



Food Sector Stock Investment Portfolio Optimization using Mean-Expected Shortfall Model with Particle Swarm Optimization

Carlos Naek Tua Tampubolon^{1*}, Betty Subartini², Sukono³

^{1,2,3}*Department of Mathematics, Faculty of Mathematics and Natural Sciences, Universitas Padjadjaran*

**Corresponding author email: carlos19002@mail.unpad.ac.id*

Abstract

One of the most promising investment products is stocks. Stocks have great profit potential, but the risks associated with this investment should not be ignored by investors. Therefore, an optimal investment strategy is needed by forming an investment portfolio, in order to minimize risk and maximize profits that can be obtained. This study aims to optimize the investment portfolio. The method used in this research is based on the Mean-Expected Shortfall (Mean-ES) model. The use of this method is expected that investors can get a more accurate picture of the level of risk associated with their stock portfolio. In addition, Particle Swarm Optimization (PSO) can also be used to optimize the allocation of funds in a stock portfolio. Applying PSO, investors can find the optimal combination of fund allocation to achieve a high level of return. Based on the results of the analysis conducted on the following five stocks AALI, BISI, DSNG, LSIP and SMAR, the results show a risk level of 0.0014 and a return level of 0.021%. Thus, investors can form a stock portfolio that has a high potential return, while minimizing the risks associated with stock investment. The implementation of this optimal investment strategy can assist investors in achieving their financial goals in a more effective manner. Considering the potential returns and risks involved, investors can make wiser investment decisions and optimize the performance of their stock portfolio.

Keywords: Investment, Risk, Optimization, Expected Shortfall, Particle Swarm Optimization, Return

1. Introduction

Investment is the commitment of funds or other resources with the aim of obtaining future profits, and can be made in real assets (such as gold, land, automotive, and buildings) as well as financial assets (such as stocks, bonds, and securities) (Embrechts, 1999).

Investment decisions are based on expected return, risk level, and the relationship between return and risk. Investors invest to make a profit and demand a certain rate of return to compensate for the opportunity costs and risks resulting from inflation (Goetzmann, 2014).

The Mean-Expected Shortfall (MES) model is used to measure and minimize risk. MES is an expected measure of risk above Value-at-Risk (VaR), which is the maximum loss at a given confidence level. PSO is an optimization algorithm used to find optimal solutions by considering the Mean-ES model as a function of goals.

In this study, the Mean-ES model was used to determine the optimal stock portfolio of several large companies by using Particle Swarm Optimization (PSO). The Mean-ES model was chosen because it can calculate average losses above VaR and is a coherent measure of risk, so it is used as a tool to calculate portfolio risk. The use of PSO in this model helps investors in making better investment decisions and minimizing potential losses.

2. Literature Review

2.1. Investment and Stocks

Investment is a delay in current consumption with the aim of being put into productive assets over a certain period of time. One form of investment is shares, the stock price reflects the value that other parties are willing to pay to

have a share of ownership in a company. Stock prices are volatile even in a short time due to the influence of demand and supply from buyers and sellers of shares (Platon, 2014).

2.2. Portfolio Theory

A portfolio is a collection of investment instruments formed to meet a general investment goal, if an investor wishes to maximize the expected return from the portfolio, then the funds should be placed in securities that have the expectation of maximum profit (Markowitz, 1952).

Stock return is the profit earned from an investment. The calculation of return itself can be calculated using the following equation:

$$R_{i,t} = \frac{P_{i,t} - P_{i,t-1}}{P_{i,t-1}}, \quad (1)$$

With expected stock returns calculated using the following equation:

$$E(R) = \sum_{i=1}^n \frac{R_{i,t}}{n}, \quad (2)$$

where:

$R_{i,t}$: stock return i in the period t

$P_{i,t}$: stock price i in the period t

$P_{i,t-1}$: stock price i in the period $t - 1$.

In the process of calculating portfolio returns, some things that need to be considered are the proportion of each stock and the return of the stock. Total proportion of shares ($w_i = 1 \dots n$). In a portfolio it is equal to one, or if it is written mathematically like the following equation:

$$\sum_{i=1}^n w_i = 1. \quad (3)$$

The portfolio return is like the following equation:

$$R_p = \sum_{i=1}^n w_i R_i \quad (4)$$

Apart from calculating the proportion of each share, calculating the expected return is also needed as a marker of the weighted average level of profit expected from each share in the portfolio. The expected return calculation is carried out using the following equation:

$$\bar{R}_p = E[R_p] = \sum_{i=1}^n w_i \bar{R}_i \quad (5)$$

where

w_i : proporsi saham i

$E[R_p]$: expected return portofolio

\bar{R}_i : rata – rata return saham i .

To calculate risk when investing in shares, the following equation is used:

a. Variance

$$\sigma^2 = \sum_{i=1}^n \frac{[R_i - E(R)]^2}{n-1}, \quad (6)$$

b. Covariance

$$\sigma_{AB} = \sum_{i=1}^n \frac{[(R_{A,i} - E(R_A)) \cdot (R_{B,i} - E(R_B))]}{n-1}, \quad (7)$$

with:

R_i : stock return to- i

$E(R)$: expected stock return

2.3. Mean-Expected Shortfall Model

Expected Shortfall is the expected value of the return, if the return exceeds the maximum return limit (Value-at-Risk). The Mean-ES model is defined as optimal portfolio formation which can be achieved by minimizing the risk value, while Mean-ES can be achieved by minimizing the risk value (Thomas, 2007). The Mean-ES model can be written mathematically as the following equation:

$$\sigma_w^2 = \frac{1}{N} \sum_i w_i^2 - 1, \quad (8)$$

then equation (8) is formed with the aim of minimizing the equation by adding equality conditions to the objective function, so the equation is as follows:

$$\text{Minimum } \sigma_p^2 = \sum_{i=1}^n \sum_{j=1}^n w_i w_j \sigma_{ij}, \quad (9)$$

with

$$\begin{aligned} \frac{1}{N} \sum_i w_i^2 - 1 &\geq 0, \\ \sum_{i=1}^n w_i &= 1 \end{aligned} \quad (10)$$

or:

Minimum

$$\begin{aligned} \sigma_p^2 &= \begin{pmatrix} w_1 \\ w_2 \\ \vdots \\ w_n \end{pmatrix}^T \begin{pmatrix} \sigma_1^2 & \sigma_{12} & \dots & \sigma_{1n} \\ \sigma_{21} & \sigma_2^2 & \dots & \sigma_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \sigma_{n1} & \sigma_{n2} & \dots & \sigma_n^2 \end{pmatrix} \begin{pmatrix} w_1 \\ w_2 \\ \vdots \\ w_n \end{pmatrix} \\ &= \begin{pmatrix} w_1^2 \sigma_1^2 & w_1 w_2 \sigma_{12} & \dots & w_1 w_n \sigma_{1n} \\ w_2 w_1 \sigma_{21} & w_2^2 \sigma_2^2 & \dots & w_2 w_n \sigma_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ w_n w_1 \sigma_{n1} & w_n w_2 \sigma_{n2} & \dots & w_n^2 \sigma_n^2 \end{pmatrix} = \mathbf{w}^T \mathbf{V} \mathbf{w}, \end{aligned} \quad (11)$$

with:

- w_i : Stock weight in the portfolio
- \mathbf{w} : Stock weight matrix in the portfolio
- \mathbf{w}^T : Transpose matrix \mathbf{w}
- \mathbf{V} : Portfolio Variance and Covariance Matrix
- $\mathbf{1}$: Unit vector with dimensions $n \times 1$

2.4. Particle Swarm Optimization

Particle Swarm Optimization (PSO) is a method inspired by the natural properties of a group of animals such as birds, termites, bees or ants. PSO imitates the natural characteristics of several organisms, which consist of habits carried out in daily activities and also the influence of one individual on other individuals in a population (Cholissodin, 2016).

The PSO method is initialized with a group of random particles and then looks for the optimal solution by updating its generations. At each iteration, each particle is updated following the two “best” values. The first is the best solution that the particles have reached. This value is then stored and referred to as pbest. The second best value sought in the PSO algorithm is the best value obtained by any particle in the population. This best value is the global best and is called gbest. After finding the two best values, the particle will update its speed and position as follows:

- a. Update particle speed

$$v_{k+1}^i = w v_k^i + c_1 r_1 (p_k^i - x_k^i) + c_2 r_2 (p_k^g - x_k^i) \quad (12)$$

- b. Update the particle position

$$x_{k+1}^i = x_k^i + v_{k+1}^i \quad (13)$$

Two random variables r_1 and r_2 produce random numbers with a range between 0 and 1. The values r_1 and r_2 are adjusted to the constants c_1 and c_2 which have a value range between $0 < c_1, c_2 \leq 2$. This constant is called the acceleration coefficient which affects the maximum range that a particle can take in an iteration. It can be seen from the speed update equation that c_2 regulates the maximum distance influenced by the particle's global best, and c_1 regulates the distance influenced by the personal best position of the particle.

3. Materials and Methods

This research will be carried out using the Mean-ES model to determine optimal portfolio diversification.

The following are the steps in the research:

- a. Research planning

This stage is the first step, at this stage it explains the outline of the research, the topic of the research problem, as well as the benefits and objectives of the research

- b. Data pre-processing
Then, after data collection, data preprocessing is carried out to detect missing data and prepare data that can be processed properly, referring to subsection 2.3.1.
- c. Calculate the return value, variance, covariance of each portfolio
Then calculate the rate of return for each stock using equation (2.1), then calculate the expected return and risk using equations (2.2) and (2.6), after that calculate the expected return value of the portfolio and the correlation of each portfolio using equation (2.5) and (2.7).
- d. Initialize the Particle Swarm Optimization component
At this stage, the components contained in equation (2.18) are determined, such as inertial weight, cognitive weight and social weight.
- e. Particle Swarm Optimization Algorithm
Then a search for optimal fund allocation is carried out according to the PSO algorithm until the specified maximum iteration has been reached with the constraint function according to the Mean-ES model, referring to subsection 2.4 in equation (2.18).
- f. Extraction of optimal solutions
After the PSO algorithm has reached the maximum iteration limit that has been determined, the optimal solution (global best) is obtained from each iteration along with the risk and rate of return. The next step is to extract the optimal solution from the algorithm results that have been obtained, namely shrimp paste which has the lowest return value or high return rate.
- g. Form an optimal portfolio
This stage is the formation of an optimal portfolio based on the Mean-ES model and has also been optimized using the PSO method

4. Results and Discussion

4.1. Research Data

This research uses closing stock price data from 5 food sector stocks selected based on their large market capitalization level and low Debt to Equity Ratio (DER). There are 1998 of each stock with a time span of 7 years. Data from each share is processed into Google Collaborator. Table 1 shows data on market capitalization values (in Rupiah) and DER of the five selected companies. The result can show in the Table 1.

Table 1: Market Capitalization and DER

No	Stock Code	Market Capitalization (Jt)	DER
1	AALI	14,771,996	30.60%
2	BISI	4,950,004	9.50%
3	DSNG	5,998,887	78.30%
4	LSIP	7,024,558	13.10%
5	SMAR	13,528,015	51.30%

4.2. Data Processing

The stock closing price value data is then processed using the Mean-ES Model, to determine the daily return, expected return and risk of each stock. Results of daily return calculations from five companies in the period January 2015–January 2023 using equation (1), following are excerpts of return calculations in Table 2.

Table 2: Calculations of daily return

Date	AALI	BISI	Return DSNG	LSIP	SMAR
1/5/2015	0.00406	0	0	0.01303	-0.14403
1/6/2015	-0.01531	0.01556	-0.01273	-0.01566	-0.03584
1/7/2015	0.01632	-0.00904	0.02531	0.00786	0.06362
1/8/2015	0.02103	0.00647	-0.00626	0.05337	0
⋮	⋮	⋮	⋮	⋮	⋮
12/26/2022	0.00312	0.00816	-0.00313	0.00491	-0.01612
12/27/2022	0.00623	-0.00816	-0.01584	0.00975	0
12/28/2022	-0.00623	-0.00823	0.00636	-0.00486	0.02607
12/29/2022	0.00312	-0.00829	0.00947	-0.00980	-0.02404
12/30/2022	0	0	0.00626	0	0.00404

Then calculate the expected return for each stock. The calculation results are as Table 3.

Table 3: The expected return for each stock

No	Stock Code	Return Expectations	Risk
1	AALI	0.00053597	0.000556
2	BISI	0.000121593	0.000705
3	DSNG	0.005916397	0.000557
4	LSIP	-0.00031511	0.000679
5	SMAR	0.004301216	0.000645

After the expected return is obtained, the variance and covariance of each stock return are calculated. The calculation results are as Table 4.

Table 4: Variance and Covariance of each stock return

Stock Code	AALI	BISI	DSNG	LSIP	SMAR
AALI	0.00056	0.00009	0.00017	0.00044	0.00006
BISI	0.00009	0.00057	0.00006	0.00006	0.00003
DSNG	0.00017	0.00006	0.00072	0.00018	0.00004
LSIP	0.00044	0.00006	0.00018	0.0006	0.00006
SMAR	0.00006	0.00003	0.00004	0.00006	0.00065

4.3. PSO Algorithm

After the PSO algorithm is carried out, the next step is to take the optimal portfolio solution from the global best particles obtained at the previous point. The global best particle is the particle in the PSO population that has the highest fitness value, which reflects a portfolio with optimal asset allocation based on the specified optimization criteria. After reaching the maximum iteration, the optimal solution was obtained from the search that had been carried out with the following allocation: AALI 15.3%; SMAR 29.4%; LSIP 18.2%; DSNG 10.3%; BISI 26.6% with a risk level of 1.44% with an expected return of 0.0021%.

5. Conclusion

Based on the discussion carried out in Chapter 4, it can be concluded that the optimal portfolio resulting from the application of the Mean-ES model and PSO optimization is able to reduce risk significantly and is in accordance with investor preferences which prioritize risk reduction and capital preservation. The optimization results of the Mean-ES model using Particle Swarm Optimization (PSO) produce optimal allocations in the food sector stock portfolio. The optimal allocation for each stock is as follows: AALI at 15.3%, SMAR at 29.4%, LSIP at 18.2%, DSNG at 10.3%, and BISI at 26.6%.

References

- Cholissodin, I. (2016). *Buku Ajar Swarm Intelligence Deep Intelligent Agriculture View project Deep Intelligent Robotic System View project*. <https://www.researchgate.net/publication/317706705>
- Embrechts, P., Resnick, S. I., & Samorodnitsky, G. (1999). Extreme Value Theory as a Risk Management Tool. *North American Actuarial Journal*, 3(2), 30–41. <https://doi.org/10.1080/10920277.1999.10595797>
- Goetzmann, W. N., Brown, S. J., Gruber, M. J., & Elton, E. J. (2014). Modern portfolio theory and investment analysis. *John Wiley & Sons*, 237.
- Platon, V., & Constantinescu, A. (2014). Monte Carlo Method in risk analysis for investment projects. *Procedia Economics and Finance*, 15, 393-400.
- Thomas, S., Repetto, R., & Dias, D. (2007). Integrated environmental and financial performance metrics for investment analysis and portfolio management. *Corporate Governance: An International Review*, 15(3), 421-426.