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Cross-venue price discovery: regulated crude futures and on-chain perpetuals

Rillor tested whether CME WTI futures lead an on-chain crude perpetual. The lead held out of sample; no net edge after execution costs reached statistical significance.

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Summary

- On held-out data, a rule that traded Lighter's WTI perpetual in the direction CME WTI futures had just moved earned a gross average of 14.8 basis points per event, with a t-statistic of 4.17. The result survives a Bonferroni correction across the 108 tests run in the study.
- Independent implementations in Python and Rust reproduced the headline results to the last digit. A prefix-invariance check found no look-ahead. The research code is byte-reproducible and covered by 95 automated tests.
- No execution variant produced a net edge that reached statistical significance. Taking liquidity on the lagging venue is a sub-second race with small capacity, and the fee schedule in force during the study offered either zero fees or low latency, never both.
- Costs were measured from venue data. The spread on Lighter's WTI perpetual was 0.8 to 1.3 basis points per side, measured from its own trade tape. Roll's estimator overstated it by about two times, and a comparable figure from another venue's top-of-book feed understated it by about three times. Funding was immaterial for holds of up to 30 minutes.
- Test-set returns for both candidate rules concentrated around the 08:30 Eastern release time for major U.S. economic data [\[20, 21, 22\]](#). Because the pattern was found in the test set, it is a hypothesis that needs fresh data.
- Two other families of rules, based on order flow and on price gaps across trading halts, showed no effect in either instrument pair studied.
- This is research on price formation across venues. It is not investment advice and does not recommend any trade.

Background

The regulated contract

CME's crude oil futures contract (product code CL) covers 1,000 barrels and is quoted in U.S. dollars and cents per barrel. The minimum price move is \$0.01 per barrel, or \$10.00 per contract. The settlement method is physical delivery, made free-on-board at pipeline or storage facilities in Cushing, Oklahoma. On CME Globex the contract trades Sunday to Friday from 5:00 p.m. to 4:00 p.m. Central Time, with a 60-minute break each day beginning at 4:00 p.m. Central Time. Trading in a contract month ends three business days before the 25th calendar day of the preceding month, or four business days before when the 25th is not a business day [1].

Two features matter for this study. The contract has a daily break and a weekend closure. And it has a finite life, so any instrument that tracks "the" WTI price has to say which contract month it follows and when it moves to the next.

The on-chain perpetual

Lighter describes itself as an application-specific Layer 2 on Ethereum. Its whitepaper, dated October 2025, describes a prover based on succinct non-interactive proofs that generates execution proofs for "complete financial operations, including price-time-priority order matching, risk management, and account updates" [2]. The whitepaper contrasts this with designs where an operator runs an off-chain order book that smart contracts cannot inspect for price-time priority [2].

Lighter's documentation states that its real-world-asset markets, which include commodities, equities and fixed income, are tradeable 24/7, and that all of them support isolated and cross margin [3]. Several commodity markets, WTI among them, use futures contracts as their underlying price. To handle expiries, the price moves from the current month's contract to the next month's contract between the 5th and 10th business day of the month. For WTI, 20% of the weight shifts each day at 5:30 p.m. Eastern, so the full roll takes five steps [4].

Pricing has two layers [5]. External oracle feeds, such as Chainlink, Pyth, Stork and prices from other exchanges, are the primary source. When oracle data becomes stale, Lighter shifts to internal pricing derived from order-book impact prices and smoothed with a time-weighted exponential moving average, with a 30-minute time constant for the index price and 2 minutes for the mark price. When an external price is available again, the internal price converges to it. The internal prices were originally capped at $\pm 1/L$ of the last oracle price, where L is the market's leverage; the documentation records that the caps were removed on 10 July 2026 for a list of markets that includes WTI, with internal prices still validated against prices from other venues [5].

Funding is paid each hour. Once a minute, at a random time, Lighter computes each market's premium, a measure of how far the order book's impact bid and ask sit from the index price; the hourly premium is the time-weighted average of the 60 samples. Most markets carry a fixed interest component of 0.01%, real-world-asset markets apply a premium multiplier of one half, and funding is clamped to 4% per eight hours [6].

On fees, Lighter's documentation on 9 October 2026 lists zero maker and zero taker fees for standard accounts, with 300 ms of taker latency and 0 ms of maker latency, and premium accounts with fees from 0.0040% maker and 0.0280% taker before staking discounts and 140 ms of taker latency [7]. The schedule in force during this study differed; the figures Rillor recorded are set out under Findings.

Market data comes through a WebSocket API. The order book channel sends a complete snapshot on subscription and then only state changes, in batches every 50 ms. Continuity is checked by matching each update's starting nonce to the previous update's nonce, because the server offset is not guaranteed to be continuous [8]. This is the structure that lets an order book be rebuilt from a snapshot and a stream of book diffs.

Crude perpetuals in 2026

On-chain crude perpetuals carried real trading in 2026, in part because they trade when CME does not. On Saturday, 28 February 2026, the U.S. and Israel carried out strikes on Iran. CoinDesk reported that an oil-linked perpetual on Hyperliquid climbed more than 5% to \$71.26 while traditional markets remained closed for the weekend [9].

The EIA's May 2026 Short-Term Energy Outlook described the Strait of Hormuz as "a major world oil transit chokepoint through which nearly 20% of global oil supply flowed prior to military action that began on February 28," effectively closed to shipping traffic since. It reported that Brent spot averaged \$117 per barrel in April and reached \$138 on 7 April [10]. The EIA's October 2026 outlook reported that Brent averaged \$114 in September 2026 and forecast an average of \$105 in the fourth quarter [11].

Castle Labs studied one of these markets in detail [12]. Using CME tick trades and Hyperliquid fills from 27 February to 16 March 2026, it compared xyz:CL, a builder-deployed (HIP-3) crude perpetual on Hyperliquid, with CME's April 2026 WTI contract. Its main measurements:

Measure	CME April 2026 WTI	Hyperliquid crude perpetual
Median volume traded within ± 2 bps of mid, per 5-minute bucket, overlapping hours	\$19 million	\$152,000
Median trade size	\$90,450	\$543

Measure	CME April 2026 WTI	Hyperliquid crude perpetual
Slippage on a simulated \$1 million order	0.79 bps	15.4 bps

Source: Castle Labs, data from 27 February to 16 March 2026 [12].

Castle Labs found that the perpetual tracked the CME contract closely during active trading hours, with a discount that widened as oil prices rose. Over the first weekend, with CME closed, the perpetual reached about 45% of the eventual Monday gap before hitting its $\pm 5\%$ discovery bound; over the second it captured about 68%, again reaching the bound [12]. Total volume in the market grew from \$31 million to over \$1 billion in three weeks [12].

Price discovery across venues

The question of which market moves first has a long literature. Hasbrouck's 1995 paper proposed measuring each market's "information share," its proportional contribution to innovations in a common efficient price, and found that for the thirty Dow stocks the NYSE had a median information share of 92.7% [13].

Results depend on the market, the period and the method. For bitcoin, Baur and Dimpfl found that the spot price led CME and CBOE futures after their December 2017 launch, and attributed this to the spot market's higher volume and longer trading hours [14]. Robertson and Zhang, using high-frequency data and the Hayashi-Yoshida lead-lag estimator, found that CME bitcoin futures play a leading role in price formation and that trade size is a key determinant of which market leads [15]. The crude case differs from both: the regulated contract is the reference market, and the perpetual is built to follow it.

Data and method

Question

Does CME WTI futures trading lead Lighter's WTI perpetual during the hours both trade, and if so, can the lead be captured after measured execution costs?

Data

The study used Rillor's market data warehouse. The warehouse holds U.S. equity and futures trade and quote history from 2018, and on-chain perpetual futures order-book data rebuilt from snapshots and book diffs. The analysis was completed in late August 2026.

Events, returns and holding periods

Events were defined from moves in CME WTI futures. For each event, the study measured the subsequent return of the Lighter WTI perpetual over holding periods of up to 30 minutes. The candidate rules traded the perpetual in the direction CME futures had just moved. Returns are reported in basis points per event, before costs (gross) and after measured costs (net).

Out-of-sample design

All headline statistics are out of sample: they come from a test set that the rules were not fitted to. A result that holds only in the data used to build it says little about data that comes after.

Multiple testing

The study ran 108 tests in total. When many tests are run, some pass a conventional threshold by chance. The common approach is to control the familywise error rate, the probability of at least one false rejection [17]. Benjamini and Hochberg proposed controlling the false discovery rate, the expected proportion of false rejections, which gives more power when that is the appropriate goal [17]. The study used the Bonferroni correction across all 108 tests, which controls the familywise rate.

For scale: under a normal approximation, a t-statistic of 4.17 corresponds to a two-sided p-value of about 0.00003. Multiplied by 108, it is about 0.003, well under 0.05. Harvey, Liu and Zhu argued that, given how many factors have been tested in finance, a new factor should clear a t-statistic above 3.0 [18]. White's reality check for data snooping is another response to the same problem [19].

Verification

Two implementations were written independently, one in Python and one in Rust, and the headline results had to match to the last digit. A prefix-invariance check recomputed results on truncated histories and confirmed that no value depended on data from after its own timestamp. The research code is byte-reproducible and covered by 95 automated tests.

Cost measurement

Each cost was measured directly:

- **Fees** from the venue schedule in force during the study, for both account types.
- **Spread** from Lighter's own WTI trade tape. Two common shortcuts were computed for comparison: Roll's implicit measure of the effective spread [16], and a stand-in taken from another venue's top-of-book feed.
- **Funding** over the holding periods studied.

One accounting rule applied throughout: every cost and return figure was measured against the raw data. No figure was derived by subtracting one count from another that might have been filtered.

Findings

The lead

Statistic	Result
Gross return per event, out of sample	+14.8 bps
t-statistic	4.17
Multiple-testing correction	Survives Bonferroni across 108 tests
Independent reimplementation	Python and Rust match every digit
Look-ahead check	Prefix-invariance check clean

The regulated futures market leads the on-chain perpetual, and the lead is large and stable enough out of sample to survive a strict correction. In this pair, the information shows up in CME prices first and in the perpetual afterward.

Measured costs

Component	Measurement
Standard account fees (study period)	0 maker, 0 taker
Standard account latency (study period)	About one second added
Premium account fees (study period)	0.2 bps maker, 2 bps taker
Premium account latency	Without the standard account's added latency
WTI perpetual spread, from Lighter's tape	0.8 to 1.3 bps per side
Roll estimator, same market	About 2 times the measured value
Another venue's top-of-book stand-in	About one third of the measured value

Component	Measurement
Funding, holds of up to 30 minutes	Immaterial

The fee and latency terms were mutually exclusive. A trader could pay nothing and wait, or pay to be fast. Lighter's current published schedule is different (300 ms of taker latency for standard accounts; premium fees from 0.40 bps maker and 2.80 bps taker before discounts), so any cost analysis has to state which schedule it used [7].

The two spread shortcuts failed in opposite directions. Roll's implicit measure [16] doubled the cost on this market. A top-of-book feed from a different venue described a different book and cut the cost to a third. Either figure would have put the wrong cost into the net analysis.

Net results

The gross figure is measured at the price available when CME moves. Capturing it requires taking liquidity on Lighter before the perpetual adjusts. That is a race decided in under a second, and the size resting at the stale price is small. The study tested several execution variants. None produced a net edge that reached statistical significance.

The net question stays open: with the events available, the data cannot distinguish the net edge from zero. The study estimates that roughly three to six times as many events would decide the question.

Concentration around 08:30 Eastern

Test-set returns for both candidate rules were concentrated around 08:30 Eastern. That is the scheduled release time for the Bureau of Labor Statistics' Employment Situation and Consumer Price Index reports [20, 21] and for the Bureau of Economic Analysis' GDP and Personal Income and Outlays releases [22].

This pattern was discovered in the test set. A pattern found in the same data used to judge the rules cannot also be validated by that data, so it is a new hypothesis. It is also worth setting against the literature: Kilian and Vega found no compelling evidence that daily energy price changes respond to U.S. macroeconomic news [23]. A concentration of intraday cross-venue returns near release times is a different question at a different horizon, and it needs its own test.

Families with no effect

Two further families of rules were tested: one based on order flow, and one based on price gaps across trading halts. Neither showed an effect in either of the two instrument pairs studied.

Implications

For researchers

The lead itself is a clean result: out of sample, corrected for 108 tests and reproduced independently. Cross-venue studies that report a lead without those controls deserve careful reading [18, 19].

Cost estimates need the venue's own data. Here, the Roll estimator doubled the spread and a stand-in feed from another venue cut it to a third. A net result built on either would have been wrong in a direction set by the shortcut chosen.

Accounting figures should be measured directly against raw data. Subtracting one count from another that may have been filtered is a common way to arrive at a plausible and wrong number.

For builders of on-chain venues

When a perpetual follows a regulated reference market, the reference market's moves are public before the perpetual reprices. Who can act on that gap depends on the venue's latency and fee design. Lighter's account tiers set a trade-off between fees and latency [7]; the study found this trade-off central to whether a taker could capture any of the gross lead.

The documentation and the Castle Labs results also show how much off-hours design matters. Lighter falls back to an internal price built from its own book when oracle data goes stale [5]. On Hyperliquid, a $\pm 5\%$ discovery bound limited how far the crude perpetual could move over the first weekend of the 2026 crisis [12]. These choices set how a perpetual behaves exactly when its reference market is closed.

For anyone using a perpetual price as a reference

During overlapping hours, the perpetual's price reflects CME's with a delay. A risk system that marks positions on the perpetual's price inherits that delay. Outside CME hours, the perpetual is the only live price, and the evidence from early 2026 is that it captured part of the move that CME later printed, in one weekend less than half [12].

What would settle the net question

Three directions follow from the evidence:

1. **Execution as a maker.** Resting orders on Lighter's zero-fee book removes the spread cost. It also exposes the orders to adverse selection, which has to be bounded with order-book data before any net figure can be trusted.
2. **Conditioning on the macro calendar.** The 08:30 Eastern concentration is a hypothesis. Testing it requires data that played no part in finding it.

3. **More events.** Roughly three to six times the current event count would give the statistical power to decide whether net returns are significant.

Limits of this analysis

- The headline result covers one regulated contract and one on-chain venue. Other venues, including the Hyperliquid markets studied by Castle Labs [\[12\]](#), have different oracles, bounds and fee schedules.
- The sample is limited by how long on-chain crude perpetuals have existed. The event count is too small to decide net significance.
- Costs reflect the fee and latency schedule in force during the study. Lighter's published schedule has since changed [\[7\]](#), and fee schedules on all venues change often.
- The gross figure measures the lead. It assumes trading at the price available when CME moves, so it overstates what an order arriving later could earn.
- The 08:30 Eastern concentration was found in the test set and is not validated.
- A lead in prices shows which market reflects information first. It does not show who holds the information or why the second market adjusts later.
- Nothing in this report is investment advice or a recommendation to trade any instrument on any venue.

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