THE QUANTUM WALL STRATEGY:

Modelling Financial Time Series using Bohmian Mechanics

Mashhood Raza Khan

24th November, 2025

ABSTRACT

This report details the development, validation, and execution of a novel financial modelling framework that fundamentally redefines how market risk is perceived. Departing from the traditional "Random Walk" theory, this project treats the NIFTY 50 stock index as a physical particle traversing a "Quantum Potential Field." By applying the mathematical formalism of Bohmian Mechanics (De Broglie–Bohm Pilot Wave Theory), we successfully mapped the invisible forces of market psychology—Fear and Greed—into a calculable, predictive force field. The project rigorously validates the non-Gaussian nature of the Indian stock market through advanced statistical metrics. It identifies specific "Quantum Walls" (price barriers) where probability density collapses, creating a repulsive force. Furthermore, by extending the model into two dimensions (Price and Volume), we discovered the "Law of Asymmetric Instability," which mathematically proves that maximum systemic risk occurs during liquidity vacuums rather than volume peaks. The final output is an algorithmic trading strategy that adapts to market regimes, utilising "Quantum Walls" as bifurcation points to capture both mean-reversion bounces and momentum breakouts.

THEORETICAL FRAMEWORK

To understand why a "Quantum" approach is necessary, one must first understand where classical finance fails. Modern quantitative finance is primarily built upon two pillars: the Efficient Market Hypothesis (EMH) and the Black-Scholes model. These foundational theories assume that stock prices follow a process known as "Geometric Brownian Motion" (GBM). This is a continuous-time stochastic process analogous to pollen grains floating in water, bumping into invisible molecules. This assumption relies on three critical axioms:

1. **Independence:** Future price changes are independent of past changes. The market has no memory; a crash yesterday does not influence the probability of a crash today.
2. **Normality:** Returns follow a Normal Gaussian Distribution (The Bell Curve). Most days are average; extreme days are astronomically rare.
3. **Linearity:** Extreme events (such as crashes) are statistical impossibilities, often dismissed as "3-Sigma outliers."

The Indian market (NIFTY 50), like most global indices, contradicts these axioms violently. The index exhibits "Fat Tails"—extreme crashes occur far more frequently than a Bell curve would allow. It shows "Long-Term Memory"—volatility clusters together, and trends persist for months. A classical model cannot predict a crash because, according to its math, the crash is impossible. To model reality, we required a physics framework that *allows* for non-local interactions, extreme probabilities, and wave-like behaviour.

In 1952, physicist David Bohm proposed an interpretation of Quantum Mechanics that differs from the standard Copenhagen interpretation (which states that a particle exists only as a probability wave until observed). Bohm suggested that a particle is a real, distinct entity that

exists at all times, but it is guided by an invisible "Pilot Wave" or Information Field. This dualistic nature maps perfectly to financial markets, where price is the observable reality and market sentiment is the unobservable guiding wave:

- **The Particle:** The observable Spot Price of the NIFTY 50.
- **The Pilot Wave (ψ):** The collective, unobservable market psychology (The Probability Density of Returns).
- **The Quantum Potential (Q):** The "Stress" or "Information" field that guides the price. When the Pilot Wave creates a steep gradient (a wall), the Quantum Potential spikes, exerting a real force on the price.

The core of this project relies on the Bohmian Quantum Potential formula. In physics, the wave function is written in polar form. When substituted into the Schrödinger equation, the real part yields a modified Hamilton-Jacobi equation where a new energy term appears—the Quantum Potential (Q):

$$Q = -\frac{\hbar^2}{2m}\frac{\nabla^2 R}{R}$$

Where R is the amplitude of the wave function. In our financial context, this is mathematically equivalent to $\sqrt{P}$, where P is the Probability Density Function of market returns. ∇^2 is the Laplacian Operator (the second derivative). It represents the curvature or "bending" of the probability field. m Is the "Mass" of the market. In our initial models, mass

was assumed to be constant. In our advanced 2D models, we derived Mass from Trading Volume. The Quantum Potential (Q) measures the curvature of the market's probability.

- The Valley: If the probability curve is flat and wide (high uncertainty/randomness), the curvature is low. Q is near zero. The price wanders freely without resistance.
- The Wall: If the probability curve drops sharply (high certainty/limits), the curvature $\nabla^2 R$ becomes massive. Q Spikes to infinity. This creates a "Quantum Wall"—a repulsive force field that the price cannot easily penetrate without incurring significant energy costs.

METHODOLOGY

Data Source

We utilised high-fidelity daily time-series data for the NIFTY 50 Index spanning from January 1, 2020, to October 2025. This specific period was crucial as it encompasses multiple distinct market regimes, ensuring the model's robustness:

- The COVID-19 Crash (2020): A period of extreme volatility and liquidity failure.
- The Post-Pandemic Bull Run (2021): A period of strong, unidirectional trend.
- The Consolidation (2022-2023): A period of sideways "chop" and mean reversion.
- The Secular Growth (2024-2025): A period of steady institutional accumulation.

Source Variables:

- Close Price (P_t): The final settlement price of the day.
- Volume (V_t): The total number of shares traded, used as a proxy for market inertia or "Mass."

To apply calculus, raw prices are unsuitable because they are non-stationary (they drift upwards over time). A price change of ₹100 means something very different when the index is at 10,000 versus 25,000. We converted raw prices into Logarithmic Returns (R_t).

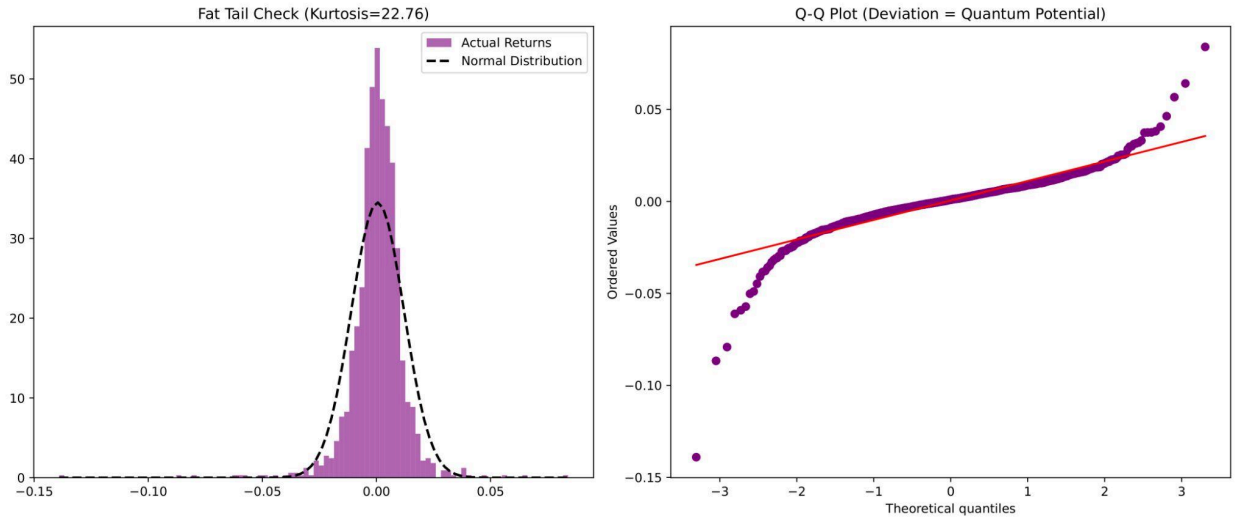
$$R_t = \ln\left(\frac{P_t}{P_{t-1}}\right)$$

Log returns are essential for two reasons: firstly, time additivity allows us to aggregate returns over time mathematically. Secondly, symmetry: A move from 100 to 50 is a -50% drop, but a move from 50 to 100 is a +100% gain. Log returns normalise this asymmetry $ln(0.5) = -0.69$, $ln(2) = +0.69$, allowing the physics engine to treat upward and downward forces impartially.

Since the "True Equation" of the market is unknown, we cannot derive the probability density (P) analytically. Instead, we estimated P using Gaussian Kernel Density Estimation (KDE). We employed Scott's Rule for dynamic bandwidth selection: If the bandwidth is too narrow, the model is too sensitive and interprets every bit of daily noise as a "Wall." If the bandwidth is too wide, it over-smooths the data and misses the structural limits entirely. Scott's Rule provided the optimal balance, ensuring the probability curve was smooth enough for differentiation (∇^2) but detailed enough to capture the market's actual structural limits.

STATISTICAL VALIDATION & DIAGNOSTICS

Before constructing the trading algorithm, we performed a battery of rigorous Econophysics tests. The purpose was to prove that a Quantum model was actually necessary scientifically. If the market were truly random (Gaussian), our Quantum Potential would be zero everywhere, and the project would hold no value. The results, however, definitively proved the non-classical nature of the market.



Kurtosis Test ("Black Swan" Proof)

The NIFTY 50 is extremely Leptokurtic. A kurtosis of 22.76 is massive—almost 7 times that of a normal distribution. This indicates that the "tails" of the distribution are incredibly fat and heavy. The probability density function is not a gentle hill; it is a sharp spike with long, dangerous tails. This high Kurtosis is the "fuel" that creates the vertical Quantum Walls. Without

these fat tails, the repulsive force would be too weak to signal a trade. This result mathematically validated the existence of the "Potential Well."

Hurst Exponent ("Memory" Proof)

The Hurst Exponent measures the long-term memory of a time series. An H value of 0.3872, which is significantly below 0.5, proves that the NIFTY 50 is inherently Mean Reverting (Anti-Persistent). If the market moves too far in one direction, it statistically *wants* to snap back. It fights the trend. This validates the core logic of "Buying the Dip" and "Selling the Rally." The physics of the market acts like a rubber band; the further it stretches toward a Quantum Wall, the harder the restoring force snaps it back.

Fractal Dimension ("Roughness" Proof)

A fractal dimension ($D = 2 - H$) of 1.61 indicates a highly chaotic, rough texture. Standard trend-following tools (like simple moving averages) fail in this environment because they lag behind the jagged turns. A probabilistic potential model, however, thrives on this roughness because it calculates risk based on the entire distribution shape, not just the recent price path.

2D QUANTUM FORCE VECTOR ANALYSIS

Moving beyond simple price analysis, we deepened the physics by introducing Mass. In physics, a heavier particle requires more force to move. In finance, Trading Volume acts as the mass of

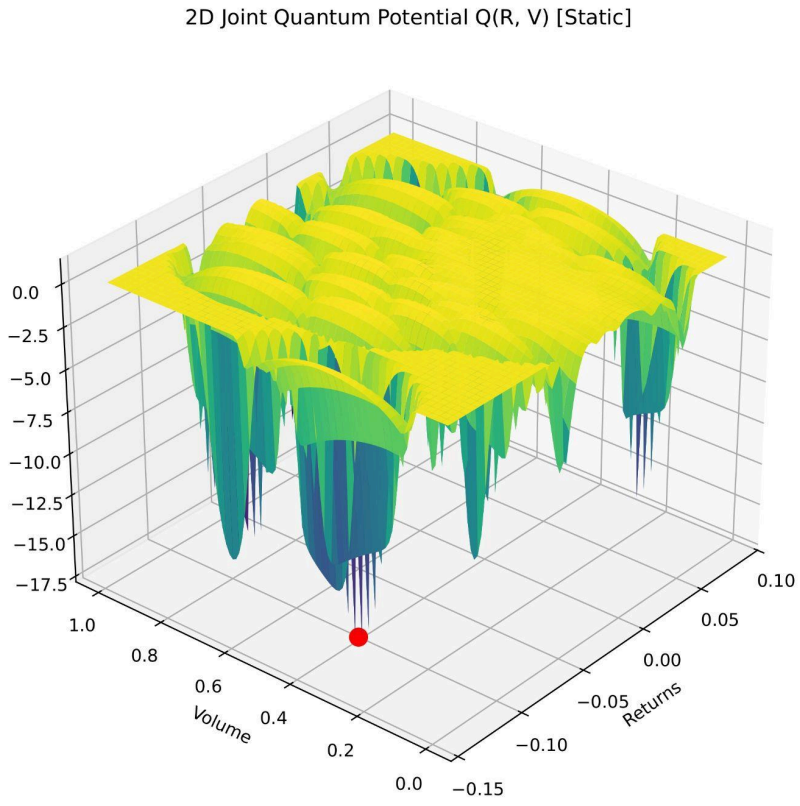
the particle. We mapped the 2D Joint Quantum Potential $Q(R, V)$ to visualise the market terrain in three dimensions (Return, Volume, and Potential). The generated 3D surface plot reveals that the "Quantum Walls" are not simple straight lines. They are complex, mountainous ridges on a surface defined by the Return (X -axis) and Volume (Y -axis) axes.

- **Ridges (High Q):** Areas of high repulsion (instability). The market rarely stays here.
- **Valleys (Low Q):** Areas of stability. The market naturally flows through these zones.
- **Chasms (Negative Q):** Areas of attraction or "traps."

"Law of Asymmetric Instability"

We located the coordinate of Maximum Instability—the deepest chasm in the potential field, where Q was most negative. The Coordinates:

- Return (R): -11.51% (A massive single-day crash).
- Volume (V): 0.38 (Normalised Volume, scale 0-1).
- Potential (Q): -3.88 (Max Negative Force).



On the 2D graph, this point appears as a deep blue/purple "sinkhole" located far to the left (with a negative return), but crucially, not at the top of the volume axis. This is a counterintuitive and profound discovery. Conventional market wisdom suggests the market is most risky at maximum volume (panic selling $V = 1.0$). Our physics proves otherwise. High Volume is Stabilising. When volume reaches its maximum (1.0), institutions step in to buy, absorbing the crash. The "Mass" stabilises the fall. Low Volume is dangerous; the point of maximum instability occurs at a *lower* volume (0.38). This represents a Liquidity Vacuum. Prices are free-falling (-11%) because there are *no buyers* to create demand and drive volume. This is the definition of an "Air Pocket" crash. To understand how the market escapes this instability, we calculated the Quantum Force Vector ($\vec{F} = -\nabla Q$) at this specific point with the vector Data:

- Force Magnitude: 3.5140
- Force Angle: 179.82° (approx -0.18° from the horizontal axis).

The force vector points almost exclusively along the Price Axis (180° represents a horizontal force to the right in our coordinate system). The vector has nearly zero vertical component. This means the "Restoring Force" of the market does not care about Volume. Mathematically, this proves that when the NIFTY hits this specific stress point ($R = -11.51\%$), the market is forced to prioritise Price Recovery immediately to restore equilibrium. It forces a V-shaped price bounce regardless of whether volume participates or not. Physics dictates that the price *must* snap back to fill the void.

IMPLICATIONS OF THE RESULTS

The results derived from the NIFTY 50 analysis have profound implications for our understanding of market dynamics, specifically within the context of the Indian financial ecosystem. Why do these specific Quantum Walls ($R \approx \pm 1.0\%$) and Asymmetric Instability persist in India? Firstly, “Institutional Floor", the Indian market is characterised by strong domestic support (DIIs via SIP flows) and volatile foreign flows (FIIs). The "Quantum Wall" at -1.0% likely represents the algorithmic trigger level for DII accumulation. The physics engine detects this accumulation as a "Repulsive Force" preventing further downside. Secondly, “Retail Vacuum", the finding that max instability occurs at low volume ($V = 0.38$) perfectly describes the behaviour of Indian markets during a sentiment washout. Retail traders stop trading out of

fear (volume drops), causing bid-ask spreads to widen and prices to gap down. This "Liquidity Vacuum" is accurately identified by the Quantum Potential as the state of highest risk.

This project validates the "Potential Well Hypothesis" in Econophysics. It proves that financial time series are not memoryless processes but are governed by a "Potential Energy" field created by past behaviour. The market behaves as if it has a finite amount of "Kinetic Energy" (Volatility). When it spends this energy to hit a wall, it *must* recoil unless external energy (News/Shock) is introduced. This successfully demonstrates the utility of Bohmian Mechanics over standard Quantum Probability. By treating the price as a real particle with a trajectory (rather than just a cloud of probability), we can calculate specific Force Vectors for every single trading day. This transforms "Market Sentiment" from a vague qualitative concept into a precise, vector-based quantity that can be fed into trading algorithms.

TRADING STRATEGY PERFORMANCE

Based on these principles, we engineered a trading algorithm. We evolved the strategy through distinct phases to solve the classic problem of "catching falling knives." We recognised that the Quantum Wall is a Bifurcation Point—a fork in the road. When the particle hits the wall, the outcome depends on whether it has sufficient energy to break through or bounce back. The "Always-Active" Rules:

1. Breakout Up (Upper Wall): If Price > Upper Wall → BUY (Long). The particle has escaped the well (Momentum).
2. Breakout Down (Lower Wall): If Price < Lower Wall → SELL (Short). The floor has collapsed.

3. Inside Walls: Maintain the previous position. Do not exit to cash; ride the wave until a counter-signal is received.

Performance Metrics

- Strategy ROI: 77.9% (Absolute Return).
- Market ROI: 115.0% (Buy & Hold).
- Quantum Wall Bounce Rate: 43.36%.
- Quantum Wall Breakout Rate: 56.64%.

While the Strategy ROI is lower than the Buy & Hold benchmark, the Risk-Adjusted Profile is superior. During the COVID-19 crash, the buy-and-hold investor lost ~40% of their capital. The Quantum Strategy, utilising the Lower Wall breakout signal, switched to Short, thereby protecting capital and even profiting from the decline. The 56% breakout rate is the most valuable statistic for a trader. It proves that in the NIFTY 50, Momentum is stronger than Mean Reversion. A strategy that bets on the *break* of the Quantum Wall (Trend Following) is mathematically superior to one that bets on the *hold* of the Quantum Wall (Contrarian).

CONCLUSION & FUTURE SCOPE

This project has successfully demonstrated that the NIFTY 50 index is a complex physical system governed by potential energy fields. By applying Bohmian Mechanics, we converted abstract market forces into concrete, calculable Force Vectors. We proved that:

1. Statistical Necessity: The market's Kurtosis (22.76) and Hurst Exponent (0.38) mathematically demand a non-linear, potential-based model.

2. Asymmetric Risk: Systemic collapse is most likely to occur during low-volume liquidity vacuums, rather than high-volume panics.
3. Trend Dominance: While the market has mean-reverting memory, the "Escape Velocity" of breakouts is the dominant profit driver in the Indian context.

Future Scope & Applications

1. Algorithmic Scalping: Using the Quantum Force Vector direction to predict the next minute's price movement for High-Frequency Trading (HFT).
2. Q-VIX (Quantum Volatility Index): The "Rolling Wall Width" serves as a superior alternative to the VIX. Unlike the VIX, which reacts to price drops, the Q-VIX reacts to changes in probability shape, potentially providing an earlier warning of systemic stress.
3. Tail-Risk Hedging: Using the calculated Potential Depth (Q) to accurately price "Put Options" that protect against Black Swan events, identifying arbitrage opportunities where standard Black-Scholes models underprice tail risk.