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The Implementation of Roy's Safety-First Criterion in Stock Portfolio Selection

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Abstract

Statistical data shows that the Indonesian capital market has experienced significant growth. This growth is attributed to public awareness of the benefits of stock investments. However, with an increasing number of new investors entering the stock market, attention to investment risks deepens. Many investors prefer stocks that are easily predictable and have low risk, as higher volatility increases the level of uncertainty in obtaining returns. The relatively high risk level in investing requires investors to minimize risks, one of which is by diversifying funds into various investment assets, commonly known as optimal portfolio selection. An optimal portfolio can be formed using various methods and approaches. One method for portfolio selection is the application of the Safety First Criterion, a method dependent on downside risk, referring to risks that result in losses. This article conducts a simulation of the implementation of Roy's Safety First Criterion using stock data from the largest companies in eleven sectors over the past year. These sectors include basic materials, communication services, consumer cyclical, consumer defensive, energy, financial services, healthcare, real estate, technology, and utilities. Based on this analysis, out of the eleven stocks, six stocks meet Roy's criteria: LIN, GOOG, AMZN, BRK-B, LLY, and AAPL, with respective weights of LIN=10.84%, GOOG=12.61%, AMZN=24.67%, BRK-B=1.37%, LLY=34.17%, and AAPL=16.35%. Using Roy's Safety First Criterion for selected stocks from various sectors indicates that the resulting portfolio has a very low risk level, specifically 1%. This means that by using the portfolio obtained from the eleven stocks, investors can achieve minimal risk, making this portfolio secure for new investors.

Keywords: Portfolio Optimization, Safety First Method, Roy's Criterion, Stock Investment

1. Introduction

In recent years, the Indonesian capital market has experienced remarkable growth, as reflected in the statistical data provided by PT. Kustodian Sentral Efek Indonesia (KSEI). In 2021 alone, the number of new stock investors surged significantly, increasing by 103.60% (Siegel, 2021). This growth aligns with the rising awareness of the benefits of stock investment among the public. However, with the increasing influx of new investors into the stock market, attention to investment risks has deepened. Many investors prefer stocks that are easy to predict and have lower risks because higher volatility implies greater uncertainty in achieving returns. Therefore, investors require information regarding stock price developments to make informed investment decisions in the capital market (Kawaguchi et al., 2017). The relatively high level of risk in investing necessitates that investors minimize such risks. One approach is by diversifying funds across various investment assets (Manurung, 2024), commonly referred to as optimal portfolio selection.

An optimal portfolio can be constructed using various methods and approaches. One method for portfolio selection involves applying the Safety First Criterion, a technique that relies on downside risk or fluctuations associated with losses. Downside risk refers to the risk that leads to financial losses. Furthermore, the portfolio formation process can be enhanced by adopting more objective criteria in line with the defined objectives (Francis & Kim, 2013).The most suitable Safety First criterion for calculating stock portfolios is Roy's First Criterion (de Haan et al., 1994).

Roy's Safety-First Criterion is a method that has evolved within portfolio theory. This method was developed by Roy (Roy, 1952), focusing on capital protection rather than seeking high returns as an alternative to conventional approaches in risk management and investment (Ball & Brown, 2012). The selection of Roy's Safety-First Criterion for this research is based on its alignment with the goals of investment risk and a conservative approach. This method is chosen because it is considered more suitable for addressing market risk and stock price fluctuations, which are the main challenges in stock portfolio management.

De Haan et al (1994) discusses the comparison of three criteria in the Safety First method for stock selection in portfolio determination (De Haan et al ,1994). Based on the existing criteria, namely Roy, Kataoka, and Telser criteria, Roy's criterion is considered the best in portfolio determination due to its low-risk value.

Therefore, this research will focus on the application of Roy's Safety-First Criterion method in stock portfolio selection. The selected stocks come from various sectors, ranging from basic materials, Communication Services, Consumer Cyclical, Consumer Defensive, Energy, Financial Services, Healthcare, Property Industry, Technology, to utility services sector.

2. Materials and Methods

2.1. Materials

This study utilizes secondary data obtained from the Yahoo Finance website. The data used consists of daily Close Stock prices from December 5, 2022, to December 4, 2023. The stock data employed in the study is sourced from the largest companies in various sectors, including basic materials, Communication Services, Consumer Cyclical, Consumer Defensive, Energy, Financial Services, Healthcare, Property Industry, Technology, and utility services sector.

2.2. Method

Roy's criterion emphasizes the restriction of low return levels, wherein the optimal portfolio is considered as a portfolio with a probability of returns below a certain minimum threshold. This is expressed by minimizing $\Pr(r_i < r_L)$, where r_i represents the stock return and r_L is the return threshold set by the investor. The construction of an optimal portfolio is achieved through the analysis of stocks, which includes the identification of actual and expected returns from each stock, along with the assessment of their risks (De Haan et al, 1994).

Formula to determine the stock return level:

$$r_{i,t} = \ln \frac{P_t}{P_{t-1}}, \quad t = 1,2,\dots,n \tag{1}$$

Then, the Expected Return is calculated using the formula:

$$E(r_i) = \frac{1}{T}\sum_{t=1}^{T} r_{i,t} \ , \ t = 1,2,\dots,n \tag{2}$$

where,

$E(r_i)$: The Expected Return for stock i.

r_i : The return rate of stock i in period t.

P_t : Stock price in period t.

T : Number of daily stock data.

Then, the risk of the stock can be determined as follows:

$$\sigma_i^2 = \sum_{t=1}^{T} \left[r_{i,t} - E(r_i)\right]^2$$

$$= \sqrt{\sum_{t=1}^{T} \left[r_{i,t} - E(r_i)\right]^2} \tag{3}$$

with σ_i representing the standard deviation or risk of stock i.

Furthermore, the expected return of the portfolio can be determined using the formula:

$$E(r_p) = E\left(\sum_{i=1}^{n} w_i r_i\right)$$

$$= \sum_{t=1}^{n} w_i E(r_i)$$

Portfolio risk can be determined as follows:

$$\sigma_p = \sqrt{\sum_{i=1}^{n} w_i^2 \sigma_i^2 + \sum_{i=1}^{n} \sum_{\substack{j=1 \\ i \neq j}}^{n} w_i w_j \sigma_{ij} \sigma_p}$$

or,

$$\sigma_p^2 \ = \boldsymbol{w}^T \times Cov \times \boldsymbol{w} \tag{4}$$

Where,

σ_p : Portfolio risk.

σ_i^2 : Variance of stock i

σ_{ij} : Covariance of stock i and j,

w_i : Weight of stock i

Then, stock selection is carried out to determine the optimal portfolio using Roy's Safety First Criterion.

$$Roy's\ ratio = \left[\frac{E(r_i) - r_L}{\sigma_i}\right] \tag{5}$$

3. Results

The stock data used includes stocks from various sectors. Detailed information about the stocks used is provided in Table 1.

Table 1: The stock data used

No.	Sektor	Code	Name
1	Basic Materials	LIN	Linde plc
2	Communication Services	GOOG	Alphabet Inc.
3	Consumer Cyclical	AMZN	Amazon.com, Inc.
4	Consumer Defensive	WMT	Walmart Inc
5	Energy	XOM	Exxon Mobil Corporation
6	Financial Services	BRK-B	Berkshire Hathaway Inc
7	Healthcare	LLY	Eli Lilly and Company
8	Industrials	UNP	Union Pacific Corporation
9	Real Estate	PLD	Prologis, Inc
10	Technology	AAPL	Appel Inc.
11	Utilities	NEE	NextEra Energy, Inc.

The stock return value can be calculated using equation (1) for 252 closing stock prices of the 11 stocks used. A calculation simulation is performed for LIN stock in the period $t = 2$:

$$r_{LIN,2} = \ln \frac{P_2}{P_{2-1}}$$
$$= \ln \frac{337.35}{337.26} = 0.00027$$

Using the same method, the return for each stock can be calculated for all time periods t.

Then, the expected return values for all stocks are calculated using equation (2). A calculation simulation is carried out for LIN stock.

$$E(r_{LIN}) = \frac{1}{250} \sum_{t=2}^{250} r_{LIN,t}$$
$$= \frac{1}{250} (r_{LIN,2} + r_{LIN,3} + \cdots + r_{LIN,251})$$
$$= \frac{1}{250} (0.00027 + (-0.0092) + \cdots + 0.00558)$$
$$= 0.00082$$

The same way is applied to obtain the expected return values for all stocks. The results are obtained in Table 2.

Tabel 2. Expected return values for stocks

Saham	$E(r_i)$	Saham	$E(r_i)$
LIN	0.00082	LLY	0.00187
GOOG	0.00107	UNP	0.00041
AMZN	0.00170	PLD	-0.00007
WMT	0.00007	AAPL	0.00102
XOM	-0.00017	NEE	-0.00149
BRK-B	0.00055	Rata-rata	0.00053

In Table 2, it can be observed that the stock with the highest expected return is LLY (Healthcare) with an expected return value of 0.00187. It is also noted that three stocks, namely XOM (Energy), PLD (Real Estate), and NEE (Utilities), have negative expected return values. The stock with the lowest expected return is NEE with a value of -0.00149. Next, the standard deviation or risk of the selected stocks can be calculated using equation (3). A calculation simulation is performed using LIN stock data, resulting in:

$$\sigma_{LIN} = \sqrt{\sum_{t=1}^{T}\left[r_{LIN,t} - E(r_{LIN})\right]^2}$$

$$= \sqrt{\left[r_{LIN,2} - E(r_{LIN})\right]^2 + \cdots + \left[r_{LIN,250} - E(r_{LIN})\right]^2}$$

$$= \sqrt{[0.00027 - 0.00082]^2 + \cdots + [0.00576 - 0.00082]^2}$$

$$= 0.19127$$

The same way is applied to calculate the risk of all selected stocks, resulting in the risk values for each stock in Table 3.

Table 3. Stock risk values

Saham	σ_i	Saham	σ_i
LIN	0.191335	LLY	0.279825
GOOG	0.308901	UNP	0.232879
AMZN	0.33866	PLD	0.257571
WMT	0.159858	AAPL	0.216742
XOM	0.253075	NEE	0.278587
BRK-B	0.140883		

Based on Table 3, it can be observed that BRK-B (Financial Services) has the smallest risk level among the eleven stock data used, with a risk level of 14.09%. On the other hand, AMZN (Consumer Cyclical) has the highest risk level at 33.87%. Following Roy's criterion, which emphasizes the restriction of low return levels, where the optimal portfolio is considered as a portfolio with the probability of returns below a certain minimum threshold, expressed by minimizing $Pr(r_i < r_L)$, the calculation can be done using equation (5). A calculation simulation is performed for LIN stock by setting an acceptable return threshold value at 0.00053.

$$Roy's\ ratio = \left[\frac{E(r_{LIN}) - r_L}{\sigma_{LIN}}\right] = \left[\frac{0.00082 - 0.00053}{0.19133}\right] = 0.00152$$

The same way is applied to calculate the Roy's criterion for other stocks, resulting in the sorted values of Roy's criterion, indicating the most optimal based on this criterion, as shown in Table 4.

Tabel 4. Nilai Roy's Safety First Ratio

Stock	$Ratio$	Stock	$Ratio$
LIN	0.001523	LLY	0.004801
GOOG	0.001773	UNP	-0.0005
AMZN	0.003466	PLD	-0.00233
WMT	-0.00286	AAPL	0.002298
XOM	-0.00275	NEE	-0.00722
BRK-B	0.000192		

Based on Table 4, it can be observed that five stocks have negative ratios. This implies that these stocks are not considered safe for investment. Therefore, in stock portfolio selection, it is recommended to focus on stocks with positive ratios. In this case, the selected stocks with positive ratios are LIN (Basic Materials), GOOG (Communication Services), AMZN (Consumer Cyclical), BRK-B (Financial Services), LLY (Healthcare), and AAPL (Technology). The selected stocks are presented in Table 5.

Tabel 5. Selected stocks based on the ratio

Stock	$Ratio$
LIN	0.001523
GOOG	0.001773
AMZN	0.003466
BRK-B	0.000192
LLY	0.004801
AAPL	0.002298

In determining the portfolio weights based on Roy's Safety-First criterion

$$w_{LIN} = \left[\frac{Ratio_{LIN}}{\sum Ratio}\right]$$

$$w_{LIN} = \left[\frac{0.00152}{0.01405}\right] = 0.10837 = 10.84\%$$

Using the same method, weights for other stocks are obtained, as presented in Table 6.

Tabel 6. Weight of stock (w_i)

Stock	w_i

LIN	10.84%
GOOG	12.61%
AMZN	24.67%
BRK-B	1.37%
LLY	34.17%
AAPL	16.35%
Total weights	100.00%

Based on Table 6, it can be observed that the largest weight allocation is given to LLY stock with a weight of 34.17%. This is because LLY has the highest expected return among the stocks, despite having a relatively high risk level of 27.98%. On the other hand, the smallest weight is assigned to BRK-B stock with a weight of 1.37%. Although BRK-B has the lowest risk level among all stocks at 14.09%, it also has the smallest expected return of 0.05.%.

Next, the portfolio risk level obtained in Table 6 will be calculated using equation (4) with the covariance values of the stock data.

$$covarian = \begin{vmatrix} 0.000146 & -1.2E\text{-}05 & 7.85E\text{-}05 & 9.51E\text{-}06 & 1.95E\text{-}05 & -2E\text{-}07 \\ -1.2E\text{-}05 & 0.000382 & -1.8E\text{-}05 & 6.54E\text{-}05 & 7.71E\text{-}06 & 0.00015 \\ 7.85E\text{-}05 & -1.8E\text{-}05 & 0.000459 & 1.18E\text{-}06 & 3.94E\text{-}05 & -1.8E\text{-}05 \\ 9.51E\text{-}06 & 6.54E\text{-}05 & 1.18E\text{-}06 & 7.94E\text{-}05 & -3.7E\text{-}06 & 5.6E\text{-}05 \\ 1.95E\text{-}05 & 7.71E\text{-}06 & 3.94E\text{-}05 & -3.7E\text{-}06 & 0.000313 & 2.76E\text{-}06 \\ -2E\text{-}07 & 0.00015 & -1.8E\text{-}05 & 5.6E\text{-}05 & 2.76E\text{-}06 & 0.000188 \end{vmatrix}$$

Therefore, the value of the portfolio risk level is

$$\sigma_p^2 = w_i^T \times Cov \times w_i$$

$$\sigma_p^2 = w_1^2\sigma_1^2 + w_2^2\sigma_2^2 + w_3^2\sigma_3^2 + w_4^2\sigma_4^2 + w_5^2\sigma_5^2 + w_6^2\sigma_6^2 + 2w_1w_2\sigma_{12} + 2w_1w_3\sigma_{13} + 2w_1w_4\sigma_{14} + 2w_1w_5\sigma_{15} + 2w_1w_6\sigma_{16} + 2w_2w_3\sigma_{23} + 2w_2w_4\sigma_{24} + 2w_2w_5\sigma_{25} + 2w_2w_6\sigma_{26} + 2w_3w_4\sigma_{34} + 2w_3w_5\sigma_{35} + 2w_3w_6\sigma_{36} + 2w_4w_5\sigma_{45} + 2w_4w_6\sigma_{46} + 2w_5w_6\sigma_{56}$$

$$= 0.00009$$

$$\sigma_p = \sqrt{0.00009} = 0.00971 \approx 1\%$$

The portfolio risk level determined using Roy's Safety-First criterion is 1%, indicating that the likelihood of facing risk is very low when using the obtained portfolio.

4. Conclusion

Roy's Safety-First criterion emphasizes the restriction of low return levels, where the optimal portfolio is considered as a portfolio with the probability of returns below a certain minimum threshold, expressed by minimizing $Pr(r_i < r_L)$, where r_i represents the stock return, and r_L is the return threshold set by the investor. In this case, the value of r_L is 0.00053. Based on this criterion, out of the eleven stocks, six stocks meet the Roy's criteria, namely LIN, GOOG, AMZN, BRK-B, LLY, and AAPL, with weights of LIN=10.84%, GOOG=12.61%, AMZN=24.67%, BRK-B=1.37%, LLY=34.17%, and AAPL=16.35%.

By using the Safety-First method, specifically Roy's criterion, for several stocks from various sectors, the obtained portfolio demonstrates a very low risk level of 1%. This implies that utilizing the portfolio for the 11 selected stocks would result in minimal risk, making it a safe option for new investors.

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