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# ANALYSIS OF OPTIMAL PORTFOLIO PERFORMANCE USING MARKOWITZ MODEL AND SINGLE INDEX MODEL (CASE STUDY ON LQ45 INDICES)

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***Abstract –*** *This study aims to analyze performance of Markowitz Model and Single Index Model to construct optimal portfolio. Descriptive analysis method with quantitative approach is used in this study. Construction of optimal portfolio using historical daily data from the first semester of the study and evaluation of optimal portfolio performance using historical daily data form the second semester of the study. This study assumed that investment applied as the optimal portfolio constructed by both models. Therefore, performance evaluation both portfolios conducted on second semester of the study using Sharpe ratio, Treynor ratio, and Jensen's Alpha. This study shows that there are no significance differences of optimal portfolio performance using Markowitz Model and Single Index Model.*

***Keywords:*** *Optimal Portfolio; Markowitz Model; Single Index Model; Sharpe Ratio; Treynor Ratio; Jensen's Alpha.*

## INTRODUCTION

The selection of portfolios is what gives the maximum expected return on a certain variance, or the portfolio with the smallest variance with a certain expected return. The Markowitz model introduced by Harry Markowitz in 1952, it used diversification of securities in the portfolio to get maximum expected return on certain variance because stocks on the portfolio are correlated.it requires a huge number of estimations to fill the covariance matrix. If the portfolio consists of $n$ stocks, then there will be $n$ variance and $(n^2 - n)$ covariance or $n(n-1)/2$ different covariance estimates. Covariance increases more if the number of shares in the portfolio is added. This is a formidable task, because it has to estimates the input list like expected return, variances and covariance to be success in portfolio selection as it depends on the quality of input list.

William F. Sharpe (1963) introduced a model that simplifies the way to construct portfolio. For example, if the portfolio consists of $n$ stocks, then there will $n$ estimates of the sensitivity coefficients $(\beta_i)$, $n$ estimates of the firm-specific variances $\sigma^2(e_i)$, and one estimate for the variance of the (common) macroeconomic factor $\sigma_M^2$. Then, these $(2n + 1)$ estimates will be able to prepare the entire input list for this single index-security universe.

Single index model assumed that stock return movements are only related to market movements. Thus, stock returns are correlated with market returns. Every company is not the same in giving respond to market changes. In single index model, the only factor that assumed to influence stock returns is market returns, where market returns change due to the market movement itself. Therefore, $e_i$ as firm-specific factors also called residual is assumed that it does not correlate with market return, $R_m$, and random error from stock returns or firm-specific factors $i$ also independent from random error of stock $j$, so that $E(e_i) = 0$, $E(e_j) = 0$, and $E(e_i e_j) = 0$.

Through those assumptions estimations of input list using Single Index Model is simpler than Markowitz Model. The single index model will ignore the correlation between stocks (it will assume it is zero), while the Markowitz model which count for the full covariance between every pair of stocks will automatically take the residual correlation into count when minimizing portfolio variance.

However, preliminary research that this study has done are used to test the assumption in single index model of 41 companies from LQ45 in range of time from January 22, 2019 until July 18, 2019.

The parametric (t-test) two tailed shown that additional assumptions from single index model is unapproved. Within this phenomenon, this study looks for the performance of the Markowitz Models that do not use any assumptions with the Single Index Model that simplifies the estimates by adding some assumption. This study will analyze both of Model's performance in constructing the optimal portfolio. Whether the Single Index Model with some additional assumptions and the simplified estimate will perform as good as Markowitz Model with a genuine assumption that need a large number of estimations.

## LITERATURE REVIEW

Return is the changes in price of the securities that could be a gain (loss) for the investors that can be represent in terms of percentage change (Purwanto and Sumarto, 2017). There are two kinds of return that can be calculated by investors to know the gain that they can receive. First, return that can be calculated using historical data of securities that is selected. It usually used to measure the performance of securities that can be used to predict expected return. The second type of return is expected return. Expected return is an estimation of return that expect to be obtained by investors in the future.

Risk means the uncertainty of outcomes (Reilly and Brown, 2012). It is the possibility of losing in the investments either some or all. Systematic risk is the risk that remains even after extensive diversification is also called market risk, risk that is attributable to market wide risk sources (Bodie et.al, 2011). This risk come from common macroeconomic factors that would affect all security and cannot be avoid with diversified securities. Then, Non-systematic risk is the risk that can be eliminated by diversification is also called firm-specific risk (Bodie et.al, 2011). Diversification will reduce risk of securities because each firm has different influences to the portfolio that will help to reduce portfolio risk.

Portfolio is a combination of securities with purpose to gain optimal return in a given level of risk (Elton and Gruber, 2003). An optimal portfolio (Reilly et.al, 2012) is portfolio at efficient frontier that has high utility for certain investors. Every investor will invest to portfolio that place in efficient frontier. Efficient frontier representing a set of portfolios that maximize expected return at each level of portfolio risk (Bodie et.al, 2011).

Modern portfolio theory (MPT) is a theory pioneered by Harry Markowitz in his paper "Portfolio Selection", published in 1952 by the Journal of Finance. This model denotes risk and return based on the composition in portfolio and also the correlation between stocks in the portfolio. The Modern Portfolio Theory reduced unsystematic and company related risk by diversified various securities and assets whose variability is different and offsetting or put in different words which are negatively correlated at all (Bodie et.al, 2011). It means that various securities will be reduced unsystematic risk cause of the correlation that have by securities towards others, especially negative correlation. This theory based on mean and variance approach, where mean is a measure of securities return and variance is a measure of securities risk.

In 1963 William F. Sharpe simplified the way to construct portfolio by offering insight into portfolio diversification that called Single Index Model. The index model assumed market index as the common factor. As stated in risk literature, common factor or macroeconomic factor cannot be reduced, but this model represents the common factor as the market index. Single index model has two additional assumption that simplified the estimation to construct portfolio. First, firm-specific factors $(e_i)$ is assumed that it does not correlate with market return $(R_m)$. Second, random error from stock return $i$ is independent towards random error of stock return $j$. The set of estimation needed for the single index model consist of only $n$ estimates of the sensitivity coefficients $(\beta_i)$, $n$ estimates of the firm-specific variances $Var_{e_i}$, plus one estimate for the variance of the (common) macroeconomic factor $Var_m$. Then, these $(2n + 1)$ will enable investors to prepare the entire input list for this single index model.

Markowitz Model identify the risk and return combinations of portfolio by minimum-variance frontier. Bodie et.al (2011), said that this frontier is a graph of the lowest possible variance that can be attained for a given portfolio expected return. Then, in order to find optimal portfolio Markowitz Model

Markowitz Model involves the risk-free asset as part of the optimization plan. The combination of risky assets and risk-free asset is drawn on capital allocation line (CAL). According to Bodie et.al (2011), the objective of portfolio optimization is to find weights that result in the highest slope of the CAL, in the other word, the weights that result in the risky portfolio with the highest reward-to-volatility ratio. According to Bodie et.al (2011), Single index model optimization process can be set up to chart the efficient frontier of the framework along the lines of Markowitz Model. Optimize the portfolio by maximize the Sharpe ratio of the portfolio.

Evaluating the performance of a portfolio is completely mistaken if only looking at the realized or expected. In order to assess the performance of a portfolio, there are 3 measurement tools that can be used. First, Sharpe Ratio, the ratio informs about how much additional return (higher than the risk-free rate) that can be receive based on the risk that undertaken. Second, Treynor Ratio that used beta of the portfolio instead of using standard deviation to measure risk. Last, Jensen's Alpha that calculates the excess return that a portfolio generates over its expected return. This measure is based on the CAPM, it means that the portfolio's return is above the average returns of the market portfolio.

According to those theory, there is differences in assumption to construct the portfolio that means there is differences of the portfolio performance between Markowitz Model and Single Index Model. Therefore, this study will examine the portfolio performance from both models using three methods which are Sharpe ratio, Treynor ratio, and Jensen's alpha with formulated hypothesis as follow.

$H_1$: Average Sharpe ratio of optimal portfolio performance using Markowitz Model is not equal to average Sharpe ratio of optimal portfolio performance using Single Index Model, $\overline{S_{MM}} \neq \overline{S_{SIM}}$ .

$H_2$: Average Treynor ratio of optimal portfolio performance using Markowitz Model is not equal to average Treynor ratio of optimal portfolio performance using Single Index Model, $\overline{T_{MM}} \neq \overline{T_{SIM}}$

$H_3$: Average Jensen's Alpha of optimal portfolio performance using Markowitz Model is not equal to average Jensen's Alpha optimal portfolio performance using of Single Index Model, $\overline{\alpha_{MM}} \neq \overline{\alpha_{SIM}}$

## METHODS

The research is descriptive research that is research to obtain data that describes the topic of interest. It involves the collection of quantitative data that gathered by other parties that we called as secondary data. This research offers systematically think about aspects in a given situation that can help make certain decision. In this study the optimal portfolio construction will be carried out using two different methods, which are the Markowitz model and the single index model. The construction of optimal portfolio used daily closing price of stocks that are listed in LQ45 (August 2019 - January 2020) from January 2019 until June 2019. The evaluation of optimal portfolio performance used daily closing price of stocks that are listed in LQ45 (August 2019 - January 2020) from July 2019 until January 2020. The details of method are described as follow (Bodie, et.al, 2011).

1. Data Collection
   Collecting daily closing price of stocks that are listed in LQ45 from January 2019 until June 2019 on www.yahoofinance.com. Bank Indonesia interest rate (Certificate of Bank Indonesia) data collection for the research period on the official website of Bank Indonesia.
2. Calculate Stocks' Return and Market's Return using the formula $R_{it} = \frac{(P_t - P_{t-1})}{P_{t-1}}$
3. Calculate Expected Return and Risk of Stocks and Market using the formula $E(R_i) = \frac{\sum_{t=1}^{n} R_i}{n}$
4. Calculate Covariance between stocks using the formula of $Cov_{ij} = \frac{1}{n-1}\sum_{i=1}^{n}\left[(R_i - \bar{R}_i)\left(R_j - \bar{R}_j\right)\right]$
5. For Single Index Model only, calculate the systematic risk $(\beta_i)$ using the formula $\beta_i = \frac{Cov_{i,m}}{Var_m}$ and unsystematic risk or firm-specific factor using the formula $e_i = R_i - \alpha_i - \beta R_m$.

6. Calculate Variance of Portfolio
   Markowitz Model: $Var_p = \sum_{i=1}^{n} w_i^2 Var_i + \sum_{i=1}^{n} \sum_{j=1}^{n} w_i w_j Cov_{ij}$ and Single Index Model:
   $Var_p = \sum_{i=1}^{n} w_i^2 [\beta_i^2 Var_m + Var_{e_i}] + \sum_{i=1}^{n} \sum_{\substack{j=1 \\ j \neq i}}^{n} w_i w_j \, \beta_i \beta_j Var_m$.
7. Calculate Portfolio Return using the formula of $E(R_p) = \sum_{i=1}^{n} w_i . E(R_i)$ and Standard Deviation or the risk of portfolio using the formula of $\sigma = \sqrt{Var_p}$.
8. Construct efficient frontier curve by minimizing the variance of portfolio from each model with help of Solver function on Microsoft excel software. The constraints that is needed to be put for the Solver function are:
   - $E(R)_p = \sum_i^n w_i R_i$, as return of portfolio.
   - $\sum_i^n w_i = 100\%$, as the total proportion of portfolio.

   Make 15 portfolios to be points that construct the efficient frontier curve by changing the return portfolio.
9. Finding the optimal portfolio in the risky asset by maximizing reward-to-variability ratio that is formulized as $S_p = \frac{[E(R_p) - r_f]}{\sigma_p}$. The process to maximize the slope helped by Solver function in Microsoft Excel software with the constraints as follow.
   - $E(R)_p = \sum_i^n w_i R_i > 0$, as return of portfolio.
   - $\sum_i^n w_i = 100\%$, as the total proportion of portfolio.

   The solved result is an optimum portfolio with maximum return in certain risk. This portfolio is an optimal portfolio compare to the other 15 portfolios in the efficient frontier curve.
10. Performance evaluation measures using three measurement tools. The performance evaluation of both portfolios is observed in the next 6 months start from July 2019 until December 2019. The calculation of daily return from each stock of portfolio multiply with the percentage of proportion that is given in each stock that constructed the portfolio along with the daily market return.
    - Sharpe ratio $S_p = \frac{[E(R_p) - r_f]}{\sigma_p}$ then the average of Sharpe ratio $\overline{S_P} = \frac{1}{n} \sum_{t=1}^{n} S_P$
    - Treynor ratio $T_p = \frac{[E(R_p) - r_f]}{\beta_p}$ then the average of Treynor ratio $\overline{T_P} = \frac{1}{n} \sum_{t=1}^{n} T_P$
    - Jensen's Alpha $R_{pt} - r_f = \alpha_p + [(R_{mt} - r_f)\beta_p] + e_{pt}$ then the average alpha $\overline{\alpha_P} = \frac{1}{n} \sum_{t=1}^{n} \alpha_P$.
11. Test the average difference from both models on each measurement tool to know the differences of optimal portfolio performance statistically. A parametric (t-test) two-tailed are used to see the average difference from both models on each measurement tool. To support the test, t-Stat are calculated using the formula
    $t = \frac{(\overline{x_1} - \overline{x_2}) - (\mu_1 - \mu_2)_0}{\sqrt{\sigma_1^2/n_1 + \sigma_2^2/n_2}}$ and $df$ are calculated using the formula of
    $df = \frac{(\sigma_1^2/n_1) + (\sigma_2^2/n_2)}{(\sigma_1^2/n_1)^2/(n_1 - 1) + (\sigma_2^2/n_2)^2/(n_2 - 1)}$ . $H_o$ is accepted and $H_a$ is rejected if t-table < t-Stat < t-table whereas $H_a$ is accepted and $H_o$ is rejected if t-table > t-Stat > t-table.

## RESULTS AND DISCUSSION

The efficient frontier constructed by changing the value of expected return as the first constrain in minimize risk process using Solver function in Microsoft Excel software. The calculation of minimize the risk of portfolio is using calculus mathematic where the minimum point achieved if the first derivative

equal to zero. The result of this calculation is the proportion of each portfolio with minimum risk and certain expected return.

The result of the research using Markowitz Model according to the method from Bodie, et.al (2011) can be seen on the Figure 1.1. The efficient frontier curve consists of risk portfolios that have expected return (as decided in the first constrain) with minimum risk.

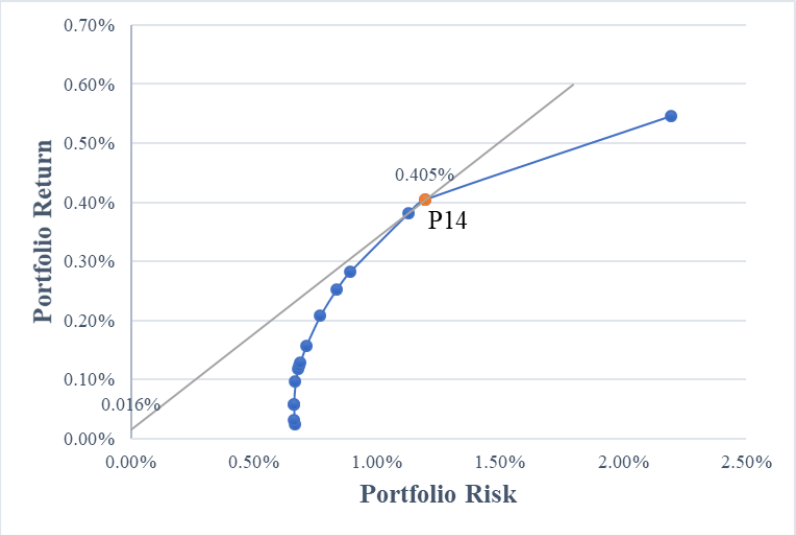


Figure 1.1. Optimal Portfolio Markowitz Model
Source: Processed Data by Solver, 2020

Every portfolio on the curve is an efficient-risk portfolio. Vertical axis shows the return of each portfolio and horizontal axis shows the amount of risk that will take by the portfolio. Even though, every portfolio on the curve is an efficient portfolio but a rational investor will not choose the portfolio with the same level of risk portfolio as the others but has lower return than the others.

Optimal portfolio is the highest comparison between variability ratio and efficient portfolio (P1-P15). This value gain by combining one of the risk portfolios on the curve with risk-free asset (Certificate of Bank Indonesia). By maximizing the variability ratio that connected risk portfolio and risk-free asset, then efficient-optimal portfolio is constructed.

Same as the calculation of minimizing the risk of portfolio, the calculation to maximizing the slope is also using the calculus mathematic where the maximum point achieved if the first derivative is equal to zero. The slope is variability ratio, that is mean an optimal portfolio is a maximum value of variability ratio.

P14 on the curve is an optimal portfolio from the optimization of variability ratio. The optimal portfolio is constructed by 10 stocks out of 45 stocks in LQ45 indices. The portfolio has the expected return amount of 0.405% per day with the risk of 1.1980%. The proportion of portfolio is constructed by each stocks portion illustrated as follow:

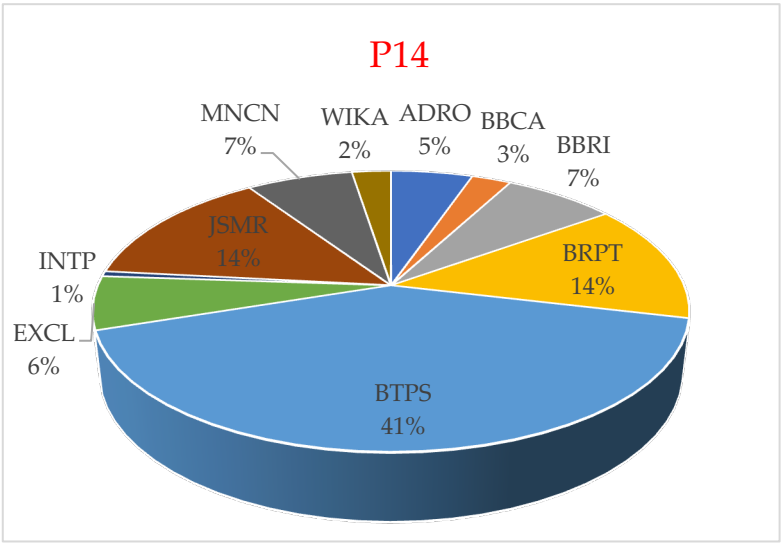


Figure 1.2. Proportion of Optimal Portfolio using Markowitz Model
Source: Processed Data by Solver, 2020

The slope line that connect risk-free portfolio amount of 0.016% per day with 0% risk with the optimal portfolio give expected return amount of 0.405% per day with the risk of 1.1980% is called Capital Allocation Line (CAL). Through that line, the alternative of investment can be set based on the proportion of risk-free portfolio with the optimal portfolio. The combinations are shown in Table 1.1.

**Table 1.1. Simulation of Optimal Portfolio and Risk-free Asset**

| Set | Proportion | | Portfolio | |
|---|---|---|---|---|
| | P13 | PRf | Return | Risk |
| S1 | 0% | 100% | 0.016% | 0.000% |
| S2 | 5% | 95% | 0.035% | 0.060% |
| S3 | 10% | 90% | 0.055% | 0.120% |
| S4 | 15% | 85% | 0.074% | 0.180% |
| S5 | 20% | 80% | 0.094% | 0.240% |
| S6 | 25% | 75% | 0.113% | 0.300% |
| S7 | 30% | 70% | 0.133% | 0.359% |
| S8 | 35% | 65% | 0.152% | 0.419% |
| S9 | 40% | 60% | 0.172% | 0.479% |
| S10 | 45% | 55% | 0.191% | 0.539% |
| S11 | 50% | 50% | 0.210% | 0.599% |
| S12 | 55% | 45% | 0.230% | 0.659% |
| S13 | 60% | 40% | 0.249% | 0.719% |
| S14 | 65% | 35% | 0.269% | 0.779% |
| S15 | 70% | 30% | 0.288% | 0.839% |
| S16 | 75% | 25% | 0.308% | 0.899% |
| S17 | 80% | 20% | 0.327% | 0.958% |
| S18 | 85% | 15% | 0.347% | 1.018% |
| S19 | 90% | 10% | 0.366% | 1.078% |
| S20 | 95% | 5% | 0.385% | 1.138% |
| S21 | 100% | 0% | 0.405% | 1.198% |

Source: Data Processed by Microsoft Excel, 2020

After the constructed of the optimal portfolio using Markowitz model, the construction of optimal portfolio using Single Index Model is quietly same. The process only differs in the calculation of the risk

due to the SIM assumption. The process to construct the efficient frontier and defined the optimal portfolio is the same. Therefore, the result of optimal portfolio using Single Index Model is shown on the Figure 1.3. The efficient-frontier curve is also constructed by 15 portfolios.

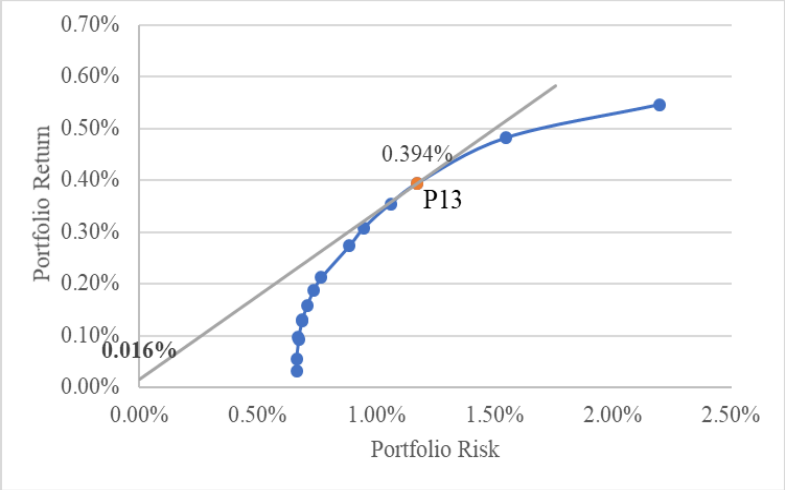


Figure 1.3. Optimal Portfolio of Single Index Model
Source: Data Processed by Solver, 2020

P13 is an optimal portfolio from the optimization of variability ratio. The optimal portfolio is constructed by 10 stocks of LQ45 indices. The portfolio has the expected return amount of 0.394% per day with the risk of 1.173%. The proportion of portfolio is constructed by each stocks portion is:

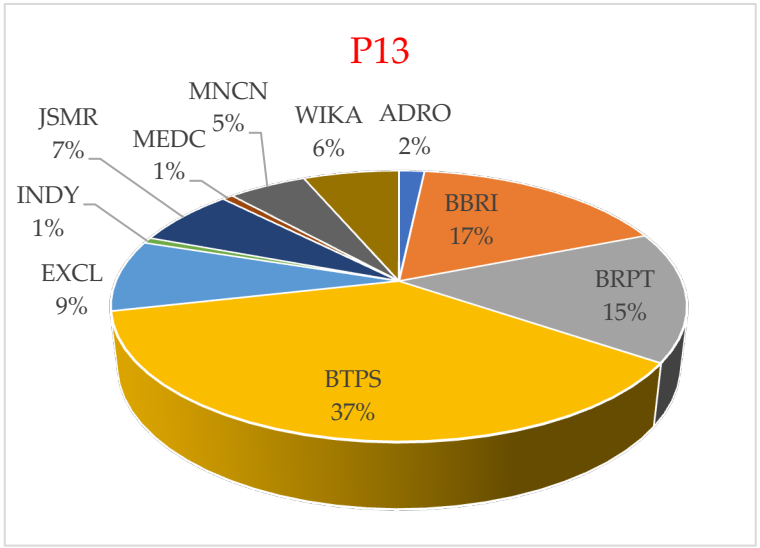


Figure 1.4. Proportion of Optimal Portfolio using Single Index Model
Source: Processed Data by Solver, 2020

The alternative of investment can be set based on the proportion of risk-free portfolio with the optimal portfolio. The combinations are shown in Table 1.2.

**Table 1.2. Simulation of Optimal Portfolio and Risk-free Asset**

| Set | Proportion | | Portfolio | |
|---|---|---|---|---|
| | P13 | PRf | Return | Risk |
| S1 | 0% | 100% | 0.016% | 0.000% |
| S2 | 5% | 95% | 0.035% | 0.059% |
| S3 | 10% | 90% | 0.054% | 0.117% |
| S4 | 15% | 85% | 0.073% | 0.176% |
| S5 | 20% | 80% | 0.092% | 0.235% |
| S6 | 25% | 75% | 0.110% | 0.293% |
| S7 | 30% | 70% | 0.129% | 0.352% |
| S8 | 35% | 65% | 0.148% | 0.411% |
| S9 | 40% | 60% | 0.167% | 0.469% |
| S10 | 45% | 55% | 0.186% | 0.528% |
| S11 | 50% | 50% | 0.205% | 0.586% |
| S12 | 55% | 45% | 0.224% | 0.645% |
| S13 | 60% | 40% | 0.243% | 0.704% |
| S14 | 65% | 35% | 0.262% | 0.762% |
| S15 | 70% | 30% | 0.281% | 0.821% |
| S16 | 75% | 25% | 0.300% | 0.880% |
| S17 | 80% | 20% | 0.318% | 0.938% |
| S18 | 85% | 15% | 0.337% | 0.997% |
| S19 | 90% | 10% | 0.356% | 1.056% |
| S20 | 95% | 5% | 0.375% | 1.114% |
| S21 | 100% | 0% | 0.394% | 1.173% |

Source: Data Processed by Microsoft Excel, 2020

The performance of optimal portfolio from both models are evaluated using three methods and the results of parametric t-test is shown on the table.

**Table 1.3. Performance Evaluation**

| | Sharpe Ratio | | Treynor Ratio | | Alpha Jensen | |
|---|---|---|---|---|---|---|
| | MM | SIM | MM | SIM | MM | SIM |
| Average | 0.11381 | 0.11247 | 0.00169 | 0.00153 | 0.00192 | 0.00183 |
| df | 252 | | 250 | | 250 | |
| $\alpha$ | 5% | | 5% | | 5% | |
| t-Stat | 0.010643 | | 0.090364 | | 0.058623 | |
| t-table | +/-1.650923 | | +/-1.650971 | | +/-1.650971 | |
| Result | $H_o$ is accepted | | $H_o$ is accepted | | $H_o$ is accepted | |

Sourced: Data Processed, 2020

A parametric (t-test) two-tailed are used to test the hypothesis. If t-table < t-stat < t-table then $H_o$ is accepted and $H_a$ is rejected. Contrarily, if t-table > t-stat > t-table then $H_a$ is accepted and $H_o$ is rejected. The test at level of significance $\alpha = 5\%$ and $df = 252$. The result is t-stat is equal to

0.010643 and t-table value that is equal to +/-1.650923 which is in acceptance area (t-table < t-stat < t-table), therefore, $H_o$ is accepted. It means there is no significance differences of optimal portfolio performance form both models measured by Sharpe ratio.

Then, The test at level of significance $\alpha = 5\%$ and $df = 250$. The result is t-stat is equal to 0.090364 and t-table is equal to +/-1.650971 which is in acceptance are (t-table < t-stat < t-table), therefore, $H_o$ is accepted. It means there is no significance differences of optimal portfolio performance form both models measured by Treynor ratio. The same result for Jensen's alpha measurement with level of significance $\alpha = 5\%$ and $df = 250$. The result is t-value equal to 0.058623 and t-table value that is equal to +/-1.650971 which is t-table < t-stat < t-table, therefore, $H_o$ is accepted. It means there is no significance differences of optimal portfolio performance form both models measured by Jensen's alpha.

## CONCLUSION AND DISCUSSION

### Discussion

Markowitz Model constructed optimal portfolio with 10 out of 45 stocks from LQ45 indices has the expected return of 0.405% per day with the risk of 1.1980%. Then, Single Index Model constructed optimal portfolio with 10 out of 45 stocks from LQ45 indices has the expected return of 0.394% per day with the risk of 1.173%. Three measurement tools which are Sharpe ratio, Treynor ratio, and Jensen's Alpha statistically show that there is no significance difference of portfolio performance either using Markowitz Model or using Single Index Model.

For further research, considered investors preference to invest on the alternative portfolio that can be determined by calculation. Then, using other financial instrument to diversified the portfolio rather than using stocks market only. The performance evaluation measurement tools also can be added to compare the result with more measurement tools.

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