Modeling Stock Price Dynamics as a Bachelier-Wiener Process

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In this report, we analyzed the historical price trends of the NIFTY stock index using stochastic modeling techniques. The price evolution is modeled as a Bachelier-Wiener process, and plots from actual financial data spanning 22 years are reproduced and interpreted. The Gaussian nature of fluctuations, exponential price trends, and changes in volatility and trade volume are observed through a series of analytical visualizations.

I. STOCK PRICE DYNAMICS

A. Model Equations

We consider the relative change in a stock price S over a finite time interval Δt:

$$\frac{\Delta S}{S} = a\Delta t + b\Delta W \tag{1}$$

Here, a is the average growth rate, b is the volatility coefficient, and ΔW represents a Wiener increment.

In an idealized situation with no volatility ($b = 0$), the solution for S is obtained via integration:

$$S(t) = S_0 \exp(at) \tag{2}$$

This leads to a linear change in the logarithm of price:

$$\Delta(\ln S) = a\Delta t \tag{3}$$

To represent fluctuation distributions, we use a Gaussian function:

$$f(\delta) = 1 + f_0 \exp\left[-\frac{(\delta - \mu)^2}{2\sigma^2}\right] \tag{4}$$

II. RESULTS AND ANALYSIS

A. Exponential Price Growth

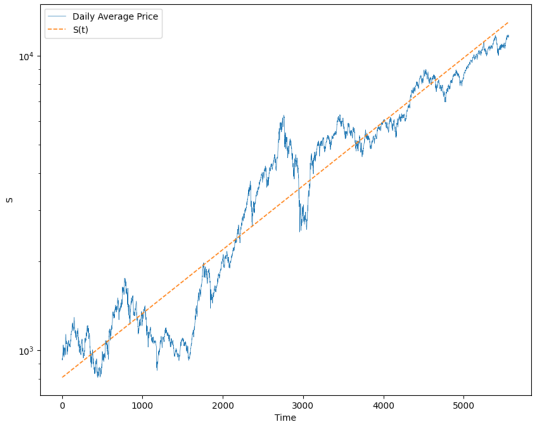

FIG. 1. Daily average price of NIFTY vs time on a linear-log scale. The fitted straight line confirms exponential growth, with a mean relative growth rate $a = 0.0005$ per day.

B. Daily Fluctuations

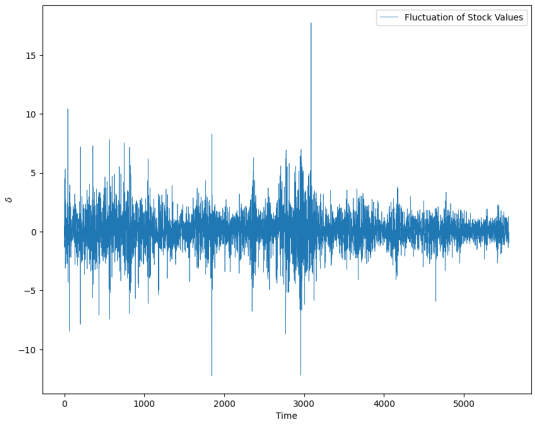

FIG. 2. Time series of daily percentage fluctuations in NIFTY prices. The values are centered around zero with a nearly symmetric distribution over the observed period.

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C. Gaussian Nature of Fluctuations

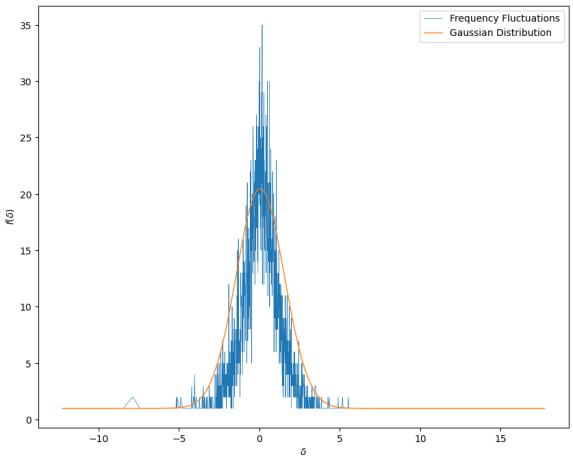

FIG. 3. Histogram of daily price fluctuations in NIFTY. The unnormalized frequency distribution closely follows a Gaussian curve with $\mu = 0.057$ and $\sigma = 1.495$.

D. Monthly Logarithmic Price Growth

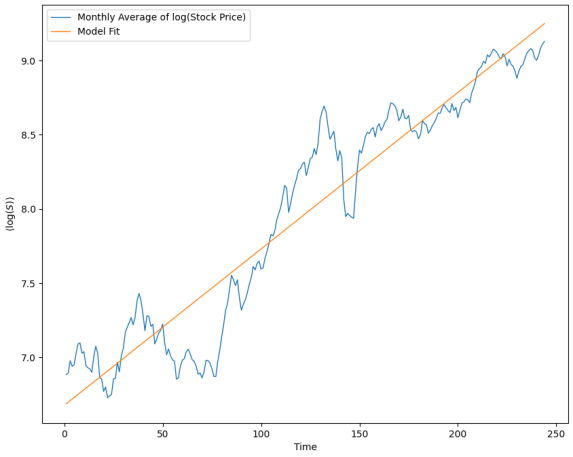

FIG. 4. Growth of monthly average of $\ln S$. A straight-line fit yields a slope $m = 0.01$ per month, indicating steady compounded growth.

E. Variance Analysis

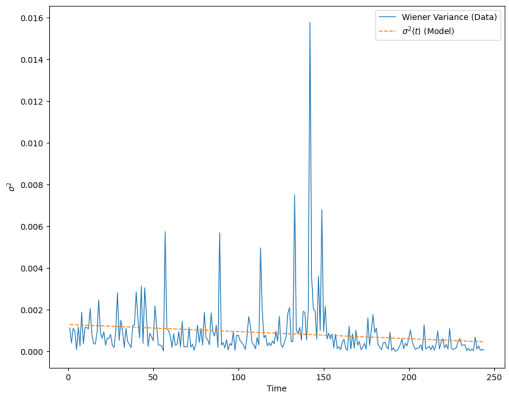

FIG. 5. Wiener variance of the monthly $\ln S$ plotted over time. A decreasing trend is observed, with a slope $w = -3.41 \times 10^{-6}$ per month, suggesting reduced volatility over time.

F. Trade Volume Growth

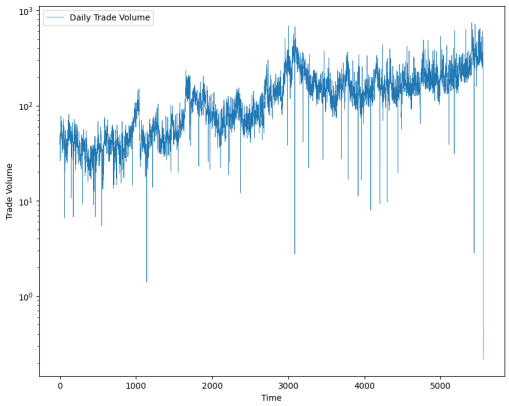

FIG. 6. Daily trade volume of NIFTY plotted over time on a linear-log scale. The exponential growth indicates increased market activity with a growth rate $v = 0.0004$ per day.

III. CONCLUSIONS

1. The price of stocks in the NIFTY index shows a consistent exponential growth pattern, with the average growth rate remaining stable over the 22-year period.

2. Daily price fluctuations are symmetrically distributed and follow a Gaussian profile, centered near zero. This validates assumptions made in stochastic modeling.

3. Both volatility and market noise diminish over time, as observed in the declining Wiener variance, while trade volume rises exponentially, indicating growing participation and market maturity.

[1] Abhin Kakkad, Harsh Vasoya and Arnab K. Ray, *Regularities in stock markets.*