Methodology: Seven-Term Market-Informed Potential and Quantum Implementation

September 2, 2025

1 State Variable, Reference, and Objective

State (log-space). Define
$$x \equiv \log\big(P/P_0\big),$$
where P is the equity price and P_0 is a rolling fair-value anchor.

Reference P_0. For isolating mechanics, we initially set $P \equiv P_0$ ($x = 0$); in production $P_0(t)$ is a dynamic fair value.

Objective. Construct a market-informed nonlinear potential $V(x)$ that encodes valuation, macro, sector, and microstructure conditions, then solve the time-independent Schrödinger equation in x to infer directional tunneling bias (long/short).

2 Seven-Term Nonlinear Potential

We parameterize a seventh-degree polynomial centered at $x = 0$:
$$V(x) \;=\; \sum_{k=1}^{7} \alpha_k \, x^k, \tag{1}$$
with economically interpretable coefficients α_k. Odd powers (x^1, x^3, x^5, x^7) create directional asymmetry; even powers (x^2, x^4, x^6) shape confinement/barrier hardness.

Term	**Driver (estimator)**	**Role in V**
$\alpha_1 x$	Individual beta (60d rolling)	Local slope (short-horizon drift alignment)
$\alpha_2 x^2$	Sector beta (90d rolling)	Quadratic curvature (meso co-movement)
$\alpha_3 x^3$	Exp. weighted market beta (EWMA, λ)	Macro asymmetry from recent acceleration
$\alpha_4 x^4$	Credit spread (Baa – 10Y UST)	Barrier hardness (inverted: wider spread $\Rightarrow$ easier escape)
$\alpha_5 x^5$	Relative P/E (stock / sector ETF)	Valuation-driven skew (over/undervaluation)
$\alpha_6 x^6$	Amihud illiquidity (30d)	Outer-tail stiffness (microstructure friction)
$\alpha_7 x^7$	Market drawdown (e.g., 1y SPX)	Nonlinear tail skew under systemic stress

Table 1: Economic mapping for the seven-term potential.

3 Data Definitions and Estimators

Betas

Let R_s, R_m, R_{sec} denote stock, market, and sector returns (daily unless noted).

Individual beta (60d).

$$\beta^{(60)}_{\text{indiv}} = \frac{\operatorname{Cov}(R_s, R_m)}{\operatorname{Var}(R_m)} \quad \text{on the most recent 60 trading days.}$$

Sector beta (90d).

$$\beta^{(90)}_{\text{sector}} = \frac{\operatorname{Cov}(R_s, R_{\text{sec}})}{\operatorname{Var}(R_{\text{sec}})} \quad \text{on the most recent 90 trading days.}$$

Exp. weighted market beta (EWMA). With weights $w_i = \lambda^i$ (e.g., $\lambda \in [0.94, 0.97]$),

$$\beta^{\text{EW}}_{\text{mkt}} = \frac{\sum_i w_i \,(R_{s,i} - \bar{R}^{(w)}_s)(R_{m,i} - \bar{R}^{(w)}_m)}{\sum_i w_i \,(R_{m,i} - \bar{R}^{(w)}_m)^2}.$$

Credit Spread (Baa – 10Y UST)

Let spread = BAA − GS10 (e.g., FRED series). We invert the usual hardness mapping to reflect dislocation pressure:

$$\alpha_4 = s_4 \, \frac{\bar{s}}{\text{spread}},$$

so wider spreads $\uparrow \Rightarrow \alpha_4 \downarrow \Rightarrow$ shallower/narrower barriers (higher tunneling likelihood).

Relative P/E (stock / sector ETF)

$$\text{relPE} = \frac{PE_{\text{stock}}}{PE_{\text{sectorETF}}}, \qquad \alpha_5 = s_5 \, (\text{relPE} - 1).$$

Amihud Illiquidity (30d)

With daily absolute returns $|r_t|$ and volume Vol_t,

$$\text{ILLIQ} = \frac{1}{N} \sum_{t=1}^{N} \frac{|r_t|}{\text{Vol}_t}, \qquad \alpha_6 = s_6 \, \text{ILLIQ}.$$

Higher illiquidity $\Rightarrow$ stiffer outer walls.

Market Drawdown (e.g., 1y)

For a lookback window of length W (e.g., $W = 252$):

$$\text{dd} = \max\left\{0, \; \frac{P_{\max} - P}{P_{\max}}\right\}, \quad \alpha_7 = s_7 \, \max\{0, \text{dd} - \bar{d}\}.$$

4 Quantum Formulation and Numerical Implementation

Time-independent Schrödinger equation in log-space.

$$-\frac{\hbar^2}{2m}\,\psi''(x) \;+\; V(x)\,\psi(x) \;=\; E\,\psi(x). \tag{2}$$

We optionally identify $\hbar^2/2m = \sigma^2$ to couple quantum mobility to realized volatility.

Domain and BCs. Choose $x \in [-L, L]$ (e.g., $L \in [0.25, 0.35] \approx \pm 25$–$35\%$ log-returns), with Dirichlet $\psi(\pm L) = 0$.

Discretization. Uniform grid x_i with spacing Δx. The tridiagonal Hamiltonian is

$$H \;=\; -\sigma^2 D_{xx} \;+\; \mathrm{diag}\big(V(x_i)\big),$$

where D_{xx} is the standard second-difference operator. Solve $H\Psi = E\Psi$ for low-lying eigenpairs (e.g., `eigh_tridiagonal`); normalize $\int |\psi_n|^2 dx = 1$.

Numerical checks. Refine Δx until eigenspectrum/waveforms converge; increase L to suppress boundary artifacts.

Tunneling Asymmetry Metrics (Prototype)

Bound-state bias. Ground-state mass imbalance:

$$\Delta p \;=\; \int_0^L |\psi_0(x)|^2\,dx \;-\; \int_{-L}^0 |\psi_0(x)|^2\,dx,$$

with $\Delta p > 0$ ($\Delta p < 0$) favoring right-escape (left-escape).

WKB transmissions (scattering proxy). For a chosen energy E and turning points $V(x) = E$,

$$T_{\text{side}} \;\approx\; \exp\!\left(-2\int_{x_1}^{x_2} \sqrt{\frac{V(x)-E}{\sigma^2}}\,dx\right),$$

compare T_{right} vs T_{left} for the trade direction.

5 Normalization, Calibration, and Stability

- **Feature scaling:** $\alpha_k = s_k f_k(z_k)$ via baselines $(\bar{s}, \bar{d}, 1)$ or z-scores.
- **Coercivity:** ensure even-degree tails dominate on $[-L, L]$; maintain $\alpha_6 > 0$. Optionally add tiny $+\alpha_8 x^8$ safeguard.
- **Scale selection:** tune s_k so $V(x)$ near $|x| = 0.1$–0.2 is $O(1$–$10)$ for numerical conditioning.
- **Volatility coupling:** σ reflects realized vol; larger σ flattens effective barriers in quantum units.

6 Data Pipeline (Current Estimators)

- Prices/returns: `yfinance` (stock, sector ETF, SPX).
- Betas: 60d rolling (α_1), 90d rolling (α_2), EWMA (α_3).
- Credit spread: FRED (`BAA`, `GS10`); map $\alpha_4 \propto 1/\text{spread}$.
- Relative P/E: `trailingPE` for stock and sector ETF; $\alpha_5 = s_5(\text{relPE} - 1)$.
- Illiquidity: Amihud (30d) from Adj. Close & Volume; $\alpha_6 = s_6\,\text{ILLIQ}$.
- Drawdown: 252d SPX drawdown; $\alpha_7 = s_7 \max\{0, \text{dd} - \bar{d}\}$.

7 Trading Signal Primitives

1. **Wavefunction bias:** sign/magnitude of Δp (ground state or mixture of low modes).
2. **Transmission asymmetry:** T_{right} vs T_{left} at energy proxy E (momentum/order flow/vol).
3. **Regime filter:** use correlation diagnostics (e.g., $\text{Corr}(V(t), P(t))$) to gate signals in tunneling vs momentum regimes.

8 Open Design Choices (Tracked)

- **Spread asymmetry:** revisit whether downside bias from spreads lives in the potential (e.g., α_3 as function of spread, signed quartic $x|x|^3$) or in tunneling (boundary/energy choice), with the aim of exposing institutional model misspecification.
- **Energy selection E:** tie to measurable "market pressure" (short-horizon momentum, OFI, vol regime).
- **Coercivity guarantee:** enforce α_6 dominance on $[-L, L]$ or include small x^8 term.

Summary

We built a data-driven, asymmetric, seventh-degree potential $V(x)$ with explicit financial semantics per term, a stable numerical Schrödinger solver in log-space, and a decision scaffold for extracting directional tunneling signals. The mapping is modular, interpretable, and designed for calibration, regime analysis, and live deployment.