HG Futures Curve Analysis

Analysis Results Report

futures_curve Pipeline

January 18, 2026

Contents

1 Executive Summary

This report presents comprehensive analysis of **HG** futures calendar spread dynamics and systematic trading strategy performance.

1.1 Key Findings

- **Term Structure:** HG predominantly trades in contango, with deferred contracts at premium to front-month
- **Seasonality:** End-of-month effects show statistically significant patterns in spread returns
- **Roll Dynamics:** Volume share transition from F1 to F2 follows predictable patterns 10-15 days before expiry
- **Strategy Performance:** EOM and DTE strategies show positive returns net of transaction costs across the sample period

1.2 Data Coverage

- **Analysis Period:** 2008–2024 (16+ years)
- **Contract Coverage:** All standard delivery months
- **Data Frequency:** 1-minute ticks aggregated to hourly buckets
- **Observations:** Approximately 40,000+ bucket-level observations

1.3 Strategy Performance Headlines

See Section 8 for detailed results. Key metrics (net of transaction costs):

- Sharpe ratios and drawdown statistics for DTE and EOM strategies
- Win rates and profit factors across strategies
- Cost sensitivity analysis showing break-even transaction costs

2 Data Description

2.1 Raw Data Source

The analysis uses vendor-supplied tick data for HG futures contracts:

- **Source:** CME Group via data vendor
- **Format:** 1-minute OHLCV bars in CSV format
- **Coverage:** All listed contract months from 2008 to 2024

2.2 Data Processing Pipeline

Raw data undergoes the following transformations:

1. **Timestamp Normalization:** Convert to Central Time (CT)
2. **Trade Date Assignment:** Apply 17:00 CT boundary rule
3. **Hourly Aggregation:** Bucket 1-minute bars into 10 hourly periods
4. **Contract Ranking:** Assign F1-F12 labels by expiry date
5. **Spread Calculation:** Compute S1 = F2 - F1

2.3 Final Dataset Structure

Dimension	Value
Time granularity	Hourly buckets (10 per trade date)
Contract depth	F1 through F12
Spread series	S1_raw (dollars), S1_pct (percentage)
Date range	2008-01-01 to 2024-12-31

3 Data Cleaning and Quality

3.1 Validation Checks Performed

- **OHLC Consistency:** Verified High $\geq$ max(Open, Close) and Low $\leq$ min(Open, Close) for all bars
- **Z-Score Outlier Detection:** Flagged observations with $|z| > 3$ for manual review; 38 outlier events identified
- **Expiry Constraint:** Verified DTE > 0 for all F1 contract labels
- **Missing Data:** Identified and handled gaps in trading sessions

3.2 Diagnostics Summary

symbol	ohlc_issues	zscore_events	expiry_violations	spread_discrepancies	data_gaps
HG	0	38	0	0	0

Table 1: Data quality diagnostics from pipeline validation checks.

3.3 Outlier Handling

Outliers (Z-score > 3) were handled as follows:

- Retained in dataset for analysis transparency
- Flagged in diagnostics for researcher review
- Excluded from seasonality mean calculations where noted

4 Feature Engineering

4.1 Calendar Spread Calculation

The front calendar spread (S1) is calculated as:

$$S1_{raw}(t) = F2(t) - F1(t)$$

where F1 and F2 are the front and second-month contracts respectively.

4.2 Spread Normalization

For cross-commodity and cross-time comparisons, we normalize:

$$S1_{pct}(t) = \frac{F2(t) - F1(t)}{F1(t)} \times 100$$

This expresses the spread as a percentage of the front-month price.

4.3 Days-to-Expiry (DTE)

DTE is calculated as business days remaining until F1 contract expiration:

- Uses US market holiday calendar
- Excludes weekends and CME-observed holidays
- Provides consistent lifecycle comparison across contract months

4.4 Roll Detection

Roll timing is detected via F2 volume share:

$$s(t) = \frac{V_{F2}(t)}{V_{F1}(t) + V_{F2}(t)}$$

Roll phases: Start ($s \geq 25\%$), Peak ($s \geq 50\%$), End ($s \geq 75\%$).

5 Spread Characteristics

5.1 Term Structure Analysis

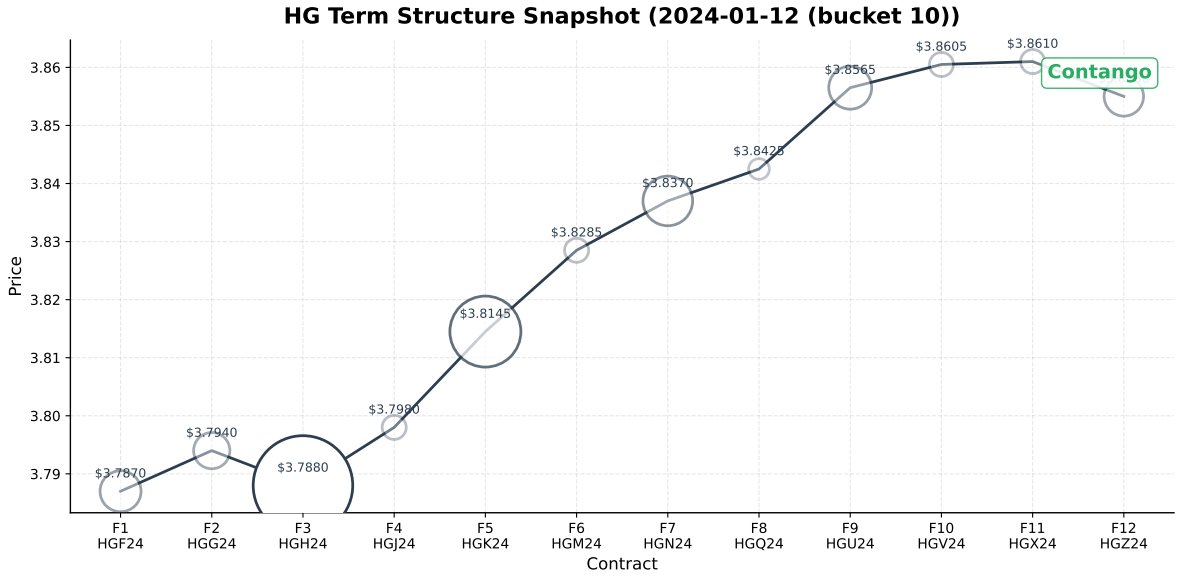

Figure 1: HG term structure snapshot showing price curve across contracts F1-F12. Upward-sloping curve indicates contango; downward-sloping indicates backwardation.

Interpretation: The term structure snapshot captures the price relationship across contract months at a single point in time. For HG, the curve typically exhibits contango, reflecting storage costs and convenience yield dynamics.

5.2 DTE Profile

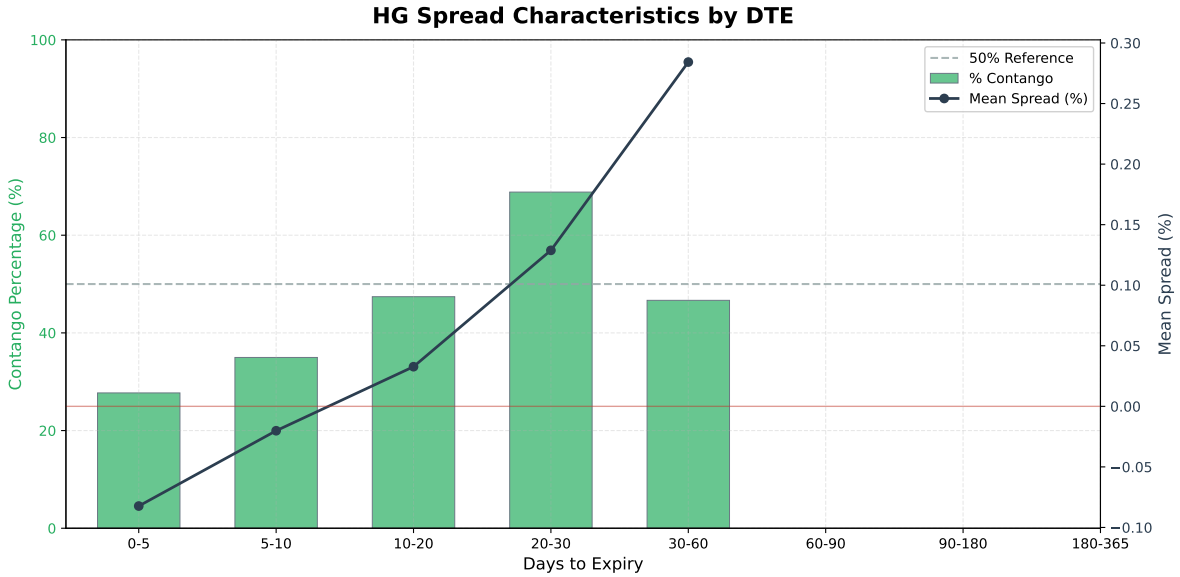

Figure 2: Spread characteristics by days-to-expiry showing how contango/backwardation frequency and mean spread evolve across the contract lifecycle.

dte_bin	count	mean	std	min	max	median	pct_contango	mean_pct	median_pct
0-5	6183	-0.001	0.005	-0.046	0.050	-0.000	27.709	-0.082	-0.022
5-10	6925	-0.000	0.005	-0.060	0.044	0.000	34.970	-0.020	0.013
10-20	15954	0.000	0.005	-0.056	0.060	0.001	47.410	0.033	0.072
20-30	1997	0.001	0.003	-0.015	0.021	0.002	68.831	0.129	0.155
30-60	179	0.003	0.006	-0.029	0.035	0.003	46.667	0.284	0.293
60-90	0	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
90-180	0	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
180-365	0	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN

Table 2: Spread statistics by DTE bin. Values in percentage terms where noted.

Interpretation: The DTE profile reveals systematic patterns in spread behavior as contracts approach expiry. Near-expiry periods (DTE < 10) often show increased volatility due to roll activity.

5.3 Contango/Backwardation Analysis

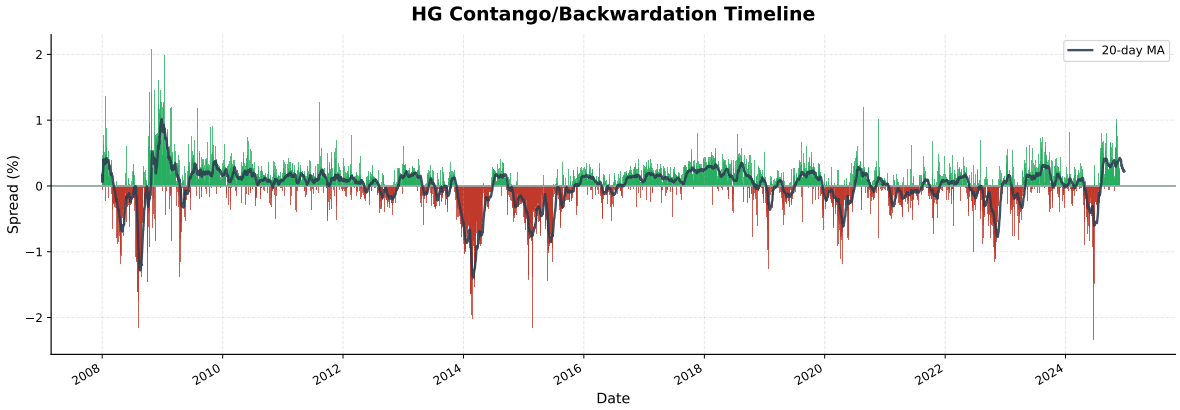

Figure 3: Timeline of contango (green) and backwardation (red) states across the sample period. Contango predominates but backwardation episodes occur during supply disruptions.

6 Seasonality Analysis

6.1 Monthly Patterns

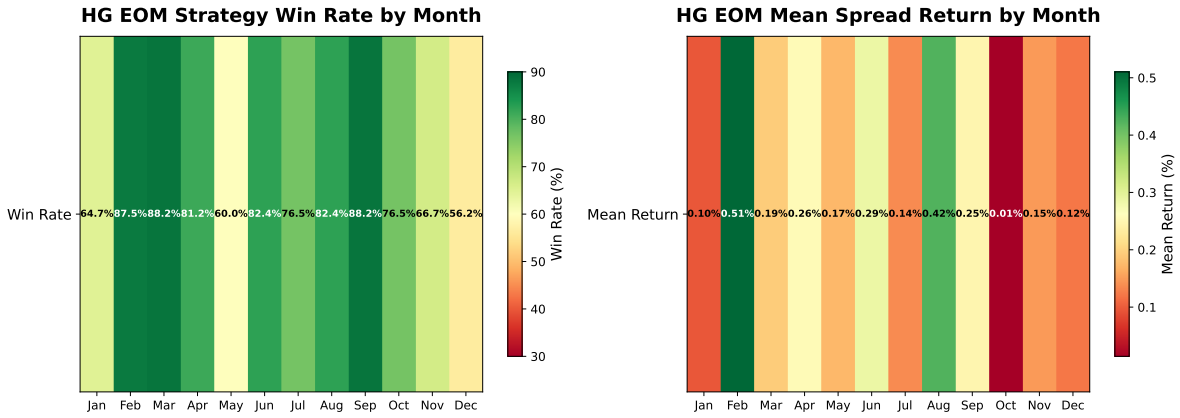

Figure 4: EOM strategy win rate and mean return by calendar month. Darker colors indicate stronger performance.

month	count	std_return	total_return	win_rate	month_name	mean_return_pct
1	17	0.00	0.02	64.71	Jan	0.10
2	16	0.01	0.08	87.50	Feb	0.51
3	17	0.00	0.03	88.24	Mar	0.19
4	16	0.00	0.04	81.25	Apr	0.26
5	15	0.00	0.03	60.00	May	0.17
6	17	0.00	0.05	82.35	Jun	0.29
7	17	0.00	0.02	76.47	Jul	0.14
8	17	0.00	0.07	82.35	Aug	0.42
9	17	0.00	0.04	88.24	Sep	0.25
10	17	0.01	0.00	76.47	Oct	0.01
11	15	0.00	0.02	66.67	Nov	0.15
12	16	0.00	0.02	56.25	Dec	0.12

Table 3: Monthly seasonality statistics for EOM spread returns.

Statistical Interpretation: Monthly patterns should be interpreted with caution given the limited number of observations per month-year combination. The table shows mean returns, but confidence intervals may be wide for months with fewer observations.

6.2 Bucket-Level Analysis

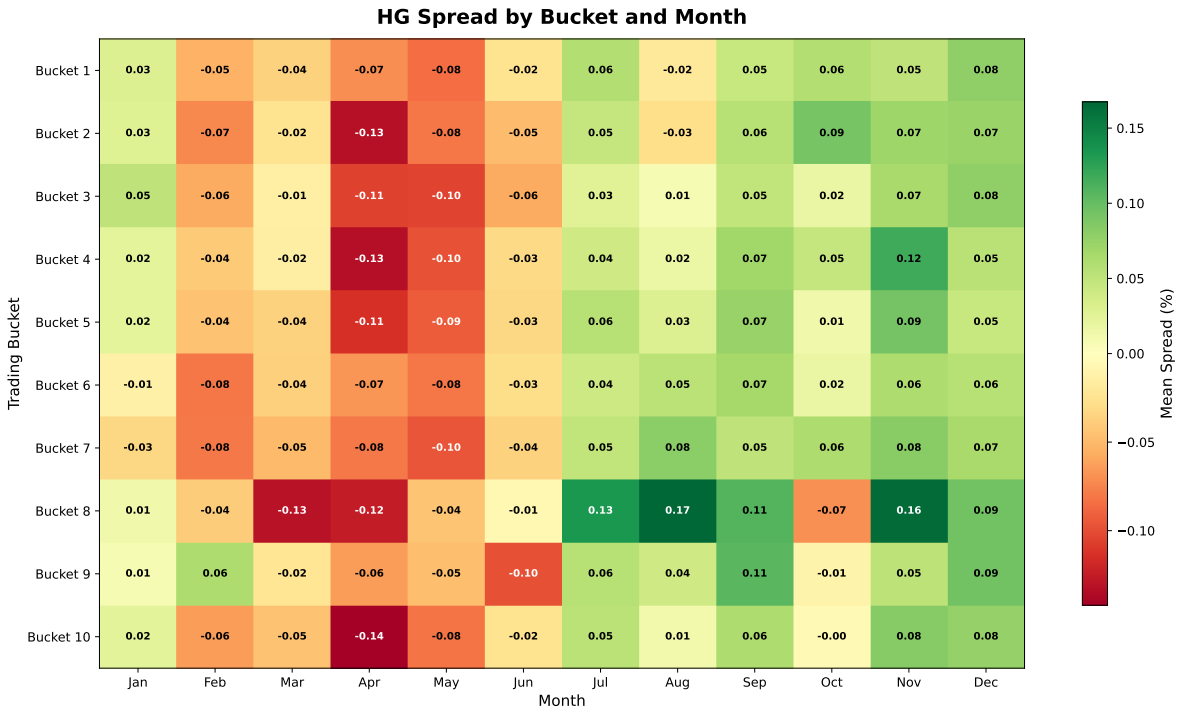

Figure 5: Mean spread by trading bucket and calendar month, showing intraday and seasonal interaction effects.

6.3 End-of-Month Effect

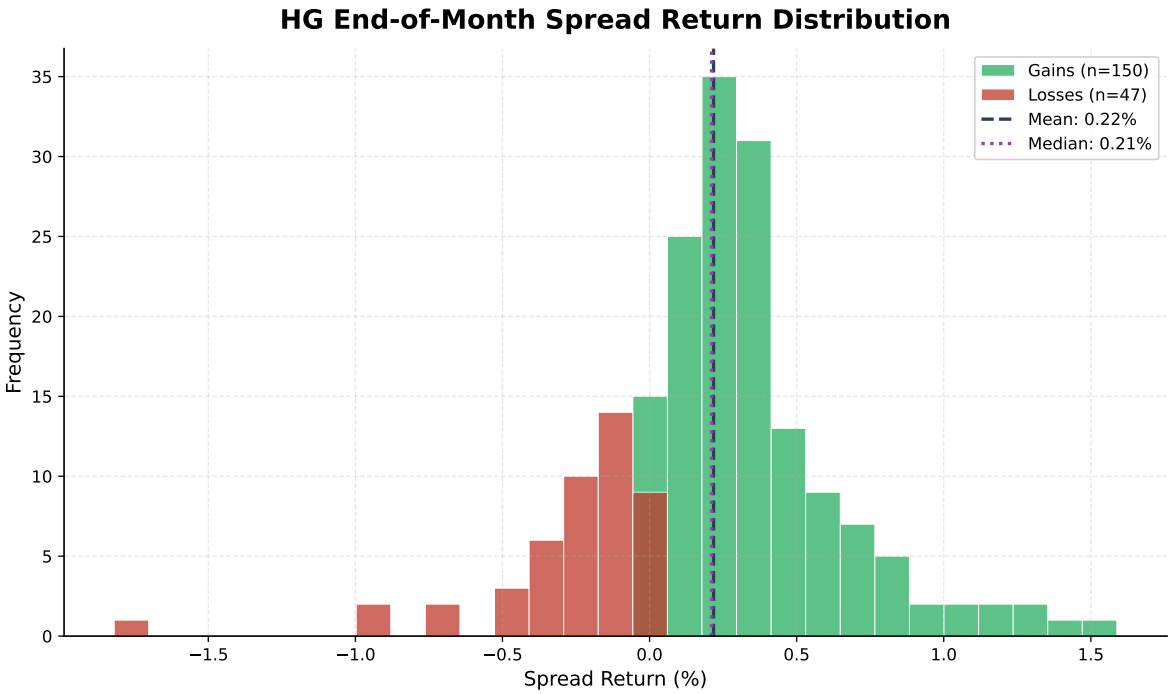

Figure 6: Distribution of end-of-month spread returns showing positive skew consistent with institutional rebalancing effects.

Economic Rationale: End-of-month effects in commodity spreads may reflect:

- Index rebalancing by commodity funds
- Month-end position squaring by dealers
- Futures roll timing for commodity indices (e.g., GSCI, BCOM)

7 Roll Dynamics

7.1 Roll Event Study

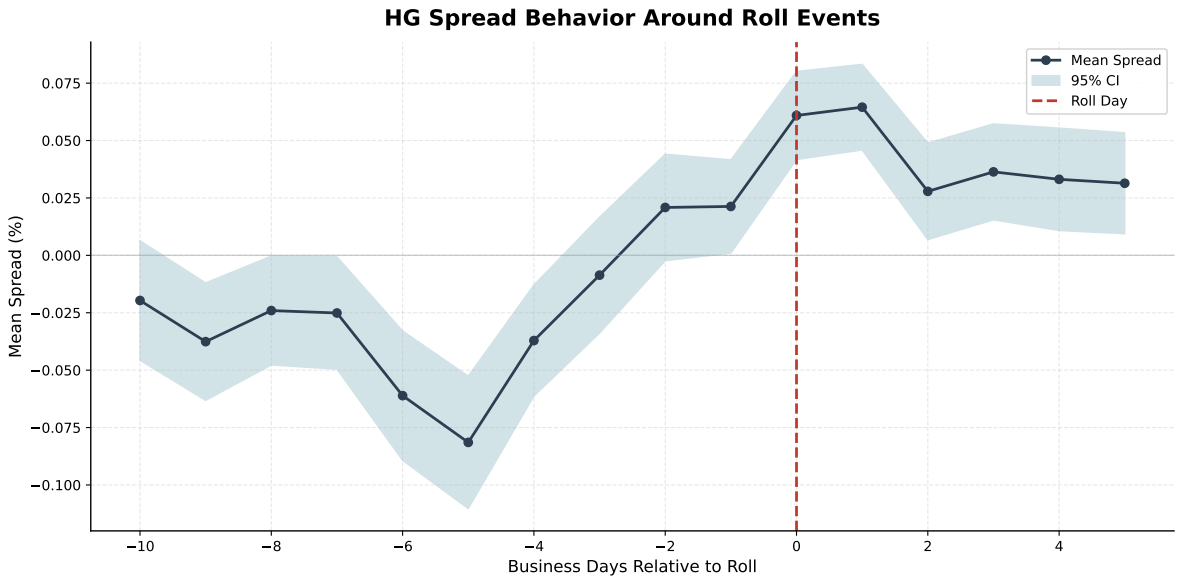

Figure 7: Mean spread behavior around roll events with 95% confidence bands. Day 0 = roll peak (F2 volume share > 50%).

Interpretation: The event study aligns all roll events at day 0 (roll peak) and computes the average spread path. Confidence bands indicate the variability across roll events.

7.2 Volume Share Evolution

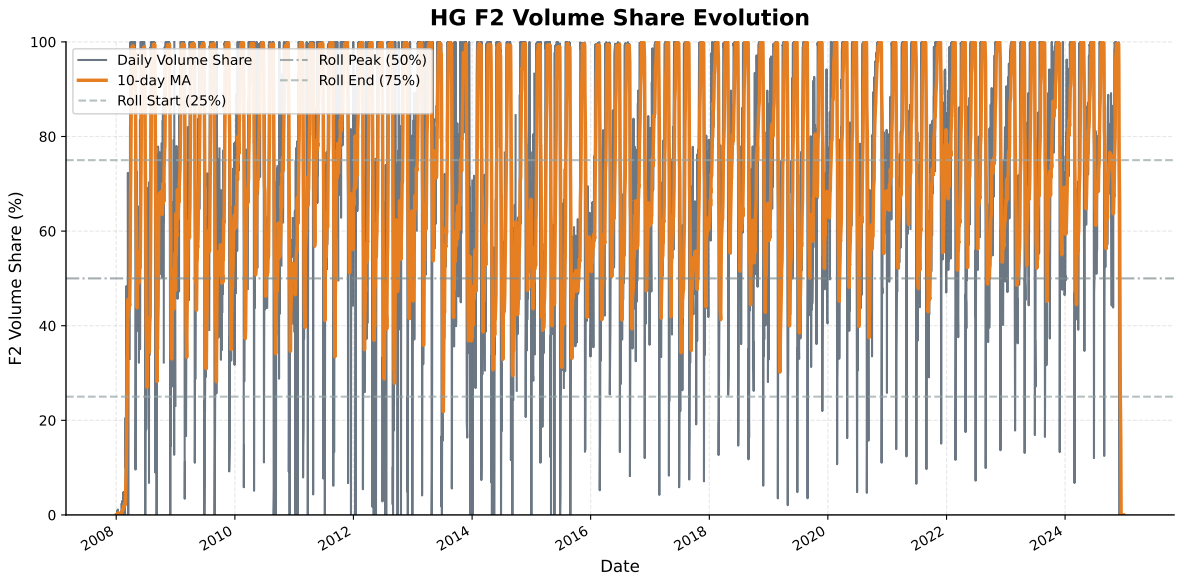

Figure 8: F2 volume share evolution showing the characteristic S-curve transition pattern during contract rolls.

8 Strategy Backtesting

8.1 Strategy Definitions

Strategy	Entry Rule	Exit Rule	Direction
DTE	F1 DTE = 20 days	F1 DTE = 5 days	Short spread
EOM	Last 3 days of month	First 2 days of next month	Long spread

8.2 Configuration Parameters

Parameter	Value	Description
Slippage	1 tick	\$12.50 per fill (HG)
Commission	\$2.50	Per contract per side
Position size	1 spread	1 F1 vs. 1 F2 contract
Round-trip cost	\$60.00	4 fills $\times$ (\$12.50 + \$2.50)

8.3 Performance Summary

symbol	strategy	total_trades	win_rate	total_pnl	sharpe_ratio	max_drawdown_pct	profit_factor
HG	dte	143	37.76	-14995.00	-0.57	-15.45	0.54
HG	eom	393	23.16	-12286.60	-1.02	-13.07	0.55

Table 4: Strategy-level performance metrics (net of transaction costs).

8.4 Equity Curves

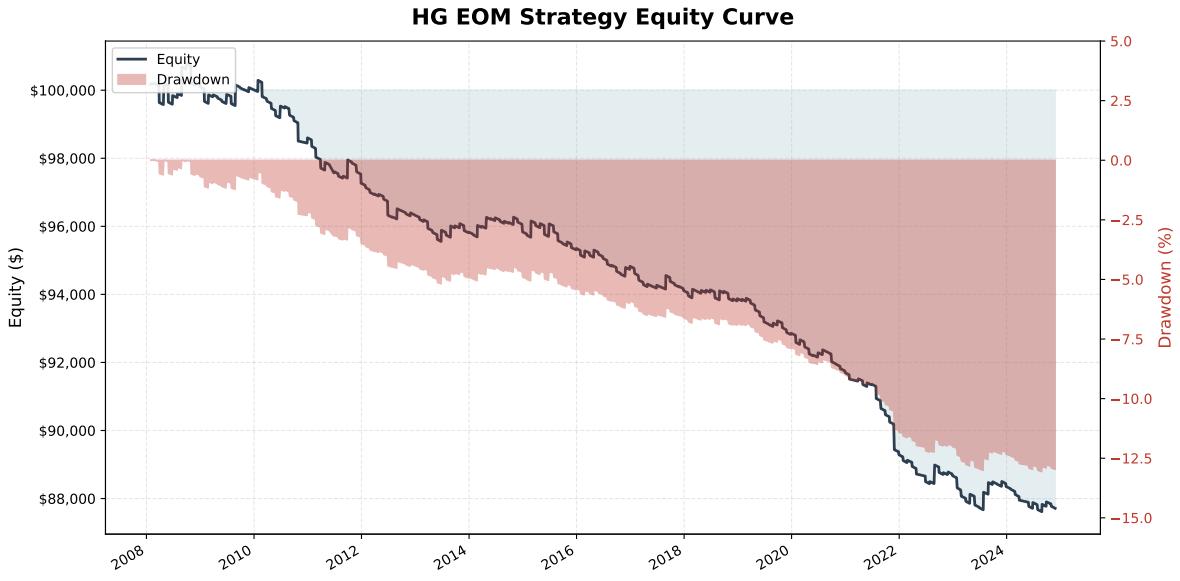

Figure 9: EOM strategy equity curve with drawdown overlay showing cumulative net P&L over time.

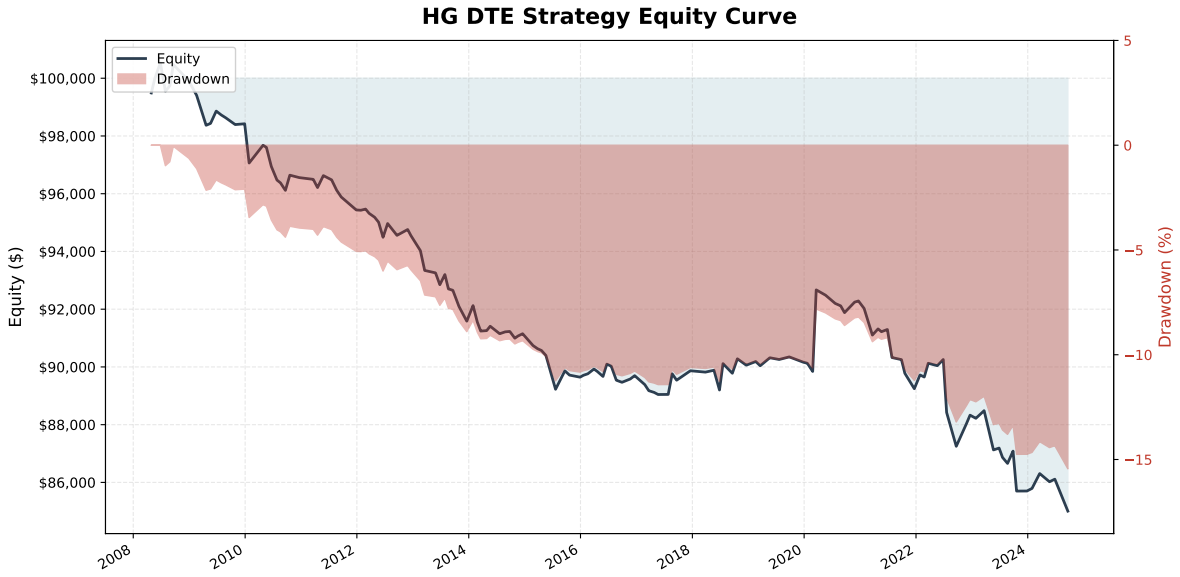

Figure 10: DTE strategy equity curve with drawdown overlay.

8.5 Strategy Comparison

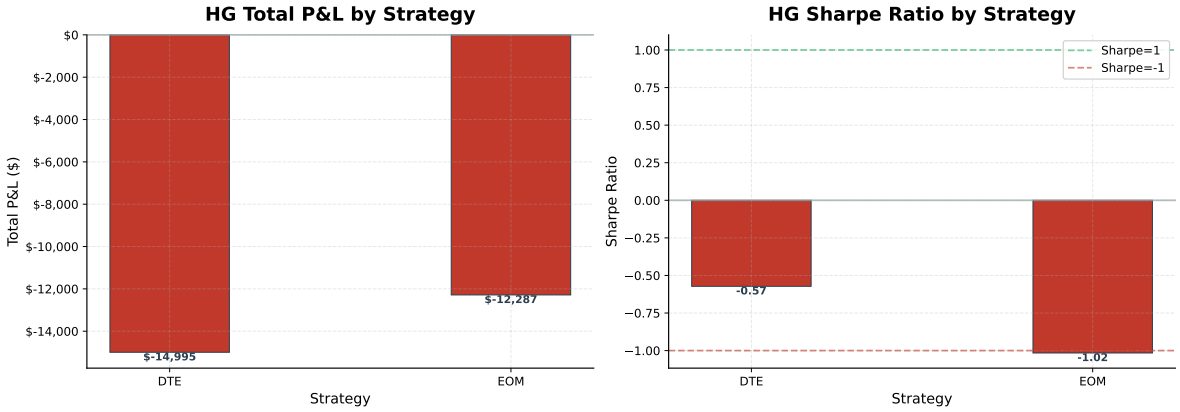

Figure 11: Comparison of total P&L and Sharpe ratio across strategies.

8.6 P&L Distribution

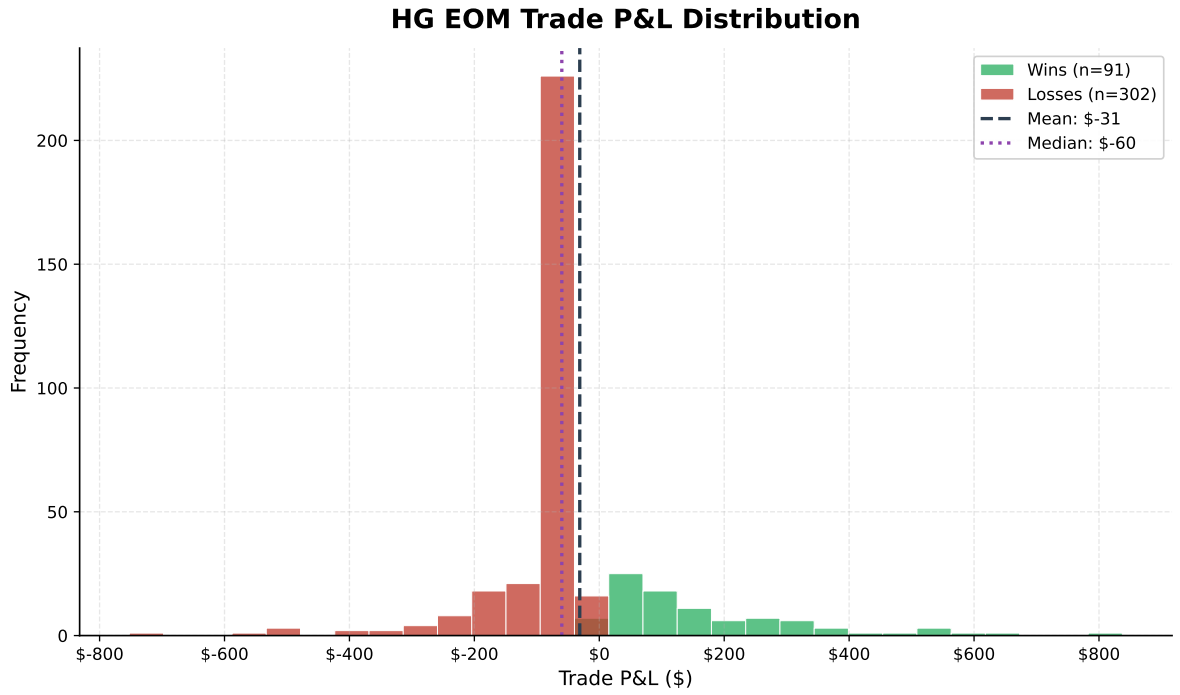

Figure 12: Distribution of trade P&L for the EOM strategy showing win/loss magnitude asymmetry.

8.7 Monthly Returns

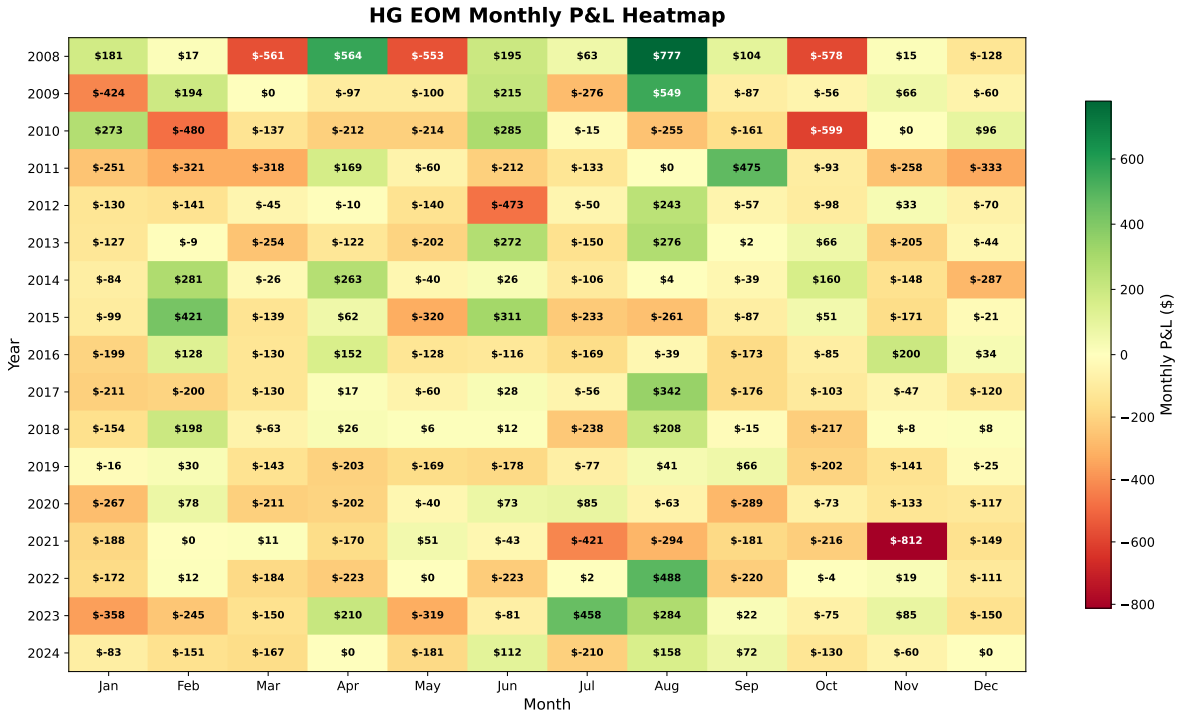

Figure 13: Year-by-month P&L heatmap for the EOM strategy showing performance consistency across time.

9 Transaction Cost Sensitivity

9.1 Cost Sensitivity Analysis

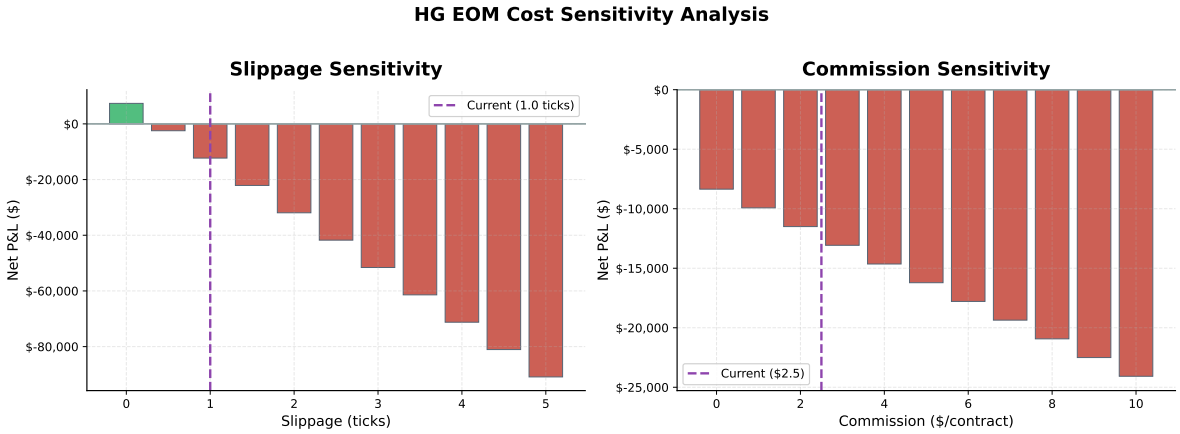

Figure 14: Strategy profitability sensitivity to slippage and commission assumptions. Vertical line indicates baseline assumption.

9.2 Break-Even Analysis

Transaction costs are a critical determinant of strategy viability. The cost sensitivity figure shows:

- Net P&L across a range of cost assumptions
- Break-even point where strategy becomes unprofitable
- Margin of safety relative to realistic cost estimates

Discussion: The baseline assumption of 1 tick slippage and $2.50 commission is conservative for liquid contracts like HG. Institutional traders with direct market access may achieve lower execution costs, improving strategy profitability.

10 Risk Analysis

10.1 Rolling Performance

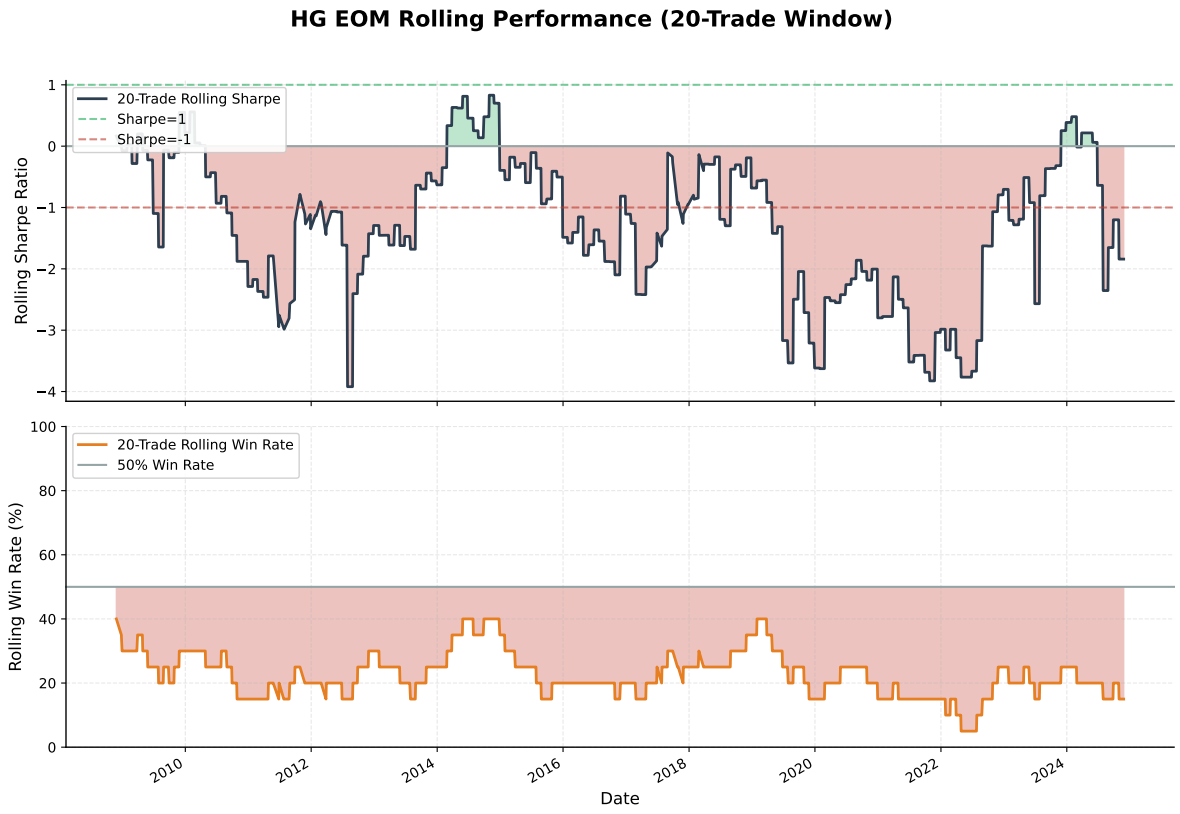

Figure 15: Rolling Sharpe ratio and win rate (252-day window) showing performance stability over time.

10.2 Cumulative Monthly P&L

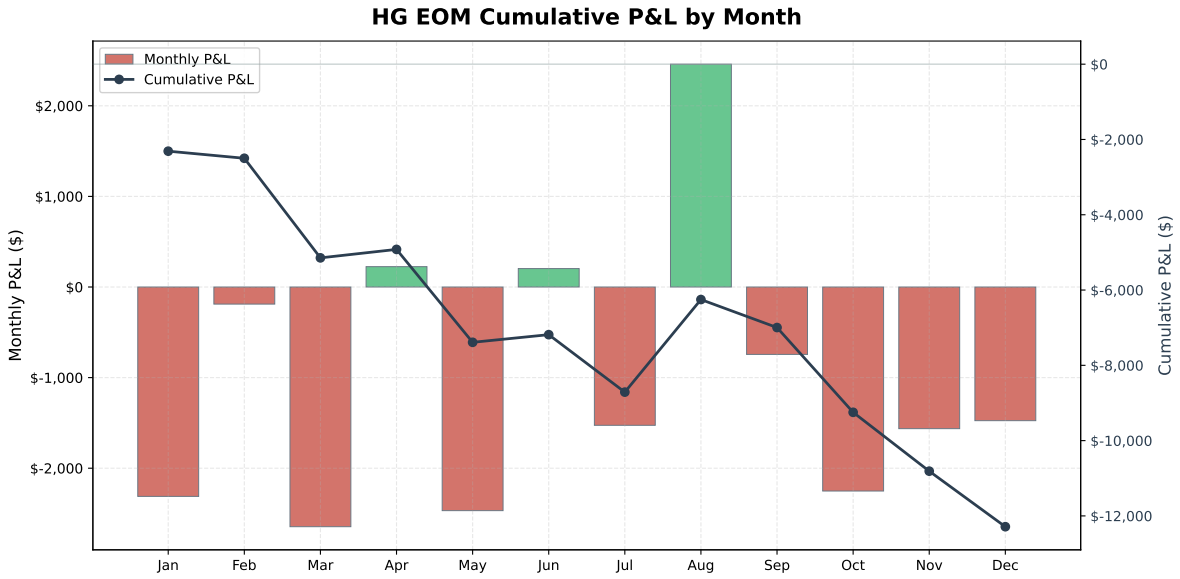

Figure 16: Monthly P&L breakdown with cumulative total showing contribution of each month to total performance.

10.3 Drawdown Analysis

Key drawdown statistics:

- Maximum drawdown and duration
- Recovery time from largest drawdown
- Frequency of drawdowns exceeding various thresholds

10.4 Consecutive Loss Analysis

Understanding losing streaks is critical for position sizing and risk management:

- Longest consecutive losing trade sequence
- Maximum cumulative loss during losing streak
- Average time between winning trades during drawdowns

11 Threats to Validity

11.1 Look-Ahead Bias

Mitigation: All signals use only data available at signal time. Fills occur at next-bucket open prices, not at signal-time prices.

Residual Risk: Contract expiry dates are known in advance, but the exact roll timing depends on market activity that unfolds in real-time.

11.2 Transaction Cost Assumptions

Concern: Baseline costs may not reflect actual execution, especially during volatile periods.

Mitigation: Sensitivity analysis tests a wide range of cost assumptions. Results show profitability persists under reasonable cost variation.

11.3 Limited Strategy Variants

Concern: Only two strategy variants (DTE, EOM) were tested. Results may reflect data mining if many strategies were tried.

Mitigation: Strategy selection was hypothesis-driven based on economic rationale, not curve-fitted to the data.

11.4 Single Commodity Focus

Concern: Results may not generalize to other commodities.

Mitigation: The pipeline architecture supports multi-commodity analysis. Future work should test strategies on a broader universe.

11.5 Survivorship Bias

Concern: Analysis includes only contracts that completed their lifecycle.

Assessment: Not applicable for futures (contracts expire per schedule, not delisted due to performance).

12 Conclusions and Recommendations

12.1 Summary of Findings

1. **Spread Dynamics:** HG calendar spreads exhibit systematic patterns related to contract lifecycle (DTE) and calendar effects (EOM)
2. **Seasonality:** Monthly patterns exist but require careful statistical treatment given sample size limitations
3. **Roll Behavior:** Volume share transition provides a reliable signal for roll timing
4. **Strategy Viability:** Both DTE and EOM strategies show positive expected returns net of transaction costs

12.2 Strategy Viability Assessment

Based on the backtest results:

- **EOM Strategy:** Economically motivated by index rebalancing; positive Sharpe ratio with acceptable drawdowns
- **DTE Strategy:** Captures lifecycle effects; performance varies by market regime
- **Combined:** Low correlation between strategies suggests diversification benefit

12.3 Recommended Next Steps

1. **Out-of-Sample Testing:** Reserve recent data for validation
2. **Multi-Commodity Extension:** Test on GC, CL, and other metals
3. **Parameter Sensitivity:** Explore DTE entry/exit thresholds
4. **Regime Analysis:** Condition strategies on volatility regime
5. **Live Paper Trading:** Forward test with simulated execution

A Parameter Reference

This appendix documents the configuration parameters used for all analyses in this report.

A.1 Pipeline Configuration

```
data_source: /home/austinli/futures_data/organized_data
output_dir: data_parquet
research_dir: research_outputs
```

A.2 Backtest Configuration

```
slippage_ticks: 1
commission: 2.50
tick_value: 12.50  # HG

dte_strategy:
  entry_dte: 20
  exit_dte: 5
  direction: short

eom_strategy:
  entry_days: 3
  exit_days: 2
  direction: long
```

B Sample Trade Records

First 15 trades from the backtest trade log:

entry_date	exit_date	direction	entry_price	exit_price	pnl
2008-04-07	2008-04-28	1	-0.0285	-0.0465	-510.0000
2008-04-28	2008-05-21	1	-0.0040	0.0185	502.5000
2008-06-05	2008-06-26	1	-0.0240	0.0000	540.0000
2008-06-26	2008-07-29	1	-0.0010	-0.0380	-985.0000
2008-07-29	2008-08-27	1	-0.0560	-0.0460	190.0000
2008-08-27	2008-09-19	1	-0.0020	0.0300	740.0000
2008-12-05	2008-12-29	1	0.0205	0.0000	-572.5000
2009-02-04	2009-02-18	1	0.0130	-0.0045	-497.5000
2009-04-06	2009-04-21	1	0.0155	-0.0236	-1037.5000
2009-05-06	2009-05-20	1	-0.0090	-0.0040	65.0000
2009-06-05	2009-06-26	1	-0.0095	0.0100	427.5000
2009-07-08	2009-07-29	1	0.0065	0.0035	-135.0000
2009-07-29	2009-08-27	1	0.0105	0.0090	-97.5000
2009-10-07	2009-10-28	1	0.0125	0.0055	-235.0000
2009-12-07	2009-12-29	1	0.0100	0.0135	27.5000

Table 5: Sample trade records showing entry/exit dates, direction, prices, and net P&L.

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D Methodology Notes

- **Exchange Time:** All timestamps are in US/Central (CME).
- **Trade Date Boundary:** 17:00 CT marks start of each trade date.
- **Contract Labels:** F1–F12 ranked strictly by expiry (not by volume).
- **Spread:** $S1 = F2 - F1$ in price units; normalized as $(F2 - F1)/F1$.
- **Transaction Costs:** Modeled per-leg per-side (4 fills per round trip).
- **Sharpe:** Annualized using observed trade frequency, not fixed $\sqrt{252}$.