Market Microstructure Dynamics in Agricultural Futures Markets

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March 22, 2018
Introduction

- Traditionally, market microstructure models explain price changes using inventory models.
  - Market makers respond to uncertainty by adjusting their inventory.
- Recently, information based models have become more popular.
  - Informed traders disclose their private information through trade and such information is progressively incorporated into prices.
- Easley and O’Hara (1992) argue that in addition to price and volume, the timing of trade also conveys information.
  - Informed traders only trade when new information enters in the market. So short durations are associated with large volumes and the presence of new information.
Motivation

- Durations convey information (Easley and O’Hara 1992)
- Limited understanding of factors influencing price durations. Most of previous research performed for highly traded stocks trading in NYSE.
  - Evidence that less frequently traded stocks may exhibit different dynamics (Manganelli 2005, and Zhang, Russell and Tsay 2001).
- Studies performed using transaction level data only. Cao et al. (2009) and Arzandeh and Frank (2017) show that the LOB contains information that contributes to price discovery.
Objective

- Estimate the relationship between price duration and its determinants in livestock markets.
  - Take into account irregularly spaced data and duration stylized facts.
  - Use the state of the LOB to explain price durations
Methods: price durations

- Price duration: time interval between a price change

\[ x_i = t(p_i) - t(p_{i-1}) \text{ such that } |p_i - p_{i-1}| > 0 \]

where \( x_i \) is a sequence of positive numbers

- Stylized facts:
  - Duration clustering: presence of either informed traders (after information events) or liquidity traders (constant intensity of trading)
  - Right-skewed shape: Use generalized gamma family of distributions (standard exponential, standard weibull, and generalized gamma)
  - Intraday seasonalities: most studies report inverted U shape. Deseasonalized durations: \( x^*_i = x_i / \phi(t_i - 1) \)
    where \( \phi(t_i - 1) \) is a smoothed estimate of the daily deterministic component.
Methods: model

- **Autoregressive Conditional Duration (ACD) model**

\[ x_i = \psi_i \varepsilon_i \]

\[ \psi_i = \omega + \sum_{j=0}^{p} \alpha_j x_{i-j} + \sum_{j=0}^{q} \beta_j \psi_{i-j} \]

where \( \psi_i \) is the conditional expected duration, \( \mathbb{E}(x_i|F_{t-1}) \), \( \varepsilon_i \sim iid \mathcal{D}(\theta) \), \( \mathcal{D} \) is a general distribution over \((0, \infty)\) with mean equal to one and parameter vector \( \theta \)

\( \omega > 0, \alpha_j \geq 0 \) for \( j = 1, \ldots, p \), \( \beta_j \geq 0 \) for \( j = 1, \ldots, q \) \hspace{1cm} \text{(non-negativity condition)}

\[ \sum_{j=0}^{p} \alpha_j + \sum_{j=0}^{q} \beta_j < 1 \]

\hspace{1cm} \text{(stationarity condition)}
Methods: exogenous variables

- **Volume**
  - Carries information about the existence of private information
  - Most studies suggest that short durations are associated with high volumes due to the increased presence of informed traders.

- **Bid-Ask spread (BAS)**
  - Also carries information about the existence of private information
  - Short durations are associated with wider spreads due to the presence of informed traders. The market maker adjust prices to reflect the higher risk of trading with informed traders.
Methods: exogenous variables

- Limit order book (LOB)

\[
LOB = \sum_{j=2}^{n} \frac{Q_j^a}{P_j^a - P_{j-1}^a} + \frac{Q_j^b}{P_{j-1}^b - P_j^b}
\]

- \(Q_j\) is the aggregate number of contracts across all orders at price \(P_j\)
- \(a\) and \(b\) represent the ask and bid sides respectively.
- \(P_j - P_{j-1}\) is the price difference between two consecutive levels of the LOB.
Methods: exogenous variables

- If the LOB contains information then changes in the “slope” should explain price durations
Data

- Lean hogs (HE), Live cattle (LE)
- Period: Nov. 23, 2015 – March 31, 2016 (Feb, Apr, and Jun contracts)
- Trading session, 8:30 am (9:05 am) to 1:05 pm
- Thinning data (results in 1.3% for HE and 1.8% for LE):
  - Drop 15 min. after opening and before closing
  - Use price changes only
  - Drop zero price durations
## Data

<table>
<thead>
<tr>
<th></th>
<th>Lean Hogs</th>
<th>Live cattle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observations</td>
<td>81,312</td>
<td>125,366</td>
</tr>
<tr>
<td><strong>Duration</strong> (seconds)</td>
<td>13.419</td>
<td>8.234</td>
</tr>
<tr>
<td>st. dev.</td>
<td>(21.778)</td>
<td>(23.003)</td>
</tr>
<tr>
<td>min</td>
<td>0.001</td>
<td>0.001</td>
</tr>
<tr>
<td>max</td>
<td>386.079</td>
<td>1772.062</td>
</tr>
<tr>
<td><strong>Volume</strong> (# contracts)</td>
<td>2.4</td>
<td>2.36</td>
</tr>
<tr>
<td>st. dev.</td>
<td>(3.69)</td>
<td>(3.27)</td>
</tr>
<tr>
<td>min-max</td>
<td>1-200</td>
<td>1-155</td>
</tr>
<tr>
<td><strong>BAS</strong> (cents)</td>
<td>0.04313</td>
<td>0.04831</td>
</tr>
<tr>
<td>st. dev.</td>
<td>(18.06)</td>
<td>(21.00)</td>
</tr>
<tr>
<td>median</td>
<td>0.050 (2 ticks)</td>
<td>0.050 (2 ticks)</td>
</tr>
<tr>
<td>min-max</td>
<td>1-27 ticks</td>
<td>1-22 ticks</td>
</tr>
</tbody>
</table>
Data

- Diurnal pattern estimated using a cubic spline function

Lean hogs

Live cattle
Data

- *Market Depth* data files from the CME Group, provide every incremental book update required to reconstruct the (5 step deep) LOB
  - Bids
  - Asks
  - Quantities
  - Order sending time
  - Changes in LOB (order deletions, bid, asks, quantities)

- Reconstruct both outright and implied limit order book and use the consolidated limit order book.
Results: lean hogs

<table>
<thead>
<tr>
<th></th>
<th>Coeff.</th>
<th>SE</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\omega$</td>
<td>0.01658</td>
<td>0.0001574</td>
<td>&lt;0.00</td>
</tr>
<tr>
<td>$x_{t-1}$</td>
<td>0.11888</td>
<td>0.0018268</td>
<td>&lt;0.00</td>
</tr>
<tr>
<td>$\psi_{i-1}$</td>
<td>0.87809</td>
<td>0.0014450</td>
<td>&lt;0.00</td>
</tr>
<tr>
<td>Volume</td>
<td>-0.00341</td>
<td>0.0000743</td>
<td>&lt;0.00</td>
</tr>
<tr>
<td>BAS</td>
<td>-0.00325</td>
<td>0.0000306</td>
<td>&lt;0.00</td>
</tr>
<tr>
<td>LOB</td>
<td>-0.00151</td>
<td>0.0001814</td>
<td>&lt;0.00</td>
</tr>
</tbody>
</table>

Distribution: Standard Exponential ($\lambda=1$)
## Results: live cattle

<table>
<thead>
<tr>
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<th>Coeff.</th>
<th>SE</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\omega$</td>
<td>0.03329</td>
<td>0.001232</td>
<td>&lt;0.00</td>
</tr>
<tr>
<td>$\chi_{t-1}$</td>
<td>0.09174</td>
<td>0.001532</td>
<td>&lt;0.00</td>
</tr>
<tr>
<td>$\psi_{i-1}$</td>
<td>0.89837</td>
<td>0.001720</td>
<td>&lt;0.00</td>
</tr>
<tr>
<td>Volume</td>
<td>-0.00798</td>
<td>0.000345</td>
<td>&lt;0.00</td>
</tr>
<tr>
<td>BAS</td>
<td>-0.01397</td>
<td>0.000820</td>
<td>&lt;0.00</td>
</tr>
<tr>
<td>LOB</td>
<td>-0.00180</td>
<td>0.000436</td>
<td>&lt;0.00</td>
</tr>
</tbody>
</table>

Distribution: Standard Exponential ($\lambda=1$)
Results

- Estimated coefficients of past and past expected durations reveal high persistence (summation close to 1).
- Volume and BAS consistent with expectations (Easley and O’Hara 1992 model). Higher volume and spreads indicate informed based trading which translates into shorter price durations.
  - For each extra contract traded, price duration reduces by 3 milliseconds in HE and by almost 8 milliseconds in LE.
  - A one tick increase of the BAS shortens the price duration by 3 milliseconds in HE and by almost 14 milliseconds in LE.
Results

 An increase in the “slope” of the LOB is associated with shorter durations, suggesting informed traders not only place market orders when new information arrives, but may also place limit orders as part of their trading strategies. This is consistent with findings of Arzandeh and Frank (2017).

 Results consistent for both commodities, with higher coefficients for live cattle.
Conclusions

- Price durations convey information as they respond to news entering the market, through an increase in the probability of informed trading.

- The dynamic relationships in livestock commodity futures is qualitatively similar to findings in more frequently traded stock markets. In both cases the results support the Easley and O’Hara (1992) model.

- The LOB captures new information in the market and should be included in microstructure studies of price behavior.

- The information contained in price durations could be used by algorithmic traders in the development of their trading strategies.
Thank you!

Questions?