Dynamics of PLDT Stock Price

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Abstract: Investing in stocks is commonly held to be a risky enterprise because of the unpredictable nature of the market. While it may be true that forecasting the exact value of stock price at some time in the future is impossible, it is believed that one can at least calculate the probability that a certain price occurs. Calculation of probabilities is generally based on past prices. This study evaluates the dynamics of PLDT stock prices by looking at the evolution of the probability density function that describes the stock price return over a period of 24 years, divided into 30-day segments with 15-day overlaps. Gaussian distribution is assumed and the mean and standard deviation (sigma) for each segment are determined. Graphical analysis of the mean, sigma, increment mean, increment sigma, and time showed that only sigma has a deterministic characteristic, with a curve-fit sine-square time dependence. With a time-dependent sigma, it is then shown that the evolution of the probability density function follows the Fokker-Planck equation. Comparison with the Feynman-Kac equation indicates that the dynamics can be described by a sigma-dependent potential, which has an oscillatory characteristic.

Key Words: stock market; probability density function; Fokker-Planck equation

1. INTRODUCTION

Stock market investments are risky because of the unpredictability of the market. Risks can however be managed if one has some level of understanding of dynamical behaviour of the market. While one may not be able to predict exactly what price a stock would have at any given time as one would expect from a completely deterministic system, stochastic analysis can at least provide some information about probabilities. Studies along this line have been conducted not only in financial circles but also in the field of econophysics. Examples of the latter are the quantum model of stock market of Zhang & Huang (2010), unified model of price returns by Bucsa et al (2011), return distribution characteristics at microscopic time scales of Gu et al (2008), return distribution at mesoscopic timescales of Silva et al (2004), temporal evolution of stock market indices of Yang et al (2011), and Chae et al (2005)

This study is part of a programme to develop a theory that would describe Philippine financial market behaviour, and is built on the earlier findings of Janairo (2010), de Belen (2011), Tano (2011), and Leoncini (2012).

The dynamics of the Philippine Long Distance Telephone Company (PLDT) stock price from May 10, 1989 to Jan. 28, 2013 is analysed in this study. Assuming ergodicity, probability density distributions over 30-day periods are determined, and assuming normal distribution, the mean and standard deviation evaluated. The functional dependencies of these parameters are then ascertained through graphical analysis, and these deterministic behaviour are used as basis for the derivation of the corresponding dynamical equation, which not surprisingly is a form of the Fokker-Plank Equation. A comparison with the Feynman-Kac Equation yields the potential that governs this dynamics.

2. METHODOLOGY

Earlier studies (Janairo 2010, de Belen 2011, Tano 2011, Leoncini 2012) indicated that Philippine stock prices dynamics can be better determined though the return

$$x_i = p_i - p_{i-1} \qquad \text{(Eq. 1)}$$

where:

x_i = Stock price return at day (i)
p_i = Closing stock price at day (i)

The stock price return time series is then divided into 30-day sections taken every 15 trading days., and the empirical probability distribution is determined from the frequency of each stock price return value x. While an earlier study (de Belen 2011) showed that the best-fit probability density function (PDF) of PLDT is not Gaussian, it is still a good enough fit. Description of the dynamical evolution would be complicated if we consider only the best-fit PDF for each interval as this changes with time. The simplifying assumption of a normal distribution is therefore taken in this study.

The functional dependencies of the mean and standard deviation (sigma) is then evaluated through graphical analysis, plotting these with each other, their increments, and with time. When a deterministic characteristic is apparent, method of least squares is employed to find the best-fit curve. Once the functional dependencies of the corresponding PDF is determined, the dynamical equation is determined through the temporal and return derivatives of the PDF.

3. RESULTS AND DISCUSSION

The mean and standard deviation (sigma) of the PLDT stock price return for each 30-day interval were evaluated and graphed against each other, their increments, and time. These graphs are shown in Figures 1 to 7. It is clear from these figures that mean and sigma are stochastic, but sigma also has a deterministic behaviour. Using the method of least squares, it is found that the deterministic part is

$$\sigma = A\sin^2(\omega t + \alpha) \qquad \text{(Eq. 2)}$$

where:

ω = 0.001
α = 3.593

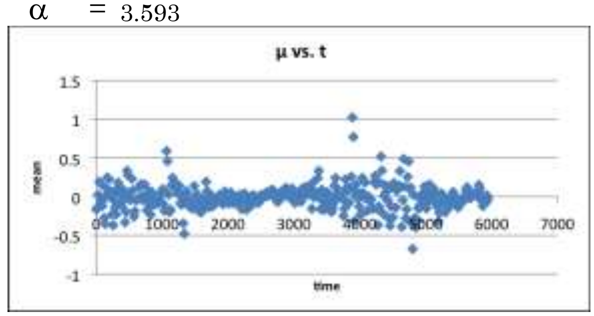

Fig. 1. Time series of mean stock price return for each 30-day interval

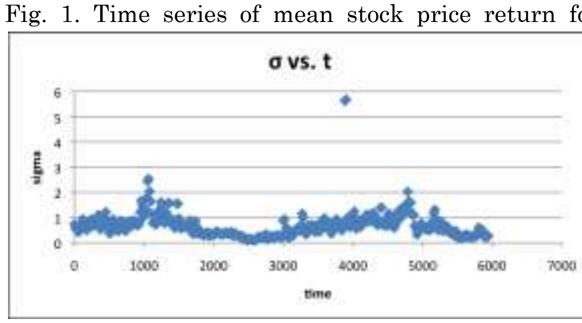

Fig. 2. Time series of stock price return standard deviation (sigma) for each 30-day interval

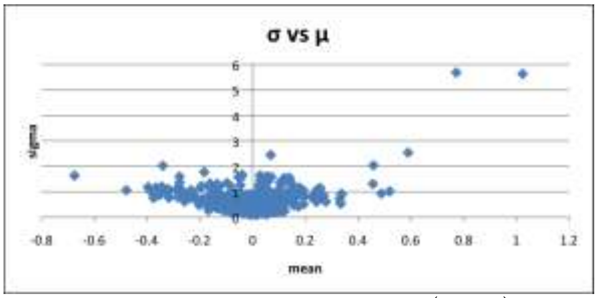

Fig. 3. A plot of standard deviation (sigma) versus mean of stock price returns for each 30-day interval

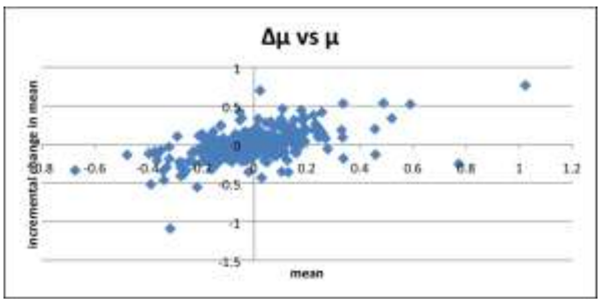

Fig. 4. A plot of increment mean versus mean of stock price returns for each 30-day interval

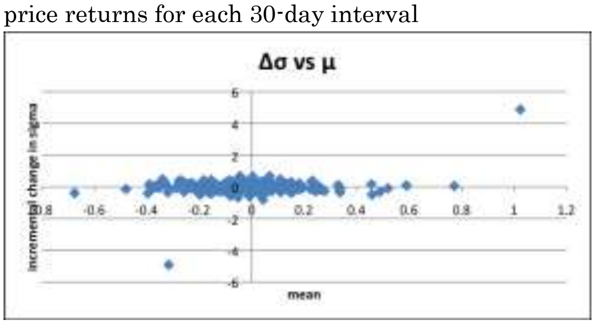

Fig. 5. A plot of increment sigma versus mean of stock price returns for each 30-day interval

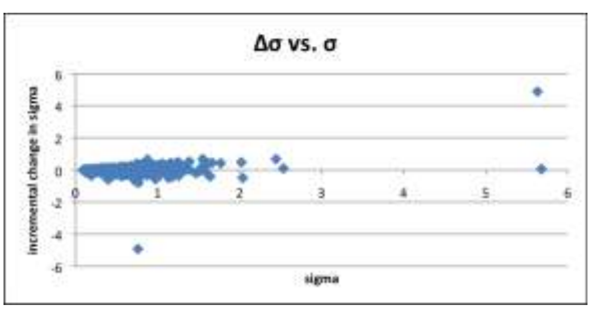

Fig. 6. A plot of increment mean versus sigma of stock price returns for each 30-day interval

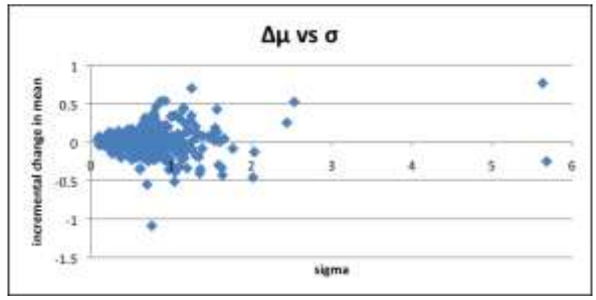

Fig. 7. A plot of increment sigma versus sigma of stock price returns for each 30-day interval

With the assumption of a normal distribution, the PDF of PLDT stock price return is

$$\Psi(x,t) = \frac{1}{\sqrt{2\pi}\sigma}\exp\left[-\frac{(x-\mu)^2}{2\sigma^2}\right]$$

(Eq. 3)

Since σ is time dependent, note that

$$\frac{\partial^2\Psi}{\partial x^2} = \left[-\frac{1}{\sigma^2} + \frac{(x-\mu)^2}{\sigma^4}\right]\Psi$$

(Eq. 4)

and

$$\frac{\partial\Psi}{\partial t} = \left[-\frac{\dot{\sigma}}{\sigma} + \frac{\dot{\sigma}(x-\mu)^2}{\sigma^3}\right]\Psi$$

(Eq. 5)

where:

$$\dot{\sigma} = \frac{d\sigma}{dt}$$

The PDF thus obeys the diffusion equation

$$\frac{\partial\Psi}{\partial t} = \sigma\dot{\sigma}\frac{\partial^2\Psi}{\partial x^2}$$

(Eq. 6)

which is a Fokker-Planck equation with zero-drift

$$\frac{\partial f}{\partial t} = -\frac{\partial \beta f}{\partial x} + \frac{\partial^2 Df}{\partial x^2} \quad \text{(Eq. 7)}$$

where:

- β is the drift
- D is the diffusion coefficient

The diffusion coefficient in this case is

$$D = \frac{d}{dt}\left(\frac{1}{2}\sigma^2\right) \quad \text{(Eq. 8)}$$

The PDF dynamical equation (Eq. 6) can also be cast as a Feynman-Kac partial differential equation

$$\frac{\partial u}{\partial t} + \beta\frac{\partial u}{\partial x} + \tfrac{1}{2}\sigma^2\frac{\partial^2 u}{\partial x^2} - Vu + g = 0 \quad \text{(Eq. 9)}$$

where the potential is

$$V(x,t) = -\frac{1}{2}\left(1 + \frac{2\dot{\sigma}}{\sigma}\right)\left[1 - \frac{(x-\mu)^2}{\sigma^2}\right] \quad \text{(Eq. 10)}$$

Note that this can be recast as

$$V(x,t) = -h(t) + \frac{h(t)}{\sigma^2}(x-\mu)^2 \quad \text{(Eq. 11)}$$

where

$$h(t) = \frac{1}{2}\left(1 + \frac{2\dot{\sigma}}{\sigma}\right) \quad \text{(Eq. 12)}$$

The potential govering the dynamics of the stock price return is then composed of a time-varying retarding function $h(t)$, and an oscillator term

$$V_{osc} = \frac{1}{2}k(x-\mu)^2 \quad \text{(Eq. 13)}$$

where the force constant varies in tune with the retarding function

$$k = 2h(t)/\sigma^2 \quad \text{(Eq. 14)}$$

4. CONCLUSIONS

With a zero drift-term, the return of the PLDT stock price is an example of a Martingale process. The dynamical evolution appears to be determined solely by sigma, which is essentially a kinetic term. Even though a potential function governing the dynamics can be expressed through the Feynman-Kac equation, this potential is a function of sigma. It is then apparent that the market is determined only by the kinetics of the system.

While this study was focused on the deterministic aspect of the stock market, it was found that the purely stochastic mean exhibited an interesting symmetry that warrants further exploration in future studies. Conclusions drawn from this study are based on an assumption of normal distribution. Since the result is surprisingly simple, it may be possible to do a more thoroughly empirical analysis that does away with assuming a particular probability density function. This study is based solely on the stock price of PLDT. The same may not be true for other stocks. It is therefore imperative that similar studies be done for other stocks. Hopefully, once a body of similar studies has been done, a generally applicable dynamical equation for stock markets can be found.

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