Reflexivity in financialized commodity futures markets. The role of information

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Based on the joint work:
V. Filimonov, D. Bicchetti, N. Maystre and D. Sornette
“Quantification of the High Level of Endogeneity and of Structural Regime Shifts in Commodity Markets”

“Understanding International Commodity Price Fluctuations”
IMF Research Department
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The opinions expressed in this paper, including designation and terminology, are those of the authors and are not to be taken as the official views of the UNCTAD Secretariat or its Member States.
Financialization of commodities

Increasing market share of commodity speculators

Source: CFTC figures charts by Mike Masters, Better Markets.

Source: Goldman Sachs, Bloomberg, CFTC Commitments of Traders CIT Supplement
Typical market makers’ reaction time

Year

Analysis is based on the TRTH data source (details on slide 16).
Volume traded per transaction

Brent Crude Oil

WTI

E-Mini S&P 500 Futures

Analysis is based on the TRTH data source (details on slide 16).
Information

- supply/demand
- interest rates
- exchange rates
- inflation
- economic conditions
- cost of production
- weather
- political stability
- etc.

Prices

???
Efficient Markets
(exogenous dynamics)

Prices are just reflecting news: the market fully and instantaneously absorbs the flow of information and faithfully reflects it in asset prices.

In particular, financial crashes are the signature of exogenous negative news of large impact.
Two views on price formation

**Efficient Markets**
*(exogenous dynamics)*

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In particular, financial crashes are the signature of exogenous negative news of large impact.

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**“Reflexivity” of markets**
*(endogenous dynamics)*

Markets are subjected to internal feedback loops (e.g. created by collective behavior such as herding or informational cascades).

Prices do influence the fundamentals and this newly-influenced set of fundamentals then proceed to change expectations, thus influencing prices.
Sources of reflexivity in financial and financialized markets

- Behavioral mechanisms such as imitation and informational cascades leading to **herding**;
- Speculation, based on technical analysis, including **algorithmic trading**;
- **Hedging** strategies (also increase cross-excitation between markets);
- Pricing of “**structured products**” such as ETFs (also contribute to cross-excitation)
- Methods of **optimal portfolio execution** and **order splitting**;
- Margin/leverage trading and **margin-calls**;
- **High frequency trading (HFT)** as a subset of algorithmic trading;
- **Stop-loss orders** and etc.
Is it possible to quantify the interplay between **exogeneity** (external impact) and **endogeneity** (internal self-excitation) in price formation?

How **efficient** are commodity markets?
“As a policy-maker during the crisis, I found the available models of limited help. In fact, I would go further: in the face of the crisis, we felt abandoned by conventional tools. In the absence of clear guidance from existing analytical frameworks, policy-makers had to place particular reliance on our experience”.

Jean-Claude Trichet (2010)
The test subject: HF price dynamics

- Last transaction price
- Best bid price
- Best ask price
- Mid-quote price
- Mid-quote price change
- Limit orders to sell
- Limit orders to buy
- Buy market order
- Sell market order
The test subject: HF price dynamics

<table>
<thead>
<tr>
<th>Time</th>
<th>Price</th>
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</table>

<table>
<thead>
<tr>
<th>Last transaction price</th>
<th>Best bid price</th>
<th>Best ask price</th>
<th>Mid-quote price</th>
<th>Transaction</th>
<th>Mid-quote price change</th>
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</table>

Limit orders to sell
Buy market order
Sell market order
Limit orders to buy

Price.

Time
Self-excited Hawkes process is the point process whose intensity $\lambda_i(t)$ is conditional on its history:

$$\lambda(t) = \mu + n \sum_{t_i < t} \varphi(t - t_i)$$
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**Background intensity**

**Self-excitation part**
The model: Self-excited Hawkes process

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$$\lambda(t) = \mu + n \sum_{t_i < t} \varphi(t - t_i)$$

- **Background intensity**
- **Self-excitation part**

**Exogenous activity**

**Endogenous feedback**
The model: Self-excited Hawkes process

Self-excited Hawkes process is the point process whose intensity $\lambda_i(t)$ is conditional on its history:

$$\lambda(t) = \mu + n \sum_{t_i < t} \varphi(t - t_i)$$

Economic applications of the Hawkes model:

- High-frequency price dynamics
- Order book construction
- Critical events and estimation of VaR
- Correlated default times in a portfolio of companies
Branching structure of earthquake sequences
Crucial parameter of the branching process is the “branching ratio” ($n$) which is defined as an average number of “daughters” per one “mother”

For $n < 1$ system is subcritical (stationary evolution)
For $n = 1$ system is critical (tipping point)
For $n > 1$ system is supercritical (with prob.$>0$ will explode to infinity)
Crucial parameter of the branching process is the “branching ratio” \( n \) which is defined as an average number of “daughters” per one “mother”

For \( n < 1 \) system is subcritical (stationary evolution)
For \( n = 1 \) system is critical (tipping point)
For \( n > 1 \) system is supercritical (with prob.\( >0 \) will explode to infinity)

In subcritical regime, the branching ratio \( n \) is equal to the fraction of endogenously generated events among the whole population.
# Selected Instruments

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Exchange / Trading platform</th>
<th>Inception of electronic trading</th>
<th>Average monthly volume in 2012</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brent Crude</td>
<td>ICE Europe / ICE</td>
<td>April 7, 2005</td>
<td>4,009,582</td>
</tr>
<tr>
<td>WTI</td>
<td>NYMEX / CME Globex</td>
<td>September 4, 2006</td>
<td>5,482,223</td>
</tr>
<tr>
<td>Soybean</td>
<td>CBOT / CME Globex</td>
<td>August 1, 2006</td>
<td>1,493,210</td>
</tr>
<tr>
<td>Sugar #11</td>
<td>ICE US / ICE</td>
<td>January 12, 2007 (March 2, 2008)</td>
<td>909,178</td>
</tr>
<tr>
<td>Corn</td>
<td>CBOT / CME Globex</td>
<td>August 1, 2006</td>
<td>2,706,229</td>
</tr>
<tr>
<td>Wheat</td>
<td>CBOT / CME Globex</td>
<td>August 1, 2006</td>
<td>1,045,313</td>
</tr>
<tr>
<td>Sugar (Europe)</td>
<td>LIFFE / NYSE Euronext</td>
<td>November 27, 2000</td>
<td>82,955</td>
</tr>
</tbody>
</table>
Data source

- We have analyzed **Front Month** futures contracts of the instruments presented at previous slide. Rolling periods were ignored.

- Data source: **Thomson Reuters Tick History**, that provides level-1 data (TAQ) with the millisecond resolution of timestamps.

- In fact due to the FAST/FIX protocol handling, the *reliability of timestamps in TRTH database is much lower than milliseconds* and is defined by the typical time between consecutive FAST/FIX packages.

### Median uncertainty in timestamps (in milliseconds)

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<tbody>
<tr>
<td>Brent (EU)</td>
<td>227</td>
<td>118</td>
<td>35</td>
<td>26</td>
<td>24</td>
<td>30</td>
<td>65</td>
<td>68</td>
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<tr>
<td>WTI (US)</td>
<td>—</td>
<td>199</td>
<td>80</td>
<td>62</td>
<td>61</td>
<td>62</td>
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<td>Soybean (US)</td>
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<td>149</td>
<td>130</td>
<td>71</td>
<td>77</td>
<td>32</td>
<td>22</td>
<td>23</td>
</tr>
<tr>
<td>Sugar #11 (US)</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>112</td>
<td>58</td>
<td>43</td>
<td>127</td>
<td>135</td>
</tr>
<tr>
<td>Corn (US)</td>
<td>—</td>
<td>151</td>
<td>174</td>
<td>75</td>
<td>106</td>
<td>45</td>
<td>32</td>
<td>26</td>
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<tr>
<td>Wheat (US)</td>
<td>—</td>
<td>174</td>
<td>179</td>
<td>91</td>
<td>86</td>
<td>29</td>
<td>30</td>
<td>22</td>
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<tr>
<td>Sugar (EU)</td>
<td>223</td>
<td>197</td>
<td>190</td>
<td>245</td>
<td>119</td>
<td>85</td>
<td>84</td>
<td>69</td>
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<tr>
<td>E-mini S&amp;P 500</td>
<td>127</td>
<td>121</td>
<td>79</td>
<td>51</td>
<td>60</td>
<td>31</td>
<td>32</td>
<td>41</td>
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</table>
Methodology

- We split the entire interval of the analysis (2005-2012) into **10 minutes** intervals, rolling them with a step of 1 minute within the RTH.

- In each of these windows we have calibrated the **Hawkes model** with the short-term exponential kernel

\[ \lambda_t(t) = \mu + \frac{n}{\tau} \sum_{t_i < t} \exp \left( -\frac{t - t_i}{\tau} \right) \]

on the timestamps of mid-quote price changes.

- Each calibration resulted in a single estimation of the **branching ration** \( n \).

- Collecting all estimates for each month (~6000-7000 estimates) we have averaged them to construct the “**reflexivity index**” for the given month.

\[ n = 0.43 \]
<table>
<thead>
<tr>
<th>mechanism</th>
<th>milliseconds</th>
<th>seconds</th>
<th>minutes</th>
<th>hours</th>
<th>days</th>
<th>weeks</th>
<th>months</th>
<th>years</th>
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<tbody>
<tr>
<td>High-frequency trading</td>
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<td>Stop-loss orders</td>
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<td>Algorithmic trading</td>
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<td>Optimal execution</td>
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<td>Margin calls</td>
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<tr>
<td>Imitation</td>
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<tr>
<td>Long-term herding</td>
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</table>
### Mechanisms of self-reflexivity

<table>
<thead>
<tr>
<th>milliseconds</th>
<th>seconds</th>
<th>minutes</th>
<th>hours</th>
<th>days</th>
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<td>Imitation</td>
<td>Long-term herding</td>
<td></td>
</tr>
</tbody>
</table>
Trading activity proxied by volume and number of mid-price changes

Dynamics of price and volatility

Rate of exogenous events (triggered by idiosyncratic “news”)

Branching ratio that quantifies reflexivity of the system (fraction of endogenous events in the system)
Crude Oil: Brent and WTI

Brent Crude (ICE Europe)

- Daily volatility
- Daily closing price

WTI (NYMEX)

- Daily volatility
- Daily closing price

Volatility

Price

Volume

Branching ratio

Year

2005 2006 2007 2008 2009 2010 2011 2012

2005 2006 2007 2008 2009 2010 2011 2012
Crude Oil: Brent and WTI

Brent Crude (ICE Europe)

WTI (NYMEX)
Soft commodities: Sugar

**Sugar #11 (ICE US)**

- Daily volatility
- Daily closing price

**Sugar (LIFFE)**

- Daily volatility
- Daily closing price

Volume, Branching ratio, and Price charts for the years 2005 to 2012.
Soft commodities: Sugar

Sugar #11 (ICE US)

Daily volatility and daily closing price over the years 2005 to 2012.

Sugar (LIFFE)

Daily volatility and daily closing price over the years 2005 to 2012.
Soft commodities: Soybean, Corn and Wheat

Soybean (CBOT)

Corn (CBOT)

Wheat (CBOT)
Soft commodities: Soybean, Corn and Wheat

**Soybean (CBOT)**

**Corn (CBOT)**

**Wheat (CBOT)**
April 27, 2010:
Significant fall of most of US markets following the cut of the credit rating of Greece and Portugal

May 6, 2010 (“flash-crash”):
The activity of high-frequency traders of the S&P 500 E-mini futures contracts leaded to a dramatic fall in other markets

Source: V. Filimonov, D. Sornette (2012)
PRE 85 (5): 056108.
Exogenous vs endogenous shocks in HF

April 27, 2010:
Significant fall of most of US markets following the cut of the credit rating of Greece and Portugal

May 6, 2010 ("flash-crash"):
The activity of high-frequency traders of the S&P 500 E-mini futures contracts leaded to a dramatic fall in other markets

Volume and Trading activity behave similar in both cases

Branching ratio (degree of reflexivity) reveals fundamental difference between two shocks

Endogenous shocks in oil market

WTI Futures Contracts (2010-2012)
6 events that are associated with the largest values of the reflexivity index
Final remarks

- We have proposed a **novel powerful metric of the short-term self-excitation** of the price movements.

- Our analysis of the commodity markets showed significant impact of the feedback mechanisms rather than fundamental news on short scales. Namely all analyzed commodities have reflexivity index of more than 60-70%, which means that **less than 30-40% of all price movements are due to external news**.

- We have identified **extraordinary** (even for financial assets) **high short-term reflexivity on oil futures during the crisis of 2008**, which indicates high degree of short-term algorithmic trading over this period.

- We have documented **recent strong upward trend on the short-term reflexivity of the Sugar #11**, which might indicate potential instability in this market.

- For Soybean, Corn and Wheat we have documented strong increase of the short-term reflexivity index in 3rd quarter of 2010, which might be triggered by the export ban on Wheat by Russia and Ukraine.

- We suggest that the **proposed measure could be used** for analysis of the nature of price anomalies, or even **for the real-time diagnostics of the upcoming instabilities**.