Variance gamma for stock model performance with excess kurtosis

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Variance gamma for stock model performance with excess kurtosis

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Abstract.

1. Introduction

The capital market is one of the ways to get funding which has been proven by many companies that use the capital market as a medium to seek investment funds and the media to strengthen their financial position.The existence of a capital market makes investment not only possible in real assets such as house, land, gold, and others but also in financial assets or financial securities such as deposit, stock, bond, mutual funds, and others. Research related to asset price modeling has been done a lot and the development is very fast (especially modeling using stochastic differential equations).

The Geometric Brownian Motion (GBM) model is used widely for model the dynamic of asset price movement. The model is very simple, so it is easy to understand and easy to apply in modeling the prices of various company assets as well as various measuring tools in risk management, such as Value-at-Risk (VaR). The model assumes that the log return of assets is normally distributed. The normal distribution is known not only by mathematicians but is widely used by researchers, scientists and practitioners of various fields of science. Another reason is that the normal distribution has a special characteristic that make it easier to derive various theories or concepts, namely the weighted sum of random variables that are normally distributed. Research using data from the prices of various assets traded in Indonesia shows the existence of excess kurtosis and tail in the log return distribution so that the performance of the Geometric Brownian Motion model is not good enough to describe the dynamic of asset prices.

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A research according to [1], there is an assumption that is not quite right to use in practical investment in bond, namely company asset data does not follow the Normal distribution, in this case it has extreme data which is shown by the existence of jump. To capture a jump in company asset data, Geometric Brownian Motion (GBM) with jump diffusion is the right model. According [2], They have conducted research on bond valuation. The bond valuation obtained is the Black-Scholes model bond valuation plus the equation associated with the third and fourth moments, namely skewness and kurtosis.

The Levy process has the ability to capture excess kurtosis and tail in a log return distribution. One of the members of the Levy Process, namely the Variance Gamma (VG) process, has a much better performance in capturing the characteristics shown by real data [3]. A three-parameter stochastic process, called the Variance Gamma process, which generalizes Brownian motion was developed as a model for the dynamic of asset log prices. This process is obtained by evaluating Brownian motion with drifts at a random time given by the Gamma process. Two additional parameters are drift of Brownian movement and time change volatility. This additional parameter provides control over the tail and kurtosis. This VG process was introduced by [4]

2. Methodology

2.1. Stochastic Process

The set of random variables $\{X(t), t \in T$ with time events and $X(t)$ events occurring at time t is called a stochastic process. . The set T is called the index set of a stochastic process. The set T is the set $t \in [0, T]$ it is said to be a stochastic process of discrete time, and it is expressed in the form $\{X(t); t = 0, 1, 2, ...\}$. While the set T is a time interval $t \in [0, T]$, it is said to be a continuous time stochastic process, and it is expressed in the form $\{X(t); t \geq 0\}$. The set of all possible values of the random variable $X(t)$ in a process is defined as the stochastic process state space [5]. A continuous time stochastic process is said to have a stationary increase if $X(t + s) - X(t)$ has the same distribution for all t, it is said to have an independent increase if for all $t_0 < t_1 < \cdots < t_n$ random variable $X_{t_1} - X_{t_0}, \ldots, X_{t_n} - X_{t_{n-1}}$ independent [6].

2.2. Gamma Process

Definition:

The Gamma process $G(t; v)$is a Levy process where the addition of $G(t + h; v) - G(t; v) = g$ has the density Gamma with mean h and variance vh:

$$f_h(g) = \frac{g^{\frac{h}{v}-1} \exp\left(-\frac{g}{v}\right)}{v^{\frac{h}{v}} Ã\left(\frac{h}{v}\right)}.$$

Its characteristic function is:

$$\phi_g(u) = \left(\frac{1}{1-iuv}\right)^{h/v},$$

And for x> 0, the density Lèvy is:

$$k_g(x) = \frac{\exp\left(-\frac{x}{v}\right)}{vx}.$$

Process $X_{VG}(t; \sigma, v, \theta)$ is defined

$$X_{VG}(t; \sigma, v, \theta) = \theta g(t; v) + \sigma W\big(g(t; v)\big)$$

The characteristic function of VG is evaluated by a conditional Gamma process. This is because $g(t; v)$ is known, X_{VG} is Gaussian, so θ

$$E\left[exp\big(iuX_{VG}(t)\big) \,\middle|\, g(t; v)\right] = exp\left(iu\theta g(t; v) - \frac{\sigma^2 u^2}{2} g(t; v)\right).$$

Then the process characteristics function is obtained $VG\phi_{X_{VG}}(u))$ by means of unconditional expectations, namely,

$$\phi_{X_{VG}}(t;u) = E[(iuX_{VG})] = \left(\frac{1}{1 - iu\theta v + \frac{\sigma^2 v}{2}u^2}\right)^{t/v}.$$

The moment of the VG process is calculated by deriving the characteristic function. The parameters θ and v each of it controls the skewness and kurtosis. Parameter estimation is done by moment method. For more details, the estimated VG parameter can be seen in [7].

A Variance Gamma $X_{VG}(t)$ process can be determined from the difference between two independent Gamma processes, that is $G_p(t)$ dan $G_n(t)$namely,

$$X_{VG}(t) = G_p(t) - G_n(t)$$

$G_p(t)$ and $G_n(t)$ are two independent Gamma processes with mean rates of each μ_p and μ_n and each the variance rates of v_p and v_n [4],

$$\mu_p = \frac{1}{2}\sqrt{\theta^2 + \frac{2\sigma^2}{v}} + \frac{\theta}{2},$$
$$\mu_n = \frac{1}{2}\sqrt{\theta^2 + \frac{2\sigma^2}{v}} - \frac{\theta}{2},$$
$$v_p = \mu_p^2 v,$$
$$v_n = \mu_n^2 v.$$

A sample path from the VG process can be obtained by simulating $G_p(t)$with the shape parameter is $\mu_p^2\ v_p$ and the scale parameter is $\mu_p v_p$; and $G_n(t)$with the shape parameter is $\mu_n^2\ v_n$and the scale parameter is $\mu_n v_n$.

Mean Absolute Percentage Error (MAPE) to determine the accuracy of data. The MAPE value is determined by the following equation:

$$MAPE = \frac{\sum_{t=1}^{n}|e_t|}{n}\ x\ 100\% \qquad \text{where} \qquad |e_t| = \left|\frac{A_t - P_t}{A_t}\right|$$

A_t is the actual value for period t. P_t is the forecast value at time t. n represents the amount of observed data.

Table 1. MAPE Accuracy Rating Scale

MAPEValue	Forcasting Accuracy
< 10%	Very good forecasting accuracy
11% - 20%	Good forecasting accuracy
21% - 50%	Forecasting accuracy is still within reasonable limits
>51%	Forecasting accuracy is not accurate

2.3. Research Stages

The steps that will be carried out in the implementation of the research are as follows.

1. Exploring data. This step is necessary to determine the distribution of the data. After that, test the normality of the stock data of PT Bank Danamon Indonesia Tbk

2. Model daily stock price movements using the Variance Gamma model
3. Calculating the daily stock price prediction of PT Bank Danamon Indonesia Tbk
4. Calculating the MAPE value

3. Research Variable

The data used in this research is secondary data, namely the daily stock price data of PT. Bank Danamon Indonesia Tbk totals 516 data, April 25^{th}, 2018 to April 24^{th}, 2020. The training data used is from April 25^{th}, 2018 to February 28^{th}, 2020, while the testing data used is from March 2^{nd} to April 24^{th},2020. The data sourced http://finance.yahoo.com. The research was conducted in the laboratory of the Department of Statistics UNDIP.

4. Result and Discussion

The first step is doneto display descriptive visual statistics, namely the histogram and summary descriptive statistics. The log returns daily stock price histogram of PT Bank Danamon Indonesia Tbk is as follows:

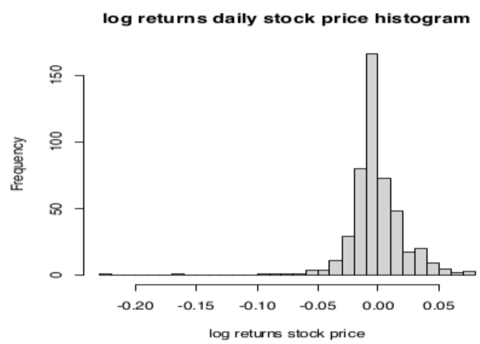

Figure 1. Stock Histogram of PT Bank Danamon Indonesia Tbk

Figure 1 shows the histogram shape of the asymmetric and leptokurtic data distribution. These results provide a rough conclusion that the data distribution is not normal. Descriptive statistics in the form of a summary of the data as follows:

Table 2. Stock Descriptive Statistics of PT Bank Danamon Indonesia Tbk

N	Mean	Variance	Minimum	Median	Maximum	Skewness	Kurtosis
477	-0.001413	0.000583563	-0.220323	0.00000	0.079481	-2.105417	22.16438

In Table 2, Descriptive Statistics shows a Skewness value equal to -2.105417, which indicates asymmetric data distribution (heavy tail). Kurtosis value equal to 22.16438 (greater than 3) indicates that the shape of the curve height (excess kurtosis) does not show the shape of a normal distribution. Based on the results of the descriptive analysis, it can be concluded that the log returns data distribution of PT Bank Danamon Indonesia Tbk stock does not spread normally. To strengthen the results obtained in descriptive analysis, formal testing is necessary. The following is the test using the Kolmogorov-Smirnov normality test, the significance level used is 5%:

Hypothesis:

H_0: The log returns daily stock sample data of PT Bank Danamon Indonesia Tbk spreads normally.

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H_1: The log returns daily stock sample data of PT Bank Danamon Indonesia Tbk does not spread normally.

Based on the calculation results, the statistical value of the test D = 0.11964 and the p-*value*= 2.347×10^{-06} which is smaller than 0.05. These results provide the decision to reject H_0 hypothesis, so that the conclusion is the log returns daily stock price sample data of PT. Bank Danamon Indonesia Tbk does not spread normally. Plot of opportunities for daily stock sample data of PT. Bank Danamon Indonesia Tbk as follows:

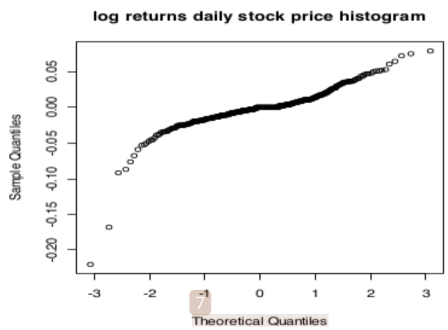

Figure 2. The q-q plot of log return daily stock price for PT. Bank Danamon Indonesia Tbk

In Figure 2. The q-q plot shows a pattern that tends to be non-linear, which indicates that the distribution of the sample data does not match its theoretical (normal) distribution.
Based on the results of descriptive analysis and formal testing, the conclusion is that the log returns daily stock data sample of PT Bank Danamon Indonesia Tbk is not normally distributed. The next stage is to model log returns daily stock prices that are not normally distributed with the Variance Gamma model.

Variance Gamma Modeling (VG)
The Variance Gamma Model has three parameters, namely $\sigma, v,$ and θ,

$$X_{VG}(t;\sigma,v,\theta) = \theta g(t;v) + \sigma W\big(g(t;v)\big)$$

The parameter estimation results are as follows:

Table 3. Estimated Value of Variance Gamma Model Parameters

Stock Name	$\hat{\sigma}$	$\hat{v}$	$\hat{\theta}$
PT Bank Danamon Indonesia Tbk	0,08071	8,00500	0,01976

Based on the results of parameter estimation in Table 3, the mean rate and variance rate are as follows:

Table 4. Value of Mean Rate and Variance Rate of Gamma Process

Gamma Process	Parameter	
$G_p(t)$	$\mu_p = 0{,}03234089$	$v_p = 0.008372695$
$G_n(t)$	$\mu_n = 0.01258089$	$v_n = 0.001267022$

The estimated value of the mean rate and variance rate parameters in Table 4 is used to estimate the shape parameter and scale parameter in the Gamma process. The estimated values for shape parameters and scale parameters are as follows:

Table 5. Value of Gamma Process Shape and Scale

Gamma Process	Parameter	
$G_p(t)$	$shape = 0{,}1249219$	$scale = 0{,}2588888$
$G_n(t)$	$shape = 0{,}1249219$	$scale = 0{,}1007100$

The estimation results of the shape and scale estimates are used to generate the Gamma $G_p(t)$ process and the Gamma $G_n(t)$.process. The VG process is obtained by setting aside $G_p(t)$with $G_n(t)$. After estimating the parameters, the next step is to predict the daily stock price. The predicted value of the daily stock price of PT Bank Danamon Indonesia Tbk based on the Variance Gamma model is as follows:

Table 6. Prediction of PT Bank Danamon Indonesia Tbk Daily Stock Value Based on Variance Gamma Model

No	Date	Actual	Prediction	No	Date	Actual	Prediction
1	March02nd, 2020	3170	3090	20	March30th, 2020	1945	2005
2	March03rd, 2020	3260	3132	21	March31st, 2020	2090	1890
3	March04th, 2020	3260	3176	22	April01st, 2020	2110	2093
4	March05th, 2020	3170	3396	23	April02nd, 2020	2010	1887
5	March06th, 2020	3120	3085	24	April03rd, 2020	2030	1957
6	March09th, 2020	2800	3036	25	April06th, 2020	2300	1956
7	March10th, 2020	2780	2726	26	April07th, 2020	2240	2239
8	March11th, 2020	2570	2691	27	April08th, 2020	2090	2180
9	March12th, 2020	2320	2502	28	April09th, 2020	2100	2034
10	March13th, 2020	2320	2664	29	April13th, 2020	2240	2043
11	March16th, 2020	2320	2870	30	April14th, 2020	2250	2180
12	March17th, 2020	2010	2609	31	April15th, 2020	2160	1796
13	March18th, 2020	1870	1964	32	April16th, 2020	2090	2033
14	March19th, 2020	1740	1820	33	April17th, 2020	2250	2018
15	March20th, 2020	1760	1553	34	April20th, 2020	2240	2190
16	March23rd, 2020	1710	1709	35	April21st, 2020	2230	2181
17	March24th, 2020	1675	1682	36	April22nd, 2020	2290	2078
18	March26th, 2020	1950	1629	37	April23rd, 2020	2410	2219
19	March27th, 2020	2060	2117	38	April24th, 2020	2420	2575

Evaluation of the forecasting results used MAPE value. Based on the forecasting results and the actual value in Table 6, the MAPE value is equal to 0.069756 or 6.9756%. These results provide the conclusion that the VG model has very good prediction accuracy.

The plot between the actual value and the predicted value of the daily stock price of PT Bank Danamon Indonesia Tbk during the period March 02nd, 2020 to April 24th, 2020 is as follows:

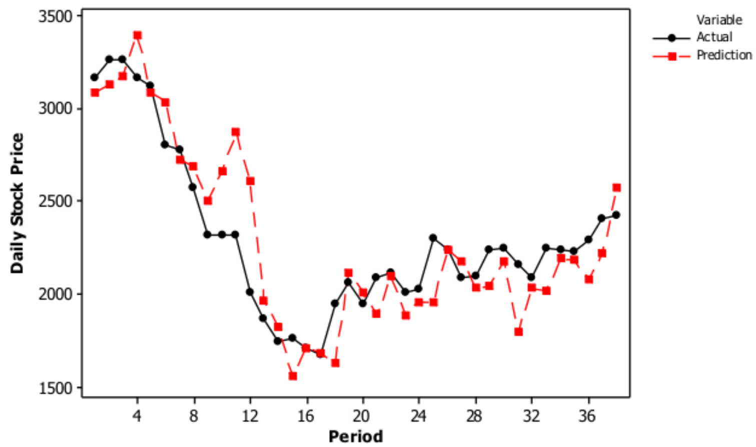

Figure 3. The plot between the prediction value and actual value

5. Conclusion

In this case, the stock sample data of PT Bank Danamon Indonesia Tbk were not normally distributed, so the model used is the Variance Gamma model. The Variance Gamma Model provides excellent prediction results for PT Bank Danamon Indonesia Tbkstocks with a MAPE value = 6.9756%.

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References

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