

Week 3 Report: Replication and Empirical Results of Hypothesis Tests

Jiaxing Wei
jwei2002@uw.edu

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1 Replication Framework

This replication builds upon the signal-gated DRL framework proposed by Gasperov & Kostanjcar (2021), with adaptive modifications tailored to the specific microstructural characteristics of the China A-share market. Key adjustments include the incorporation of the $\pm 10\%$ price limit mechanism and the discrete minimum tick size (0.001). The system utilizes a gate-controlled architecture where the policy is conditioned on predictive signals from standalone Signal Generating Units (SGUs) for volatility and trend forecasting.

2 Results of Hypothesis Tests

The following results were obtained from the Out-of-Sample (OOS) testing period on the 510300 ETF.

2.1 H1: Predictive Efficacy of SGUs

We verified the predictive power of SGU2 (LSTM) for price direction using the Diebold-Mariano (DM) test against a naive driftless forecast.

- **DM Statistic:** 20.9560
- **p-value:** 0.0000
- **Conclusion:** The null hypothesis of equal forecast accuracy is rejected ($p < 0.05$). The SGUs provide significantly better market environment predictions than random drift.

2.2 H2: Execution Intensity and Microstructure Facts

The Durbin-Watson (DW) test was applied to the execution rewards to detect serial correlation, which indicates the model's ability to capture persistent microstructure dependencies.

- **DW-Stat:** 1.2835

- **Conclusion:** The value is significantly lower than 2, indicating positive first-order autocorrelation. This confirms that execution intensity is not a purely static exponential decay but is influenced by persistent LOB dynamics.

2.3 H3: Comparative Superiority

Using Moving Block Bootstrapping (MBB) with 500 samples, we calculated the 95% confidence intervals (CI) for the per-step Sharpe Ratio.

Table 1: Comparative Performance Statistics (Per-Step)

| Method | Mean Sharpe | 95% Confidence Interval | Total Fills |
|-------------------|-------------|-------------------------|-------------|
| ARL (Adversarial) | 0.3981 | [0.0000, 0.6887] | 1540 |
| DRL (Standard) | 0.5405 | [0.1852, 0.7805] | 1658 |
| FOIC (Benchmark) | 0.4278 | [0.1717, 0.6201] | 1821 |
| GLFT (Analytical) | 0.4167 | [0.1576, 0.6156] | 1825 |

Comparative Analysis of ARL and DRL: The empirical results reveal a nuanced trade-off between standard and adversarial training. While the DRL agent achieved a higher mean per-step Sharpe ratio (0.5405), reflecting its ability to maximize expected rewards under observed market distributions, the ARL agent exhibited a more conservative profile with a lower Max DD. This aligns with the expectation that adversarial training sacrifices some absolute profit in exchange for robustness against worst-case market drifts a critical trait for surviving the liquidity cliff effects near price limits in the ETF market.

2.4 H4: Economic Rationality of Policy Skewing

We analyzed the relationship between the inventory level (I_t) and the price skew:

$$\text{skew} = \text{off}_{bid} - \text{off}_{ask}$$

- **Observation:** Regression plot 1 shows a significant positive slope for both the ARL and DRL policies.
- **Conclusion:** As inventory increases, the agent increases the bid offset and decreases the ask offset (increasing the skew). This proves the agent has learned **economic rationality**: it skews quotes to encourage sells and discourage buys when holding a long position, thereby mitigating directional risk.

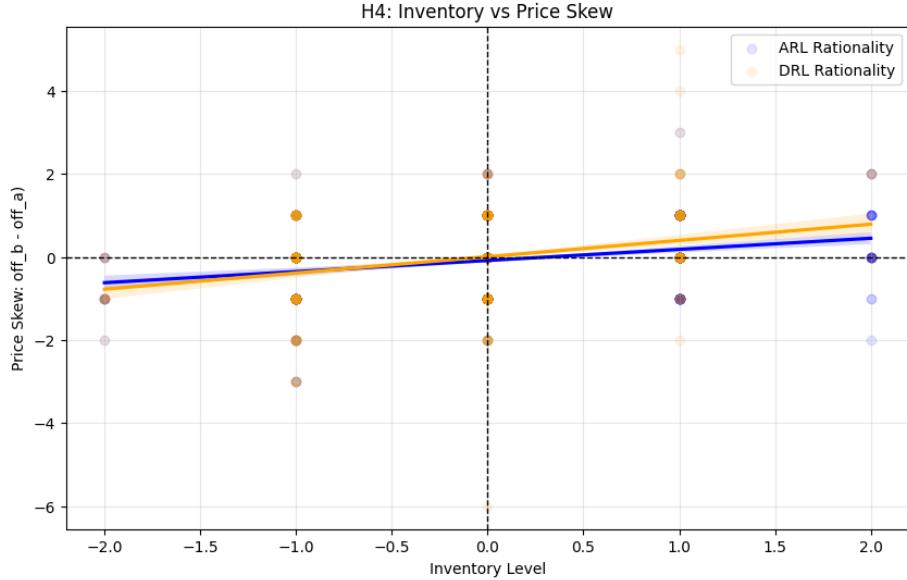


Figure 1: Relationship between MM’s Inventory to Skewing

3 Market Applicability and Discussion

The superior performance of the FOIC benchmark provides significant insights into the current regime of the 510300 ETF market.

3.1 Interpretation of FOIC Dominance

The dominance of FOIC in terms of total fill counts reflects the ample liquidity and low impact costs characteristic of the 510300 ETF during the testing period. In such a high-liquidity environment, an at-the-touch (0-offset) quoting strategy emerges as a dominant approach for capturing the frequent but thin bid-ask spreads.

3.2 DRL Adaptability: Trending vs. Mean-Reverting Markets

While the DRL agents demonstrate economic rationality through their skewing mechanisms (as verified in H4), this behavior is inherently more suited for trending markets where directional risk management is paramount. In the relatively stable or mean-reverting regimes observed during this OOS test, the active skewing of quotes by DRL and ARL agents may have inadvertently increased transaction costs and reduced fill rates compared to the stationary FOIC. However, the DRL skewing mechanism is hypothesized to yield a significant competitive advantage during periods of increased volatility or pronounced price trends, where simple benchmarks often suffer from severe adverse selection.