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Optimizing Green Investment Portfolios Using the Markowitz Model for Sustainable Financial and Social Returns

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Abstract

Purpose: This research aims to create an optimal portfolio that is not only profitable from a financial perspective, but also considers the concept of natural and social environmental sustainability (green investment).
Research Methodology: The chosen research approach was quantitative, with an analysis based on the Markowitz Model. The Markowitz Model was used to construct a stock portfolio from stocks included in the SRI-Kehati index during the period of 2020-2023. The collected data were then analyzed using the Solver Add-ins in Microsoft Excel.
Results: The study findings indicated that out of the 12 stocks tested, four stocks were ideal to include in the optimal portfolio, consisting of BBCA (with a weight of 37.59%), KLBF (with a weight of 30.44%), SIDO (with a weight of 21.67%), and TLKM (with a weight of 10.30%).
Conclusions: Sustainable or green investment is increasingly important, and the Markowitz Model can be applied to optimize portfolios of sustainable stocks, as shown in this study where four stocks (BBCA, KLBF, SIDO, and TLKM) formed an optimal portfolio with an expected return of 0.00522211 and a risk of 0.0391.
Limitations: This study relies on historical data and monthly closing stock prices, which may not accurately predict future returns. Future research could incorporate daily prices, macroeconomic factors, market sentiment, and external variables such as global news to improve portfolio optimization and accuracy.
Contributions: This study integrates the Markowitz model with green investment strategies, providing a practical approach to constructing an optimal portfolio that considers both financial returns and ESG criteria.

Keywords: *Green Investment, Markowitz Model, Optimal Portofolio, SRI-Kehati Index*

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1. Introduction

In recent years, the trend of eco-friendly products has increased and has become a major concern (Pangkong et al., 2020). Consumers currently prefer products that are free from environmental issues (Chao, 2018), such as US climate change and pollution, and tend to choose companies that have reduced their carbon footprint in their production processes (Anggraini, 2021a, 2021b; Page & Panariello, 2018). The reason for this trend is because sustainable products are considered a way to minimizes the negative

impacts of human activities on the environment (Han, 2021; Pangkong et al., 2020).

Second, consumer awareness of the use of hazardous chemicals and toxins in many conventional products is increasing (Alamsyah & Muhammed, 2018; Aprillita & Perkasa, 2021; Leković, 2018). Furthermore, the trend of using eco-friendly products is becoming increasingly popular because consumers are starting to realize the long-term benefits of making environmentally conscious choices (Abdullah, 2021; Alamsyah & Muhammed, 2018; Aprillita & Perkasa, 2021). By choosing eco-friendly products, consumers can reduce their environmental impact and save money in the long run. For example, energy-efficient appliances can help lower utility bills, and organic products can improve health and reduce the risk of pesticide exposure.

Similar to consumption trends, in investment activities, there is also a trend of increasing investor awareness to choose to invest their capital in issuers with a positive reputation (Cunha et al., 2021; Satria, 2021; Solihin, 2021). Climate change, depletion of natural resources, and pollution are causing significant damage to the earth, and increasing awareness of society to take action to address these issues is one of the highest factors causing investment in green companies (Alamsyah & Muhammed, 2018; Fathihani, 2021; Fathihani & Nasution, 2021). By investing in companies committed to reducing their carbon footprints, conserving resources, and promoting renewable energy, individuals can play a role in contribute to a more sustainable future. Moreover, some invest in companies that prioritize sustainability, which is related to the potential for financial gain. Ikhsani et al. (2021), Rizqi and Sakinah (2021), and Sulastri et al. (2016) states that companies with strong environmental, social, and governance (ESG) practices tend to outperform their competitors financially over the long term. This is because sustainable practices can result in cost savings, increased efficiency, and improved brand reputation, all of which can result in a competitive advantage and increased profitability for companies (Gómez-Bezares et al., 2017; Satria, 2021; Wardhani & Ully, 2021).

In addition, as consumer preferences shift toward more environmentally friendly products and services, companies that fail to adapt to sustainable practices risk losing market share and facing reputational damage (Abdullah, 2021; Ayuningtyas & Ilman, 2021; Husnan, 2001). By investing in companies that align with changing consumer preferences and sustainable trends, investors can position themselves to gain more benefits from the opportunities presented by existing trends. However, the next question that arises is "what are the best considerations needed in choosing sustainable investments?". This question arises as a result of the fact that companies that prioritize the concept of sustainability cannot always maintain their financial performance well. In other words, investors cannot only consider the concept of sustainability carried out by a company; they also need to consider the sustainability of the benefits of the investment itself. This is because one of the main goals of an investor is to obtain profits and control rights over the company from the investment mechanism (Al-Haddad & Whittington, 2019; Luong & Ha, 2011; Santos et al., 2019). For this purpose, investments are made to obtain income or income from each share they invest in the company, which is referred to as dividends (Leković, 2018; Solihin, 2021).

However, economic reality will always be related to returns and risk (Leković, 2018). In other words, profits obtained from dividends or capital gains may be accompanied by the risk of losses. Based on this assumption, every investor needs to be rational by estimating the future, analyzing the most potential investments, and estimating the risks while trying to identify certain investment alternatives. This is referred to as US investment diversification, which is a strategy for managing risk and maximizing potential profits in an investment portfolio (Sulastri et al., 2016). Investment diversification refers to dividing investments into different types of assets, sectors, or geographic regions to reduce the negative impact of market fluctuations on the overall value of the portfolio (Leković, 2018). In other words, diversification aims to not put all "potential eggs" in one basket. This strategy is based on the principle that different assets do not always move in the same direction at the same time, so that the bad movement

of one asset can be offset by the positive performance of another asset (Page & Panariello, 2018). In short, this strategy aims to reduce the specific risks associated with a single investment. This risk, often referred to as US idiosyncratic or unique risk, arises from factors that only affect one company or sector (Liu & Wang, 2021). For example, if an investor only invests in the shares of one technology company and that company experiences a decline in performance, the entire investment portfolio could be affected. By diversifying investments into sectors such as energy, healthcare, and finance, and various types of assets such as stocks, bonds, and real estate, the risks faced are more spread out and not concentrated in one point.

However, it is important to note that diversification is not an absolute guarantee against losses. Although this strategy can reduce risk, no investment method is completely risk-free. Diversification can only reduce certain risks and help manage risk more effectively; it cannot eliminate all possible losses (Chao, 2018; Setyawati & Aristiyanto, 2021). Therefore, investors must remain wise in choosing assets and continue to monitor and adjust their portfolios according to changes in market conditions and their investment objectives. One way to build an optimal investment portfolio is using the Markowitz model developed by Harry Markowitz in 1952 (Berlian Rms & Wahyuningsih, 2021; Hanif et al., 2021; Saputra & Kusnadi, 2021). This model emerged as an improvement on the efficient portfolio, which only considers the higher rate of return compared to other portfolios with the same level of risk or provides the smallest risk with the same expected rate of return (Halim, 2015; Syahrial & Sudono, 2021; Wahyuningsih et al., 2021). The optimal portfolio also considers risk preferences and investment returns that match investors. In other words, an efficient portfolio is not always an optimal portfolio, whereas an optimal portfolio is definitely an efficient portfolio.

In determining the optimal portfolio, there is an assumption that all investors are "risk-averse," or prefer lower returns with minimal risk, compared to high returns with uncertain risk. This study was conducted to determine the optimal portfolio that investors can choose for companies that prioritize sustainability (Heriyanto, 2021; Kuncoro & Harahap, 2021). This study can make it easier for investors to choose decisions and determine a green portfolio that is considered efficient and optimal, namely, with a certain expected return with the lowest risk. The green portfolio in this study refers to investments created by issuers that have been proven to contribute to the development of the environment, society, and the economy of the community. Thus, the companies selected as data in this study refer to various companies included in the SRI-Kehati index, which is one of the stock market indices in Indonesia designed to measure the performance of stocks that meet the criteria for sustainability and corporate social responsibility (Keke et al., 2021; Targanski & Murhadi, 2021). This index was launched in 2009 by the Kehati Foundation (Indonesian Biodiversity Foundation), a non-governmental institution that focuses on biodiversity conservation and sustainable development in Indonesia (Agusinta et al., 2021; Ricardianto et al., 2021; Zulkafli et al., 2017).

The gap in this research lies in the fact that the Markowitz model used in previous studies only assumes that returns and risks can be measured by a normal distribution, where investors behave rationally. However, the researchers assumed that the distribution of market returns may not be normal, and that investors often exhibit behavior that is not entirely rational or that there are certain emotional considerations. In other words, in addition to including complex return distributions, human behavioral factors, such as US investor preferences, need to be discussed. Moreover, based on the researchers' scientific research, few studies have used the Markowitz Model and integrated it with social and environmental factors to form an optimal portfolio. Thus, the novelty of this study is related to the fact that although there have been many studies that review the use of the Markowitz model in forming an optimal investment portfolio, previous studies only considered aspects of liquidity and company financial performance. While in this study, the Markowitz model also considers the selection of companies that has credibility in terms of the Environment, Social, and Governance (ESG) Index, so that it is in accordance

with investor preferences that prioritize investments that are not only sustainable in terms of finance, but also contribute to nature and society.

2. Literature Review

2.1 Sustainable and Green Investment

Sustainable investment, often referred to as green investment, has emerged as a crucial aspect of modern finance. With growing concerns over climate change and social responsibility, investors are increasingly focused on not only financial returns but also the environmental, social, and governance (ESG) performance of companies (Falcone, 2020). Green investments aim to support companies that prioritize sustainability, reduce carbon emissions, and contribute positively to social welfare (Gómez-Bezares et al., 2017). Research has shown that sustainable investments can outperform traditional investments over time due to the long-term benefits of reducing environmental risks and enhancing brand reputation (Cunha et al., 2021).

2.2 The Markowitz Model and Portfolio Optimization

The Markowitz Model, developed by Harry Markowitz in 1952, revolutionized portfolio management by introducing the concept of diversification to reduce risk and maximize returns (Pistorius, 2017; Zaimovic et al., 2021). This model emphasizes constructing a portfolio by considering the correlation between asset returns and their individual risks, rather than selecting stocks based solely on their individual performance. The model assumes that investors are risk-averse, seeking the highest return for a given level of risk Halim, 2015. Markowitz's approach has since been extended and applied to various contexts, including green investments, to balance financial goals with sustainability considerations Hanif et al., 2021.

2.3 The Role of ESG Criteria in Investment Decisions

Environmental, social, and governance (ESG) criteria are increasingly influencing investment decisions. Companies with strong ESG practices are seen as more likely to perform well financially due to increased operational efficiency, lower regulatory risks, and improved stakeholder relations (Leković, 2018). Research on socially responsible investing (SRI) has shown that investors who incorporate ESG factors into their portfolios may achieve long-term financial success while also contributing to sustainable development (Folqué et al., 2021; Schoenmaker & Schramade, 2019; Sciarelli et al., 2021). The SRI-Kehati index in Indonesia, for example, includes companies that meet sustainability and corporate social responsibility criteria, offering a platform for investors interested in aligning their financial goals with environmental and social responsibility Susanto et al., 2021; Targanski and Murhadi, 2021.

2.4 Limitations of the Markowitz Model in Sustainable Investment

While the Markowitz Model has been widely applied in portfolio optimization, its use in sustainable investing has limitations (Setyawati et al., 2021; Susanto & Parmenas, 2021). The model typically relies on historical data to estimate returns and risks, which may not accurately predict future performance, particularly in rapidly changing sectors such as green technology (Husnan, 2001; Parmenas, 2021). Moreover, the model assumes a normal distribution of returns, which may not hold true in markets where returns are affected by unpredictable factors like environmental policies or market sentiment. Future research should focus on integrating the Markowitz Model with other methods that account for non-normal distributions and incorporate ESG-specific factors to improve the accuracy and relevance of green investment portfolios (**nnij** ; Sumaryadi & Kusnadi, 2021).

2.5 Combining the Markowitz Model with Green Investment Strategies

Recent studies have explored combining the Markowitz Model with green investment strategies to create optimal portfolios that align financial goals with sustainability. By incorporating ESG criteria into portfolio optimization, investors can achieve financial returns while supporting companies committed to environmental and social responsibility (Chatzitheodorou et al., 2019; Prijono et al., 2021; Saputra & Kusnadi, 2021; Shabbir & Wisdom, 2020). This approach has gained traction in the context of indices like the SRI-Kehati index, which provides a benchmark for socially responsible investments in Indonesia. The use of the Markowitz Model in sustainable investing helps identify optimal stock combinations that maximize returns while minimizing the environmental and social risks associated with investments (Suyanto et al., 2021; Targanski & Murhadi, 2021).

3. Methodology

This study used a quantitative approach with secondary data obtained from the Indonesia Stock Exchange (IDX). The data used are a list of closing stock prices from issuers included in the SRI-Kehati index. The inclusion criteria were as follows: a) issuers or companies listed on the IDX during the 2020-2023 period; b) issuers are consecutively listed as companies in the SRI Kehati index during the 2020-2023 period; c) issuers have attributable dividend profits and do not conduct stock splits during the 2020-2023 period; and d) companies present dividend and stock value data consecutively during the 2020-2023 period. Of the 25 companies listed in the SRI-Kehati index in 2023, 10 do not meet the second criterion because they are not consecutively listed in the SRI-Kehati index during the study period, and 3 them do not meet the third criterion because they have negative profits; therefore, they do not have attributable dividend profits during the study period (Hanif et al., 2021; Liu & Wang, 2021; Luong & Ha, 2011). Thus, the total number of companies used in this study was 12, consisting of Astra International Tbk (ASII), Bank Central Asia Tbk (BBCA), Bank Negara Indonesia (Persero) Tbk (BBNI), Bank Rakyat Indonesia (Persero) Tbk (BBRI), Mandiri Bank (Limited) Tbk (BMRI), Indofood Success Prosperous Tbk (INDF), Kalbe Pharmacy Tbk (KLBF), Sido Herbal Medicine and Pharmaceutical Industry Tbk (SIDO), Semen Indonesia (Persero) Tbk (SMGR), Telekomunikasi Indonesia (Persero) Tbk (TLKM), United Tractors Tbk (UNTR), and Unilever Indonesia Tbk (UNVR). The collected data were then analyzed using the Markowitz Model with the help of Microsoft Excel, with the stages described as follows.

1. The return of each stock is calculated using the following formula:

$$R_{it} = \frac{P_t - P_{t-1} + D_t}{P_{t-1}} \tag{1}$$

Informations:

R_{it} = Return at expected time
P_{t-1} = Stock price at the beginning of the period
P_t = Stock price at the end of the period
D_t = Dividends distributed

Source: Hartono (2013)

2. The expected return on each company's shares is calculated using the following formula:

$$E(R_i) = \sum_{j=1}^{n} P_j \times R_{ij} \tag{2}$$

Informations:

$$E(R_i) = \text{Expected return of the issuer at time i}$$
$$n = \text{Number of possible returns}$$
$$P_j = \text{Probability of return occurrence at time j for issuer i}$$

Source: Hartono (2013)

3. The risk (variance and standard deviation) for $n < 30$ was calculated using the following formula:

$$\sigma^2 = \frac{\sum_{j=1}^{n} P_j(R_{ij} - E(R_i))^2}{n-1} \tag{3}$$

$$\sigma = \sqrt{\frac{\sum_{j=1}^{n} P_j(R_{ij} - E(R_i))^2}{n-1}} \tag{4}$$

Informations:

$$\sigma^2 = \text{Variance of return}$$
$$\sigma = \text{Standard deviation or risk}$$
$$R_{ij} = \text{Return at time j for issuer i}$$
$$n = \text{Number of possible returns}$$

Source: Husnan (2001)

4. The correlation coefficient of stock prices between companies is calculated using the following formula:

$$(R_A B) = \frac{\sigma_{AB}}{\sigma_A x \sigma_A} \tag{5}$$

5. The covariance between two stocks in a portfolio is calculated using the following formula:

$$\text{Cov}(R_A, R_B) = \sigma_{R_A, R_B} \tag{6}$$

$$\sigma_{RA.RB} = \sum_{i=1}^{n} ((R_{Ai} - E(R_A)) \cdot (R_{Bi} - E(R_B)) \tag{7}$$

Informations:

- $\text{Cov}(R_A, R_B)$ = Covariance of stock A with stock B
- R_{Ai} = Future return of stock A at time condition i
- R_{Bi} = Future return of stock B at time condition i
- $E(R_A)$ = Expected return of stock A
- $E(R_B)$ = Expected return of stock B

Source: Hartono (2013)

6. Microsoft Excel Solver was used to minimize the ratios and optimize the stock proportions.
7. Determining optimal portfolio investment decision-making.
8. Calculating the expected return of the optimal portfolio:

$$E(R_p) = \sum_{i=1}^{n} X_i \times E(R_i) \tag{8}$$

Informations:

- $E(R_p)$ = Expected return of portfolio
- $E(R_i)$ = Expected return of stock i
- X_i = Proportion of funds invested in stock i

Source: Husnan (2001)

9. Calculate the risk (variance and standard deviation) of the optimal portfolio.

$$\sigma_p^2 = X_A^2 \cdot \sigma_A^2 + X_B^2 \cdot \sigma_B^2 + 2X_A X_B \sigma_{AB} \tag{9}$$

If expressed US a standard deviation, then portfolio risk can be expressed using the followingformula:

$$\sigma_p = \sqrt{X_A^2 \cdot \sigma_A^2 + X_B^2 \cdot \sigma_B^2 + 2X_A X_B \sigma_{AB}} \tag{10}$$

Informations:

- σ_p^2 = Variance of portfolio
- σ_p = Standard deviation or risk of portfolio
- σ_A^2 = Variance of stock A
- σ_B^2 = Variance of stock B
- σ_{AB} = Covariance between return of stock A and return of stock B
- X_A = Proportion of funds invested in stock A
- X_B = Proportion of funds invested in stock B

Source: Hartono (2013)

In general, this research consists of a flow that is described as follows.

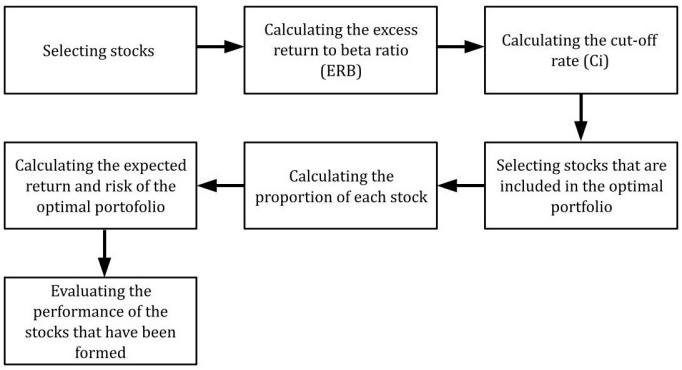

Figure 1. Research flow

Based on Figure 1, the process begins with selecting stocks and calculating the excess return to beta ratio (ERB) to assess risk-adjusted returns. Next, the cut-off rate (Ci) is determined to identify the optimal stocks for the portfolio. Afterward, the expected return and risk of the portfolio are calculated, followed by determining the proportion of each stock in the portfolio. Finally, the performance of the selected stocks is evaluated to ensure the portfolio's effectiveness in achieving the desired financial g

4. Results and Discussion

4.1 Results

The data used in this study are the closing price data of shares of companies included in the SRI-Kehati index in 2020-2023, which are presented in the following figure.

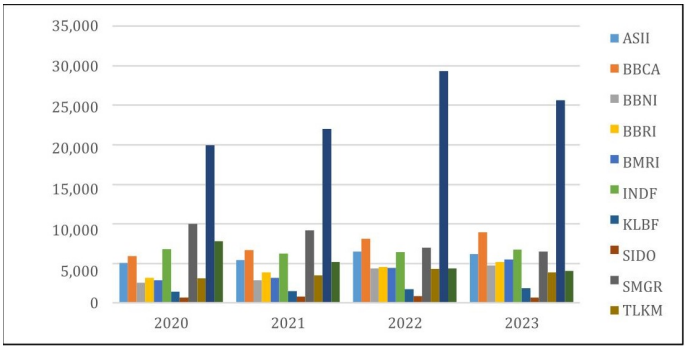

Figure 2. Average Shares of Sample Companies

Based on Figure 2, it can be said that all companies have closing stock prices that always change from year to year. All companies have an average (mean) closing price that fluctuates, and there is no pattern of always going up or down during the period 2020–2023. Overall, for the research period from 2020 to 2023, UNTR had the highest mean closing price compared to other sample companies, with the highest mean closing price obtained in 2022.

The expected return level for each share is presented in the following table.

Table 1. Expected Return of Each Stock

Company	Expected Return or E (Ri)
ASII	0.204%
BBCA	0.950%
BBNI	1.590%
BBRI	1.096%
BMRI	1.418%
INDF	**- 0.222**
KLBF	0.413
SIDO	0.033
SMGR	**- 0.728**
TLKM	0.312
UNTR	0.914
UNVR	**- 1,470**

Based on Table 1, the expected return level is the average return for each stock from 2020 to 2023. Stocks with an expected return with a positive sign indicate that the stock can provide benefits to its shareholders. INDF, SMGR, and UNVR in Table 1 are known to have expected returns with a negative sign, indicating a loss to shareholders. Thus, in the next stage, INDF, SMGR, and UNVR will be eliminated because they cannot be used to form an optimal portfolio.

Table 2. Individual Stock Risk

Company	Risk
ASII	9.547%
BBCA	5.607%
BBNI	11.540%
BBRI	8.394%
BMRI	8.699%
KLBF	5,800
SIDO	7.633
TLKM	6.930
UNTR	10.903

Based on Table 2, after eliminating the negative expected stock returns, the next step was to calculate the investment risk for each stock. The common method for calculating risk in stocks is standard deviation or denoted as σ_i which assesses the absolute deviation of the realized return with its expected returns. Return and risk in stocks have a correlation that is in the same direction, positive, or directly proportional. In the sense that an investment with a high rate of return also has the possibility of a high risk. Table 2 shows that the highest risk (standard deviation) is obtained for BBNI shares, at 11,540%. The lowest standard deviation was in BBCA at 5.607%. The higher the standard deviation, the greater the deviation between the actual and expected returns. Therefore, investors are advised to choose stocks with the lowest investment standards among several other stocks when forming a portfolio.

Furthermore, it is very important in the concept of portfolio optimization to consider the correlation coefficient between issuers, where Markowitz suggested that forming a portfolio of stocks with less than perfect positive coefficients results in a better level of diversification. Therefore, the covariance must be calculated first, and the results of the covariance calculation in this study are presented in the following

table.

Table 3. Variance-Covariance Matrix between Stocks

	ASII	**BBCA**	**BBNI**	**BBRI**	**BMRI**	**KLBF**	**SIDO**	**TLKM**	**UNTR**
ASII	0.009114	0.003119	0.004640	0.003946	0.005418	0.001124	-16	0.001466	0.002773
BBCA	0.003119	0.003143	0.003921	0.003137	0.003542	0.000604	0.000021	0.001657	0.002230
BBNI	0.004640	0.003921	0.013317	0.006730	0.007394	0.000020	0.000000	0.004374	0.002201
BBRI	0.003946	0.003137	0.007030	0.007445	0.004793	0.000737	0.000032	0.002818	0.001867
BMRI	0.005418	0.003542	0.007394	0.004793	0.007567	0.001242	0.000019	0.003228	0.002424
KLBF	0.001124	0.000604	0.001720	0.000637	0.001242	0.003364	0.000080	0.001086	0.002421
SIDO	0.000016	0.000021	0.000000	0.000032	0.000019	0.000080	0.000326	0.000386	0.000394
TLKM	0.001466	0.001657	0.004374	0.003218	0.001928	0.000086	0.000386	0.004803	0.002239
UNTR	0.002773	0.002230	0.004301	0.002867	0.002424	0.002421	0.002494	0.002239	0.011887

Based on Table 3, covariance indicates whether the assets in a portfolio move in the same direction as the market. A positive covariance indicates that the assets generally move in the same direction, whereas a negative covariance indicates that the movement between assets is not in the same direction. For example, the covariance between ASII and SIDO has a negative sign (i.e., -0.000016), which indicates the opposite movement of the stock. The covariance between ASII and BBCA has a positive sign (i.e., 0.003119), which means that the stock moves in the same direction. In the table, it is known that the highest covariance is in BBNI with BMRI, which is 0.003542, both of which are in the same sector (finance). The lowest covariance is in BBCA with SIDO, which is -0.000021, both of which are in different sectors (finance and health). In building a portfolio, it is important to select assets that have negative or low covariance between one another so that the overall risk can be suppressed.

However, covariance can only be used to measure the direction between two stocks being compared, not to indicate the strength of the relationship between one asset and another. Therefore, a correlation coefficient is also required for portfolio diversification. It is important to consider the correlation between the expected returns and expected volatility between investments or stocks when forming a portfolio. The correlation was calculated on a scale of -1.0 to 1.0. A correlation value of 1.0 indicates that one stock has a highly related return to the other. For example, if an asset has a correlation of 1.0 with another asset, the profit from each asset is 50% in the proportion of the two assets. Likewise, if a loss occurs, both assets experience losses in the same proportion. In short, the higher the correlation value between assets, the less likely the diversification in the portfolio. Thus, it is important for investors to consistently look for asset columns with low correlation values or close to zero to limit risk. In this study, the correlation coefficient matrix is presented as follows:

Table 4. Correlation Coefficient Matrix Between Stocks

	ASII	BBCA	BBNI	BBRI	BMRI	KLBF	SIDO	TLKM	UNTR
ASII	1.000000	0.753265	0.443250	0.591091	0.774675	-0.179524	-0.520823	0.062931	0.063871
BBCA	0.753265	1.000000	0.752323	0.864915	0.921418	-70.308795	-0.617155	0.437216	0.133652
BBNI	0.443250	0.752323	1.000000	0.857898	0.837758	-0.081646	-0.148863	0.624070	-0.196883
BBRI	0.591091	0.864915	0.857898	1.000000	0.850468	-0.304382	-0.416790	0.563734	-0.118860
BMRI	0.774675	0.921418	0.837758	0.850468	1.000000	-0.133917	-0.464435	0.354922	-0.041350
KLBF	-0.179524	-0.308795	-0.081646	-0.304382	-0.133917	1.000000	-0.083707	-0.091249	-0.032525
SIDO	-0.520823	-0.617155	-0.148863	-0.416790	-0.564435	-0.083707	1.000000	-0.332474	-0.300043
TLKM	0.062931	0.437216	0.624070	0.563734	0.354922	-0.091249	0-0.332474	1.000000	0.081331
UNTR	0.063871	0.133652	-0.196883	-0.118860	-0.041350	-0.032525	-0.300043	0.081331	1.000000

Table 4 shows that each column has a negative and positive correlation coefficient. This means that there is a possibility of optimizing expected returns at a certain risk level with a combination of tested stocks. A negative correlation coefficient indicates that the tendency to lose value at the same time can be suppressed.

In determining the expected return and portfolio risk, the first step was to determine the proportion or weight of each stock. The proportion of stocks is determined by finding the stock variance using the MMULT function in Microsoft Excel, so that the Variance and Weight of each stock are obtained as follows:

Table 5. Variance and Weight of Portfolio

Stocks	Variance 1 (V1)	Variance 2 (V2)	Weight 1 (W1)	Weight 2 (W2)
ASII	-15.84368855	-1.971433227	-0.002639519	-0.665791632
BBCA	327.5615362	2.567623528	0.419060332	0.867136779
BBNI	-173.7215605	0.179950326	-0.222247751	0.060772751
BBRI	48.72454965	0.536522006	0.062334932	0.181193995
BMRI	61.15158074	1.57780736	0.078233244	0.532856463
KLBF	216.8482673	0.87041125	0.277421177	0.293954935
SIDO	186.674237	-0.09181083	0.238818582	-0.031006316
TLKM	150.4840381	-1.136207558	0.192519218	-0.383719557
UNTR	-20.22176714	0.428173502	-0.025870377	0.144602582

Based on Table 5, the Variance and Weight of Portfolio for each stock is presented, with two different variance values (V1 and V2) and their corresponding weights (W1 and W2). The table includes key stocks like ASII, BBCA, BBNI, BBRI, BMRI, KLBF, SIDO, TLKM, and UNTR, with their respective variances and portfolio weights. The variance values are calculated for each stock, reflecting their respective risk levels, while the weights represent the proportion of each stock in the portfolio. These weights and variances are critical for determining the optimal portfolio that aligns with specific risk and return objectives.

The next step was to calculate the expected return and risk of the portfolio with the alpha that was determined as follows:

Alpha	Weights of Each Stocks									Expected Return of Portfolio	Variance of Portfolio	Risk
	ASII	BBCA	BBNI	BBRI	BMRI	KLBF	SIDO	TLKM	UNTR			
0.1	-0.6012	0.8223	0.0325	0.1693	0.4874	0.2923	-0.0040	-0.3261	0.1276	0.0172	0.0054	0.0732
0.2	-0.5367	0.7775	0.0042	0.1574	0.4419	0.2906	0.0230	-0.2685	0.1105	0.0157	0.0045	0.0671
0.3	-0.4721	0.7327	-0.0241	0.1455	0.3965	0.2890	0.0499	-0.2108	0.0935	0.0142	0.0037	0.0612
0.4	-0.4076	0.6879	-0.0524	0.1337	0.3510	0.2873	0.0769	-0.1532	0.0764	0.0127	0.0031	0.0556
0.5	-0.3430	0.6431	-0.0807	0.1218	0.3055	0.2857	0.1039	-0.0956	0.0594	0.0113	0.0025	0.0504
0.6	-0.2785	0.5983	-0.1090	0.1099	0.2601	0.2840	0.1309	-0.0380	0.0423	0.0098	0.0021	0.0457
0.7	-0.2139	0.5535	-0.1373	0.0980	0.2146	0.2824	0.1579	0.0196	0.0253	0.0083	0.0017	0.0416
0.8	-0.1494	0.5087	-0.1656	0.0861	0.1692	0.2807	0.1849	0.0773	0.0082	0.0068	0.0015	0.0385
0.9	-0.0848	0.4639	-0.1939	0.0742	0.1237	0.2791	0.2118	0.1349	-0.0088	0.0053	0.0013	0.0365

Figure 3. Risk and Expected Return of All Formed Portfolios

Based on the Figure 3, the smallest risk is obtained at alpha 0.9, with a risk of 0.0365 and an expected return of 0.0053. This risk is not a weighted average of each stock's risk in the portfolio but rather the risk of the portfolio as a whole.

Table 6. Proportion of Stocks in an Optimal Portfolio

Company	Proportion		Expected Return of Portfolio	Risk
ASII	0.0000	0.00%	0.00522211	0.0391
BBCA	0.3759	37.59%		
BBNI	0.0000	0.00%		
BBRI	0.0000	0.00%		
BMRI	0.0000	0.00%		
KLBF	0.3044	30.44%		
SIDO	0.2167	21.67%		
TLKM	0.1030	10.30%		
UNTR	0.0000	0.00%		
Total	1.0000	100.00%	0.00522211	0.0391

Table 6 shows the proportion of each stock in the portfolio. Of the 12 stocks tested, four stocks are optimally combined in the portfolio. The four stocks, sorted from the highest to the lowest proportion, include:

- BBCA (Financial Sector), has a proportion of shares in the portfolio of 37.59%
- KLBF (Health Sector), has a proportion of shares in the portfolio of 30.44%
- SIDO (Health Sector), has a proportion of shares in the portfolio of 21.67%
- TLKM (Technology Sector), has a proportion of shares in the portfolio of 10.33%

This confirmed that the highest proportion in the portfolio was in BBCA shares, and the lowest proportion was in TLKM shares. The return for each share in the portfolio is as follows:

Table 7. Return of Each Stock in the Optimal Portfolio

Company	Proportion	E(Ri)	Expected Return of Portfolio
BBCA	37.59%	0.009498	0.00357081
KLBF	30.44%	0.004135	0.00125852
SIDO	21.67%	0.000332	0.00007186
TLKM	10.30%	0.003117	0.00032092
Total			**0.00522211**

Based on Table 7, the return of each stock in the optimal portfolio is shown. The highest proportion of shares in the portfolio is held by BBCA (37.59%), followed by KLBF (30.44%), SIDO (21.67%), and TLKM (10.33%). The expected return of each stock in the portfolio is also displayed, with BBCA having the highest expected return of 0.00357081, while TLKM has the lowest expected return of 0.00032092. The total expected return of the portfolio is 0.00522211. This confirms that BBCA holds the highest proportion, while TLKM has the lowest, contributing to the overall portfolio performance.

4.2 Discussion

Before the publication of Markowitz's article "Portfolio Selection" in 1952, investors only made asset selections by estimating their returns and risks from individual stocks and then selecting the stocks that were considered most profitable to combine and form a portfolio. The investment decision process was based only on selecting issuers with higher returns or lower risks and, therefore, forming a portfolio with weights consistent with the estimated returns and risks. In contrast, Markowitz dealt with portfolio formation based on overall returns and risks, which is called portfolio diversification, meaning that portfolios are selected in aggregate rather than selecting each separate security based on a specific evaluation of its risk and return. In detail, the expected return of the portfolio (E[rp]) can be considered US a measure of the return of this investment, and so the standard deviation of the portfolio (p) can be obtained to measure the risk of investment. The significance of this theory comes from the idea of diversification put forward by Markowitz, because it draws attention to the fact that considering the covariance between portfolio assets can be an important factor in estimating the overall risk of the portfolio, and then the selection decision itself. In this study, the covariance between each stock in the portfolio was also used to determine the optimal portfolio (Koumou, 2020).

In this study, each asset or stock in the portfolio has its own positive and negative covariance with a particular stock. Covariance indicates whether the assets in a portfolio move in the same direction. Covariance with a positive sign indicates that the assets generally move in the same direction, while covariance with a negative sign indicates that the movement between assets is not in the same direction. In building a portfolio, it is important to select assets that have negative covariance with each other so that the overall risk can be suppressed. After determining the covariance, the researchers calculated the optimal portfolio value by determining the weight or proportion of each stock (Kaczmarek et al., 2020; Zhang et al., 2018).

In this study, the lowest risk level was at alpha 0.9, with a risk of 0.0365 and an expected return of 0.0053. Thus, the optimal portfolio was at the lowest risk level of 3.65% with an expected portfolio return of 0.53%, because, as previously explained, the optimal portfolio can be determined by setting the lowest investment risk level and with a certain return level (due to the assumption that investors are risk averse). The next step was to optimize the portfolio using Solver in Microsoft Excel to minimize the risk. By using Solver in Microsoft Excel, a new proportion was obtained, which is considered US the most optimal, consisting of BBCA (37.59%), KLBF (30.44%), SIDO (21.67%), and TLKM (10.30%) with a new risk of the portfolio of 0.0391 and an expected return of 0.00522211.

5. Conclusions

Sustainable or green investment has become an increasingly important topic in today's global context as awareness of climate change, environmental sustainability, and social responsibility increases. The Markowitz Model, known as the modern portfolio theory, offers a mathematical method for optimizing investment portfolios to maximize returns while minimizing risk. When applied to sustainable stocks, the Markowitz Model can help investors design portfolios that are not only financially profitable but also contribute to sustainability goals. For example, in this study, the Markowitz Model is used to determine the optimal portfolio of stocks included in the SRI-Kehati index in Indonesia for the period 2020 to 2023. Using Solver in Microsoft Excel, the research findings showed that there are four stocks that are ideal to be included in the optimal portfolio, consisting of BBCA (37.59%), KLBF (30.44%), SIDO (21.67%), and TLKM (10.30%). Of the four stocks, the expected return that may be obtained from the investment portfolio is 0.00522211, and the stock portfolio risk is 0.0391.

Although this research was completed well, the researchers also realized that there are several limitations that may be improved in future research. First, this study used the Markowitz model, where parameter estimates such as expected return, variance, and covariance are based on historical data that may not be accurate for future projections. Moreover, the researchers used data in the form of monthly closing prices with fluctuations that are often not patterned and did not use daily closing price data. Thus, future research should focus on better estimation methods or data smoothing techniques to improve the accuracy of parameter estimates and their impact on optimal portfolios. In addition, research using the Markowitz model does not consider external factors such as US macroeconomics, global news, or market sentiment that can affect stock returns. Therefore, future researchers are advised to explore the integration of the Markowitz Model with other models such as US multifactor or news-based models, to improve accuracy and relevance in a broader market context. Also, the Markowitz Model needs to be done by calculating covariance and variance for many stocks so that it requires accurate data and sophisticated mathematical techniques, which can be complicated for inexperienced investors. Thus, future researchers can use other techniques that are considered accurate but at the same time considered easier to use as references by investors and practitioners.

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Author Contributions

MMH conceptualized the research, conducted the data analysis, and wrote the manuscript. N provided assistance with the literature review, contributed to the methodology, and revised the manuscript. JS supervised the study, contributed to the theoretical framework, and reviewed the manuscript.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this study. This research was conducted independently, and no financial or personal relationships influenced the results or interpretation of the findings.

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