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Risk Analysis on Foreign Exchange Using Value-at-Risk Parametric Approach

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Abstract

Foreign Exchange or usually known as Forex are one of the most famous investment objects. When investing in Forex, it is necessary to know the movements of the foreign exchange price as well as the risk that might happen. The purpose of this study is to predict the level of risk, seeing the characteristics of foreign exchange, and compare which foreign exchange is better to invest in. The Value-At-Risk (VaR) models used to predict the risk of the foreign exchange are VaR of standard normal distribution approach, VaR of Student-t distribution approach, and Modified VaR normal. Based on the research, the potential loss for AUD is IDR 9,445.26, CAD is IDR 7,972.62, CHF is IDR 7,073.74, EUR is IDR 6281.90, GBP is IDR 9,234.37, JPY is IDR 10,971.68, SGD is IDR 3,988.65, and USD is IDR 2,896.47 with an assumption that an investor invests as much as IDR 1,000,000.00 to each foreign exchange. USD is the best foreign exchange to choose because it has the lowest potential risk based on its VaR.

Keywords: Forex, VaR, modified VaR, student-t, investment.

1. Introduction

Investment can be made by everyone, both individuals and institutions, and there are many instruments in investment such as Foreign Exchange or commonly known as Forex. Forex is one of the most popular investment objects in Indonesia because of its high investment return. But in investing, investor should know that high profit means high risk. That's why it is necessary to analyze the risk when investing.

In Sukono *et al.* (2019) research, they modeled Modified Value-at-Risk (VaR) for the skewed Student-*t* distribution based on Cornish-Fisher expansion then implemented it on 10 stocks and found that the performance of each VaR models are great because of its QPS score nearing 0. According to Swami *et al.* (2016), Student-*t* model produced the most accurate VaR estimation for India's Forex. According to Tamara (2011), the more stocks in a portfolio means bigger risk and a confidence level of 99% has more loss than a confidence level of 95%.

Based on the description above, there are a lot of research of risk analysis using VaR but a few about it being implemented on Forex, especially in Indonesia. So, this research is aimed at analyzing risk of Forex in Indonesia using Value-at-Risk.

2. Literature Review

2.1 Return

Return is a profit gained by an individual or an institutions or a company from the return on investment in an investment instrument. According to Tsay (2005), the value of return can be calculated by.

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

Where r_t is the return at time *t*, P_t is the price at time *t*, and P_{t-1} is the price at time $(t-1)$.

2.2 Parameter Estimation Method Using Likelihood

According to Hogg & Craig (1995), assume that $X_1, X_2, \dots, X_n$ is a random variable with $f(x;\theta)$, for $\theta \in \Omega$. Its combined probability density function is given by.

$$\theta^{\sum x_i}(1-\theta)^{n-\sum x_i} \tag{2}$$

where x_i has the value of 0 or 1, $i = 1, 2, \dots, n$. If the probability density function is expressed as a function of θ, then it is called a likelihood function which is denoted with $L(\theta)$.

In maximizing the likelihood function $L(\theta)$ or its logarithm, the function is given by.

$$\ln L(\theta) = \left(\sum_{i=1}^{n} x_i\right)\ln\theta + \left(n - \sum_{i=1}^{n} x_i\right)\ln(1-\theta) \tag{3}$$

so that,

$$\frac{d\ln L(\theta)}{d\theta} = \frac{\sum x_i}{\theta} - \frac{n - \sum x_i}{1-\theta} = 0 \tag{4}$$

It is known that the value of θ is not 0 or 1, so the function is given by.

$$(1-\theta)\sum_{i=1}^{n} x_i = \theta\left(n - \sum_{i=1}^{n} x_i\right) \tag{5}$$

where the solution for θ is $\sum_{i=1}^{n} x_i/n$. Statistic $\hat{\theta} = \frac{1}{n}\sum_{i=1}^{n} x_i$ is called *Maximum Likelihood Estimator* (MLE).

2.3 Anderson-Darling Test

The Anderson-Darling test is used to measure distribution deviations based on data. For the Anderson-Darling test, the function is given by.

$$A^2 = -n - \frac{1}{n}\sum_{i=1}^{n}(2i-1)\{\ln Z_i + \ln(1 - Z_{n+1-i})\} \tag{6}$$

where $Z_i = F(X_i), i = 1, 2, \dots, n$ is a cumulative distribution function of a certain distribution.
Hypothesis used in the Anderson-Darling test is:

H_0: Forex returns follows the distribution

H_1: Forex returns does not follow the distribution

Test criteria is to reject H_0if the value of $A^2_{calculation} < A^2_{table}$(crit value), or Probability $(A^2_{calculation}) < \alpha$, where α is the confidence level used. (Stephens, 1947).

2.4 Value-at-Risk of Standard Normal Distribution Approach

The standard method assumes that asset returns univariate normal distribution has two parameters: the mean μ and standard deviation σ. The issue of VaR estimation is how to determine the percentile to α of the standard normal distribution z_a:

$$\alpha = \int_{-\infty}^{q} f(r)\,dr = \int_{-\infty}^{z_a}\Phi(z)\,dz, \text{ quantile } q = z_\alpha\sigma + \mu \tag{7}$$

Where Φ(z) is the density function of the standard normal distribution, $N(z_\alpha)$ is the cumulative function of the standard normal distribution, r is the random variable of portfolio return, f(r) is the normal distribution density function to return (log returns) with the mean (μ) and standard deviation (σ), and q is the log returns the smallest if given confidence level α (Dokov et al. 2008). VaR estimation is done by the equation:

$$VaR = -W_0 \times q = -W_0 \times (z_a\sigma + \mu) \tag{8}$$

Where W_0 is the initial investment value, and the minus sign (-) reported a loss (losses).

2.5 Value-at-Risk of Standard Student-*t* Approach

If it is assumed that the return r is the standard Student-*t* distributed with the degrees of freedom is *v*, then the quantile of the distribution is $q = \mu + t_v^*(\alpha)\sigma$, where $t_v^*(\alpha)$ is the quantile to α of standard Student-*t* distribution with the degrees of freedom $v = T - 1$, and T is the number of data observations. The relationship between the quantile of standard Student-*t* distribution with degrees of freedom is *v*, denoted by t_v, and the standard distribution denoted by t_v^*, is:

$$p = P(t_v \leq q) = P\left(\frac{t_v}{\sqrt{v/(v-2)}} \leq \frac{q}{\sqrt{v/(v-2)}}\right) = P\left(t_v^* \leq \frac{q}{\sqrt{v/(v-2)}}\right) \quad (9)$$

Where $v > 2$. Therefore, if given probability α and an initial investment of W_0, the Value-at-Risk (VaR) can be calculated using the equation:

$$VaR = -W_0 \times q = -W_0\left(\mu + \frac{t_v(\alpha)\sigma}{\sqrt{v/(v-2)}}\right) \quad (10)$$

Where $t_v(\alpha)$ is the quantile to α of standard Student-*t* distribution with degrees of freedom $v = T - 1$, and T is the number of data observations, and assuming a negative value to a smallest α. (Tsay, 2005; Hu, 2008; Khindanova, 2000).

2.6 Modified Value-at-Risk Normal

Cornish-Fisher expansion is used to determine the percentile of the distribution of non-normal distribution. Cornish-Fisher expansion is intended to provide an adjustment factor to the estimated percentile of the distribution of non-normality, and the adjustment of the given normality is small. Therefore, Cornish- Fisher expansion can be used to the estimation of the VaR whenever Profit/Loss (P/L) has a distribution of non-normality. Suppose that z_α is the percentile of the standard normal distribution for the confidence level of α (for example $z_{0.05} = -1.645$ and so on). The meaning of Cornish-Fisher expansion is given by.

$$z_\alpha + \frac{1}{6}(z_\alpha^2 - 1)S + \frac{1}{12}(z_\alpha^3 - 3z_\alpha)K - \frac{1}{36}(2z_\alpha^3 - 5z_\alpha)S^2 + hot \quad (11)$$

Where *S* is the skewness, *K* is the kurtosis, and *hot* is higher order terms. If *hot* is eliminated because it is assumed the smaller influence of normality, the expansion becomes:

$$z_\alpha + \frac{1}{6}(z_\alpha^2 - 1)S + \frac{1}{12}(z_\alpha^3 - 3z_\alpha)K - \frac{1}{36}(2z_\alpha^3 - 5z_\alpha)S^2 \quad (12)$$

The existence of non-normality of the asset that can be used as a guide for choosing the portfolio is different with regard to assumptions. According to Dowd (2002) and Linsmeier and Pearson (1996), Cornish-Fisher in 1937 developed a new measure where the risk is measured by standard deviation, skewness (for return asymmetry) and kurtosis (for return fat tails). The measure of this risk is called Modified Value-at-Risk (MVaR), which is similar to a classic Value-at-Risk approach. According to Benninga and Wiener (1998), MVaR is formulated as:

$$MVaR = -W_0\left\{\mu + \left(z_\alpha + \frac{1}{6}(z_\alpha^2 - 1)S + \frac{1}{12}(z_\alpha^3 - 3z_\alpha)K - \frac{1}{36}(2z_\alpha^3 - 5z_\alpha)S^2\right)\sigma\right\} \quad (13)$$

Where μ is the mean, σ is the standard deviation, *S* is the skewness, *K* is the kurtosis, and z_a is the percentile of the standard normal distribution with a significance level of α.

2.7 Backtesting for Performance Evaluation of VaR

According to Sukono *et al* (2015), after getting the VaR value, backtesting is done, which is a method to see the performance of VaR. The loss function used to test the performance the VaR risk measure proposed by Lopez in 1998 which is Lopez-II approach is given by.

$$C_t = \begin{cases} 1 + (r_t - VaR_t)^2, & \text{if } r_t > VaR_t \\ 0, & \text{if } r_t \leq VaR_t \end{cases} \quad (14)$$

Where r_t is the daily return. The statistic test used to test the performance of the VaR risk measure is Quadratic Probability Score (QPS) given by.

$$QPS = \frac{2}{n}\sum_{t=1}^{n}(C_t - p)^2 \quad (15)$$

Where p is the probability. The value of QPS is located between [0,2]. If its value is close to 0, the risk measure has a great performance.

3. Materials and Methods

3.1. Materials

Materials used in this study is the data of the closing price of 8 foreign exchange, which is Australian Dollar (AUD), Canadian Dollar (CAD), Swiss Franc (CHF), Euro (EUR), British Pound (GBP), Japanese Yen (JPY), Singapore Dollar (SGD), and US Dollar (USD). Data used is data from 2 January 2019 until 31 December 2021. Data was obtained from https://investing.com/ and https://finance.yahoo.com/.

3.2. Methods

First, using Microsoft Excel, calculate the daily return of each data. Then using Minitab 20 to calculate mean, variance, standard deviation, skewness, and kurtosis of return from each data. Then, estimate each data distribution and test its suitability from its Q-Q Plot and Anderson-Darling tests using Minitab 20 and IBM SPSS statistics 25 software. After getting each data suitable distribution, then calculate the VaR and its QPS using Microsoft Excel.

4. Results and Discussion

Based on the research results, Descriptive Statistics of return such as mean, standard deviation, skewness, kurtosis, and variance from each data obtained by using Minitab 20 is given in Table 1.

Table 1: Descriptive Statistics of Forex Return Value

	AUD	CAD	CHF	EUR
Mean	0.000031	0.000074	0.000086	-0.000015
St. Dev	0.006529	0.005544	0.005459	0.005201
Skewness	0.18	0.71	0.63	0.91
Kurtosis	7.02	9.47	7.12	8.21
Variance	0.000043	0.000031	0.000030	0.000027
	GBP	JPY	SGD	USD
Mean	0.000073	-0.000090	-0.000002	-0.000019
St. Dev	0.006111	0.006615	0.004271	0.004524
Skewness	0.18	0.24	1.20	1.55
Kurtosis	3.47	5.25	17.01	25.92
Variance	0.000037	0.000044	0.000018	0.000020

After getting the Descriptive Statistics, making Q-Q Plot for each Forex and calculate its Anderson-Darling value to determine its distribution. Examples given in Figure 1.

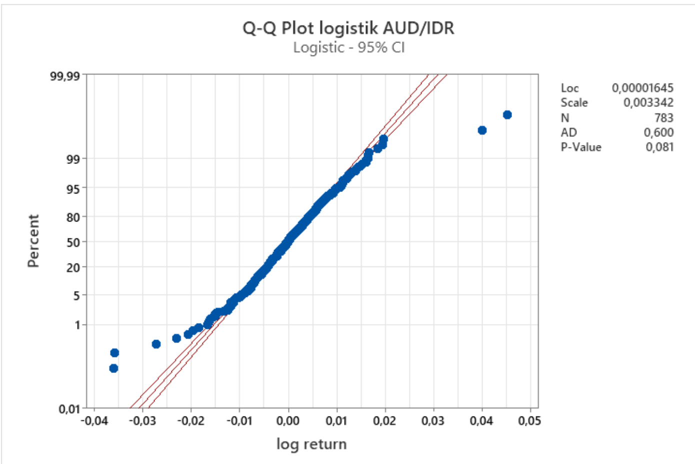

Figure 1: Distribution of Logistic Q-Q Plot Forex Return of AUD/IDR

After comparing the Q-Q Plot and Anderson-Darling value for each distribution, distribution for each Forex can be determined. The distribution of each Forex is given in Table 2.

Table 2: Forex and Its Distribution

Forex	Distribution
AUD	Logistic
CAD	Logistic
CHF	Logistic
EUR	Logistic
GBP	Logistic
JPY	Normal
SGD	Logistic
USD	Logistic

After determining each Forexes distribution, VaR and QPS can be obtained using equation (7), equation (12), equation (13), and equation (14), given in Table 3.

Table 3: VaR and QPS of Each Forex

Forex	*VaR*	*QPS*
AUD	-0.009445	1,713536
CAD	-0.007973	1.701907
CHF	-0.007074	1.736705
EUR	-0.006282	1.646625
GBP	-0.009234	1.706614
JPY	-0.010972	1.759629
SGD	-0.003989	1.609718
USD	-0.002896	1.251194

Based on Table 3, if an investor decided to invest as much as $W_0 =$ Rp $1{,}000{,}000.00$ to each Forex, the potential loss from AUD is Rp 9,445.26, from CAD is IDR 7,972.62, from CHF is IDR 7,073.74, from EUR is IDR 6281.90, from GBP is IDR 9,234.37, from JPY is IDR 10,971.68, from SGD is IDR 3,988.65, and from USD is IDR 2,896.47

5. Conclussion

From the results, USD has the lowest VaR value, lowest QPS value, and lowest potential loss. It means that USD is the best Forex to invest in because it has lower risk and better risk measure performance than other Forexes.

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