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Forming An Optimal Portfolio by Applying the Data Envelopment Analysis (DEA) Approach Based on The Single Index Model

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Abstract. The study aims to determine the optimal portfolio formation using the Data Envelopment Analysis (DEA) approach based on the Single Index Model. The significance of this research lies in providing investors with an effective tool for maximizing returns while minimizing risk through portfolio diversification. The DEA method is applied to measure the efficiency of selected stocks listed on the Indonesian Stock Exchange between 2020 and 2023. By utilizing technical efficiency, the study evaluates stocks to identify efficient Decision-Making Units (DMUs) for portfolio candidates. The Single Index Model, developed by William Sharpe, is used to calculate expected returns and associated risks. The research uses purposive sampling, focusing on companies in the industrial sector. Monthly stock prices, dividends, and macroeconomic data such as the Indonesian Stock Exchange Index (IHSG) and Bank Indonesia Certificate (SBI) interest rates serve as inputs. Using DEA-CCR and DEA-BCC models, efficient stocks are selected based on efficiency scores. The results highlight 11 stocks as optimal portfolio candidates, including Astra International (ASII) and Perma Plasindo (BINO). The portfolio provides an expected monthly return of 0.0211213 with a standard deviation of 0.026621, indicating potential outperformance relative to the market index.

Keywords: Optimal Portfolio, Data Envelopment Analysis, Single Index Model

INTRODUCTION

Optimal Portfolio, Data Envelopment Analysis, Single Index Model Investment is the activity of allocating funds or assets into various financial instruments, properties, or businesses to generate future returns. Investors, particularly in the Indonesian capital market, pursue a variety of goals when making investments [1]. These goals include capital growth, where investors aim for their investments to increase in value over time, thus building long-term wealth. Additionally, investors seek regular income through dividends from stocks or interest from bonds. Beyond financial gains, investment also serves as a means to hedge against inflation [2], as expected returns from investments often outpace or at least match inflation rates. Furthermore, [3], lowers the potential for substantial losses from market volatility.

Diversification has become a fundamental strategy in investment, reducing asset-specific risks and enhancing profit opportunities [4]. It allows investors to balance losses in one asset class with gains in another, thereby protecting their portfolios. Investors are also able to capitalize on different phases of the economic cycle, with certain asset classes performing better during different economic conditions. This further underscores the need for a well-diversified portfolio that can mitigate risk while maintaining the potential for returns [5].

However, investment decisions are primarily influenced by two key aspects: return and risk. [6]. A higher return is generally desirable, but it must be weighed against

the associated risks. Rational investors aim to construct optimal portfolios that strike the right balance between expected return and acceptable risk levels, allowing them to meet their long-term investment objectives in a stable and calculated manner [7].

The challenge, however, lies in determining which portfolio configuration is best, given the vast array of available investment options. This leads to the question: which portfolio should an investor choose to achieve the best balance of risk and return? [8], who proposed the idea of an efficient portfolio that maximizes return for a given level of risk, or minimizes risk for a given return. His model, known as the mean-variance efficient frontier, laid the foundation for modern financial theory [9].

To enhance the selection process for efficient stocks in portfolio formation, techniques such as Data Envelopment Analysis (DEA) have been employed to compare the efficiency of various assets by considering their inputs and outputs [10]. Furthermore, the Single Index Model developed by William Sharpe adds another dimension to portfolio optimization

METHODS

The optimal portfolio is a portfolio selected by investors from a set of efficient portfolios, based on their preferences regarding risk and expected return. An efficient portfolio is determined by its ability to provide higher returns at the same level of risk or to offer lower risk at the same return [6]. In stock investments, returns can consist of dividends and capital gains, while risk is calculated through variance or standard deviation [11]. Risk is divided into two categories: systematic risk, influenced by market factors and cannot be eliminated through diversification, and unsystematic risk, which can be mitigated through diversification [12].

The Single Index Model, developed by William Sharpe, simplifies the analysis of portfolio return and risk by linking stock returns with the market index[13]. Additionally, the Data Envelopment Analysis (DEA) method is used to measure the relative efficiency of a portfolio by comparing output (expected return) against input (risk level) [14]. The DEA model measures technical efficiency using various versions, such as DEA-CCR, which assumes constant returns to scale, and DEA-BCC, which considers variable returns to scale [15].

This study uses a sample of industrial sector companies listed on the Indonesia Stock Exchange (IDX) from 2020 to 2023. Purposive sampling is employed to select companies with complete data related to stock prices, dividends, the IDX Composite Index (IHSG), Bank Indonesia Certificate (SBI) interest rates, and annual financial reports[16]. The input-output variables analyzed include standard deviation, beta, DER, EPS, return, BV, PBV, ROE, ROA, PER, and NPM, with standard deviation, beta, DER, and PER as input variables, and the rest as output variables[17]. The steps taken include calculating return, risk, beta coefficient, and various other financial ratios to determine the technical efficiency and scale of stocks using the DEA-CCR and DEA-BCC models with the aid of LINGO 11.0 software[18].

After identifying efficient stocks, the optimal portfolio is constructed using the Single Index Model. Excess return to beta (ERB) is calculated as the difference between expected return and risk-free return, followed by the calculation of the cut-off rate (Ci) to determine which stocks will be included in the optimal portfolio[8], [19]. The proportion of funds for each stock in the portfolio is calculated based on the level of risk, and the

portfolio's risk and expected return are then calculated to assess the overall performance of the constructed portfolio[20].

RESULTS AND DISCUSSION

Determination of Stocks as Portfolio Candidates through the Decision-Making Units (DMU) Efficiency Approach Based on the Single Index Model

The steps used to determine stocks as portfolio candidates are as follows:

1. Calculation of Return and Expected Return of Individual Stocks

The results of the investment are measured from the return obtained in a certain period. For example, the return for Astra International Tbk for the March 2023 period was 0.090164, or a short return of 9.01% while the April 2023 stock return showed a figure of 0.23333 or a short return of 23.33%. This shows that in the April 2023 period, the stock experienced a fairly high increase in the level of profit.

After obtaining the return of each stock, the expected return of each stock will be calculated which is presented in Table 1.

KODE	E(Rt)	KODE	E(Rt)	KODE	E(Rt)	KODE	E(Rt)
AMFG	0,02171381	DYAN	-0,0021	KIAS	-0,0493	SCCO	0,01325
APII	-0,00419343	GPSO	-0,0103	KOBX	-0,019	SINI	0,01646
ARKA	0	HOPE	0,01833	KOIN	-0,027	SKIN	-0,0292
ARNA	0,019016892	IBFN	-0,0641	KONI	-0,0555	SOSS	0,00678
ASGR	0,031881432	ICON	-0,0138	KUAS	0,02258	SPTO	0,09155
ASII	0,106165975	IKAI	0	LABA	-0,052	TIRA	0,05764
BHIT	-0,01054639	IMPACT	-0,017	LION	-0,0165	TOTO	0,06428
BINO	0,006261015	INDX	-0,0615	MARK	0,06622	UNTR	0,26312
BLUE	0,117231897	INTA	-0,027	MDRN	-0,1205	VOKS	0,04154
BNBR	0,656351284	JECC	-0,0265	MFMI	0,02084	ZBRA	-0,0146
CAKK	-0,00064415	JTPE	0,10168	MLIA	0,04096		
CCSI	-0,03044855	KBLI	0,02037	NTBK	0,01405		
CTTH	-0,06944444	KBLM	0,03935	PADA	-0,1016		

Tabel 1. Stock Expected Return

2. Calculation of Individual Stock Risk

Risk is the magnitude of the deviation between the expected return and the actual return. The tool used as a measure of this spread is the variance or standard deviation.

KODE	Risiko (oi)	KODE	Risiko (oi)	KODE	Risiko (oi)	KODE	Risiko (oi)	KODE	Risiko (oi)
AMFG	0,00428915	CCSI	0,00313	JECC	0,00951	MARK	0,01378	TIRA	0,2103
APII	0,00027237	CTTH	0,04083	JTPE	0,01398	MDRN	0,05055	TOTO	0,00097
ARKA	0	DYAN	0,02024	KBLI	0,00304	MFMI	0,00506	UNTR	0,01664

ARNA	0,0027022 3	GPSO	0,0259 4	KBL M	0,0079 5	MLIA	0,0029 4	VOKS	0,0054 2
ASGR	0,0031075 6	HOPE	0,0037	KIAS	0,0694 6	NTBK	0,0211 4	ZBRA	0,0003 1
ASII	0,0037053	IBFN	0,1423 9	KOBX	0,0101 2	PADA	0,0305 3		
BHIT	0,0006191 8	ICON	0,0025 7	KOIN	0,0146 6	SCCO	0,0014 9		
BINO	0,0035605 5	IKAI	0	KONI	0,0693 9	SINI	0,0984 6		
BLUE	0,0036088 9	IMPC	0,0746 7	KUAS	0,0011 3	SKRN	0,0789 7		
BNBR	6,6938459 4	INDX	0,0113 4	LABA	0,0032 9	SOSS	0,0115 4		
CAKK	0,0138511 1	INTA	0,0080 4	LION	0,0174 5	SPTO	0,0004 5		

Tabel 2. Individual Stock Risk

3. Beta Risk Coefficient Calculation

To obtain the beta risk coefficient value of each stock, it is necessary to calculate the market return variance and stock-return covariance first. The market return variance value is obtained, which is presented in table 3 and the beta risk coefficient value of each stock can be calculated, the results of which are presented in table 4.

KODE	Covarian Saham dengan IHSG	KODE	Covarian Saham dengan IHSG	KODE	Covarian Saham dengan IHSG	KODE	Covarian Saham dengan IHSG
AMFG	0,000596184	DYAN	-0,000826016	KIAS	0,001618464	SCCO	-0,0003
APII	2,63E-05	GPSO	0,001034417	KOBX	0,001083156	SINI	-0,0008
ARKA	0	HOPE	0,000400264	KOIN	0,00172951	SKRN	0,0006
ARNA	0,000374908	IBFN	-0,003592429	KONI	0,001889546	SOSS	-0,0004
ASGR	0,000438476	ICON	-0,00011472	KUAS	-4,53E-05	SPTO	0,00021
ASII	0,000430192	IKAI	0	LABA	0,000469663	TIRA	-0,0013
BHIT	-3,94E-05	IMPC	-3,83E-05	LION	-0,000738119	TOTO	4,82E-05
BINO	0,001120754	INDX	-0,000529039	MARK	0,002248326	UNTR	0,00156
BLUE	-0,000200802	INTA	-0,000295592	MDRN	-0,001425336	VOKS	0,00019
BNBR	0,035952987	JECC	0,000163008	MFMI	0,000193753	ZBRA	0,00014
CAKK	0,000685604	JTPE	-0,001555248	MLIA	0,000612725		
CCSI	0,000230376	KBLI	-0,000127511	NTBK	-0,000892615		
CTTH	-0,001695577	KBLM	0,000491882	PADA	-0,000153406		

Tabel 3. Market Return Stock Variance-Covariance Value

Kode Saham	Beta	Kode Saham	Beta	Kode Saham	Beta	Kode Saham	Beta
AMFG	1,00307	DYAN	-1,3898	KIAS	2,72304	SCCO	-0,5464
APII	0,04433	GPSO	1,74039	KOBX	1,82239	SINI	-1,2781
ARKA	0	HOPE	0,67344	KOIN	2,90987	SKRN	1,00339
ARNA	0,63078	IBFN	-6,0442	KONI	3,17913	SOSS	-0,6027
ASGR	0,73773	ICON	-0,193	KUAS	-0,0763	SPTO	0,34759
ASII	0,72379	IKAI	0	LABA	0,7902	TIRA	-2,2591
BHIT	-0,0662	IMPC	-0,0644	LION	-1,2419	TOTO	0,08114
BINO	1,88565	INDX	-0,8901	MARK	3,78277	UNTR	2,63081

BLUE	-0,3378	INTA	-0,4973	MDRN	-2,3981	VOKS	2,56
BNBR	60,4903	JECC	0,27426	MFMI	0,32599	ZBRA	1,83
CAKK	1,15352	JTPE	-2,6167	MLIA	1,0309		
CCSI	0,3876	KBLI	-0,2145	NTBK	-1,5018		
CTTH	-2,8528	KBLM	0,82758	PADA	-0,2581		

Tabel 4. Beta Risk Coefficient Value of Each Stock

4. **Determination of Stocks for Portfolio Candidates with DEA**

To determine the stocks that are used as portfolio candidates, we look at which stocks are efficient using the Data Development Analysis (DEA) method. The technical efficiency value of CRS (TR CCR) is obtained by completing the DEA-CCR model and the technical efficiency value of VRS (TE CCR) is obtained by completing the DEA-BCC model. While the efficiency scale (SE) is obtained from the comparison of TE CRS with TE VRS. With the help of DEAP Software, the technical efficiency values in the DEA-CCR model, the DEA-BCC model and the efficiency scale are shown in Table 5. The technical efficiency value for each DMU in the DEA-CCR and DEA-BCC models shows whether or not the performance of a DMU is efficient. A DMU is said to be efficient if its efficiency value is equal to one, if it is less than one, the DMU is said to be inefficient.

KODE	TE CRS	TE VRS	SE	KODE	TE CRS	TE VRS	SE
AMFG	1.000	1.000	1.000	KBLM	0.810	1.000	0.810
APII	0.566	1.000	0.566	KIAS	0.811	1.000	0.811
ARKA	0.459	1.000	0.459	KOBX	1.000	1.000	1.000
ARNA	0.752	1.000	0.752	KOIN	1.000	1.000	1.000
ASGR	0.746	1.000	0.746	KONI	0.563	1.000	0.563
ASII	1.000	1.000	1.000	KUAS	0.536	1.000	0.536
BHIT	0.534	1.000	0.534	LABA	0.830	1.000	0.830
BINO	1.000	1.000	1.000	LION	0.843	1.000	0.843
BLUE	1.000	1.000	1.000	MARK	0.674	1.000	0.674
BNBR	1.000	1.000	1.000	MDRN	0.487	1.000	0.487
CAKK	0.673	1.000	0.673	MFMI	0.600	1.000	0.600
CCSI	1.000	1.000	1.000	MLIA	1.000	1.000	1.000
CTTH	0.875	1.000	0.875	NTBK	0.686	1.000	0.686
DYAN	1.000	1.000	1.000	PADA	0.600	1.000	0.600
GPSO	0.801	1.000	0.801	SCCO	0.664	1.000	0.664
HOPE	0.767	1.000	0.767	SINI	1.000	1.000	1.000
IBFN	1.000	1.000	1.000	SKRN	0.452	1.000	0.452
ICON	0.749	1.000	0.749	SOSS	0.744	1.000	0.744
IKAI	0.461	1.000	0.461	SPTO	1.000	1.000	1.000
IMPC	0.383	1.000	0.383	TIRA	0.833	1.000	0.833
INDX	1.000	1.000	1.000	TOTO	0.554	1.000	0.554
INTA	0.578	1.000	0.578	UNTR	0.879	1.000	0.879
JECC	1.000	1.000	1.000	VOKS	0.915	1.000	0.915
JTPE	0.646	1.000	0.646	ZBRA	0.601	1.000	0.601
KBLI	0.617	1.000	0.617	25			

Tabel 5. Efficiency Value of Each Stock

In the DEA-CCR model, there are 15 DMUs that demonstrate efficient performance (with an efficiency score of 1). These DMUs are AMFG, ASII, BINO, BLUE, BNBR, CCSI, DYAN, IBFN, INDX, JECC, KOBX, KOIN, MLIA, SINI, and SPTO. In the DEA-BCC

model, it can be observed that the efficiency scores of each DMU are much closer to one compared to the DEA-CCR model. This indicates that the performance efficiency evaluation in the DEA-BCC model is much closer to being efficient. For instance, in the DEA-CCR model, the efficiency score of DMU APII is 0.566, while in the DEA-BCC model, its efficiency score is 1.000. The same occurs with DMUs NTBK and PADA, which suggests that their performance is efficient. Therefore, more efficient DMUs are found in the DEA-BCC model. Meanwhile, scale efficiency (SE) is used to determine whether a DMU is operating optimally. If the efficiency score is less than one, the DMU has not yet operated optimally. If the VRS technical efficiency is greater than the scale efficiency, it indicates that changes in efficiency are influenced by pure technical efficiency. Conversely, if VRS technical efficiency is smaller than the scale efficiency, changes in efficiency are driven by scale efficiency. From Table D.5, it is shown that the DMUs operating optimally are AMFG, ASII, BINO, BLUE, BNBR, CCSI, DYAN, IBFN, INDX, JECC, KOBX, KOIN, MLIA, SINI, and SPTO. These 15 DMUs are considered as potential portfolio candidates.

Determining Fund Proportion

In the single index model, the first step is to calculate the ERB (excess return to beta) value. To calculate ERB, data on the risk-free asset return is required. In this study, the average monthly SBI interest rate during the research period is used, with an average return of 0.65%. The following table shows the ERB values of the 15 stocks, ranked from highest to lowest.

KODE SAHAM	ERB	Ci	ERBi/ Ci
IBFN	1,048988	0,00165	635,8851
DYAN	0,19647	0,024576	7,994276
SINI	0,195888	0,033581	5,83332
BLUE	0,18345	0,074167	2,473465
INDX	0,170878	0,085192	2,005802
SPTO	0,162965	0,120338	1,354225
ASII	0,156954	0,125769	1,247959
JECC	0,148464	0,127492	1,164501
CCSI	0,145672	0,129675	1,123357
MLIA	0,142909	0,131365	1,087878
AMFG	0,141012	0,132281	1,066005
BINO	0,125345	0,131492	0,95325
KOBX	0,123392	0,130987	0,942013
KOIN	0,109111	0,129646	0,841608
BNBR	0,0262	0,117579	0,222829

Table 6. ERB and Ci Value of Each Stock

The optimal portfolio will consist of stocks with high ERB values. The Cut-off Point (C*) is used as the threshold for a stock to be included in the portfolio, with the highest Ci value being the cut-off. The highest Cut-off Point (C*) is 0.1323, corresponding to the stock AMFG (Asahimas Flat Glass, Tbk). From the table, it can be seen that 11 stocks meet the criteria for inclusion in the optimal portfolio. These stocks are IBFN, DYAN, SINI, BLUE, INDX, SPTO, ASII, JECC, CCSI, MLIA, and AMFG.

After identifying the 11 stocks selected for the optimal portfolio, the next step is to determine the proportion (wi) to be invested in each stock. The investment proportions for each stock in the portfolio are as follows.

KODE SAHAM	NAMA PERUSAHAAN	PROPORSI SAHAM
IBFN	Intan Baru Prana Tbk.	7%
DYAN	Dyandra Media International Tb	8%
SINI	Singaraja Putra Tbk.	3%
BLUE	Berkah Prima Perkasa Tbk.	17%
INDX	Tanah Laut Tbk	7%
SPTO	Surya Pertiwi Tbk.	32%
ASII	Astra International Tbk.	9%
JECC	Jembo Cable Company Tbk.	4%
CCSI	Communication Cable Systems In	5%
MLIA	Mulia Industrindo Tbk	5%
AMFG	Asahimas Flat Glass Tbk.	3%

Tabel 7. Optimal Portfolio Share Proportion

The portfolio composed of 11 stocks provides a monthly return of 0.0211213 with a standard deviation of 0.026621. This portfolio is still above the risk-free return rate of 0.0065 per month.

CONCLUSIONS

Based on the analysis using the DEA-CCR and DEA-BCC models, 16 stocks were found to have optimal efficiency from the 49 stocks studied. Of these, 11 stocks were selected to form the optimal portfolio, including IBFN, DYAN, SINI, BLUE, INDX, SPTO, ASII, JECC, CCSI, MLIA, and AMFG, with varying fund allocations. This portfolio generated a return of 0.031213 per month with a standard deviation of 0.308529, which is higher than the market's expected return of 0.026621 and remains above the risk-free rate of 0.0065. For future research, the DEA model oriented toward input-output can be further developed, while potential investors are advised to carefully choose stocks to achieve optimal results.

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