Closing Pressure, Predatory Trading, and the Negative Price of Oil

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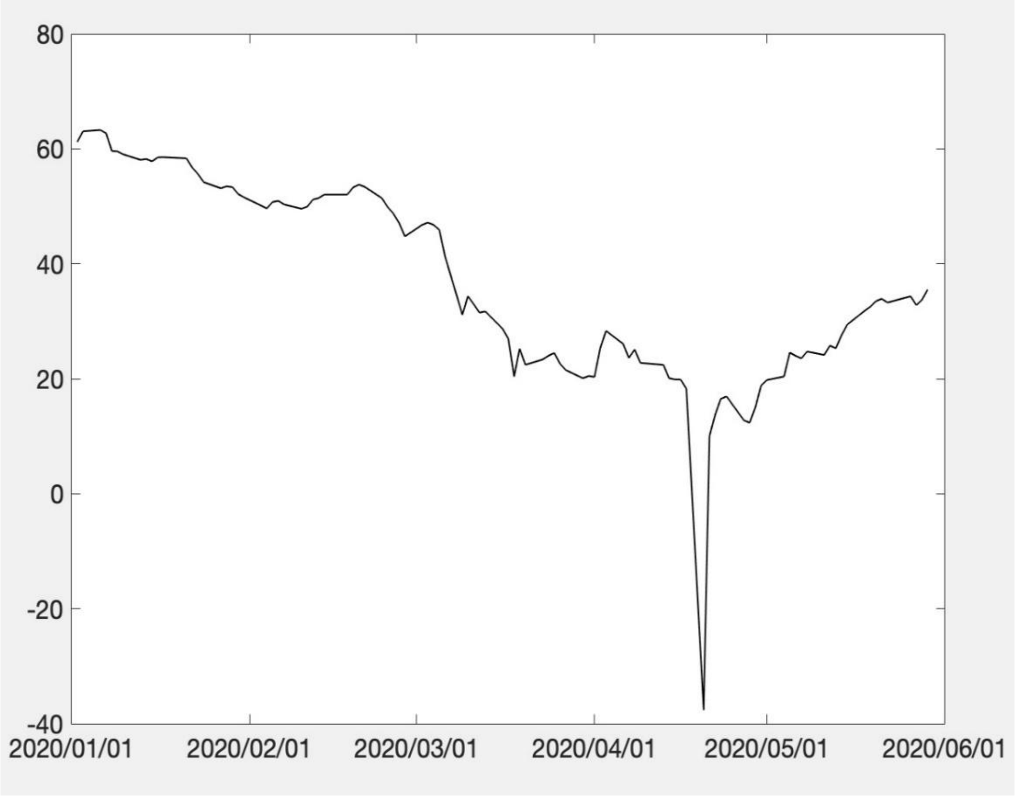
Negative Price of WTI

- Oil is the most important production input for transportation, electricity, chemical and other pillar industries. It is closely related to the real economy and contributes to over a third of the world's energy consumption. It's also the important driver of global inflation and the economy growth engine for oil-exporting countries.
- WTI Crude Oil Futures are one of the most actively traded securities in global financial markets. Average annual trading volume for WTI contracts for 2019-2021 is $8 trillions.
- However, price of the May-2020 WTI Contract unprecedentedly dropped below zero on April 20, 2020, and the settlement price was extremely negative at **-$37.63**/barrel.

Effects on Real and Financial Players

The negative price shock has widespread effects:

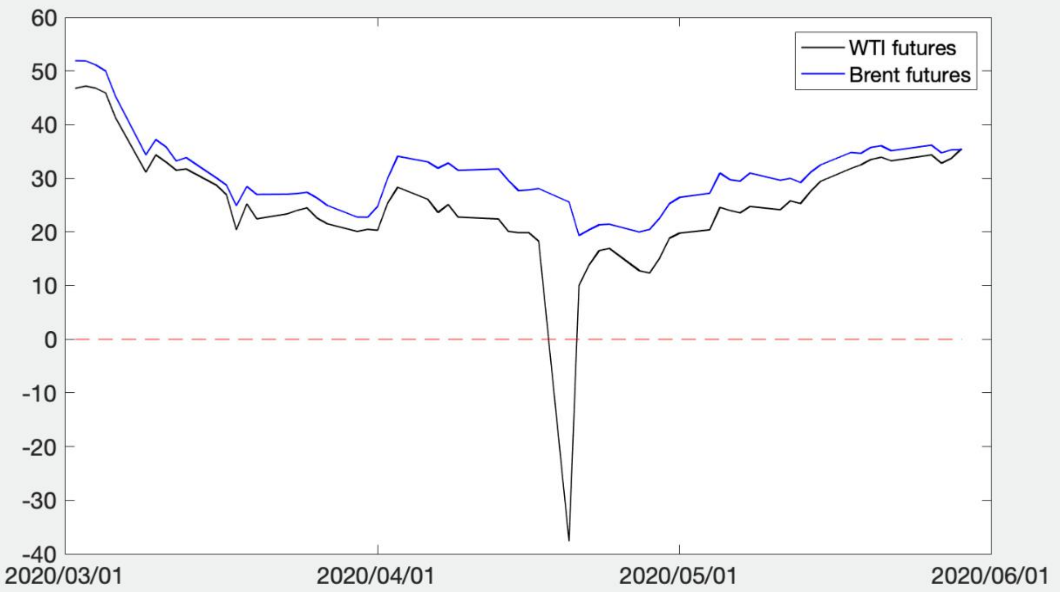
- Firms with physical purchase contracts indexed to WTI futures shut in production at greater rates after this event than those who did not (Gilje et al., 2021).
- International investors suffered huge losses with financial products linked to WTI futures including Interactive Brokers, Bank of China, Multi Commodity Exchange in India, and other financial institutions worldwide.



WTI crude oil futures price

Benchmark against Brent

- WTI price is somewhat lower than the Brent price in regular situations, but April 20 recorded an abnormal price divergence with a spread of **-63** dollars.
- The spread between WTI first-nearby and second-nearby contracts was also extremely negative at **-58** dollars on April 20, 2020.
- The negative price is unlikely to be solely a fundamental-driven issue, since these fundamentals also function for Brent futures and the second-nearby WTI contract, and they cannot change substantially in only one day.



		First-nearby	Second-nearby
April 17	WTI	18.27	25.03
	Brent	28.08	31.58
April 20	WTI	-37.63	20.43
	Brent	25.57	29.21
April 21	WTI	10.01	11.57
	Brent	19.33	23.12

Settlement Rules

➢ Physical settlement vs. cash settlement

- WTI futures take physical settlement rules that traders, who still have their positions open after expiration, must take deliveries of real crude oil at Cushing.
- Brent futures take cash settlement rules that traders can choose to transfer the net cash positions after expiration.

➢ Contract rolling

- Participants unwilling to take deliveries have to close positions in the first-nearby WTI contract before its expiration.
- Most traders will not wait until the nominal last trading day because if they fail to close the contracts on this day, they will really have to accept physical deliveries.
- Therefore, the penultimate trading day is the de facto last trading day for closing the contracts.
- Only 1% of WTI contracts traded go to physical deliveries. (Source: EIA)

➢ The last trading day for WTI

Trading of the first-nearby WTI contract terminates three business days before the 25^{th} calendar day of the month prior to the contract month. The May-2020 WTI Contract is the first-nearby contract in April and its maturity date is April 21, 2020.

Informal Discussions in Practice

- **Common explanation in media**

- CNBC: There is limited tanker storage as a result of the collapse in oil demand, and WTI price is under pressure.
- REUTERS, April 21, 2020: "The frenzied selling was driven by a lack of storage space to hold a glut of crude, meaningtraders were willing to pay buyers to take oil off their hands."

- **High open interest**

Open interest before the trading of April 20, 2020, is 108k, about 70% higher than its trailing 12-month average.

- **High oil inventory and lack of storage space**

76% of the working storage capacities at Cushing had been occupied before April 20, and most of others was leased out or committed. (Source: EIA)

- **Closing pressure**

Long-side traders are afraid of taking deliveries since Cushing has run out of storage space; they are more eager to sell contracts before expiration but have difficulty finding counterparties, and thus are faced with closing pressure.

What Do We Do?

- Empirically examine the informal argument
  - Some consistent evidence, but quantitatively difficult

- Build a simple dynamic model
  - Illustrate the importance of price/liquidity dynamics and TAS arbitrageurs
  - Quantitatively generate the negative price

- Highlight the roles of physical settlement rule and TAS/commodity financialization in determining futures prices

Hypothesis Development

Total starting open interest on the de facto last trading day: A

- **Liquidity demanders**
  - $Financial\ Settler_L$ (long-position financial settler): Sell contracts $a_L A$
  - $Financial\ Settler_S$ (short-position financial settler): Buy contracts $a_S A$
- **Liquidity provider:** $F - F_0 = -\lambda \times D$ D is the net selling demand
- **Market clearing:** $D = a_L A - a_S A \Rightarrow F - F_0 = -\lambda \times (a_L - a_S)A$

$\Rightarrow$ **Prices:** $F = F_0 - \lambda \times (a_L - a_S)A$

Further assumption: $a_L - a_S = \gamma \times I$ (with γ>0)

Define closing pressure: $CLP = A \times I$

$$\Rightarrow \quad F = F_0 - \lambda\gamma \times CLP$$

- **Hypotheses:**
  - Higher closing pressure leads to lower WTI futures price: $\frac{\partial F}{\partial CLP} = -\lambda\gamma < 0$
  - The negative price effect of closing pressure is strengthened by the drying-up of market liquidity: $\frac{\partial}{\partial \lambda}\left|\frac{\partial F}{\partial CLP}\right| = \gamma > 0$

Data and Measures (1)

- **Futures data**
  - Daily closing price, trading volume and open interest of WTI first-nearby contracts
  - Sample period: January 2003 to March 2020, excluding the data point of the negative price
- **Price spread measurement**

$$WBdollarspread_{M,T} = P_{WTI,M,T,1} - P_{Brent,M,T,1}$$

$$WBpercspread_{M,T} = \frac{P_{WTI,M,T,1} - P_{Brent,M,T,1}}{P_{Brent,M,T,1}}$$

T is the de facto last trading day (the nominal penultimate trading day) for each contract.

- **Closing pressure measurement**

$$Closing\ pressure_{M,T-1} = Open\ Interest_{M,T-1} * Inventory^{*}_{M,T-1}$$

$$Inventory^{*}_{M,T-1} = \frac{Inventory_{M,T-1}}{(\sum_{m=M-12}^{M-1} Inventory_{m,T_m-1})/12}$$

Data and Measures (2)

Market illiquidity measurement

- Daily illiquidity of day t, month M:

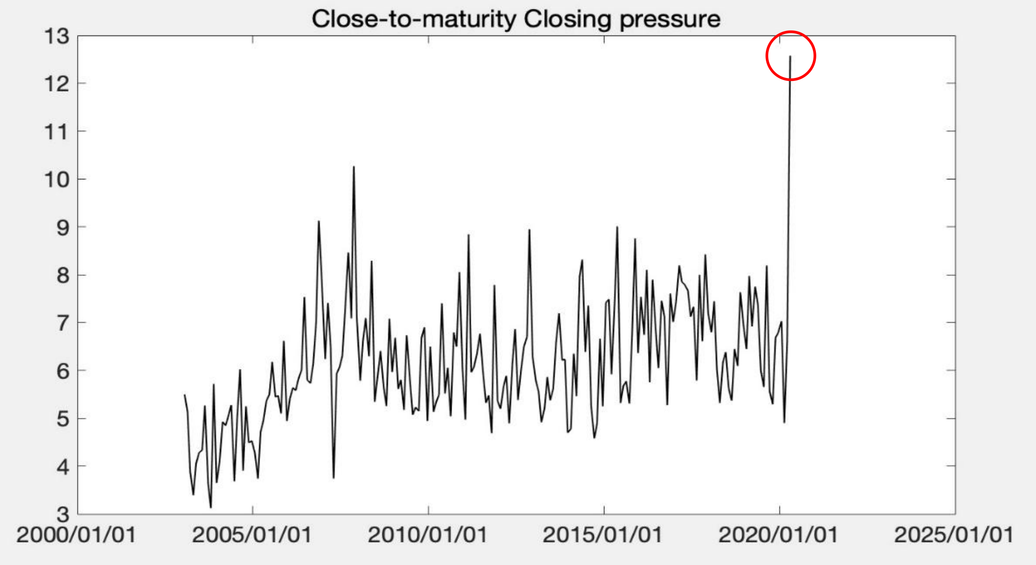
$$Amihud_{M,t} = \frac{|Return_{M,t}|}{Trading\,Volume_{M,t}}$$

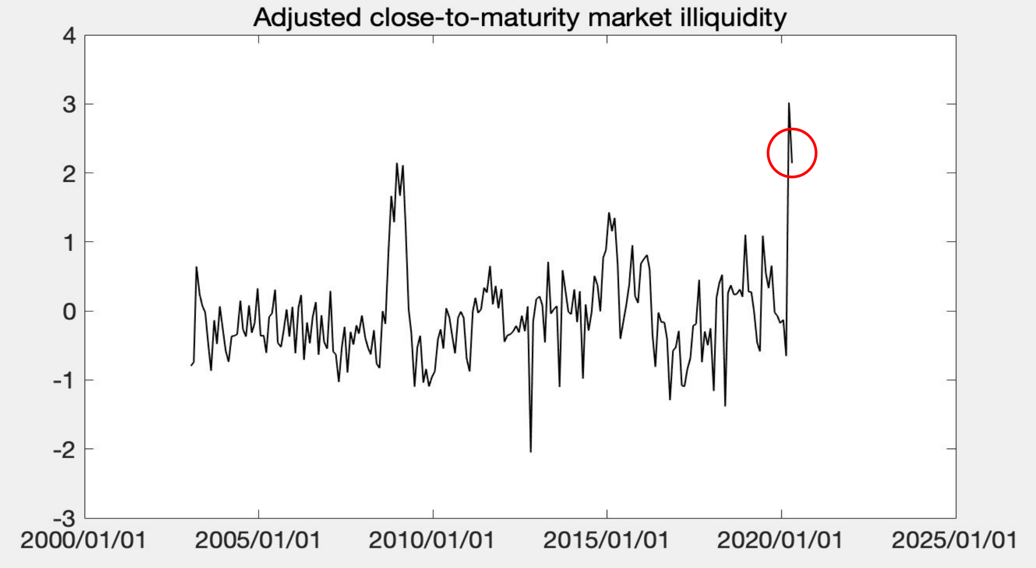
- Average illiquidity before maturity in month M:

$$Amihud_{M,T-1} = \log\left(\sum_{t=T-5}^{T-1} Amihud_{M,t}/5\right)$$

- Detrend:

$$Amihud^{*}_{M,T-1} = Amihud_{M,T-1} - \frac{\left(\sum_{\mathrm{m=M-12}}^{\mathrm{M-1}} \mathrm{Amihud}_{\mathrm{m},T_m-1}\right)}{12}$$





Baseline Regression

$$WBdollarspread_{M,T}$$
$$= \alpha + \beta_1 * Closing\ Pressure_{M,T-1} + \beta_2 * Closing\ Pressure_{M,T-1} * Amihud^*_{M,T-1}$$
$$+ \sum_{k=2}^{12} \beta_{3,k} * D_k(Month_M) + \beta_4 * Inventory_{M,T-1} + \beta_5 * Return_{M,T-1} + \varepsilon_M$$

Predictions: $\beta_1 < 0, \beta_2 < 0$

Baseline Results (1)

$$WBdollarspread_{M,T} = P_{WTI,M,T,1} - P_{Brent,M,T,1}$$

Estimated Coefficients	*(1)*	*(2)*	*(3)*	*(4)*
Closing Pressure	-0.869** (-2.36)	-0.951*** (-2.60)	-1.058*** (-2.61)	-1.045** (-2.53)
*Closing Pressure*Illiquidity*		-0.255** (-2.33)	-0.262** (-2.28)	-0.268** (-2.10)
Normalized Inventory				-1.574 (-0.19)
Return				-0.058 (-0.30)
Month Effect	No	No	Yes	Yes
R^2	2.6%	5.2%	5.7%	5.8%
No.	207	207	207	207

Baseline Results (2)

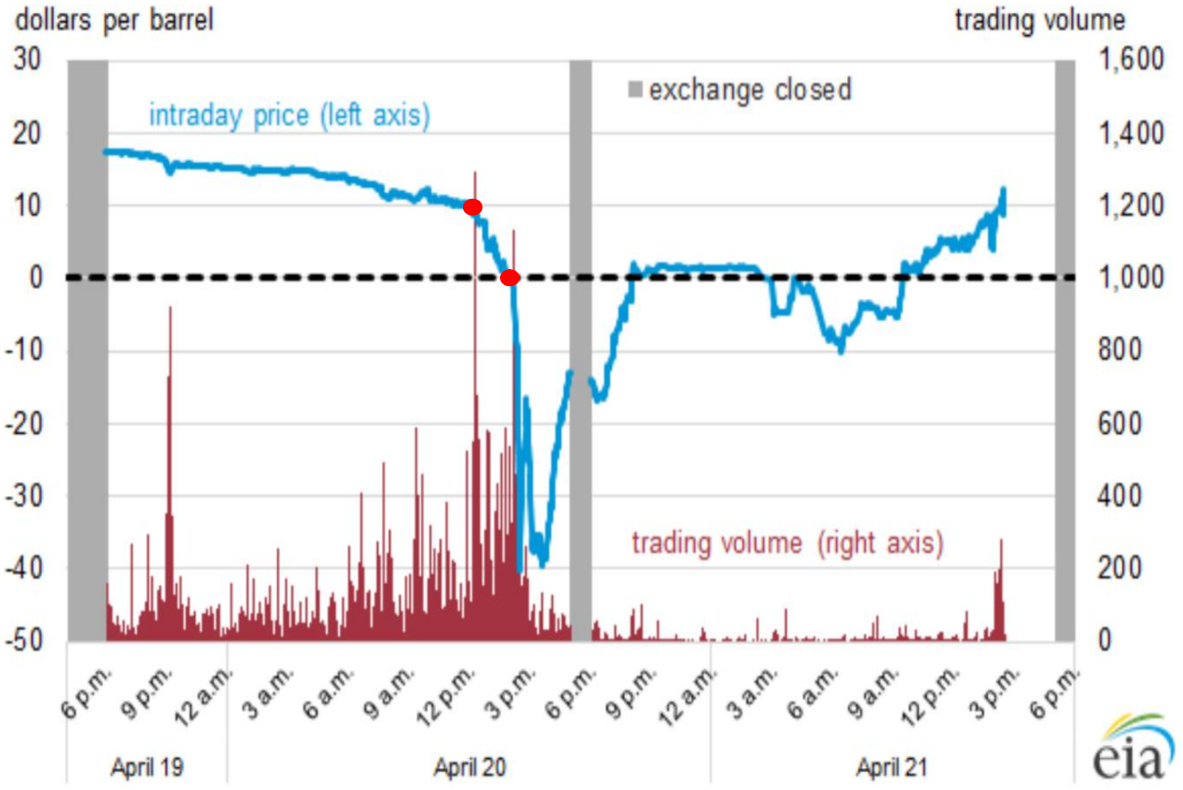
$$WBpercspread_{M,T-1} = \frac{P_{WTI,M,T,1} - P_{Brent,M,T,1}}{P_{Brent,M,T-1,1}} * 100$$

Estimated Coefficients	*(1)*	*(2)*	*(3)*	*(4)*
Closing Pressure	-2.294*** (-5.14)	-2.473*** (-5.73)	-2.814*** (-5.95)	-2.705*** (-5.64)
*Closing Pressure*Illiquidity*		-0.550*** (-4.27)	-0.554*** (-4.13)	-0.496*** (-3.34)
Normalized Inventory				-12.87 (-1.37)
Return				0.010 (0.04)
Month Effect	No	No	Yes	Yes
R^2	11.4%	18.7%	20.5%	21.3%
No.	207	207	207	207

Does the Simple Mechanism Work? Yes, But Not Sufficient

- Estimate WTI-Brent dollar spread and the corresponding WTI futures price on April 20, 2020, based on the baseline regression estimates that come from the historical data.
- The fitted WTI price is approximately $7/barrel.
  - Closing pressure does push down WTI futures price on April 20, 2020, but is not sufficient to fully explain the extremely negative price of -37 dollars.
- There are two missing points in the simple argument:
  - Intraday price dynamics on April 20, 2020;
  - The role of TAS arbitrageurs (predatory traders across outright and TAS markets).

Dynamics of Prices



The intraday price dynamics on April 20, 2020, can be divided roughly into three phases:

- Trading started the preceding evening at 18:00 EST with an opening price of $17.73, and the price dropped slowly to $10 at 12:00.
- The price declined more quickly after 12:00 and reached zero at 14:00.
- The price then collapsed 30 minutes right before the daily settlement period (14:28 to 14:30) and went to a shocking settlement price of -$37.63.

Dynamics of Liquidity

	Before 12:00	12:00-14:00	14:00-14:30
Estimated λ_i	0.0303^{***} (25.13)	0.2738^{***} (26.74)	0.6211^{***} (7.92)

Estimate market illiquidity with tick-by-tick data:

- Classify each transaction with tick rule: If trading price is higher than the prevailing mid-quote price, define the transaction as buyer-initiated ($Ticker_j = 1$). If lower, seller-initiated ($Ticker_j = -1$). If the two prices equals, compare the prevailing trading price with that of the last transaction.
- Estimate market illiquidity following Kyle (1985):

$$P_j - P_{j-1} = \theta_i + \lambda_i * OrderImbalance_j + \varepsilon_j \quad i=1, 2, 3$$

where $OrderImbalance_j = Ticker_j * TradingVolume_j$; $P_j - P_{j-1}$ is the price change in dollar amount.

- For the purpose of expression convenience, we report lambda by multiplying with 100.

TAS Arbitrageurs

- **TAS (Trading-at-Settlement) orders**

TAS is an order type that allows participants to establish positions with yet-to-be-determined daily settlement price (VWAP between 14:28 and 14:30) at any time during the trading session.

- **Commodity financialization**

Financial index traders establish long positions in oil futures via TAS orders conducted by swap dealers. They target settlement prices, do not take physical deliveries, and have to roll the contracts ahead of time. Aa result, there is great selling demand in the TAS market before contract expiration.

- **TAS predatory trading strategy across two markets**

- Buy as many futures as possible (from swap dealers) in the TAS market;
- Sell the same number of futures in the outright futures market right before the settlement period to push down the daily settlement price (the contract purchase price).

Anecdotal evidence on TAS Arbitrageurs

- Bloomberg Business Week

Nine traders in Vega Capital London Ltd. (a London based hedge fund) may have had the largest impact on prices, making $**660 million**s in just a few hours from negative price.

- Commodity Futures Trading Commission

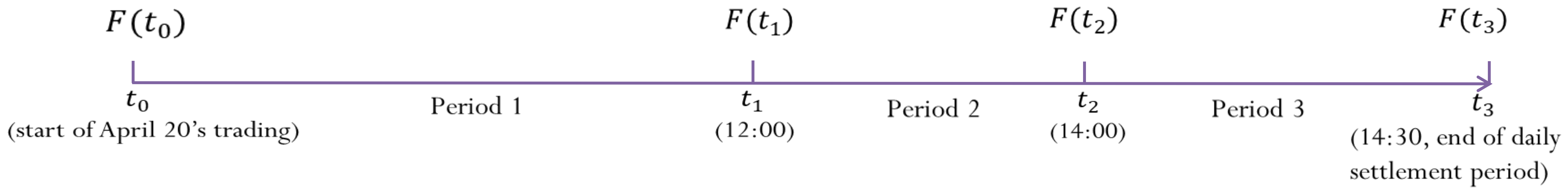
Dan M. Berkovitz, Commissioner of CFTC, has called for an investigation into the potential manipulation of TAS trading.

- Oil producer

Chairman of Continental Resources Inc. (an oil producer) argues for an investigation on the possible failed market system.

A Simple Three-Period Model

- **Three periods**



- **Liquidity demanders:**

- $Financial\ Settler_L$

  Initial endowment: long-position $a_L A$. Sell contracts in the outright market.

- $Financial\ Settler_S$

  Initial endowment: short-position $a_S A$. Buy contracts in the outright market.

- $TAS\ arbitrageur$:

  Initial endowment: 0. Buy Δ contracts in the TAS market and sell equal amount in the outright market.

- **Liquidity provider:** $F(t_i) - F(t_{i-1}) = -\lambda_i \times D_i$

- Assumption: $\lambda_1 < \lambda_2 < \lambda_3$

Trading Decisions

- $Financial\ Settler_L$

Sell x_{L1} in period 1, sell x_{L2} in period 2, and close the rest $a_L A - x_{L1} - x_{L2}$ in period 3. Maximize total profit:

$$F(t_1) \times x_{L1} + F(t_2) \times x_{L2} + F(t_3) \times x_{L3}$$

$$\text{subject to } x_{L1} + x_{L2} + x_{L3} = a_L A$$

- $Financial\ Settler_S$

Buy x_{S1} in period 1, buy x_{S2} in period 2, and close the rest $a_S A - x_{S1} - x_{S2}$ in period 3. Minimize total cost:

$$F(t_1) \times x_{S1} + F(t_2) \times x_{S2} + F(t_3) \times x_{S3}$$

$$\text{subject to } x_{S1} + x_{S2} + x_{S3} = a_S A$$

- $Financial\ Settler_T$

Buy Δ in the TAS market. Sell Δ_1 in period 1, sell Δ_2 in period 2, and close the rest Δ_3 in period 3. Maximize total profit:

$$F(t_1) \times \Delta_1 + F(t_2) \times \Delta_2 + F(t_3) \times \Delta_3 - F(t_3) \times \Delta$$

$$\text{subject to } \Delta_1 + \Delta_2 + \Delta_3 = \Delta$$

Market Clearing and Prices (1)

- **Market-clearing conditions**

Period 1: $F(t_1) - F(t_0) = -\lambda_1 \times D_1$ $\quad D_1 = x_{L1} + \Delta_1 - x_{S1}$

Period 2: $F(t_2) - F(t_1) = -\lambda_2 \times D_2$ $\quad D_2 = x_{L2} + \Delta_2 - x_{S2}$

Period 3: $F(t_3) - F(t_2) = -\lambda_3 \times D_3$ $\quad D_3 = x_{L3} + \Delta_3 - x_{S3}$

- **Prices**

$$\Delta_1 = \frac{3\lambda_3\Delta + (\frac{4\lambda_1\lambda_3}{\lambda_2} - \lambda_1)(a_L - a_S)A}{16\lambda_3 - 3\lambda_2}$$

$$\Delta_2 = \frac{\lambda_3\Delta + (6\lambda_1 - \frac{\lambda_1\lambda_2}{\lambda_3} - \frac{4\lambda_1\lambda_3}{\lambda_2})(a_L - a_S)A}{16\lambda_3 - 3\lambda_2}$$

$$F(t_1) = F(t_0) - \lambda_1 \frac{16\lambda_3 - 3\lambda_2 - \frac{4\lambda_1\lambda_3}{\lambda_2}}{16\lambda_3 - 3\lambda_2} \times (a_L - a_S)A - \frac{9\lambda_1\lambda_3}{16\lambda_3 - 3\lambda_2} \times \Delta$$

$$F(t_2) = F(t_0) - \lambda_1 \frac{20\lambda_3 - 4\lambda_2 - \frac{4\lambda_1\lambda_3}{\lambda_2}}{16\lambda_3 - 3\lambda_2} \times (a_L - a_S)A - \frac{\lambda_3(9\lambda_1 + 3\lambda_2)}{16\lambda_3 - 3\lambda_2} \times \Delta$$

$$F(t_3) = F(t_0) - \lambda_1 \frac{21\lambda_3 - 4\lambda_2 - \frac{4\lambda_1\lambda_3}{\lambda_2}}{16\lambda_3 - 3\lambda_2} \times (a_L - a_S)A - \frac{\lambda_3(9\lambda_1 + 4\lambda_3)}{16\lambda_3 - 3\lambda_2} \times \Delta$$

Market Clearing and Prices (2)

- Further assumption $a_L - a_S = \gamma \times I$ (with γ >0)
- Define closing pressure $CLP = A \times I$
- Final solutions

$$F(t_1) = F(t_0) - \gamma\lambda_1 \frac{16\lambda_3 - 3\lambda_2 - \frac{4\lambda_1\lambda_3}{\lambda_2}}{16\lambda_3 - 3\lambda_2} \times CLP - \frac{9\lambda_1\lambda_3}{16\lambda_3 - 3\lambda_2} \times \Delta$$

$$F(t_2) = F(t_0) - \gamma\lambda_1 \frac{20\lambda_3 - 4\lambda_2 - \frac{4\lambda_1\lambda_3}{\lambda_2}}{16\lambda_3 - 3\lambda_2} \times CLP - \frac{\lambda_3(9\lambda_1 + 3\lambda_2)}{16\lambda_3 - 3\lambda_2} \times \Delta$$

$$F(t_3) = F(t_0) - \gamma\lambda_1 \frac{21\lambda_3 - 4\lambda_2 - \frac{4\lambda_1\lambda_3}{\lambda_2}}{16\lambda_3 - 3\lambda_2} \times CLP - \frac{\lambda_3(9\lambda_1 + 4\lambda_3)}{16\lambda_3 - 3\lambda_2} \times \Delta$$

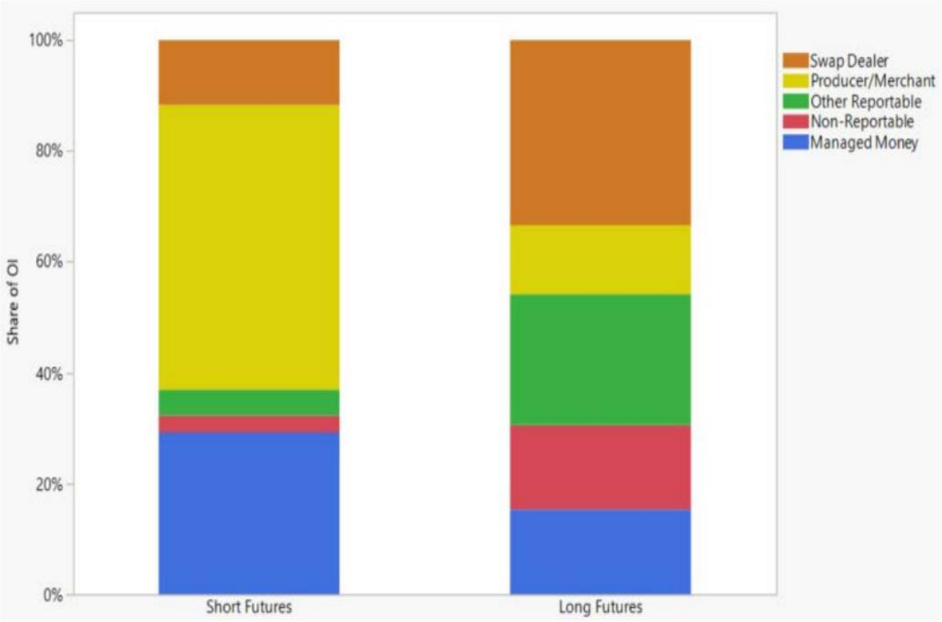
Parameter Calibration

- $a_L - a_S = 16\%$

Aggregate Managed Money, Other Reportable, and Non-Reportable as financial settlers.

- $\Delta = 25\% \times A$

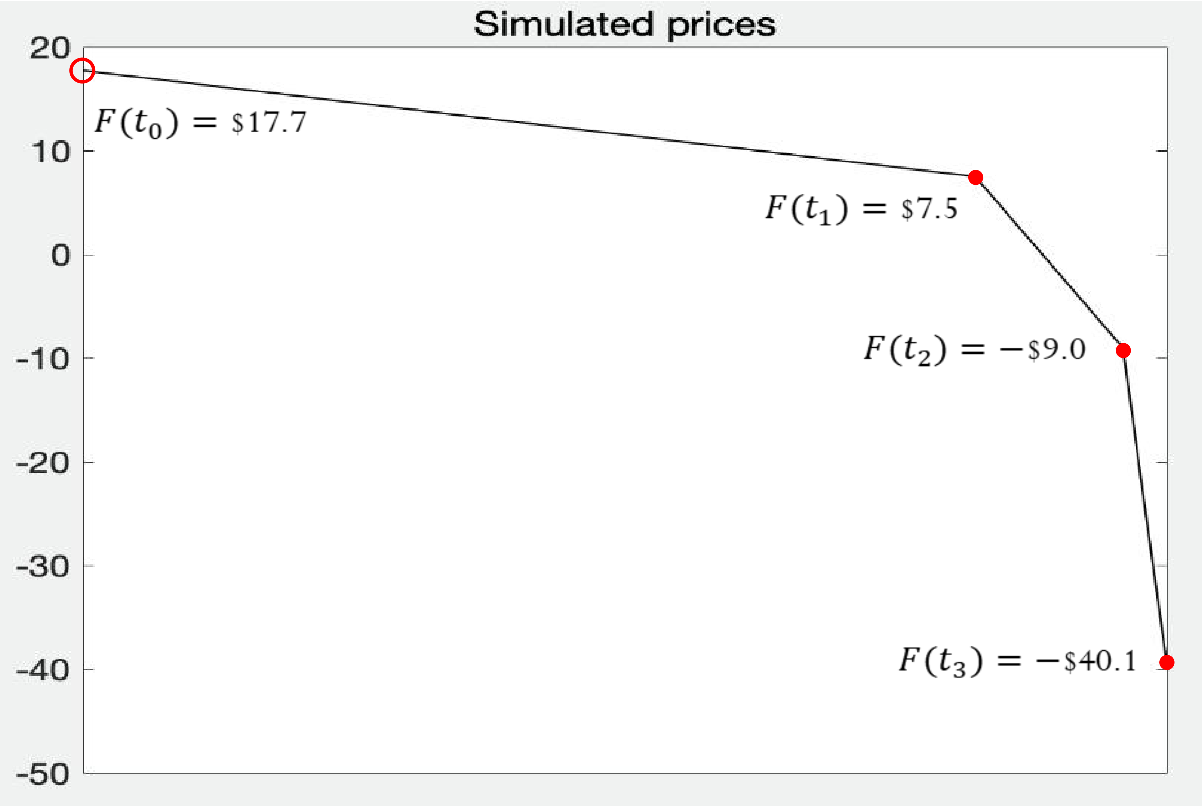
Interpret Swap Dealer as TAS settlers. Index traders normally gain exposure to oil futures by trading with swap dealers targeting settlement price, and swap dealers hedge their risks via TAS orders.



Starting open interest on April 20, 2020 for May Contract, by DCOT trader type (Source: CFTC Interim Staff Report)

- $I = 1.16$ based on empirical data $\Rightarrow \gamma = \frac{a_L - a_S}{I} = 0.14$
- λ_i: $\lambda_1 = 0.0303,\ \lambda_2 = 0.2738,\ \lambda_3 = 0.6211$
- $A = 108{,}593$ contracts
- $F(t_0) = \$17.72$/barrel

Price Simulation

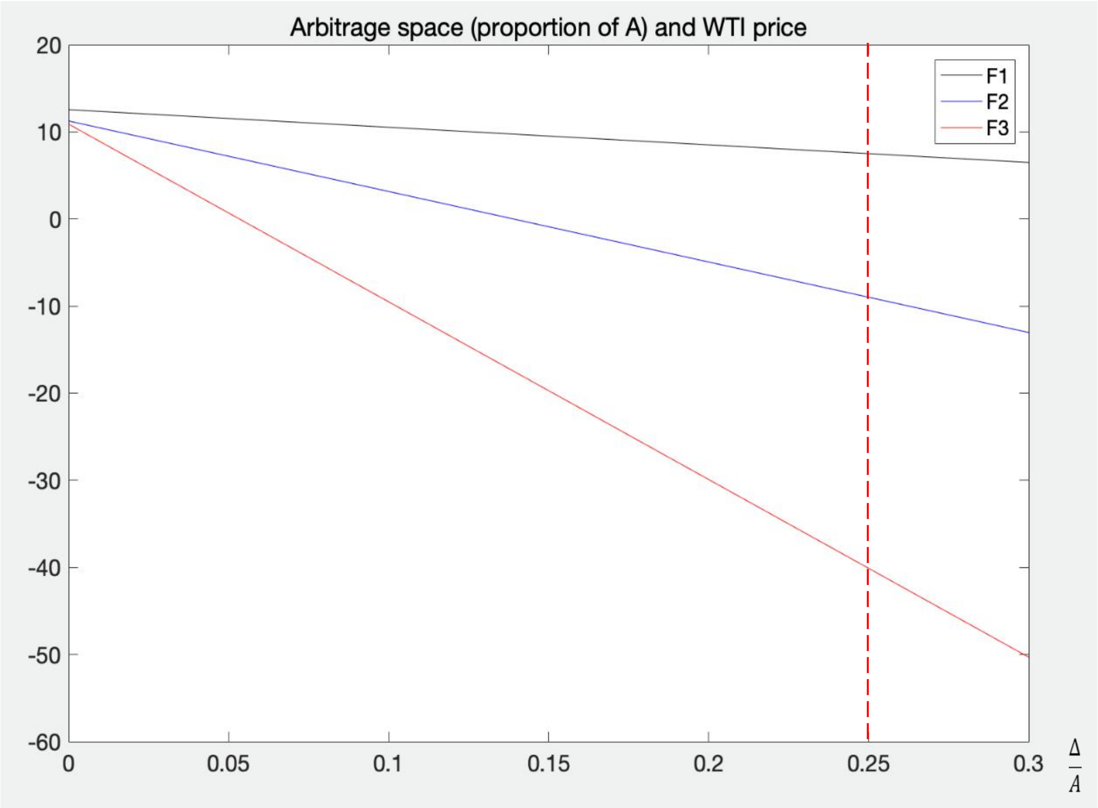


Prices: $F(t_1) = \$7.5$ $F(t_2) = -\$9.0$ $F(t_3) = -\$40.1$

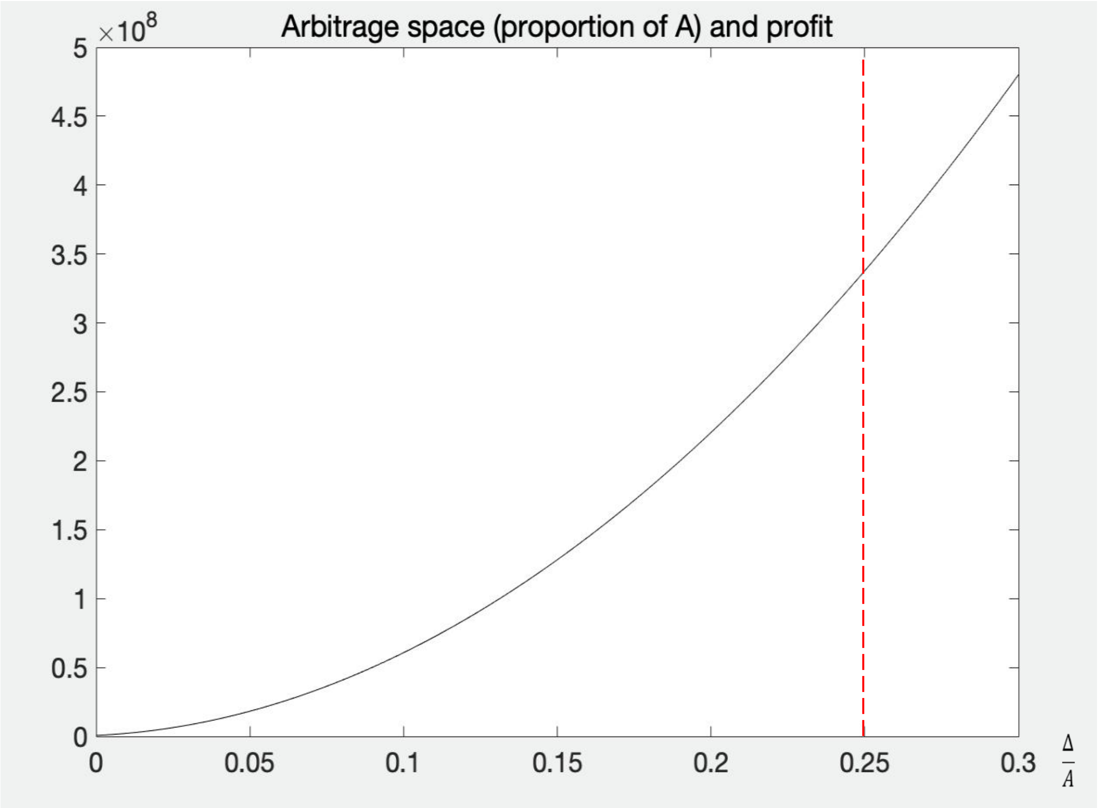
Quantities: $\Delta_1 = 6022$ contracts $\Delta_2 = 1644$ contracts

Profits: The arbitrageur makes a profit of **\$338 millions**, consistent with the report of Bloomberg Business Week (\$660 millions).

Robustness



Arbitrage space (proportion of A) and WTI price



Arbitrage space (proportion of A) and predatory profit

Conclusion

- Empirically examine the effect of closing pressure on oil futures prices.
- Highlight the role of physical settlement rule in affecting prices.
- Quantify the negative price based on TAS/commodity financialization.