Set-11: Modelling stock price variations as a Bachelier-Wiener process

Shail Patel (202201297)* and Divyakumar Tandel (202201469)†
Dhirubhai Ambani Institute of Information & Communication Technology, Gandhinagar, Gujarat 382007, India
CS302, Modeling and Simulation

This report models NIFTY stock price variations using the Bachelier-Wiener process. It analyzes 22 years of data through price trends, fluctuations, and trade volumes. Results are visualized using time series and statistical distribution plots based on five datasets.

I. MODEL :

The forward relative change of a stock price S over a finite time interval Δt is given by

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

Under an idealized, volatility-free condition, we set $b = 0$, which leads to the integration in continuous time yielding steady compounded growth of S. The integral solution for S is exponential in time:

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

This implies the logarithmic change is linear in time:

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

Now consider a Gaussian function with unity added:

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

*Electronic address: 202201297@daiict.ac.in
†Electronic address: 202201469@daiict.ac.in

II. RESULTS

A. Stock price v/s Time.

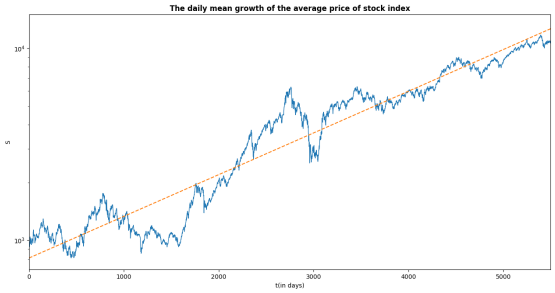

FIG. 1: The daily mean growth of the average price of the stock index, NIFTY (NSE, India).The straight line in this linear-log plot is fitted by the least-squares method, and indicates that the mean growth of S is exponential.With b = 0, the mean relative growth rate of stock values is a. For this plot $a = 0.05\%$ per day and initial price value $S_0 = 808.700012$

B. Daily percentage fluctuation of stock values v/s Time.

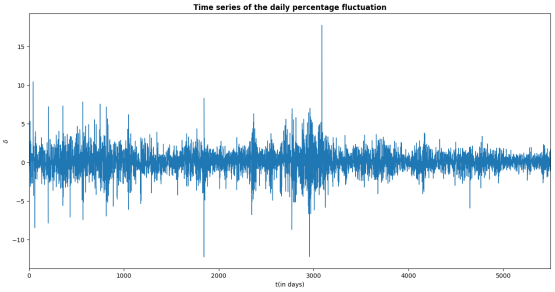

FIG. 2: The time series of the daily percentage fluctuation of prices in the stock index, NIFTY (NSE, India).The daily percentage fluctuation of prices is quantified by δ, which, over two decades, has an equal distribution of positive and negative values about $\delta = 0$.

C. The unnormalized frequency distribution of the daily percentage fluctuation of prices in the stock.

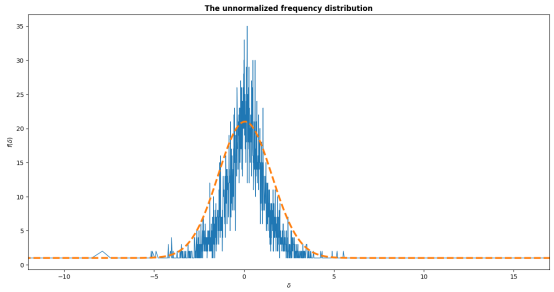

FIG. 3: The unnormalized frequency distribution of the daily percentage fluctuation of prices in the stock index, NIFTY (NSE, India).The distribution appears Gaussian, and is centred around a mean value, $\mu = 0.057$, with a standard deviation, $\sigma = 1.495$ and initial frequency $f_0 = 20$.

D. The growth of the monthly average of lnS v/s Time.

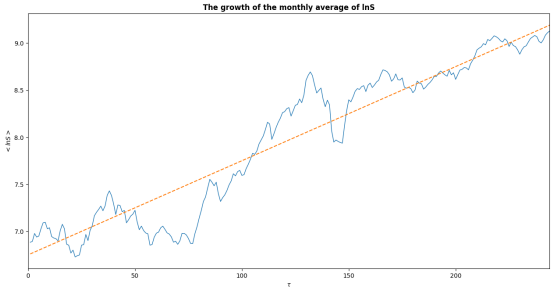

FIG. 4: The growth of the monthly average of lnS for NIFTY (NSE, India), as opposed to its daily growth in Fig(1).The straight line, showing the mean growth, is fitted by the least-squares method, and its slope is m = 0.01 per month and intercept c = 6.75.

E. the variance of the monthly prices v/s Time.

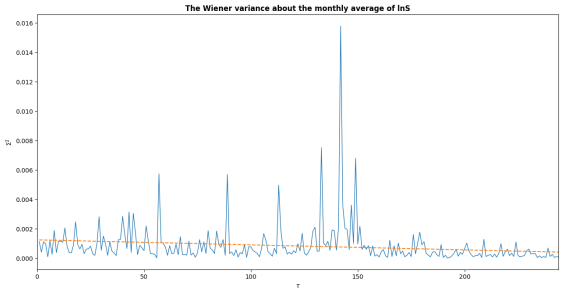

FIG. 5: The Wiener variance about the monthly average of lnS for NIFTY (NSE, India) decreases with time,(in months).The straight line, fitted by the least-squares method, traces the mean decline, with a slope of $w = 3.41 * 10^{-6}$ per month and intercept = 0.00125. With $w < 0$, volatility also reduces with time.

F. The growth of the daily trade volume v/s Time.

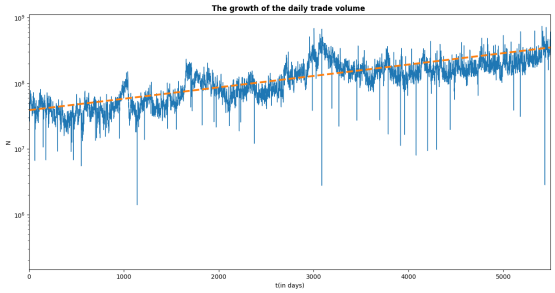

FIG. 6: The growth of the daily trade volume of the NIFTY (NSE, India) index.The straight line in this linear-log plot,fitted by the least-squares method, implies an exponential mean growth of N. The slope of the straight line, $v = 0.04\%$ per day and the initial trade volume is $T_0 = 38950000.8$, gives the mean relative growth rate of the daily volume of trade.

III. SALIENT FEATURES:

1. Global Regularities: The study reveals consistent patterns across six major stock markets, including the USA, China, Japan, Germany, Britain, and India. These regularities encompass the daily mean growth of stock values, Gaussian fluctuations around this mean, self-similarity in monthly fluctuations, and the exponential growth of daily trade volume. Such global regularities provide insights into the fundamental behaviors of stock markets irrespective of geographic location.

2. Exponential Growth and Volatility: Stock values

demonstrate exponential growth on a daily basis, with narrow ranges of relative growth rates observed across different markets. Despite this growth trend, stock prices exhibit Gaussian fluctuations around the mean, with a notable decline in volatility over time. This suggests a stabilizing effect within mature stock markets, where volatility diminishes as markets evolve.

3. Market Health Indicators: The study underscores the significance of daily trade volume as a key indicator of market health. The exponential growth in trade volume reflects the increasing activity within stock markets, while the observed fluctuations in volume further highlight the interplay between speculation and market dynamics. Understanding these regularities can inform investment strategies and risk management practices in global financial markets.