

HG Futures Curve Analysis

Analysis Results Report

futures_curve Pipeline

January 19, 2026

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Contents

| | | |
|----------|---|----------|
| 1 | Executive Summary | 3 |
| 1.1 | Key Findings | 3 |
| 1.2 | Data Coverage | 3 |
| 1.3 | Strategy Performance Headlines | 3 |
| 2 | Data Description | 3 |
| 2.1 | Raw Data Source | 3 |
| 2.2 | Data Processing Pipeline | 4 |
| 2.3 | Final Dataset Structure | 4 |
| 3 | Data Cleaning and Quality | 4 |
| 3.1 | Validation Checks Performed | 4 |
| 3.2 | Diagnostics Summary | 4 |
| 3.3 | Outlier Handling | 4 |
| 4 | Feature Engineering | 5 |
| 4.1 | Calendar Spread Calculation | 5 |
| 4.2 | Spread Normalization | 5 |
| 4.3 | Days-to-Expiry (DTE) | 5 |
| 4.4 | Roll Detection | 5 |
| 5 | Spread Characteristics | 6 |
| 5.1 | Term Structure Analysis | 6 |
| 5.2 | DTE Profile | 7 |
| 5.3 | Contango/Backwardation Analysis | 8 |

| | | |
|-----------|---|-----------|
| 6 | Seasonality Analysis | 8 |
| 6.1 | Monthly Patterns | 8 |
| 6.2 | Bucket-Level Analysis | 9 |
| 6.3 | End-of-Month Effect | 10 |
| 7 | Roll Dynamics | 11 |
| 7.1 | Roll Event Study | 11 |
| 7.2 | Volume Share Evolution | 12 |
| 8 | Strategy Backtesting | 12 |
| 8.1 | Strategy Definitions | 12 |
| 8.2 | Configuration Parameters | 12 |
| 8.3 | Performance Summary | 12 |
| 8.4 | Equity Curves | 13 |
| 8.5 | Strategy Comparison | 14 |
| 8.6 | P&L Distribution | 14 |
| 8.7 | Monthly Returns | 15 |
| 9 | Transaction Cost Sensitivity | 15 |
| 9.1 | Cost Sensitivity Analysis | 15 |
| 9.2 | Break-Even Analysis | 16 |
| 10 | Risk Analysis | 16 |
| 10.1 | Rolling Performance | 16 |
| 10.2 | Cumulative Monthly P&L | 17 |
| 10.3 | Drawdown Analysis | 17 |
| 10.4 | Consecutive Loss Analysis | 17 |
| 11 | Threats to Validity | 17 |
| 11.1 | Look-Ahead Bias | 17 |
| 11.2 | Transaction Cost Assumptions | 18 |
| 11.3 | Limited Strategy Variants | 18 |
| 11.4 | Single Commodity Focus | 18 |
| 11.5 | Survivorship Bias | 18 |
| 12 | Conclusions and Recommendations | 18 |
| 12.1 | Summary of Findings | 18 |
| 12.2 | Strategy Viability Assessment | 18 |
| 12.3 | Recommended Next Steps | 19 |
| A | Parameter Reference | 19 |
| A.1 | Pipeline Configuration | 19 |
| A.2 | Backtest Configuration | 19 |
| B | Sample Trade Records | 19 |
| C | Figure Index | 20 |
| D | Methodology Notes | 21 |

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 | 1 | 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

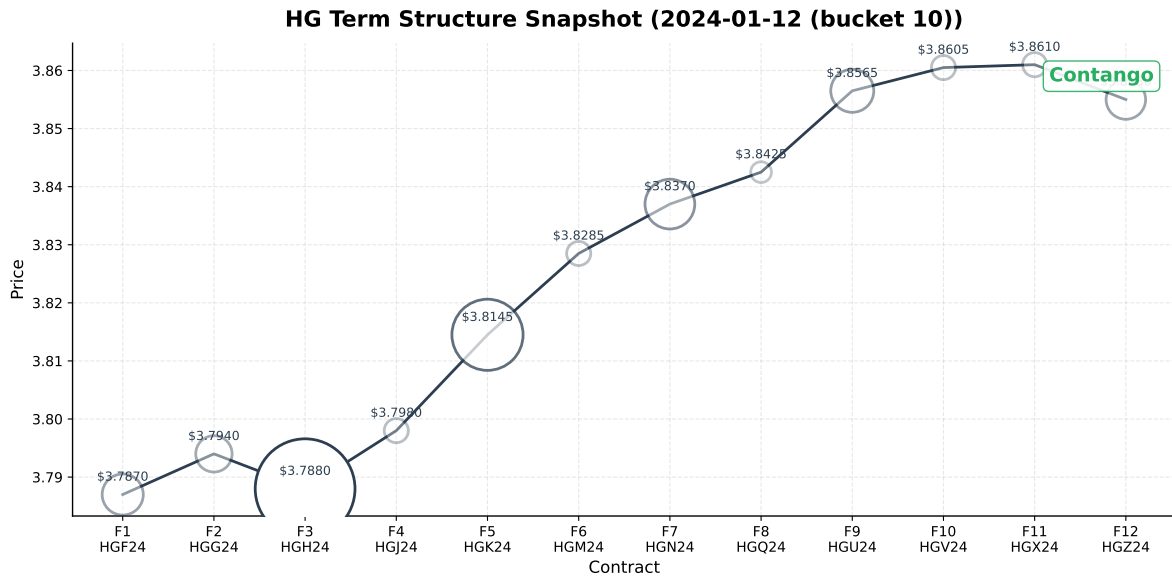


Figure 1: HG term structure snapshot showing price curve across contracts F1-F12. Upward-sloping curve indicates contango; downward-sloping indicates backwardation.

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

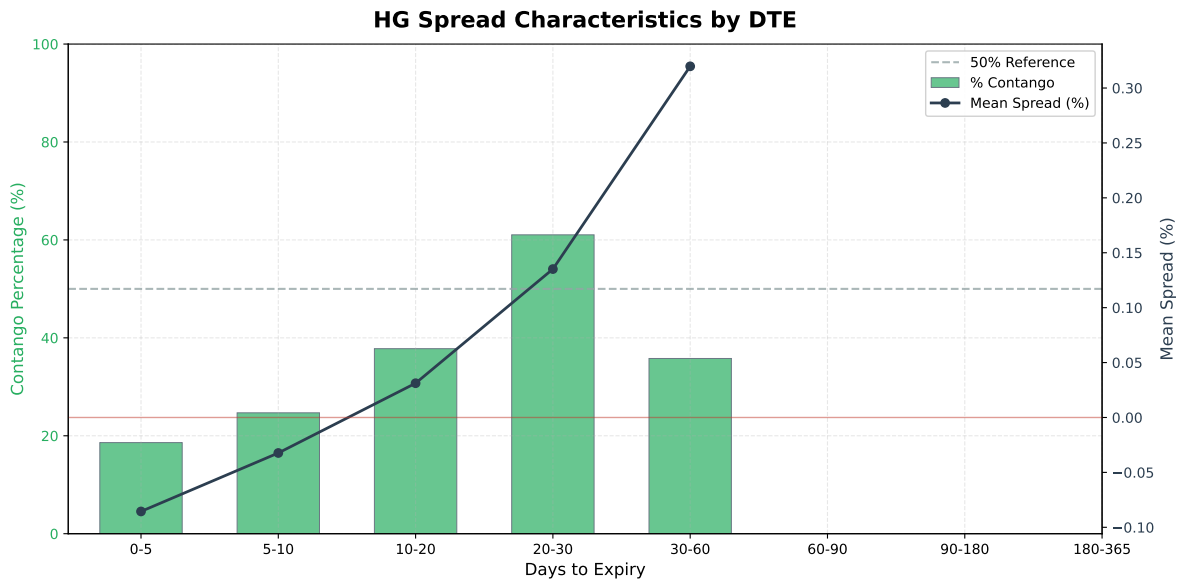


Figure 2: Spread characteristics by days-to-expiry showing how contango/backwardation frequency and mean spread evolve across the contract lifecycle.

| dte_bin | count | mean | std | min | max | median | pct_contango | mean_pct | median_pct |
|---------|-------|--------|-------|--------|-------|--------|--------------|----------|------------|
| 0-5 | 4187 | -0.001 | 0.004 | -0.030 | 0.037 | -0.000 | 18.604 | -0.086 | -0.022 |
| 5-10 | 4918 | -0.000 | 0.004 | -0.060 | 0.027 | 0.000 | 24.688 | -0.032 | 0.012 |
| 10-20 | 12520 | 0.000 | 0.004 | -0.024 | 0.053 | 0.001 | 37.788 | 0.031 | 0.073 |
| 20-30 | 1208 | 0.001 | 0.003 | -0.014 | 0.012 | 0.002 | 61.036 | 0.135 | 0.153 |
| 30-60 | 135 | 0.003 | 0.004 | -0.008 | 0.020 | 0.003 | 35.786 | 0.320 | 0.313 |
| 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

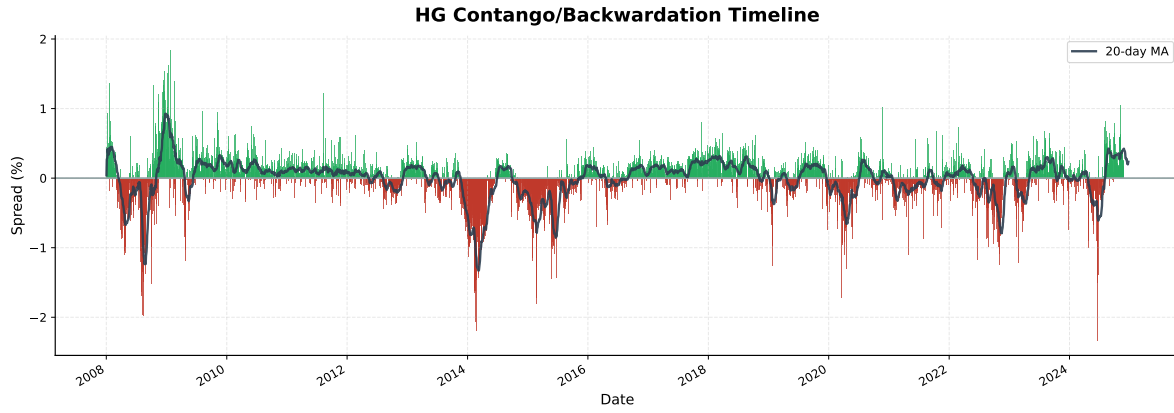


Figure 3: Timeline of contango (green) and backwardation (red) states across the sample period. Contango predominates but backwardation episodes occur during supply disruptions.

6 Seasonality Analysis

6.1 Monthly Patterns

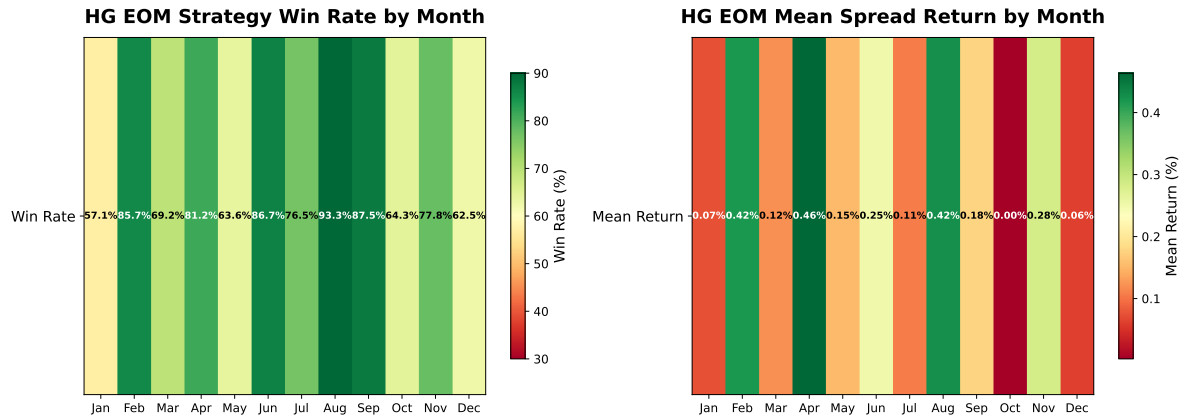


Figure 4: EOM strategy win rate and mean return by calendar month. Darker colors indicate stronger performance.

| month | count | std_return | total_return | win_rate | month_name | mean_return_pct |
|-------|-------|------------|--------------|----------|------------|-----------------|
| 1 | 14 | 0.00 | 0.01 | 57.14 | Jan | 0.07 |
| 2 | 14 | 0.00 | 0.06 | 85.71 | Feb | 0.42 |
| 3 | 13 | 0.00 | 0.02 | 69.23 | Mar | 0.12 |
| 4 | 16 | 0.00 | 0.07 | 81.25 | Apr | 0.46 |
| 5 | 11 | 0.00 | 0.02 | 63.64 | May | 0.15 |
| 6 | 15 | 0.00 | 0.04 | 86.67 | Jun | 0.25 |
| 7 | 17 | 0.00 | 0.02 | 76.47 | Jul | 0.11 |
| 8 | 15 | 0.00 | 0.06 | 93.33 | Aug | 0.42 |
| 9 | 16 | 0.00 | 0.03 | 87.50 | Sep | 0.18 |
| 10 | 14 | 0.00 | 0.00 | 64.29 | Oct | 0.00 |
| 11 | 9 | 0.00 | 0.03 | 77.78 | Nov | 0.28 |
| 12 | 16 | 0.00 | 0.01 | 62.50 | Dec | 0.06 |

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

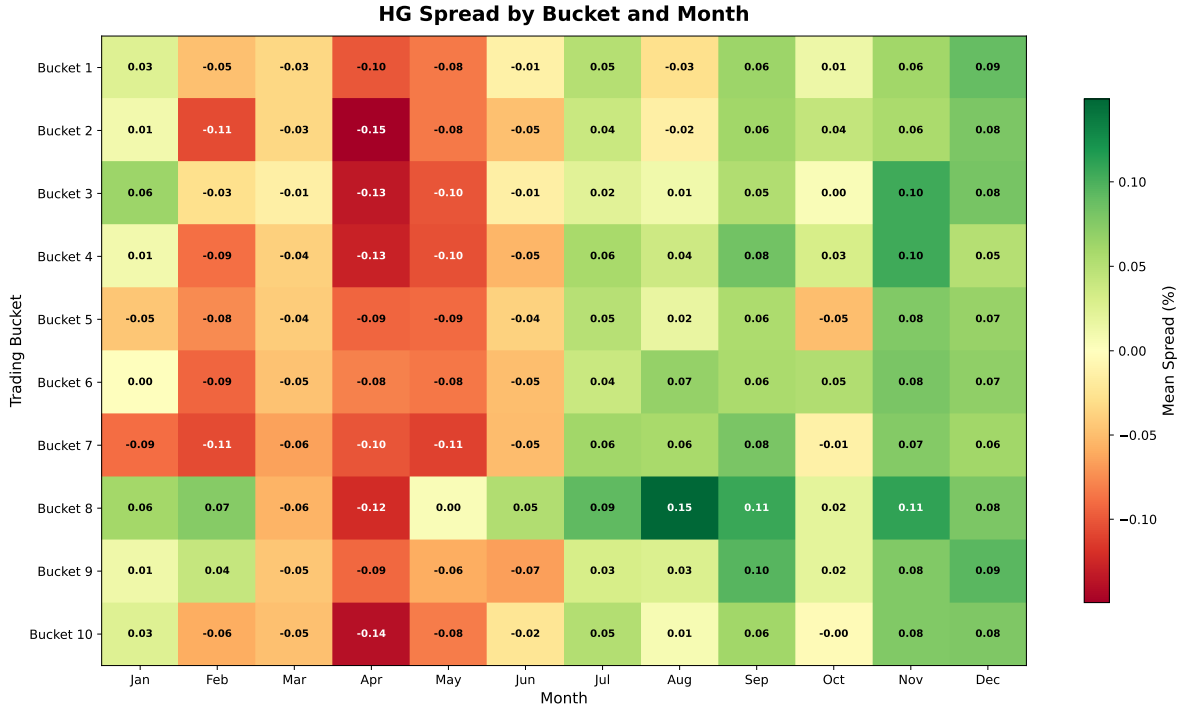


Figure 5: Mean spread by trading bucket and calendar month, showing intraday and seasonal interaction effects.

6.3 End-of-Month Effect

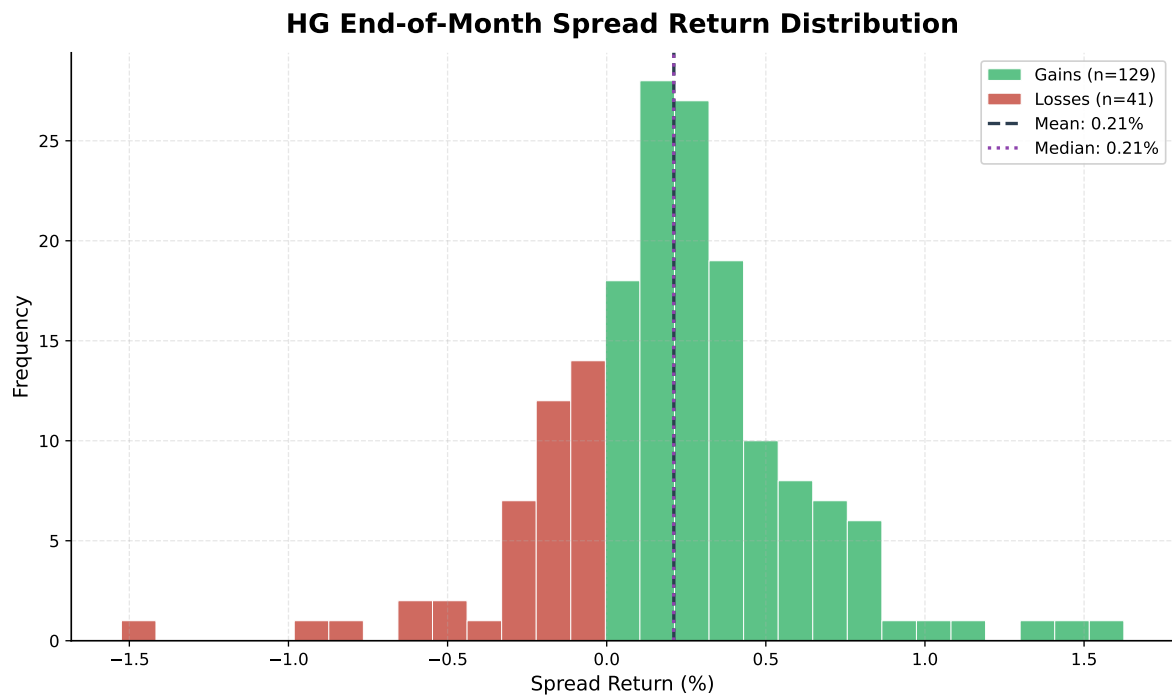


Figure 6: Distribution of end-of-month spread returns showing positive skew consistent with institutional rebalancing effects.

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

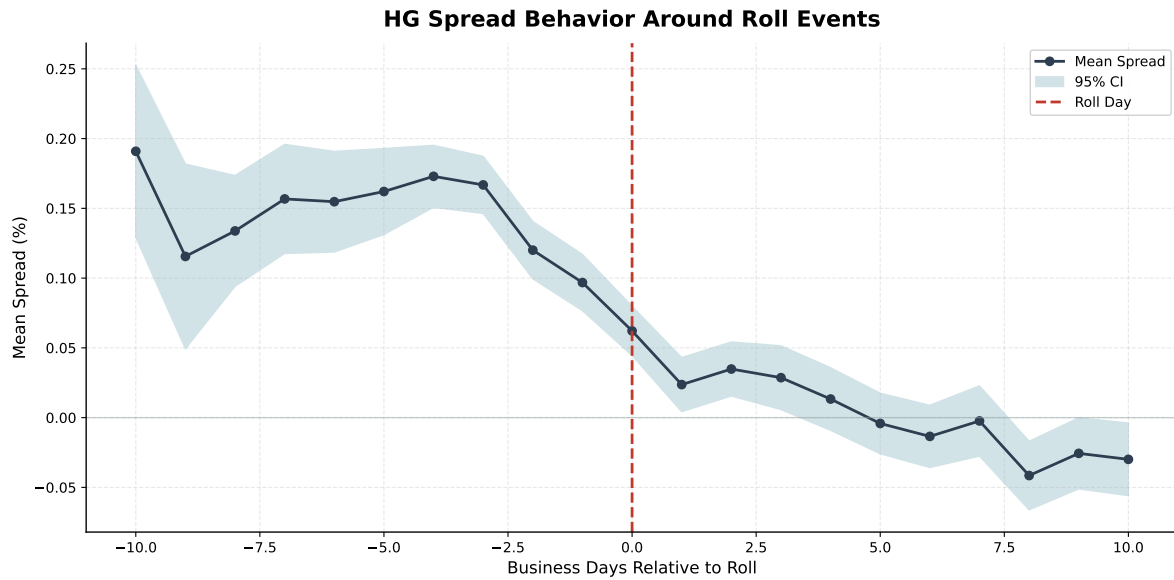


Figure 7: Mean spread behavior around roll events with 95% confidence bands. Day 0 = roll peak (F2 volume share > 50%).

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

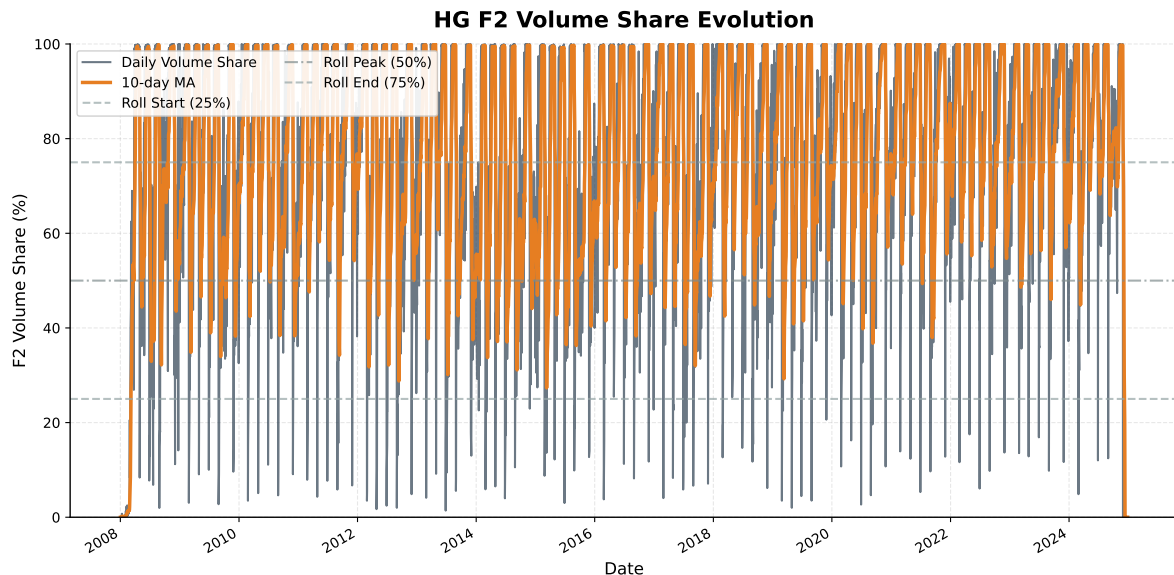


Figure 8: F2 volume share evolution showing the characteristic S-curve transition pattern during contract rolls.

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 | 111 | 47.75 | -5975.00 | -0.34 | -7.50 | 0.72 |
| HG | eom | 174 | 68.39 | 20472.38 | 1.16 | -1.42 | 2.92 |

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

8.4 Equity Curves

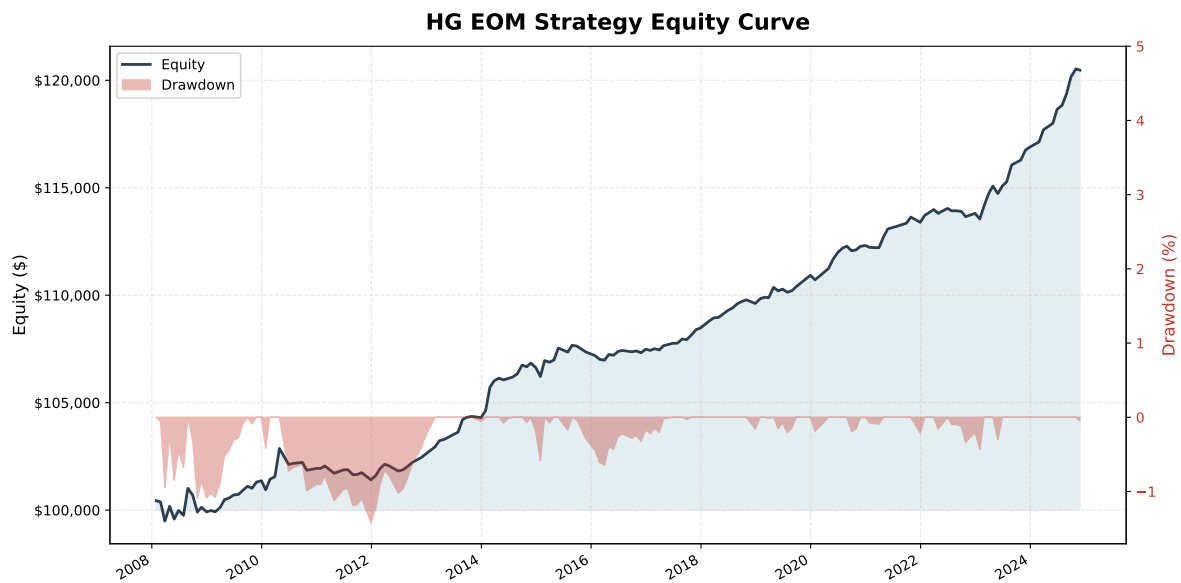


Figure 9: EOM strategy equity curve with drawdown overlay showing cumulative net P&L over time.

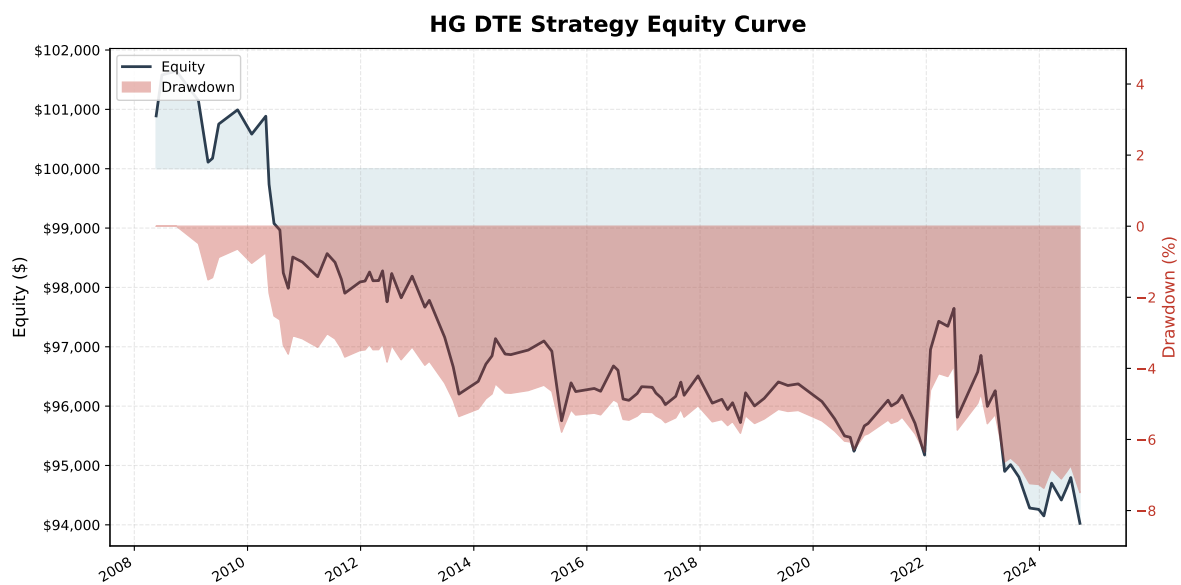


Figure 10: DTE strategy equity curve with drawdown overlay.

8.5 Strategy Comparison

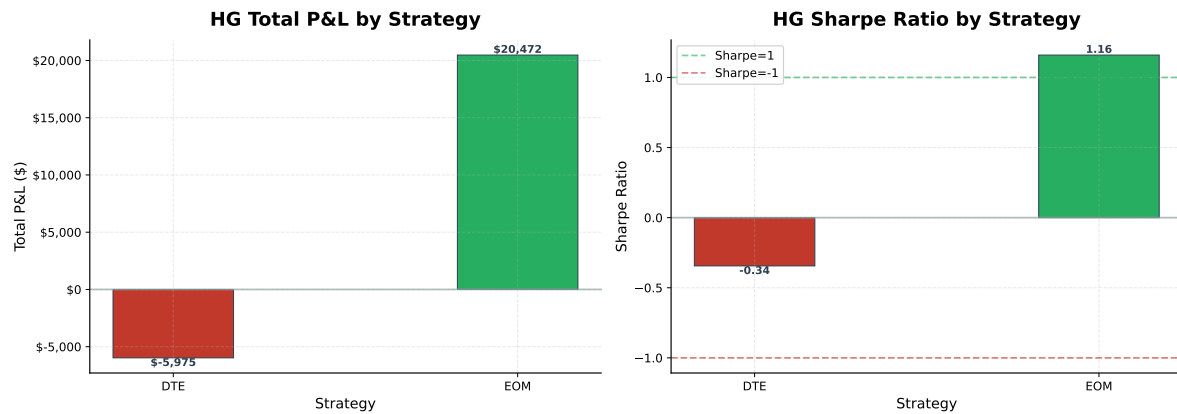


Figure 11: Comparison of total P&L and Sharpe ratio across strategies.

8.6 P&L Distribution

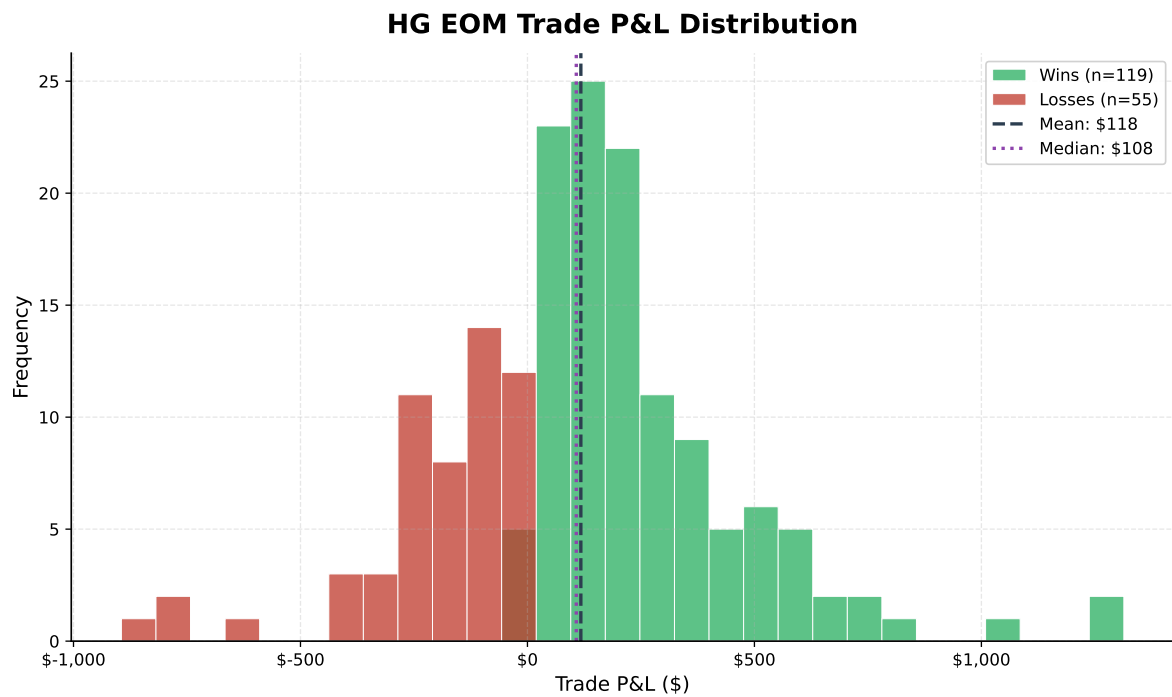


Figure 12: Distribution of trade P&L for the EOM strategy showing win/loss magnitude asymmetry.

8.7 Monthly Returns

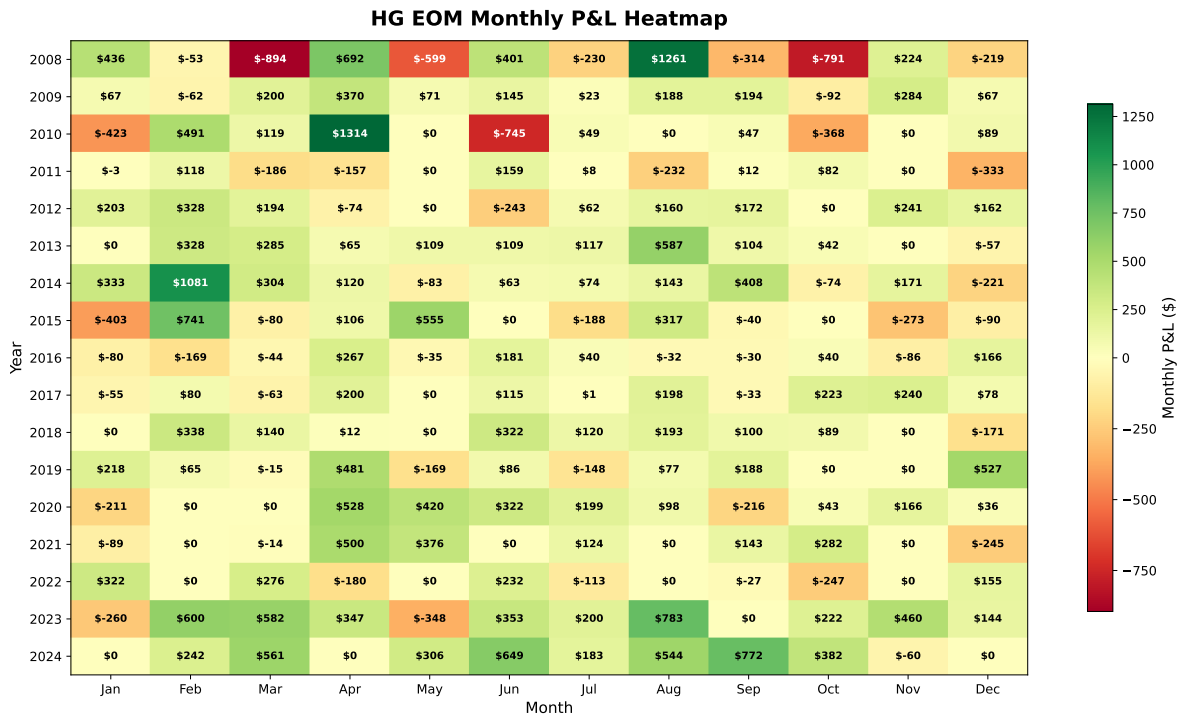


Figure 13: Year-by-month P&L heatmap for the EOM strategy showing performance consistency across time.

9 Transaction Cost Sensitivity

9.1 Cost Sensitivity Analysis

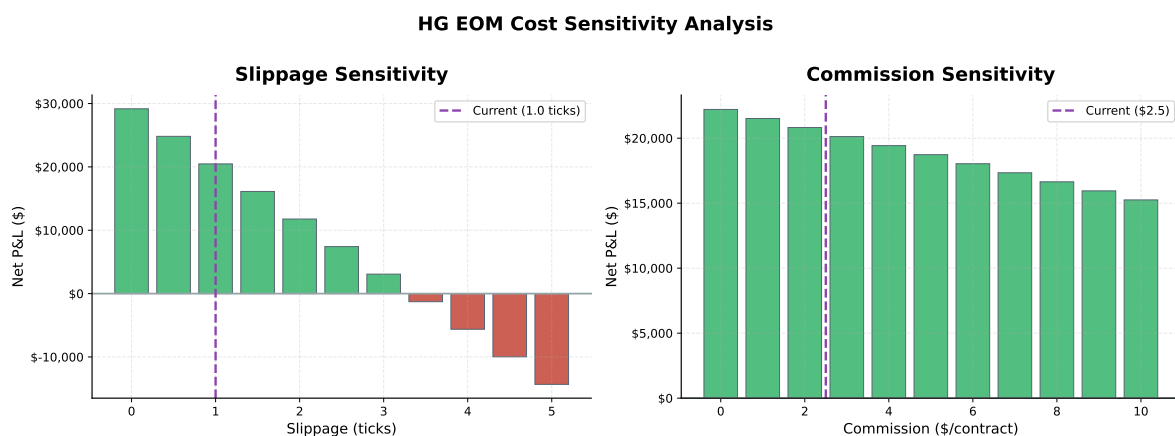


Figure 14: Strategy profitability sensitivity to slippage and commission assumptions. Vertical line indicates baseline assumption.

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

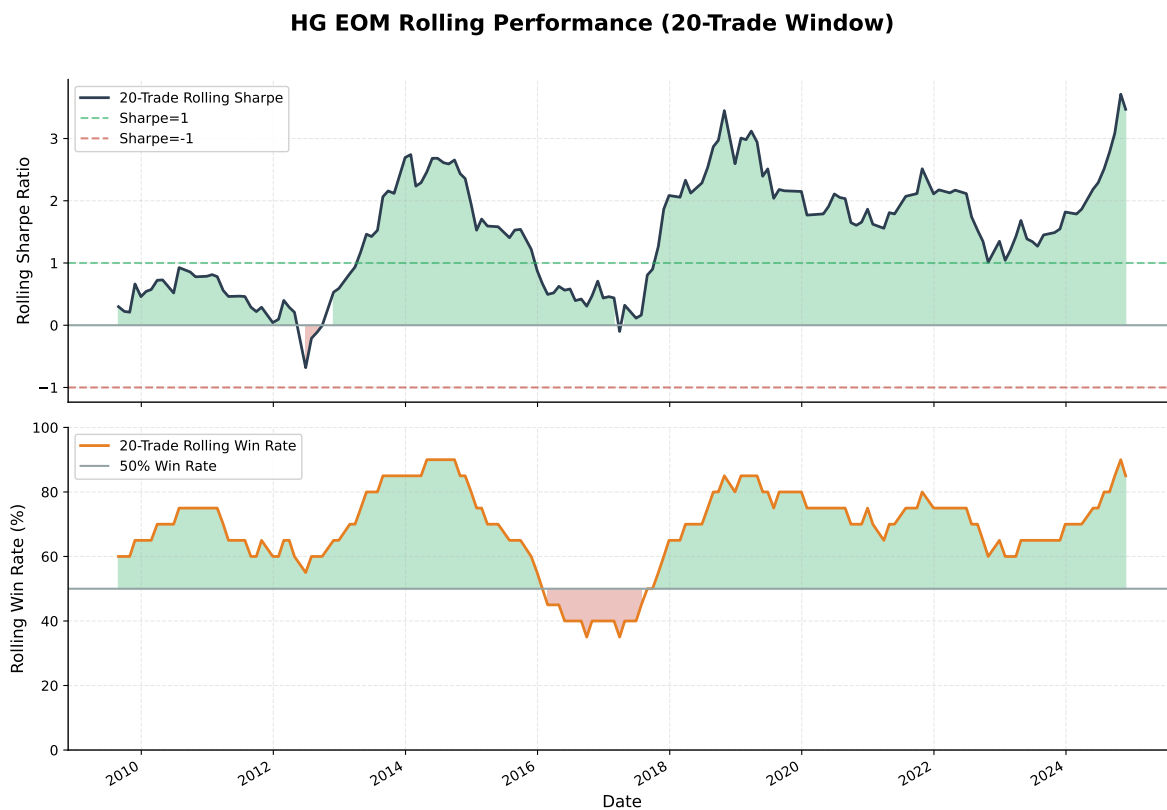


Figure 15: Rolling Sharpe ratio and win rate (252-day window) showing performance stability over time.

10.2 Cumulative Monthly P&L

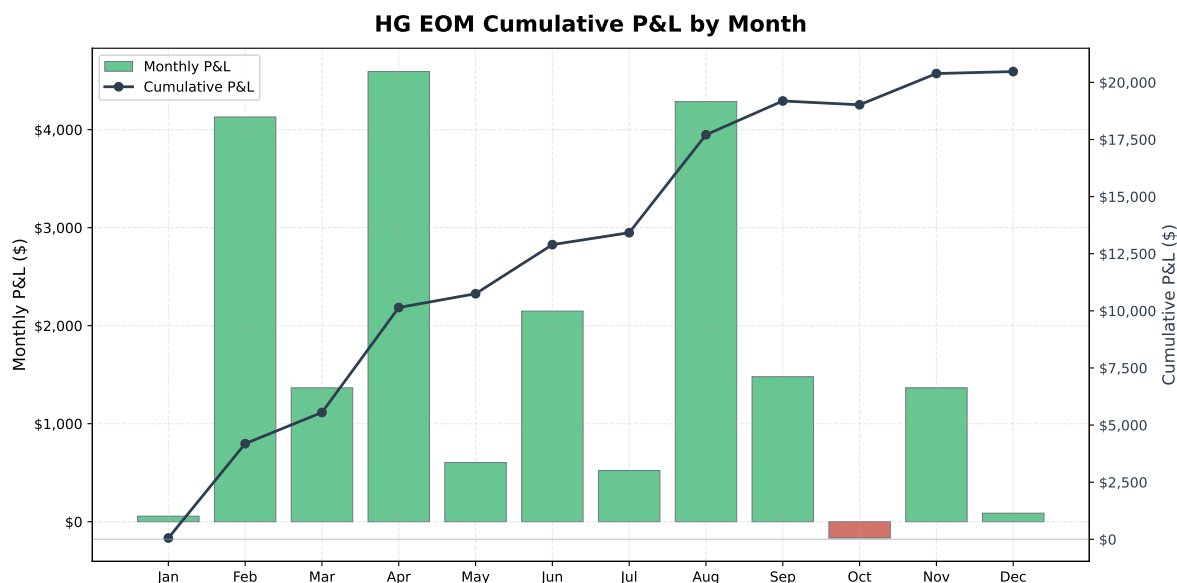


Figure 16: Monthly P&L breakdown with cumulative total showing contribution of each month to total performance.

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 | NaN | 1 | -0.0285 | NaN | NaN |
| 2008-05-07 | 2008-05-21 | 1 | -0.0195 | 0.0185 | 890.0000 |
| 2008-06-05 | 2008-06-27 | 1 | -0.0240 | 0.0060 | 690.0000 |
| 2008-09-05 | 2008-09-29 | 1 | -0.0090 | -0.0040 | 65.0000 |
| 2008-12-05 | NaN | 1 | 0.0205 | NaN | NaN |
| 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 | 2009-06-29 | 1 | -0.0095 | 0.0160 | 577.5000 |
| 2009-10-07 | 2009-10-29 | 1 | 0.0125 | 0.0245 | 240.0000 |
| 2009-12-07 | NaN | 1 | 0.0100 | NaN | NaN |
| 2010-01-06 | 2010-01-28 | 1 | 0.0190 | 0.0050 | -410.0000 |
| 2010-04-07 | 2010-04-29 | 1 | -0.0030 | 0.0115 | 302.5000 |
| 2010-05-06 | 2010-05-20 | 1 | 0.0505 | 0.0070 | -1147.5000 |
| 2010-06-07 | 2010-06-21 | 1 | 0.0100 | -0.0140 | -660.0000 |

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

C Figure Index

List of Figures

| | | |
|---|---|----|
| 1 | HG term structure snapshot showing price curve across contracts F1-F12. Upward-sloping curve indicates contango; downward-sloping indicates backwardation. | 6 |
| 2 | Spread characteristics by days-to-expiry showing how contango/backwardation frequency and mean spread evolve across the contract lifecycle. | 7 |
| 3 | Timeline of contango (green) and backwardation (red) states across the sample period. Contango predominates but backwardation episodes occur during supply disruptions. | 8 |
| 4 | EOM strategy win rate and mean return by calendar month. Darker colors indicate stronger performance. | 8 |
| 5 | Mean spread by trading bucket and calendar month, showing intraday and seasonal interaction effects. | 9 |
| 6 | Distribution of end-of-month spread returns showing positive skew consistent with institutional rebalancing effects. | 10 |
| 7 | Mean spread behavior around roll events with 95% confidence bands. Day 0 = roll peak (F2 volume share > 50%). | 11 |
| 8 | F2 volume share evolution showing the characteristic S-curve transition pattern during contract rolls. | 12 |
| 9 | EOM strategy equity curve with drawdown overlay showing cumulative net P&L over time. | 13 |

| | | |
|----|---|----|
| 10 | DTE strategy equity curve with drawdown overlay. | 13 |
| 11 | Comparison of total P&L and Sharpe ratio across strategies. | 14 |
| 12 | Distribution of trade P&L for the EOM strategy showing win/loss magnitude asymmetry. | 14 |
| 13 | Year-by-month P&L heatmap for the EOM strategy showing performance consistency across time. | 15 |
| 14 | Strategy profitability sensitivity to slippage and commission assumptions. Vertical line indicates baseline assumption. | 15 |
| 15 | Rolling Sharpe ratio and win rate (252-day window) showing performance stability over time. | 16 |
| 16 | Monthly P&L breakdown with cumulative total showing contribution of each month to total performance. | 17 |

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 $\sqrt{252}$.