>
<th>FTR positions sinking at Velva</th>
<th>LDES Settlement Agreement (146 FERC ¶ 61,072)</th>
<th>Analysis of publicly available data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Virtual trading at Velva (DECs only)</td>
<td>About $6 million in profits</td>
<td>$6,021,175</td>
</tr>
<tr>
<td>Virtual trading “at other nodes in the area”</td>
<td>-$390,353</td>
<td>-$388,823</td>
</tr>
<tr>
<td></td>
<td>+$314,159</td>
<td><strong>What other nodes?</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td>-$5,365 (INC only) at Coal Creek and Antelope; -$499,454 (INC and DEC) in the MISO West</td>
</tr>
</tbody>
</table>
Preliminary results on types of equilibrium manipulation and current work

**MANIPULATION OF DA PRICES**

- $E(S) \neq E(v)$
- $E(S) = E(v)$
  - AND
  - $\text{Var}(S)$ is the same
    - [relative to the case in which there is no manipulator and $E(S) = E(v)$]

| Empirical implications | Price differential bounded by entry costs | ✓Randomized trading strategies on the FTR market $\rightarrow$ CREDIBLE?
| ✓Corr($\Delta$, $S$) $> 0$

**Kumar-Seppi framework**

- Current work and model extensions:
  - Entry of a second informed trader and equilibrium with respect to entry
  - Generalization of the K-S framework to a two-node network (FTR source and sink)
  - Repeated interactions
2. **DATE 1**

2.1 **Manipulator’s problem**

\[
\begin{align*}
    &\text{Max}_{x} E\{E_{x,x,x}(\Delta \frac{\mu}{2} + \frac{\nu}{2} + \lambda_{ks}u + \frac{\lambda_{ks}}{2}(1-k)\Delta - \frac{\lambda_{ks}}{2}ke - F) + \\
    &\quad + \frac{\Delta(1+k) + e_k}{2} [v - \frac{\mu}{2} - \frac{\nu}{2} - \lambda_{ks}u - \frac{\lambda_{ks}}{2}(1-k)\Delta + \frac{\lambda_{ks}}{2}ke] \} \}
\end{align*}
\]

s.t. |Δ| ≤ |W|

The efficient futures price \( F \) is equal to:

\( F = E(S | y_{1T}) = \mu \)

The objective function is then:

\[
\begin{align*}
    &\text{Max}_{x} E\{\frac{\lambda_{ks}}{2}(1-k)\Delta - \frac{\lambda_{ks}}{2}ke\}[\Delta - \frac{\Delta(1+k) + ke}{2}] = [\frac{\lambda_{ks}}{2}(1-k)\Delta - \frac{\lambda_{ks}}{2}ke] \frac{\Delta(1-k) - ke}{2} = \\
    &= \frac{\lambda_{ks}}{2} \frac{1}{2} [\Delta(1-k) - ke][\Delta(1-k) - ke] = \frac{\lambda_{ks}}{4} [\Delta^2(1-k)^2 + k^2e^2 - 2\Delta(1-k)ke]
\end{align*}
\]

Since \( E(e) = 0 \) and \( E(e^2) = Var(e) - [E(e)]^2 = Var(e) \), the manipulator’s problem becomes:

\[
\begin{align*}
    &\text{Max}_{x} \frac{\lambda_{ks}}{4} [\Delta^2(1-k)^2 + k^2e^2] \\
    &\text{s.t. } |\Delta| \leq |W|
\end{align*}
\]

Since the maximand is increasing in \( \Delta^2 \), the manipulator is indifferent between the two corner solutions of going long \( |W| \) and short \(-|W|\) futures contracts at date 1, and randomizes with equal probability over these orders. The manipulator expects to gain:

\[
[\frac{\lambda_{ks}}{2}(1-k)\Delta - \frac{\lambda_{ks}}{2}ke] \Delta
\]

and expects to lose:

\[
[\frac{\lambda_{ks}}{2}(1-k)\Delta - \frac{\lambda_{ks}}{2}ke] \frac{\Delta(1+k) + ke}{2} = [\frac{\lambda_{ks}}{2}(1-k)\Delta - \frac{\lambda_{ks}}{2}ke] E(z | y_{1T})
\]
### Application of Kumar and Seppi (1992)

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FTR market</strong></td>
<td><strong>DA market</strong></td>
<td><strong>RT market</strong></td>
</tr>
<tr>
<td>Noise traders</td>
<td>Noise traders</td>
<td>Noise traders</td>
</tr>
<tr>
<td>Uninformed trader</td>
<td>Uninformed trader</td>
<td>Informed trader</td>
</tr>
</tbody>
</table>

| Noise traders’ position | $e \sim N(0, \sigma^2_e)$ | $u \sim N(0, \sigma^2_u)$ |
| Uninformed trader’s position | $\Delta \sim N(0, \sigma^2_W)$ | $z$ |
| Informed trader’s position | | $x$ |
| Aggregate position | $y_{1f} = e + \Delta$ | $y_{2s} = x + u + z$ |
| Price | $F$ | $S$ | $v \sim N(\mu, \sigma^2_v)$ |

- The uninformed trader manipulates the DA price
- Manipulator’s problem:

  $\max_{\Delta} \mathbb{E}_e \left\{ \max_{z} \mathbb{E}_{v,u,x} \left\{ \Delta [S(y_{1f}, y_{2s}) - F(y_{1f})] + z[v-S(y_{1f}, y_{2s})] | y_{1f} \right\} \right\}$

  s.t. $|\Delta| \leq |W|$
Numerical illustration of the impacts of manipulation

> Assumed parameters: $\sigma_e = 5; \sigma_w = 10; \sigma_u = 10; \sigma_v = 16; \mu = 50; v = 62$

A. Expectation and variance of the DA price

<table>
<thead>
<tr>
<th></th>
<th>Noise traders</th>
<th>Informed trader + Noise traders (Kyle, 1985)</th>
<th>Informed trader + Uninformed trader + Noise traders (Kumar and Seppi, 1992)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$E(S)$</td>
<td>$\mu = 50$</td>
<td>$\mu = 50$</td>
<td>$\mu = 50$</td>
</tr>
<tr>
<td>$\text{Var}(S)$</td>
<td>0</td>
<td>$\frac{1}{2} \sigma_v^2 = 128$</td>
<td>$\frac{1}{2} \sigma_v^2 = 128$</td>
</tr>
<tr>
<td>$\text{Var}(v-S)$</td>
<td>$\sigma_v^2 = 256$</td>
<td>$\frac{1}{2} \sigma_v^2 = 128$</td>
<td>$\frac{1}{2} \sigma_v^2 = 128$</td>
</tr>
<tr>
<td>$\text{Var}(y2s)$</td>
<td>$\sigma_u^2 = 100$</td>
<td>$2 \sigma_u^2 = 200$</td>
<td>$\infty$</td>
</tr>
</tbody>
</table>
Numerical illustration of the impacts of manipulation

- Assumed standard deviations: $\sigma_e = 5; \sigma_W = 10; \sigma_u = 10; \sigma_v = 16$

### A. Ex ante profits

#### Informed trader

<table>
<thead>
<tr>
<th></th>
<th>No manipulation</th>
<th>Manipulation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FTR market</strong></td>
<td>$E_{e,u,v,x}[x(v-S)] = 80$</td>
<td>$E_{e}\Delta_{u,v,x,z}[x(v-S)] = 81.98$</td>
</tr>
<tr>
<td><strong>DA market</strong></td>
<td>$E_{u,v,x}[x(v-S)] = 80$</td>
<td>$E_{e}\Delta_{u,v,x,z}[x(v-S)] = 81.98$</td>
</tr>
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#### Uninformed trader

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<tr>
<td><strong>FTR market</strong></td>
<td>-</td>
<td>$E_{e}\Delta_{u,v,x,z}[\Delta(S-F)] = 7.81$</td>
</tr>
<tr>
<td><strong>DA market</strong></td>
<td>-</td>
<td>$E_{e}\Delta_{u,v,x,z}[z(v-S)] = 3.90$</td>
</tr>
</tbody>
</table>

#### Noise traders

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<th>Manipulation</th>
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</thead>
<tbody>
<tr>
<td><strong>FTR market</strong></td>
<td>$E_{e}\Delta_{u,v,x,z}[e(S-F)] = 7.81$</td>
<td>$E_{e}\Delta_{u,v,x,z}[e(S-F)] = 7.81$</td>
</tr>
<tr>
<td><strong>DA market</strong></td>
<td>$E_{u,v,x}[u(v-S)] = -80$</td>
<td>$E_{e}\Delta_{u,v,x,z}[u(v-S)] = 78.07$</td>
</tr>
</tbody>
</table>
## Numerical illustration of the impacts of manipulation

- Assumed parameters: $\sigma_e = 10$; $\sigma_{\Delta} = 5$; $\sigma_u = 10$; $\sigma_v = 16$; $\mu = 50$
- Case realized: $v = 62$

<table>
<thead>
<tr>
<th>Participants</th>
<th>Noise traders</th>
<th>Noise traders, Informed trader</th>
<th>Noise traders, Informed trader, Uninformed trader</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Market setting</strong></td>
<td>DA, RT</td>
<td>DA, RT</td>
<td>FTR, DA, RT</td>
</tr>
<tr>
<td><strong>E(S)</strong></td>
<td>50</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td><strong>$\lambda$</strong></td>
<td>0</td>
<td>0.80</td>
<td>0.78</td>
</tr>
<tr>
<td><strong>$1/\lambda$</strong></td>
<td>$\infty$</td>
<td>1.25</td>
<td>1.28</td>
</tr>
<tr>
<td><strong>St. Dev.(y2s)</strong></td>
<td>10</td>
<td>14.14</td>
<td>14.66</td>
</tr>
<tr>
<td><strong>St. Dev.(S)</strong></td>
<td>0</td>
<td>11.31</td>
<td>11.31</td>
</tr>
<tr>
<td><strong>St. Dev.(v-S)</strong></td>
<td>16</td>
<td>11.31</td>
<td>11.31</td>
</tr>
</tbody>
</table>