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Optimal Portfolio Models for an Inefficient Market

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Abstract

This research attempts to formulate a new mean-risk model to replace the Markowitz mean-variance model by altering the risk measurement using ARCH variance instead of the original variance. In building the portfolio, samples used are closing prices of Indonesia Composite Stock Index and Indonesia Composite Bonds Index from 2013 to 2018. This study is a qualitative study using secondary data from the Indonesia Stock Exchange and Indonesia Bonds Pricing Agency. This research found that Markowitz's model is still superior when utilized in daily data, while the mean-ARCH model is appropriate with wider gap data like monthly observation. The Historical return has also proven to be more appropriate as a benchmark in selecting an optimal portfolio rather than a risk-free rate in an inefficient market. Therefore Mean-ARCH is more appropriate when utilized under data that have a wider gap between the period. The research findings show that the portfolio combination produced is inefficient due to the market inefficiency indicated by the meager return of the stock, while bears notable standard deviation. Therefore, the researcher of this study proposed to replace the risk-free rate as a benchmark with the historical return. The Historical return proved to be more realistic than the risk-free rate in inefficient market conditions.

Keywords: Modern Portfolio Theory, Mean-ARCH Model, Optimal Portfolio, Inefficient Market, Weighted Historical Return

JEL Classification Code: C53, C18, F13, G14

1. Introduction

Allocating certain types of financial instruments is an essential key in formulating a portfolio to attain the desired return associated with a certain amount of risk. Markowitz (1952), in a Modern Portfolio Theory (MPT), explained how a portfolio is formulated by utilizing the combination of the mean as the portfolio expected return with variance as the portfolio holding risk, therefore known as mean-variance analysis. Afterwards, all possible means and variances combinations of the portfolio are then plotted into the Efficient Frontier Curve (EFC) and used by investors to choose their optimum portfolio combination by using Sharpe Ratio (1966). This is to compare portfolio expected return to risk-free rate as a benchmark while taking into account the risk lies in the assets of the portfolio. However, MPT works under the assumption that the markets are efficient. Nevertheless, in reality, the market condition in emerging countries, for instance, Indonesia, is inefficient.

The researcher's pre-research using 5-year daily and monthly closing price data of Indonesian stock and bonds index also suggested revising the MPT model. 5-year annual average returns from stock price movement only offer 5.90%, much lower than the returns offered by bonds, which is 13.94%, while stock bears higher volatility risk than bonds. The optimal portfolio is then determined using Sharpe Ratio to plot Capital Market Line (CML) on EFC. Obligasi Retail Indonesia series 16 (ORI-016) was used as a risk-free rate basis, which offered a 6.80% interest rate. EFC from Figures 1 to 4 shows that every model with a different period basis suggests the portfolio with 100% investment in bonds is the best performing portfolio overall. While stocks-dominated portfolios have a negative Sharpe Ratio, suggesting that

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investing in stocks reduce portfolio performance over time. Thus, this pre-research shows an indication of inefficient market conditions in the Indonesian market.

There are several pieces of research about estimating the coefficient of non-diversifiable risk; for example, according to Tan et al. (2018), the research examines the alternative ways of estimating the coefficient of non-diversifiable risk, namely beta coefficient, in the Capital Asset Pricing Model (CAPM). Introduced by Sharpe (1964), Capital Asset Pricing Model (CAPM) is an essential element of assessing the value of diverse assets. This study proposes a new mean-risk model in building an optimal portfolio using ARCH as a proposed risk measurement to replace the standard deviation used by Markowitz. As standard deviation only capable of estimating risk by observable data, which is the return from asset's closing price, finding a new benchmark in choosing optimal portfolio under inefficient market conditions. This study, qualitative in nature, uses secondary data from Indonesia Stock Exchange (IDX) and Indonesia Bonds Pricing Agency (IBPA). The study has its limitation. First, this study use data from one country, which is Indonesia. Second, the observation period is limited from 2013 to 2018 due to the availability of bonds price is accessible from 2013. This study also only uses the data of the closing price of the Indonesia Composite Stock Index (IHSG) and Indonesia Composite Bonds Index (ICBI).

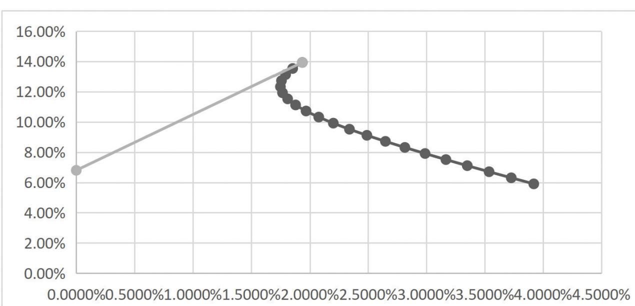

Figure 1: Mean-Variance Portfolio EFC on Daily Basis

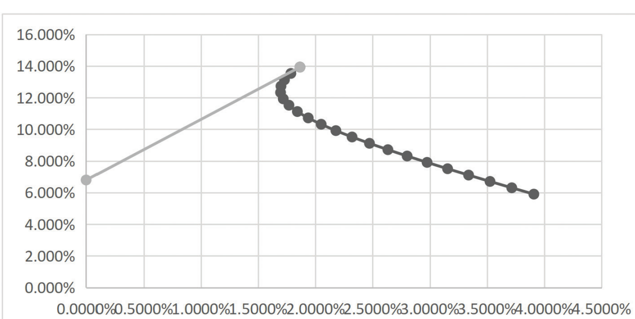

Figure 2: Mean-ARCH Portfolio on Daily Basis

The researcher in this study researches on portfolio optimization by utilizing new risk measurement by using ARCH. According to the model simulated under ARCH standard deviation, compared to the original mean-variance model by Markowitz, furthermore, this study found that the new model is more superior if employed in a period with longer intervals, for example, monthly or quarterly. Even though the standard deviation generated using ARCH displays a lower risk profile in terms of a daily basis, it does not appear to reflect the real volatility risk in daily observation. Therefore, the model produced higher error terms compared to the original variance model. Despite that, ARCH standard deviation performs better in valuing risk terms under a monthly period of observation.

In this research, the EFC results from another approach and concept as the alternative proposed by Markowitz (1952). This alternative was calculated because in certain conditions, especially in a crisis, the interest rate is higher than the market expected return or individual stock return. In a crisis, the company's performance is low; it causes stock price performance also relatively lower. The new picture for the EFC can be seen as follows.

In order to find the most optimal portfolio with the highest return following the lowest risk combination based on the model simulated, the researcher used the Sharpe ratio (1966) in assessing each portfolio performance. Each model is plotted into an efficient frontier curve based on each portfolio return and risk and Capital Market Line drawn based on the portfolio Sharpe ratio. All portfolios under different risk measurement and observation periods display that every portfolio resulted in a 100% investment in bonds gives the best performing portfolio according to the Sharpe ratio.

This finding occurred due to the meager return of the stock index while holding an incredibly high volatility risk. Indonesia's stock index yields a lower return yet bears a high standard deviation is evidence of inefficient capital market conditions in Indonesia. Annually, the stock index only offers a 5.90% return on average, while on the other side, the latest Indonesia government bond as the risk-free asset comparison, ORI-016, offers a 6.80% return. If the portfolio were constructed with the stock index only, the portfolio would have a negative Sharpe ratio, and the EFC would be below the CML and risk-free rate. Therefore, the researcher concluded that a risk-free rate is not appropriate in assessing the optimal portfolio in inefficient market conditions. Thus, the researcher proposed a new basis for assessing portfolio performance to replace the risk-free rate and derive the CAPM equation.

Conceptually, the expected return and standard deviation could be calculated as follows:

$$E_{(R_P)} = aE_{(R_i)} + (1-a)E_{(R_E)} \tag{1}$$

$$\sigma_p = [a^2\sigma^2 + (1-a)^2\sigma_m^2 + 2a(1-a)\sigma_{im}]^{1/2} \quad (2)$$

Where $E_{(R_p)}$ is expected portfolio return, $E_{(R_i)}$ is the risk-free rate, $E_{(R_m)}$ is expected return from the market, a is assets weight, ó$_p$ is portfolio variance, ó$_m$ is market variance and ó$_{im}$ is the coefficient correlation between the asset. However, in investment, $R_{i,}$ which is derived from a risk-free rate, needs to be reviewed because, in reality, there is no such as risk-free investment. Instead, the risk-free rate should be replaced with the historical return. Therefore (1) and (2) could be changed as follows:

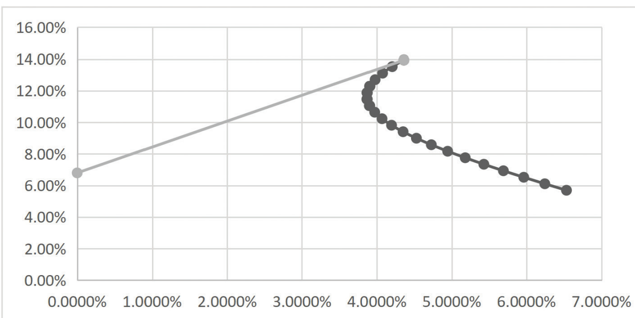

Figure 3: Mean-Variance Portfolio on Monthly Basis

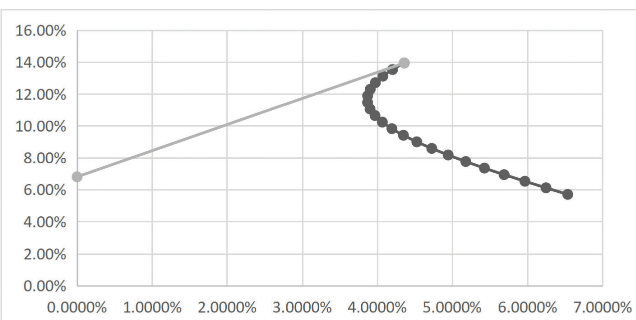

Figure 4: Mean-ARCH Portfolio on Monthly Basis

$$E_{(R_p)} = aE_{(R_h)} + (1-a)E_{(R_m)} \quad (3)$$

$$\sigma_p = \left[a^2\sigma_h^2 + (1-a)^2\sigma_m^2 + 2a(1-a)\sigma_{hm}\right]^{1/2} \quad (4)$$

In which $E_{(R_H)}$ is expected historical return and ó$_h$ is the historical variance. Thus, if equation (3) and (4) is differentiated:

$$\frac{\partial E_{(R_P)}}{\partial a} = E_{(R_h)} - E_{(R_m)} \quad (5)$$

$$\frac{\partial \sigma_p}{\partial a} = \frac{1}{2}[a^2\sigma_h^2 + (1-a)^2\sigma_m^2 + 2a(1-a)\sigma_{hm}]^{-1/2} x \quad (6)$$
$$[2a\sigma_h^2 - 2a\sigma_m^2 + 2\sigma_{hm} - 4a\sigma_{hm}]$$

If adjustment toward expected return done with risk, the equation (5) and (6) then could be derived as follows:

$$\frac{\partial E_{(R_P)}}{\partial a}\Big|_{a=0} = E_{(R_h)} - E_{(R_m)} \quad (7)$$

$$\frac{\partial \sigma_p}{\partial a}\Big|_{a=0} = \frac{1}{2}({\sigma_m}^2)^{-1/2}(-2{\sigma_m}^2 + 2\sigma_{hm}) \quad (8)$$
$$\frac{\partial \sigma_p}{\partial a}\Big|_{a=0} = \frac{\sigma_{hm} - \sigma_m^2}{\sigma_m}$$

$$\frac{\partial E_{(R_p)}}{\partial \sigma_p} = \frac{E_{(R_h)} - E_{(R_m)}}{\frac{\sigma_{hm} - \sigma_m^2}{\sigma_m}} \quad (9)$$

On the other side, if a review was done on CML, the change could be described as follows:

Therefore, from the chart above, it could be concluded that:

$$E_{(R_p)} = R_h + \left[\frac{E_{(R_m)} - R_h}{\sigma_m}\right] x\ \sigma_p \quad (10)$$

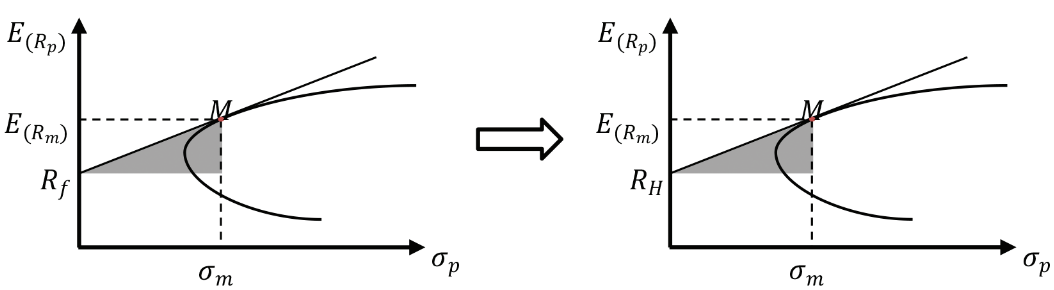

Figure 5: Risk-free rate and historical return CML comparison

Where CML slope is a tangent α function from the angle between CML, R_h and σ_H is:

$$\frac{E_{(R_m)} - R_h}{\sigma_m} \tag{11}$$

With is the return of the weighted average of price. Therefore, equation (9) must be equal to equation (11):

$$\frac{E_{(R_m)} - R_h}{\sigma_m} \approx \frac{E_{(R_h)} - E_{(R_m)}}{\frac{\sigma_{hm} - \sigma_m^2}{\sigma_m}} \tag{12}$$

$$\frac{E_{(R_m)} - R_h}{\sigma_m} = \frac{E_{(R_h)} - E_{(R_m)}}{\frac{\sigma_{hm} - \sigma_m^2}{\sigma_m}} \tag{13}$$

$$\left[\frac{E_{(R_m)} - R_h}{\sigma_m}\right] x \left[\frac{\sigma_{hm} - \sigma_m^2}{\sigma_m}\right] = E_{(R_h)} - E_{(R_m)}$$

$$E_{(R_h)} - E_{(R_m)} = \frac{[E_{(R_m)} - R_h] x [\sigma_{hm} - \sigma_m^2]}{\sigma_m^2}$$

Where

$$\frac{[\sigma_{hm} - \sigma_m^2]}{\sigma_m^2} = \beta$$

Therefore, the equation could be simplified as follows:

$$E_{(R_h)} = \beta[E_{(R_m)} - R_h] - E_{(R_m)} \tag{14}$$

Where $E_{(R_h)}$ is the expected return under the historical return framework, β is the beta of the asset, $E_{(R_m)}$ is the market expected return, and R_h is the weighted average historical return of the asset.

Based on the equations described above, there are several reasons why the historical return is more superior to be used in assessing optimal portfolio when compared to the risk-free rate. First, a Risk-free rate is the product of the government. The risk-free rate is always determined based on government investment. Second, there are possibilities that the government could go bankrupt. For instance, when the Indonesian market crash in 1998 due to the monetary crisis, the SBI rate rose excessively to more than 60%. Third, return from the weighted average of the asset price is more realistic and makes sense to be utilized as standard in investing with no risk in inefficient market conditions. The weighted average return is derived from the average of total historical price multiplied by the sales volume, which is more realistic to assess portfolio performance rather than the risk-free rate.

2. Literature Review

2.1. Efficient Market Hypothesis

Fama (1970) stated that all the information available had been reflected in the asset price at any period in an efficient market model or known as the Efficient Market Hypothesis (EMH). Fama (1970) explained that there are conditions to describe whether a market is efficient or not. There are no transaction costs in settling investment transactions; investors could freely access all information available. The last condition is that the information is reflected in the asset price.

Empirically, Fama (1970) explained three forms of the market considering the relationship of available information efficiency to the price of the assets, which are weak form, semi-strong form, and strong form. Firstly, the weak form explains that the current asset price reflects all the asset's historical prices. In this form, investors could not gain from using technical analysis and only utilized fundamental analysis in the short term. A semi-strong form of an efficient market is when the asset price is completely incorporated into all publicly available financial information. Using either fundamental or technical analysis is not capable of achieving gain on returns has been implied in this efficient market form. The strong form is when not only publicly available information is reflected in the asset price but also privately obtained or insider's information as well, which means no investor could benefit from abnormal returns.

2.2. Modern Portfolio Theory

According to Nguyen (2020), Modern Portfolio Theory (MPT) has played a significant role in constructing investment portfolios for over 65 years. Markowitz (1952) is acknowledged as the father of Modern Portfolio Theory by his mean-variance framework in selecting an optimal portfolio. The expected return of the portfolio, or mean, is the weighted average return of each individual assets proportioned in the portfolio from one observation period, and variance of the return is the risk measurement of the portfolio while taking into consideration the proportion of assets and how each of the assets correlated to each other in the portfolio. Combinations of mean and variance estimated from the varieties of the asset's weight afterward presented in form EFC and applied as investors' guidance in choosing preferred their portfolio based on the set of efficient mean-variance combinations. There are several assumptions that lie on MPT, which are the distribution of assets returns assumed to be normal, investors considered to reach the maximum return whereas being risk-averse in choosing what investment to invest in, next is investors are assumed capable taking a rational investment decision, each investor has the same access to all available information, and no transaction cost applied.

Portfolio mean resulted from weighting each asset return. Mathematically, the expected return of the portfolio could be expressed as follows:

$$E_{(R_p)} = \sum_i w_i E_{(R_i)} \tag{15}$$

In which $E_{(R_p)}$ is the portfolio expected return, w_i is the weight of the asset i in the portfolio and $E_{(R_i)}$ is the return of the asset i. whereas the variance of the portfolio could be written as follows:

$$\sigma_P^2 = \sum_i w_i^2 \sigma_i^2 + \sum_i \sum_{j \neq i} w_i w_j \sigma_i \sigma_j \rho_{ij} \tag{16}$$

Where σ_p^2 is portfolio variance, the weight of asset i and j is w_i and w_j, σ_i and σ_j is asset i and j standard deviation while ρ_{ij} is the coefficient correlation between asset i and j.

However, criticism also elongated on the MPT model. Markowitz himself, in 1999, wrote a review paper titled 'The Early History of Portfolio Theory' and explained the problems which lie in his research of 1952. In this research, there are two technical errors in describing EFC. The study failed to mention that standard deviation, instead of variance, is an eloquent dispersion measurement—finally, the views of why and what of mean-variance he put in a question on his research of 1952. Moreover, since MPT assumes that the assets returns are normally distributed, MPT failed to consider the sample with abnormal characteristics, which resulted in return with excessive growth and decreased volatility. Especially, MPT lies in the assumption that investors are rational in making investment decisions and can access all information available for free.

2.3. Capital Asset Pricing Model as the Portfolio Theory

Nurhayati (2020) said One of the assumptions underlying the price formation CAPM model is the existence of a perfect market where there are no trade costs, no taxes in transactions; investors are price takers, markets are always in equilibrium, etc.

Capital Asset Pricing Model (CAPM) was first developed based on the research by Treynor (1962), Sharpe (1964), Lintner (1965), and Mossin (1966) and utilized as bases in pricing financial assets or portfolio. CAPM explained the relationship on how the asset's systematic risk influences the assets expected return. In calculating an asset's expected return under the CAPM framework, investors need to consider the market risk premium over the return of the risk-free assets and the asset's beta to the market. Therefore, the expected return calculated under the CAPM framework explained as follows:

$$E_{(R_i)} = R_f + \beta(E_{(R_m)} - R_f) \tag{17}$$

In which $E_{(R_i)}$ is the asset expected return, risk-free rate of return is R_f, β is beta of the asset, and $E_{(R_m)}$ is the market expected rate of return. Since CAPM is formulated based on the Markowitz's MPT and asset diversification, CAPM also works under the same assumption as MPT in which the market is considered to be an inefficient condition.

2.4. Autoregressive Conditional Heteroscedasticity

Autoregressive Conditional Heteroscedasticity (ARCH), which is for the first time introduced by Engle (1982), is a model in econometrics used to analyze the time-series statistical data. In the ARCH model, recent historical data of return is employed to forecast the current one-period variance. The ARCH model was invented for the purpose of estimating volatility and volatility clustering used to make investment decisions. Engle tested the ARCH model to forecast the inflation rate in the United Kingdom. The findings were significant and displayed extensive growth of estimated variance through the worst times in the United Kingdom in the seventies.

Variance calculated from the error terms resulted from the mean equation. Mean autoregressive model or AR(q) considered as follows:

$$r_t = a_0 + \sum_{i=1}^{n} a_i r_{t-i} + \varepsilon_t \tag{18}$$

Hence, the ARCH conditional variance for the given error term is:

$$\sigma_t^2 = Var(\varepsilon_t \mid \varepsilon_{t-1}, \varepsilon_{t-2}, ...) \tag{19}$$

The variance of the error terms is conditional due to the capability to affect the previous variance. The characteristics of the non-uniformity or heteroskedastic error term in the econometric model are in some circumstances.

Numerous researchers after that developed new models based on the original ARCH model introduced by Engle. Bollerslev (1986) formulated one of the popular models, which is derived from the ARCH model, is Generalized Autoregressive Conditional Heteroskedasticity (GARCH). Bollerslev (1986), in formulating the GARCH model, pointed out that the ARCH model for estimating the conditional variance might usually result in a non-negativity constraint violation. The ARCH model commonly uses free lag distribution time-series data.

2.5. Sharpe Ratio

Sharpe ratio, named after the developer itself, William F. Sharpe (1966), assesses portfolio performance by comparing the difference of portfolio's return with risk-free asset's rate adjusted to the portfolio volatility risk or the standard deviation. A significant advantage in Sharpe ratio calculation is that the value could be easily derived from any observation period without any further information regarding portfolio profitability. Sharpe ratio defined in the mathematical model as described below:

$$S_p = \frac{R_p - R_f}{\sigma_p} \tag{20}$$

Where S_p is portfolio Sharpe ratio, portfolio expected or actual return is R_p, R_f is the risk-free rate of return and σ_p is portfolio standard deviation. The higher the portfolio's Sharpe ratio is, the better the portfolio performance is over its risk. A negative Sharpe ratio is also possible to occur in one's portfolio. A portfolio might produce a negative Sharpe ratio due to the risk-free rate being higher than the portfolio return, or the portfolio return itself is negative. Hence, there is no beneficial value behind the negative portfolio Sharpe ratio.

3. Research Method

The sample of this study is the Indonesian Composite Index (IDX) and Indonesia Corporate Bond Index (ICBI) closing prices. The research sample is taken in the period of 2013 to the end of 2018, which in total is 5-years observation. The length of intervals used is on a daily basis and monthly basis. The researcher follows several steps in achieving the objectives of this research. First of all, the researcher derives return from stock and bonds index closing price data on both a daily and monthly basis. The average return, variance, standard deviation, and coefficient correlation are calculated based on the return for both stock and bonds index and annualize the average return and standard deviation result. Variance and standard deviation of each asset were calculated two times by using the original Markowitz's MPT model and ARCH model. After that portfolio constructed with various combination of each asset's weight and calculate portfolio weighted return and each model standard deviation. Next, an optimum portfolio selected by calculating each portfolio combination's Sharpe ratio and plotted in EFC. Afterward, the researcher examines each model's accuracy in the Mean-Squared Error framework. The last is formulating a new comparison basis for choosing an optimum portfolio that more appropriate than the risk-free rate of return to be utilized in inefficient market conditions based on the result and discussion from previous steps.

4. Results

The average annual return of the Indonesia composite stock index from 2013 to 2018 based on the calculation made by the researcher only gives 5.90% with 15.54% annualized standard deviation while the bonds index gives 13.94% annualized returns with 5.81% annualized standard deviation. Based on the table of the summary of statistics, daily average returns and standard deviations of each asset are lower than the average returns and standard deviation when calculated in monthly intervals, which indicates the existence of autocorrelation in the time-series data employed.

4.1. Optimal Mean-Risk Portfolio Model for Inefficient Market

In plotting each risk measurement portfolio, the return was calculated using arithmetic return for each asset class. Arithmetic return is calculated by dividing the observed period's total return by the total number of observation periods. Mathematically, the arithmetic return could be described as follows:

$$R_{AM} = \sum_{t=1}^{n} \frac{r_t}{n} \tag{21}$$

RAM is arithmetic return, rt is the return of the observed period, and n is the total number of observations. Subsequently, risk calculated based on each model using the return produced previously. Returns and risks of each asset are annualized before the portfolio combination is produced. Portfolio combination is formed with different assets weight for different portfolios.

Table 1: Descriptive Analysis

	Daily	Monthly
Indonesia Composite Stock Index		
Observations	2,906	142
Average Return	0.0244%	0.4816%
Standard Deviation	0.9859%	3.5398%
Maximum Return	4.5400%	7.5500%
Minimum Return	-5.7500%	-12.0000%
Indonesia Composite Bonds Index		
Observations	2,906	142
Average Return	0.0225%	0.4608%
Standard Deviation	0.3901%	2.2481%
Maximum Return	4.4500%	5.6100%
Minimum Return	-3.8700%	-5.9000%

4.2. Mean-Variance Portfolio

The Mean-Variance model for portfolio optimization formulated by Markowitz in 1952 as 'Modern Portfolio Theory' employs mean as investment return measurement and standard deviation as the risk measurement. The standard deviation for two types of assets distributed based on the asset's weight as follows:

$$\sigma_P = \sqrt{W_S^2 * \sigma_S^2 + W_S^2 * \sigma_B^2 + 2 * W_S * W_B * \sigma_S * \sigma_B * \rho_{S,B}} \quad (22)$$

In which σ_P is the portfolio standard deviation, W_S is the stock's weight in the portfolio, W_B is the weight of the bonds in the portfolio, σ_S is the stock standard deviation, σ_B is the bonds standard deviation, and $ñ_{S,B}$ is the correlation coefficient between the returns of the two assets. Calculation result shows that the daily basis of portfolio standard deviation ranges from 1.93% up to 3.92%, while on a monthly basis, standard deviation produced slightly higher than daily, ranging from 4.34% to 6.59%.

4.3. Mean-ARCH Portfolio

In the Autoregressive Conditional Heteroskedasticity framework, the variance is derived from the residual of the mean autoregressive equation. Researchers utilize ARCH first-order in calculating portfolio variance. ARCH (1) mean equation mathematically described as follows:

$$r_t = a_0 + a_1 r_{t-1} + \varepsilon_t \quad (23)$$

Where r_t is the mean equation, a_0 and a_1 is regression constant, r_{t-1} is the first derivative of the return function, and is the error produced from the regression function. The ARCH standard deviation on a daily basis is ranged from 1.86% to 3.71%. On the other side, the monthly ARCH standard deviation ranged from 4.35% to 6.53%. This finding explains that risk terms produced using the ARCH model display lower risk when measured on a daily basis compared to the variance model. On the contrary, the ARCH risk is higher when presented on a monthly basis rather than variance.

Table 2: Forecast Result Analysis Summary

	RMSE	MSE	Rank
Daily Basis			
Variance	0.001296365	0.000001681	1
ARCH	0.001307460	0.000001709	2
Monthly Basis			
Variance	0.001785389	0.000003188	2
ARCH	0.001765850	0.000003118	1

4.4. Model Testing under Root Mean-Squared Error Framework

Both models produced higher risk when calculated on a monthly basis rather than daily. To test each model's effectivity, the researcher employs a Mean-Squared Error (MSE) analysis on the risk of each model. MSE is derived from the squared difference between forecasted values and real values and averaged. MSE could be described in mathematical terms as follows:

$$MSE = \frac{1}{n}\sum_{i=1}^{n}\left(Y_i - \hat{Y}_i\right)^2 \quad (24)$$

Where n is the total number of observations, Y_i is the actual values whereas $\hat{Y}_i$ is the forecasted values. MSE is employed to test the quality of the model by measuring the error produced from estimation. Smaller the value of MSE, the better the model is. In other words, the smaller the MSE values, the smaller the error results from the model.

MSE result is produced by forecasting the risk using the Simple Exponential Smoothing forecast technique. The table below describes Root Mean-Square Error (RMSE) and MSE value summary on each model based on different period intervals.

Forecast result analysis indicated that variance as risk measurement produced lower error with MSE value of 1.68 x 10^{-6} in daily basis calculation. On the other side, calculation on a monthly basis produced lower risk in ARCH with an MSE value of 3.12 x 10^{-6}.

5. Conclusions

This research attempt to formulate a new mean-risk model to replace the Markowitz mean-variance model by altering the risk measurement using ARCH variance instead of the original variance. In building the portfolio, samples used are closing prices of Indonesia Composite Stock Index and Indonesia Composite Bonds Index from 2013 to 2018.

This study found that the annualized average return of the stock index is significantly lower than the bonds index, indicating that the Indonesian capital market is inefficient. Markowitz's model is superior if utilized under big data rather than the proposed model. Therefore Mean-ARCH is more appropriate when utilized under data that have a wider gap between the period. The research findings show that the portfolio combination produced is inefficient due to the market inefficiency indicated by the meager return of the stock while bears notable standard deviation. Therefore, the researcher of this study proposed to replace the risk-free rate as a benchmark with the historical return. Historical return proved to be more realistic than the risk-free rate in inefficient market conditions.

This research also has several limitations and suggestions for future research based on the limitation. First, looking at the observation period limited to 5 years and the country observed was only Indonesia, observing other countries' markets with similar characteristics of market inefficiency and a more extended period of observation is suggested. Second, using another risk measurement other than ARCH, such as Value-at-Risk (VaR), Conditional Value-at-Risk (CVAR), GARCH, or realized volatility, might give a different perspective and research result.

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