Extrema Precision 2.0: A Framework for Evaluating Reversal Signal Localization

Sofien Kaabar, CFA
sofien-kaabar@hotmail.com

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Abstract

Reversal trading strategies aim to identify local or global turning points in financial markets. Despite their widespread use, the evaluation of reversal signals remains largely dependent on profit-and-loss metrics or visually subjective chart inspection. These approaches fail to quantify whether a trading signal genuinely aligns with structurally meaningful extrema in price dynamics. This paper introduces an upgraded formulation of the Extrema Precision Index (EPI), a metric designed to measure the structural localization quality of reversal signals. The proposed framework addresses four major limitations present in EPI 1.0, the original metric presented in a previous research paper. First, it removes the subjectivity associated with fixed bar-distance thresholds by replacing discrete proximity rules with a continuous distance-based scoring function. Second, the metric incorporates volatility normalization to ensure scale invariance across market regimes and assets. Third, a randomized benchmark is introduced to quantify statistical skill relative to chance, allowing the separation of genuine structural edge from incidental alignment. Finally, the relationship between swing-point detection horizons and signal evaluation horizons is formalized, ensuring temporal consistency between extrema definition and signal assessment. The resulting framework transforms reversal evaluation from a heuristic assessment into a statistically grounded diagnostic tool capable of comparing strategies across assets, timeframes, and market regimes. Applications include strategy validation, signal filtering, and structural alpha diagnostics within systematic trading pipelines.

1 Introduction

Reversal detection represents one of the oldest and most persistent objectives in financial market analysis. Traders and researchers alike seek signals capable of identifying exhaustion points in price dynamics, where prevailing trends weaken and directional changes become likely. While modern quantitative finance has made substantial progress in forecasting volatility, trend persistence, and cross-sectional returns, the evaluation of reversal signals remains surprisingly underdeveloped. In practice, reversal strategies are often judged using realized profitability metrics such as Sharpe ratios, drawdowns, or win rates. Although necessary, these measures conflate multiple layers of a trading system, including execution rules, position sizing, and risk management. As a result, they provide limited insight into the intrinsic structural quality of the signal itself. A reversal signal may possess strong localization properties around market extrema while appearing unprofitable due to suboptimal execution design, or conversely, a profitable strategy may succeed despite weak structural alignment. The Extrema Precision Index (EPI) was originally conceived as a diagnostic measure intended to quantify how frequently trading signals occur near swing highs or swing lows. The initial formulation relied on counting signal occurrences within a fixed number of bars surrounding detected extrema. While intuitive and operationally simple, such an approach introduces several methodological limitations.

First, fixed bar-distance thresholds introduce subjectivity and scale dependence. A distance of two bars may represent negligible temporal displacement in low-volatility environments but substantial structural deviation in highly volatile markets. Second, binary hit-or-miss classifications discard information about the magnitude of misalignment between signals and extrema. Third, without a baseline comparison, observed alignment may simply reflect the natural clustering of extrema in financial time series rather than genuine predictive skill. Finally, the horizon used to define swing points is rarely aligned with the temporal horizon implicit in the trading signal itself, leading to inconsistencies in evaluation.

This paper proposes a generalized formulation of EPI designed to overcome these limitations. The contributions of this work are fourfold:

1. The replacement of discrete bar thresholds with a continuous proximity measure that removes subjective parameter dependence.
2. The introduction of volatility-adjusted distance metrics, allowing comparisons across assets and regimes while preserving structural meaning.
3. The construction of a randomized benchmark framework to evaluate whether observed extrema alignment exceeds what would be expected under random signal generation.
4. The formal coupling of swing-point detection periods with evaluation horizons, ensuring temporal coherence between extrema definition and signal assessment.

2 Methodology

2.1 Formal Definition of Swing Points

The evaluation of reversal signals requires an objective definition of market extrema. Let P_t denote the observed price series at discrete time index $t \in \{1, \ldots, T\}$.

A swing point is defined relative to an evaluation horizon H, representing the temporal scale at which structural reversals are assessed. A price observation at time t is defined as a swing high if

$$P_t = \max\{P_{t-H}, \ldots, P_{t+H}\}, \tag{1}$$

and a swing low if

$$P_t = \min\{P_{t-H}, \ldots, P_{t+H}\}. \tag{2}$$

The parameter H therefore determines the structural resolution of extrema detection. Unlike heuristic swing definitions, this formulation explicitly links extrema identification to a temporal horizon, ensuring consistency between signal intent and evaluation scale.

Let $\mathcal{E} = \{e_1, e_2, \ldots, e_N\}$ denote the set of detected extrema timestamps.

A key principle of the proposed framework is that the swing-point horizon H should match the intended holding or forecasting horizon of the trading signal, preventing scale mismatch between signal generation and evaluation.

2.2 Distance Metric Construction

Let $\mathcal{S} = \{s_1, s_2, \ldots, s_M\}$ denote timestamps at which a reversal signal occurs.

Traditional formulations classify signals as successful if they occur within a fixed number of bars from an extremum. Such binary thresholds introduce subjectivity and ignore the magnitude of temporal misalignment. Instead, we define a continuous distance measure.

For each signal time s_i, define the temporal distance to the nearest extremum as

$$d_i = \min_{e_j \in \mathcal{E}} |s_i - e_j|. \tag{3}$$

To ensure comparability across volatility regimes, distance is normalized using local market volatility. Let σ_{s_i} denote a volatility estimator (e.g., ATR or rolling standard deviation). The volatility-adjusted distance is defined as

$$\tilde{d_i} = \frac{d_i}{\sigma_{s_i}}. \tag{4}$$

This normalization produces a scale-invariant measure, allowing signals across assets and timeframes to be evaluated under a unified structural metric.

2.3 Continuous Extrema Precision Index

Rather than applying a binary hit criterion, the upgraded Extrema Precision Index assigns a continuous score based on proximity to extrema.

Each signal receives a proximity weight defined by an exponential decay function:

$$w_i = \exp\left(-\frac{\tilde{d}_i}{\tau}\right), \tag{5}$$

where $\tau > 0$ is a decay parameter controlling tolerance to temporal displacement.

Signals occurring exactly at extrema receive weight $w_i = 1$, while distant signals contribute progressively less to the score.

The Continuous Extrema Precision Index (EPI) is then defined as

$$\mathrm{EPI} = \frac{1}{M}\sum_{i=1}^{M} w_i. \tag{6}$$

This formulation transforms reversal evaluation into a smooth functional measuring expected structural proximity rather than discrete success frequency.

Importantly, EPI measures localization quality independently of trade profitability, isolating signal intelligence from execution design.

2.4 Benchmark Construction

Observed proximity between signals and extrema must be evaluated relative to chance. Financial time series naturally exhibit clustered extrema, meaning random signals may appear structurally aligned.

To establish statistical skill, we construct a randomized benchmark process.

Let $\mathcal{S}^{(k)}$ denote a randomized signal set generated by sampling timestamps uniformly from the trading period while preserving the original signal count M. For each simulation $k = 1, \ldots, K$, a benchmark EPI is computed:

$$\mathrm{EPI}_{\mathrm{rand}}^{(k)}. \tag{7}$$

The benchmark expectation is

$$E[\mathrm{EPI}_{\mathrm{rand}}] = \frac{1}{K}\sum_{k=1}^{K} \mathrm{EPI}_{\mathrm{rand}}^{(k)}. \tag{8}$$

We define the excess structural precision as

$$\mathrm{EPI}_{\alpha} = \mathrm{EPI}_{\mathrm{strategy}} - E[\mathrm{EPI}_{\mathrm{rand}}]. \tag{9}$$

Positive values indicate structural alignment exceeding random expectation, providing a direct measure of reversal signal skill.

2.5 Multi-Horizon Extension

Financial markets exhibit multi-scale structure consistent with fractal and self-similar dynamics. A reversal signal may align strongly with short-term extrema while failing to capture higher-order turning points.

To account for this property, EPI is evaluated across multiple horizons $H \in \{H_1, H_2, \ldots, H_L\}$.

For each horizon, extrema sets $\mathcal{E}^{(H_l)}$ are constructed and an EPI score computed:

$$\mathrm{EPI}(H_l). \tag{10}$$

The resulting vector

$$\mathbf{EPI} = [\mathrm{EPI}(H_1), \mathrm{EPI}(H_2), \ldots, \mathrm{EPI}(H_L)] \tag{11}$$

describes the structural sensitivity of the signal across temporal scales.

This multi-horizon representation allows researchers to distinguish between micro-reversal detectors, intermediate exhaustion signals, and macro turning-point strategies, providing a richer diagnostic characterization than single-scale evaluation.

3 Implementation

3.1 Implementation Methodology

The upgraded Extrema Precision Index (EPI) is designed to be computationally simple while remaining statistically rigorous. The implementation follows four sequential steps:

1. Construct the price series and estimate local volatility.
2. Detect extrema using a predefined evaluation horizon H.
3. Compute volatility-adjusted distances between signal timestamps and extrema.
4. Aggregate proximity scores using the continuous decay formulation.

Algorithmically, the procedure requires only linear passes over the data and nearest-neighbor distance computations, resulting in computational complexity approximately $\mathcal{O}(T)$ for a time series of length T. This makes the framework suitable for large-scale cross-asset evaluation and high-frequency datasets.

Signals may originate from any model, including technical indicators, machine learning classifiers, or rule-based trading systems. Importantly, EPI operates as a diagnostic layer independent of signal construction.

4 Empirical Evaluation on Major FX Markets

4.1 Experimental Procedure

To evaluate the practical behavior of the upgraded Extrema Precision Index (EPI), the methodology described in Section 2 was applied to a set of major foreign exchange markets using daily data obtained through the `yfinance` API. The selected currency pairs were EURUSD, USDCHF, GBPUSD, USDJPY, and USDCAD, representing highly liquid and globally traded instruments.

For each market, the following procedure was executed:

1. Daily closing prices were downloaded beginning in 2003.
2. Local volatility was estimated using a 20-day rolling standard deviation.
3. Structural extrema were detected using a symmetric horizon of $H = 5$ trading days.
4. A reversal signal set was generated using a classical RSI strategy, where signals occur when RSI falls below 30 or rises above 70.
5. A naive benchmark was constructed by generating random signal timestamps matching the exact number of RSI signals.
6. The continuous, volatility-normalized EPI was computed for both the RSI strategy and the randomized benchmark.
7. Structural skill was measured using the excess precision metric

$$\mathrm{EPI}_\alpha = \mathrm{EPI}_{\mathrm{RSI}} - \mathrm{EPI}_{\mathrm{Random}}.$$

This framework isolates structural localization ability independently from profitability, allowing reversal intelligence to be evaluated across markets under consistent assumptions.

4.2 Results

Table 1 reports the EPI values obtained for each currency pair.

Table 1: Extrema Precision Index Results Across Major FX Pairs

Pair	**EPI (RSI)**	**EPI (Random)**	**EPI Alpha**	**Interpretation**
EURUSD	0.1449	0.1284	0.0165	Weak edge
USDCHF	0.1440	0.1174	0.0266	Weak edge
GBPUSD	0.1532	0.1289	0.0243	Weak edge
USDJPY	0.4517	0.3820	0.0698	Moderate edge
USDCAD	0.1400	0.1342	0.0057	Weak edge
Average	—	—	**0.0286**	Weak overall edge

4.3 Performance Summary

Across the five currency pairs examined, the RSI reversal strategy demonstrates a consistently positive but modest structural advantage relative to random signal placement. The average excess precision of 0.0286 indicates that RSI signals occur closer to detected extrema than would be expected under a null model of random timing.

However, the magnitude of this advantage varies substantially across markets. USDJPY exhibits a noticeably stronger alignment with extrema, achieving an EPI Alpha of 0.0698, classified as a moderate structural edge. This suggests that reversal dynamics in USDJPY may exhibit stronger mean-reverting behavior or clearer exhaustion structures at the evaluated horizon.

In contrast, EURUSD, USDCHF, GBPUSD, and USDCAD display only weak structural improvements over randomness. While positive, these values indicate that a significant portion of RSI signal placement can be explained by the natural clustering of extrema in financial time series rather than strong predictive localization.

Importantly, none of the markets exhibit negative EPI Alpha values, implying that the RSI heuristic retains some degree of structural information even in highly efficient FX markets. Nevertheless, the relatively small magnitudes suggest that raw RSI signals alone are unlikely to constitute a robust reversal detector without additional filtering or regime conditioning.

4.4 Conclusion

The cross-market evaluation demonstrates that the upgraded Extrema Precision Index successfully differentiates between random signal placement and structurally meaningful reversal behavior. By incorporating volatility normalization and benchmark comparison, the metric provides a quantitative measure of signal localization independent of trading profitability.

Empirical results suggest that classical RSI reversal signals possess limited but non-zero structural intelligence in major FX markets. The presence of a moderate edge in USDJPY highlights the importance of market-specific dynamics and supports the hypothesis that reversal efficiency varies across instruments.

More broadly, these findings illustrate the role of EPI as a diagnostic framework rather than a trading rule. The metric enables researchers to evaluate whether signals genuinely target turning points before considering execution or risk management layers. Future research may extend this framework through multi-horizon aggregation, statistical significance testing, and integration with machine learning–based signal generation.