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Research Article

Determining an optimal investment portfolio in agricultural industries: A case study of food and beverage industries

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ABSTRACT- As a crucial tool, the stock market plays a significant role in economic growth by facilitating price formation, reducing risk, and optimizing capital allocation, thereby creating a conducive environment for economic prosperity. Determining the optimal portfolio is a fundamental decision for investors in the stock market. Therefore, this study built on the Foster-Hart model to determine an optimal investment portfolio in food and beverage industries listed on the Tehran Stock Exchange, excluding sugar companies. The required data were collected from the stock exchange website, and the optimal investment portfolio was determined at different levels of risk aversion using three risk measurement indices, namely, variance, conditional value at risk, and Foster-Hart. The study results show that applying different risk measurement indices leads to diversity in the optimal stock portfolio. Moreover, a comparative analysis of optimal portfolios constructed using the three mentioned risk measurement indices across varying risk aversion levels demonstrates the superior performance of the Foster-Hart method in portfolio optimization. Given the higher efficiency of the Foster-Hart risk index, we recommend its application to determine risks more accurately in order to increase returns and reduce risks when selecting an investment portfolio.

INTRODUCTION

A key pathway to flourishing the agricultural sector is the development of the food industry. Indeed, the food industry leverages agricultural products as raw materials to enhance the effective use of these products (Farahbakhsh and Norouzi, 2002). The food industry can contribute significantly to a country's economy thanks to its comparative advantages in exports, value creation, job generation, and development of agricultural activities. Currently, the food industry has a share of 3.7% of the gross domestic product and a share of 18% of the total industrial employment. Also, Iran's food industry has a share of nearly 11% of the added value of the industry sector (Iran Chamber of Commerce, Industries, Mines and Agriculture, 2024). According to the reports published by the Statistical Center, about 19.3% of industrial workshops and 17.1% of employees in the industrial sector are engaged in the food industry. The share of this sector in the total value produced by industries in Iran is approximately 13.3%, constituting 8.25% of total non-oil exports (Mojtahedi et al., 2020). Roughly 95% of the food the population requires is produced domestically, amounting to approximately 135 million tons produced by domestic manufacturers. Despite the strategic importance of the food industry in advancing economic objectives and its significant contribution to the country's gross production, this sector receives a relatively low share of national investment (Shakeri and Mousavi, 2004). Therefore, focusing on investment in this sector and identifying ways to secure financing is essential. Issuing and offering shares on the stock market provides a potential avenue for securing the necessary funding to drive growth in this industrial sector (Duffie and Pan, 1997). Markowitz posits that investors consider risk and return simultaneously and allocate their capital among various investment opportunities based on the interaction between these two factors. It is generally assumed that investors are risk-averse and seek to invest in asset classes that offer the highest return with the least risk. Risk and return criteria ultimately determine the investor's utility, which is derived from their choice of asset portfolio. The optimal formation of a portfolio hinges on a precise understanding of risk. Given the critical role of risk assessment, it is necessary to employ the most suitable methods to measure risk accurately for the chosen set of assets (Bayat and Asadi, 2017).

Zahra and Dasman (2024) utilized the Capital Asset Pricing Model (CAPM) and the Arbitrage Pricing Theory

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(APT) approach to determine the optimal portfolio of agricultural companies listed on the stock exchange in Indonesia. The results indicated that the APT model suggests a greater number of shares in the optimal portfolio than the CAPM model. Additionally, the APT model generated a return of 14.08%, while the CAPM model yielded a return rate of 5.74%.

Anuno et al. (2024) determined the optimal portfolio with the aim of minimizing risk and achieving maximum return on Timor-Leste stocks in the international capital market for the period from January 2006 to December 2019. The empirical findings of this study indicated that JPM's (John Pierpoint Morgan) share had a very strong positive correlation with one of the twenty assets, that is, the share of BAC (Bank of America Corporation (Charlotte, NC.) (0.80). Out of twenty stocks, the optimal portfolio offered the four shares of DGE.L (Diageo plc (London, UK) (10.69%), NSRGY (Nestle SA, Packaged Foods (Vevey, Switzerland) (10.37%), JPM (John Pierpoint Morgan, New York, NY.) (10.04%), and T(Dallas, TX.) (10.30%). Moreover, the evaluation of the optimal portfolio using Markowitz parameters showed that the highest expected return and the lowest risk were 1.22% and 3.12%, respectively.

According to the study by Sarchami et al. (2023), the deep learning model outperformed the Markowitz model in forming the optimal portfolio. The study by Sadeghi and Khalaj (2023) revealed that the HARQ (Heterogeneous Autoregressive Quarticity) model provided better results when calculating the value at risk (VaR). Lu (2023) demonstrated that VaR could be a reliable index for measuring the risk index as a practical guide for risk management and control for securities investments. The study results by Jahanian et al. (2022) indicated that the Markowitz model based on the CO-GARCH (Continuous-time Generalised Autoregressive Conditionally Heteroscedastic) model had a significant difference compared to market efficiency.

Irwan et al. (2022) used the Markowitz model to determine the optimal portfolio of food and beverage companies in the Kenyan stock market, whereby seven stocks were selected as candidates for forming the optimal portfolio. The ratio of allocation of each share in the optimal portfolio included STTP (Siantar Top) (10.14%), FOOD (Sentra Food Indonesia) (8.95%), PANI (Pratama Abadi Nusa Industri) (5.06%), PCAR (Prima Cakrawala Abadi) (0.37%), ULTJ (Ultrajaya Milk Industry & Trading Company) (20.61%), ROTI (Nippon Indosari Corpindo) (48.05%), and SKBM (Sekar Bumi) (6.82%). With this combination, the expected return was 21.12%, and the risk level amounted to 7.95%.

Chizari and Vazirian (2021) determined an optimal portfolio of agricultural companies (food, sugar, and beverage industries) on the Tehran Stock Exchange. Monthly data of thirty-two agricultural companies on the Tehran Stock Exchange were collected from 2014 to 2020. This study investigated portfolio optimization using the Markowitz model under two distinct scenarios. The objective was to determine the optimal portfolio allocation that minimized portfolio variance while maximizing portfolio returns. They analyzed this both with and without applying constraints: a minimum investment of 1% and a maximum investment of 20% in any single asset. The results showed that the food and beverage industry was more efficient than the sugar industry portfolio, and the model suggested that 86.7% of the portfolio should be allocated to the shares of Salemin Factory, while 13.3% of the portfolio should be allocated to Mahram Company.

Mojtahedi et al. (2020) focused on determining the optimal portfolio for food industry companies listed on the Tehran Stock Exchange using the systematic risk approach. Their study found that when considering systematic risk, optimal portfolios typically favor stocks from companies less susceptible to the market fluctuations. Huang (2020) stated that automatically adjusting different parameter values can yield an optimal securities portfolio and more accurate stock price forecasting. Asefi et al. (2019) used the Foster-Hart index to optimize the portfolio. Their study indicated that the Foster-Hart index outperforms other methods. In the study by Hong Vo et al. (2019), the desired risk was measured using the Conditional Value at Risk (CVaR) model and the optimal portfolio was formed based on Markowitz's theory.

In the study by Ardia et al. (2018), risk forecasting was conducted using the Markov switching index to manage risk and improve managerial performance. This study examined GARCH methods for risk prediction and compared single regime and Markov switching approaches, ultimately concluding that the Markov switching model provided a more accurate VaR calculation. Hosseini Kasgari et al. (2017) focused on selecting the optimal portfolio of food industry stocks listed on the Tehran Stock Exchange using the mean-variance-skewness model. The results indicated that prices determined by the combined method had an advantage in pricing, and the mean-variance-skewness model yielded higher returns.

Yoshida (2017) introduced the mean VaR for fuzzy random variables as a model for optimal portfolio allocation. The results obtained included the determination of the mean VaR, with higher levels considered for times of economic crisis and lower levels for periods of economic recession. Anand et al. (2016) reviewed the classical optimal portfolio and measured the portfolio risk using the Foster-Hart index. Their results showed that the portfolio obtained using this index was more optimal than other methods. Based on the research by Hassanloo (2015), applying bankruptcy constraints at different time horizons significantly affects the selection of the optimal portfolio compared to when the bankruptcy constraint is not applied.

Zomorodian (2015) conducted a study to determine the optimal portfolio of twenty-one investment companies active in the Iranian capital market, examining VaR using both parametric and non-parametric methods. The results indicated the superiority of the parametric method over the non-parametric method in explaining VaR for the purpose of selecting the optimal portfolio. Asgharpoor and Rezazadeh (2015) focused on determining the optimal stock portfolio using the VaR method. The optimization of the stock portfolio was performed by minimizing the portfolio's VaR while considering a specified expected return through nonlinear

programming. The highest weight in the optimal portfolio was attributed to the stocks with high expected returns or the lowest VaR. Based on the findings, to optimize the stock portfolio of food industry companies, a significant portion of the capital should be allocated to Behshahr Industrial Development Companies, Salmin Company, Pegah Khorasan Pasteurized Milk, and Pegah Isfahan Pasteurized Milk.

Asgharpoor et al. (2013) compared the optimal portfolios of food industry stocks listed in the Tehran Stock Exchange using parametric and non-parametric approaches. The results indicated that the optimal portfolios calculated under the framework of VaR from both methods did not differ significantly, as the total return rates from both VaR methods for the portfolios were nearly identical. Ghadiri Moghadam and Rafiei Darani (2010) examined the optimal portfolio concerning the stocks of active food industry companies on the Tehran Stock Exchange based on the VaR index.

A review of domestic and international studies indicates that it would be critical to consider both risk and return when determining and selecting an optimal portfolio. Therefore, meticulous application of suitable methods for measuring and mitigating risk can assist decision-makers in achieving more beneficial outcomes. In portfolio determination, many of the examined studies have utilized various methods to estimate these two parameters, which have served as distinguishing characteristics of each study. Among the methods employed to control risk volatility are VaR, CVoR, Markov-switching models, and Data Envelopment Analysis, among others. The applicability of the Foster-Hart risk index in determining the optimal portfolio has rarely been investigated in domestic studies. In fact, only one domestic study has employed the Foster-Hart index for optimal portfolio determination. However, it did not consider varying degrees of risk aversion and primarily aimed at risk reduction.

In the present study, the optimal portfolio is calculated and compared using the Foster-Hart index along with two other significant risk measures: variance and CVaR. The optimal portfolios obtained from each model are also calculated at different levels of risk aversion. This can provide appropriate guidance for individuals with varying levels of risk aversion and facilitate informed decisions regarding stock selection and suitable investment strategies.

MATERIALS AND METHODS

One of the most important steps in optimal stock portfolio formation is determining the risk index, which has also been addressed in Markowitz's initial theories and classical economics. In recent years, various indices have been used for this purpose.

In the Markowitz model (1952) (classical optimization), the mean, expected return, and variance represent the portfolio risk. The optimal portfolio is a set of assets that can be expressed as Eq. (1).

$$\max(w^T\mu)$$
$$s.t$$
$$w^T\Omega w \le \sigma_*^2 \qquad \text{Eq. (1)}$$
$$i^T w = 1$$
$$w \ge 0^T$$

where $w = (w_1,\ldots,w_n)^T$ is the share of each of the company's stocks, $\mu = (\mu_1,\ldots,\mu_n)^T$ is the vector of the average returns of the company's stocks, and Ω is the variance-covariance matrix of the returns of the stocks in the investor's portfolio. Moreover, i is the unit vector, and σ_*^2 is the maximum variance of the company's stocks in the investor's portfolio. The last two restrictions prevent the short-term sale of the portfolio of assets. Eq. (1) can also be rewritten in the form of Eq. (2), which is certainty equivalent.

$$\max(w^T\mu - cw^T\Omega w)$$
$$\text{s.t: } i^T w = 1 \qquad \text{Eq. (2)}$$
$$w \ge 0^T$$

In Eq. (2), the parameter C is the investor's degree of risk aversion. A very low value of this parameter indicates that the risk is trivial, causing the investor to focus on the asset with the highest expected return. On the other hand, higher values of this parameter indicate greater importance of variance compared to the return.

As mentioned, the mean-variance model was the first model proposed for modeling the risk and return of a stock portfolio, after which it has been improved in various studies to obtain better risk approximations. If ρ is the risk measure of the optimal portfolio, Eq. (1) can also be written as Eq. (3):

$$\max(w^T\mu - cw^T\Omega w)$$
$$s.t:$$
$$Risk \le \rho(w) \qquad \text{Eq. (3)}$$
$$i^T w = 1$$
$$w \ge 0^T$$

Certainly, if ρ is measured by variance, Eq (3) will be the same as Eq (1).

Different portfolio risk conceptualizations lead to different decisions and the selection of different portfolios by the investor. In the Markowitz model, variance is the risk measure. This model aims to minimize the total deviations (positive and negative) from the mean, which can be a weakness of the model. In order to rectify this deficiency, new risk measurement metrics such as VaR and CVaR have been introduced, which specifically measure only deviations below the mean (negative risks). The Foster-Hart index is also one of the new measures designed for this purpose.

Therefore, this study investigates and compares the solutions to Eq. (1) and Eq. (3) using the CVaR criterion and the Foster-Hart index.

The VaR metric was first introduced by Baumol in 1963 (Asgharpoor and Rezazadeh, 2015). The VaR index expresses the overall risk of the stock portfolio as a single number, representing a percentage of the investor's total investment budget (Ghadiri Moghadam and Rafiei Darani, 2010). In other words, VaR is designed to provide the analyst with a specific number that includes condensed information about the portfolio's risk. In the traditional application of the VaR model, it was assumed that the asset returns would have a normal distribution. However, studies on asset return changes have shown that the distribution of asset returns is not normal and has

kurtosis and skewness more than the normal distribution. Therefore, ignoring this important point leads to an incorrect estimation of the VaR (Khiabani and Saroughi, 2011). Another fundamental problem with the VaR model is the lack of coherence in this method. Accordingly, researchers have developed this method into CVaR so as to eliminate the associated problems. The CVaR approach offers a dynamic assessment of risk that effectively captures the desirable characteristics of the data. This leads to higher accuracy and enables timely responses to the market fluctuations (Fallahpoor et al., 2014). This metric focuses on the distribution of changes in the stock portfolio.

Foster and Hart (2009) introduced a new index aimed at finding a suitable tool to prevent bankruptcy. This is a new risk measure that quantifies the minimum capital reserves—a factor that is needed to prevent bankruptcy. Risky investments are known as constrained bets, which are considered in a discrete period to prevent bankruptcy with the probabilities of Eq. (4). Indeed, the bounded condition is defined as a real-valued discrete random variable (bounded random variables with positive expectations and positive loss probability).

$$E(g) > 0 \text{ and } \rho(g < 0) > 0 \qquad \text{Eq. (4)}$$

Parameter g is considered the return, and the Foster-Hart index minimizes risk to achieve a specific expected return. The main result of Foster-Hart (2009) is that for each case, there is a specific amount of R(g) that is a positive and unique solution to the following equation:

$$E\left(\log\left[1+\frac{g}{R(g)}\right]\right)=0 \qquad \text{Eq. (5)}$$

R(g), Foster-Hart's risk measurement index, is the minimum reserve required to carry out a risky investment, which has characteristics including homogeneity, collectability, compatibility with first- and second-order and continuous random dominance, etc. The Foster-Hart index is always slightly higher than the maximum possible loss (Anand et al., 2016).

The overall structure of the research methodology in the present study is as follows. At first, the daily stock prices were used to determine the rate of return for each company. This metric serves as a performance measurement criterion used to assess the efficiency of an investment or to compare returns across multiple investments. The rate of return for each company is calculated by computing the difference between the secondary price and the initial price divided by the initial price. Subsequently, the mean, variance, variance-covariance matrix, VaR, and CVaR values are calculated. Next, the optimal stock portfolio is determined to maximize the rates of return. For each of the Foster-Hart, variance, and CVaR models, the optimization model is estimated to maximize the rate of return, solely constrained by the company's shareholding limits, without accounting for risk. Then, with the inclusion of risk constraints in the model, the optimal stock portfolio was re-estimated using the optimization model with the goal of maximizing stock returns and all risk and non-risk constraints in different scenarios of high-risk aversion (10%), medium-risk aversion (5%), and low-risk aversion (1%) using the GAMZ software. The required data consisted of the daily stock prices of the active food industry companies listed on the Tehran Stock Exchange from 2020 to 2023. Based on the available data for each active company during the mentioned period, 16 food industry companies were selected, as shown in Table 1.

The symbols assigned to each company listed on the Tehran Stock Exchange are determined by the nature of the company and its activities. In fact, these symbols succinctly represent the nature of the companies' activities or the industries to which they belong.

RESULTS AND DISCUSSION

Table 2 displays the outcomes of optimal portfolio formation in the variance model, with the objective of optimizing the optimal portfolio's return rate in conditions with and without risk consideration at varying levels of risk aversion.

Table 1- The names of the companies listed on the Tehran Stock Exchange

Row	Company name	Symbol	Industry subgroup
1	Behnoush Iran	BENN	Non-alcoholic barley and beer products
2	Behshahr Industries Development	TSBE	Subgroup of other food products
3	Pars Animal Feed	KDPS	Production of ready animal feed
4	Dasht Morghab	DMOR	Cultivation and preservation of fruits and vegetables
5	Salemin Factory	SLMN	Production of bread and related products
6	Pasteurized Milk Pegah Khorasan	SPKH	Dairy production
7	Pasteurized Milk Pegah Isfahan	SPPE	Dairy production
8	Shahdiran Industrial Company	SHAD	Growing and storing fruits and vegetables
9	Behshahr Industrial	SBEH	Production of animal and vegetable oils
10	Piazar Agro.	PIAZ	Growing and storing fruits and vegetables
11	Pak Dairy	LPAK	Dairy production
12	Kalber Dairy	KLBR	Dairy production
13	Gorji Biscuit	GORJ	Production of bread and related products
14	Chin Chin	CHCH	Production of other food products
15	Pars Minoo	MINO	Production of cocoa, chocolates, and sweets
16	Mahram Production	MRAM	Production of other food products

Table 2. The results of the optimal portfolio in the presence and absence of risk considerations based on the variance criterion

Stock/model	The model of maximizing the rate of return in the presence of risk consideration	The model of maximizing the rate of return in the absence of risk consideration		
		Low degree of risk aversion	Average degree of risk aversion	High degree of risk aversion
Company 4 (DMOR)	0	0.005064	0.025961	0.053716
Company 5 (SLMN)	1	0.994936	0.974039	0.946284
Total rate of return	0.009185	.009157	0.009155	0.009152
Total variance	0.110421	0.109316	0.104899	0.099378
Total CVaR	-0.081150	-0.0811	-0.080898	-0.080621
Total Foster- Hart	0.095	0.085217	0.088673	0.093263

Source: Research findings

According to Table 2, if the sole objective of the optimal portfolio is to maximize the overall rate of return and the risk of the companies is disregarded, it is advisable for the investor to select only the shares of company 5, which produces bread and related products, and allocate 100% of their shares to the company. By choosing these shares, the investor can achieve an average daily rate of return of nearly 0.009185. The total deviation in this case is approximately 0.11, which indicates the degree of data dispersion around the mean. The total CVaR under these conditions is -0.081150, indicating the maximum potential loss. Furthermore, the Foster-Hart amount, or the minimum capital and wealth required to prevent investor loss, is 0.095. Considering the risk indices, the optimal investment portfolio among the different food industry companies using the variance model consists of Companies 4 (DMOR) and 5 (SLMN). According to the optimal portfolio's results at various risk aversion levels, the shares of Companies 4 (DMOR) and 5 (SLMN) are 0.005 and 0.99, respectively, in the optimal portfolio at a low-risk aversion level. The rate of return obtained from this model is approximately 0.009157.

As observed in Table 2, at higher levels of risk aversion, the allocation of shares in SLMN Company is gradually reduced, while shares in DMOR Company are increased. The decrease in shares of SLMN Company in the optimal portfolio for individuals with high-risk aversion may indicate a higher investment risk associated with selecting shares of SLMN. This finding can be justified by the lower overall variance of this optimal portfolio (0.099378). Individuals with a greater degree of risk aversion will choose a smaller proportion of shares from Company 5 and a larger proportion from Company 4 in their optimal portfolio. The findings on the reduction in the optimal portfolio's rate of return with increasing risk aversion are consistent with those of Hosseini Kasgari et al. (2017) using the variance risk index.

Table 3 presents the results of determining the optimal investment portfolio under conditions in the presence and absence of risk considerations at various levels of risk aversion, using the CVaR model to maximize the optimal portfolio's return rate.

As shown in Table 3, the optimal investment portfolio among various companies in the food industry, determined using the CVaR model, includes companies 5 (SLMN) and 10 (PIAZ). The results indicate that at a low level of risk aversion, the allocations for companies 5 (SLMN) and 10 (PIAZ) are 0.97% and 0.021%, respectively, in the optimal portfolio. Consequently, the rate of return from this optimal portfolio is calculated to be 0.008971.

The findings demonstrate that as levels of risk aversion increase, the allocation to SLMN shares decreases while the allocation to PIAZ shares increases in the optimal portfolio. This shift may be attributed to the lower rate of return and higher standard deviation of returns associated with SLMN shares. One of the reasons for this result could be the lower return rate and higher standard deviation of the return rates for Company 5's shares. An analysis of the mean and variance of actual returns for both companies during the study period supports this conclusion, leading investors to favor portfolios that minimize the standard deviation of share returns.

Table 3. The results of the optimal portfolio under conditions in the presence and absence of risk considerations based on the Conditional Value at Risk (CVaR) criterion

Stock/model	The model of maximizing the rate of return in the presence of risk consideration	The model of maximizing the rate of return in the absence of risk consideration		
		Low degree of risk aversion	Average degree of risk aversion	High degree of risk aversion
Company 5 (SLMN)	1	0.978133	0.890663	0.663797
Company 10 (PIAZ)	0	0.021867	0.109337	0.336203
Total rate of return	0.009185	0.008971	0.008224	0.006285
Total variance	0.110420	0.105643	0.087629	0.049066
Total CVaR	-0.081150	-0.081962	-0.085208	-0.093627
Total Foster-Hart	0.095	0.085121	0.088084	0.095771

Source: Research findings

Furthermore, as noted in Table 3, the variance significantly decreases with higher levels of risk aversion, reflecting lower data dispersion at elevated risk aversion levels. Analysis of the Foster-Hart value across varying degrees of risk aversion reveals an upward trend associated with higher risk aversion levels. This suggests that to mitigate losses in investment decisions and select an optimal portfolio, an increase in risk aversion necessitates a greater minimum capital requirement. According to the CVaR metric, even for highly risk-averse individuals, the potential loss will not exceed 0.093627.

Table 4 presents the results of optimal portfolio investment under varying risk considerations and levels of risk aversion, utilizing the Foster-Hart model, with the objective of maximizing the optimal portfolio return rate. According to Table 4, the analysis of the optimal portfolio across different risk aversion levels revealed that, at a low-risk aversion level, the optimal portfolio comprised shares of Companies 4 (DMOR), 5 (SLMN), and 6 (SPKH) with respective allocations of 4.7%, 80%, and 15.2%. As the levels of risk aversion increased, the selected companies shifted to SLMN, CHCH, and MINO. Consequently, the shares of Companies 4 and 6 reduced to zero in the optimal investment portfolio, while shares of companies 14 and 15 were added to the optimal investment portfolio.

An analysis of the average return rates and the standard deviation of the return rates of shares from Companies 4 and 6 compared to those from Companies 14 and 15 during the study period revealed that, due to the higher coefficient of variation in the return rates of companies 4 and 6, risk-averse individuals avoided selecting shares from these two companies and instead included shares from companies 14 and 15 in their optimal portfolio. The CvaR value increases with an increase in the risk aversion. This criterion signifies that the maximum potential loss, under the conditions of the most risk-averse individuals, will not exceed 0.080713.

Furthermore, the optimal portfolio results based on the Foster-Hart criterion indicated that as the level of risk aversion increased, the Foster-Hart value decreased. This implies that with an increase in risk aversion, the minimum wealth or capital required to avoid bankruptcy in investment is lower compared to other examined conditions. The findings obtained from applying the Foster-Hart index in determining the optimal investment portfolio align with the study conducted by Asefi et al. in 2019, which utilized the Foster-Hart method to determine the optimal investment portfolio in the Tehran Stock Exchange and established the minimum requirement for bankruptcy.

To better compare the results of the different risk models in determining the optimal investment portfolio, the results of these models at the medium risk aversion level are presented in Table 5.

Table 4. The results of the optimal portfolio in the presence and absence of risk considerations based on the Foster-hart criterion

Stock/model	The model of maximizing the rate of return in the presence of risk consideration	The model of maximizing the rate of return in the absence of risk consideration		
		Low degree of risk aversion	Average degree of risk aversion	High degree of risk aversion
Company 4 (DMOR)	1	0.047988	0.022062	0
Company 5 (SLMN)	0	0.8000	0.8000	0.8000
Company 6 (SPKH)	0	0.152012	0.17861	0
Company 14 (CHCH)	0	0	0	0
Company 15 (MINO)	0	0	0	0.170186
Total rate of return	0.009158	0.00852	0.008451	0.00766
Total variance	0.110420	0.071848	0.071861	0.07076
Total CVaR	-0.08115	-0.078629	-0.078534	-0.080713
Total Foster - Hart	0.095	0.094	0.090	0.085

Source: Research findings

Table 5. Comparison of results from different models in determining the optimal portfolio considering a moderate level of risk aversion

Stock/model	The model of maximizing the rate of return in the presence of risk consideration	Risk model		
		Variance Model	CVaR Model	Foster-Hart Model
Company 4 (DMOR)	0	0.025961	0	0.022062
Company 5 (SLMN)	1	0.974039	0.890663	0.800
Company 6 (SPKH)	0	0	0	0.177938
Company 10 (PIAZ)	0	0	0.109337	0
Total rate of return	0.009158	0.009155	0.008224	0.008451
Total variance	0.110420	0.104899	0.087529	0.071861
Total CVaR	-0.080115	-0.080895	-.0085208	-0.078534
Total Foster-Hart	0.0890	0.088673	0.088084	0.090
CV	36.28	35.37	35.99	31.72

Source: Research findings

Table 5 details the results related to the average stock return rate and the risk value of all three models, namely, variance, CVaR, and the Foster-Hart model. The coefficient of variation parameter was used to determine the superior model and compare the efficiency of the different models used in this study to determine the optimal investment portfolio. In the financial field, especially in the evaluation of risk models, this criterion (coefficient of variation) can be used as a suitable tool to compare the performance and validity of the models (Johnson and Wichern, 2014). Certainly, the lower the value of this parameter, the higher the return and the more efficient the final model. As can be observed in Table 5, the coefficients of variation for the variance, CVaR, and Foster-Hart models are 35.37, 35.99, and 31.72, respectively. Based on this, the Foster-Hart model is considered the preferred index compared to the variance and CVaR models, as it has a lower coefficient of variation.

The results in Table 5 indicate that the diversification of the optimal investment portfolio, as assessed by the Foster-Hart model, exceeds that of the variance and CVaR models. By incorporating risk according to the Foster-Hart model, the optimal investment portfolio can exhibit higher confidence. The diversity of shares from various companies in the food industry, along with the low ratio of standard deviation to the average return rate in this optimal portfolio, indicates the superior capability of this risk index in selecting an optimal investment portfolio.

The Foster-Hart risk index indicates that Company 6, exhibiting a lower standard deviation and a higher average return than Company 10 during the study period, is included in the optimal investment portfolio based on the initial data analysis of the companies' return rates. By incorporating companies with higher return rates and lower return variability into the optimal portfolio, investors can enhance portfolio efficiency. This approach aligns with the Foster-Hart risk index, which emphasizes company diversity and a lower coefficient of variation, leading to a more robust investment strategy. This approach is recommended as a suitable strategy for investment decision-making under risky conditions.

The results of this study are consistent with the findings of Anand et al. (2016), which indicate the superior performance of the Foster-Hart index compared to other risk measurement criteria. Additionally, our results are consistent with studies by Sarchami et al. (2023), Sadeghi and Khalaj (2023), Lu (2023), Hong vo et al. (2019), and Asefi et al. (2019).

CONCLUSION

Given the importance of the two parameters of risk and return in investment decision-making, using appropriate tools for efficient management and allocation of scarce resources is crucial. The objective of the present study is to identify a suitable and effective (superior) risk index that provides a more accurate measurement of risk, thereby contributing to the effective selection of an optimal investment portfolio. Consequently, in this study, the optimal investment portfolio was determined using three risk measurement indices: Variance, CVaR, and Foster-Hart. The results of determining the optimal portfolio to maximize returns in the presence of risk considerations indicated that 100% of the shares were allocated to the company SLMN, resulting in a total return of 0.00918. When considering risk and utilizing the variance index, the companies SLMN and DMOR were identified as suitable for investment in the optimal portfolio, with varying share ratios at different levels of risk aversion. The total return for the portfolio obtained with a moderate risk aversion coefficient was calculated to be 0.00915. By applying the CVaR index, the companies SLMN and PIAZ were selected for this portfolio, with different share allocations at various levels of risk aversion. The total return for this portfolio at a moderate risk aversion level was found to be 0.0082. The results of using the Foster-Hart index to determine the optimal portfolio identified the companies DMOR, SLMN, SPKH, CHCH, and MINO as selected, with varying investment shares at different levels of risk aversion. The optimal portfolio obtained using the Foster-Hart index and a moderate risk aversion level had a total return of 0.0084.

The findings indicate that applying risk indices leads to diversification in the optimal stock portfolio. Additionally, determining the optimal portfolio while considering different levels of risk aversion allows individuals to face varied investment choices. The coefficient of variation was employed to compare the three indices used in the study, where a lower value of this parameter indicated the suitability and superiority of the respective index. The Foster-Hart risk index, with a variation coefficient of 31.72, was selected as the superior index compared to the variance and CVaR indices, which had variation coefficients of 35.37 and 35.99, respectively. Therefore, based on the obtained results, the following recommendations are proposed:

- Investors do not allocate their entire capital to the purchase of a single share and consider diversity. By purchasing a set of shares from different companies, they can reduce their investment risk.
- Given the Foster-Hart model results and the selection of four companies out of 16 listed companies in the optimal portfolio, there is a need to create financial support for food industry companies so that they do not leave the industry due to the financial weakness during fluctuations.
- Based on the findings of this study, experts in economics and investment should use the Foster-Hart risk index to select the appropriate portfolio investment. This index is more efficient (in terms of lower relative volatility compared to the stock return rate and a lower coefficient of variation) in determining the precise amount of risk than other risk measurement indices.

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DECLARATION OFCOMPETING INTEREST

The authors declare no conflicts of interest.

ETHICAL STATEMENT

All authors are aware of the content of the manuscript and consented to submit it to *Iran Agricultural Research* journal. We did not send this article to another journal.

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