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Evaluation of Fixed Income Mutual Funds' Performance with Data Envelopment Analysis

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Abstract. This paper introduces a model for evaluating the performance of fixed-income mutual funds, particularly within the Iranian market. The model uses a risk measure as input and generates two output returns: expected return and excess return. It aims to identify funds that maximize returns for investors with moderate risk tolerance. We assess the efficiency of various Iranian mutual funds and establish a benchmark for those aiming to provide returns similar to banking rates or bonds, with additional returns to counter inflation. The model also evaluates the funds' ability to utilize risk-free market instruments and optimize portfolio management. We demonstrate the model's application using data from 15 Iranian mutual funds between 2011 and 2020, showcasing its utility in identifying efficient funds that offer both stable returns and potential excess returns

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1. Introduction

Since portfolio optimization model proposed by Markowitz [9], several tools, models and approaches for decision-making have been developed in the financial and economics literature to evaluate the performance of portfolios of financial assets. Markowitz work, laid the base of the frontier approach under the mean-variance (MV) framework [9]. This model was due to the nature of the variance in quadratic form and tries to decrease variance as a risk parameter in all levels of mean. Even after half a century since its publication, the model is not well-understood yet and demands further interrogations in order to be more relevant, either in practical application or theoretical discussions. Over time, a lot of works have been addressing this issue proposed new concepts and incremented studies about portfolio theory. The mean-variance approach introduced by Markowitz relies on the construction of a frontier relative to which portfolio performance is measured [14].

To measure the mutual funds' performance, some numerical indexes have been devised in the literature and are widely used in the practice: let us just remind the well-known reward-to-volatility ratio [12]. The index is a ratio between the expected excess return of portfolio and a risk indicator; in this way they take into account both expected return and

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risk and synthesize them in a unique numerical value. Nevertheless, they do not consider the subscription and redemption cost required by the investment which contribute to determine the overall return on the investment.

Diversification (nonlinear DEA) and DEA approaches are two of the most popular estimation approaches. Morey and Morey [8] first proposed a diversification model with quadratic constraints, where the input is variance and the output is expected return. Moreover, taking the initial and final investment-costs into account, one can utilize the performance measurement methodology that allows to evaluate the efficiency of a decision making unit in the presence of several inputs and outputs. [1]

A technique with this characteristic that can be used is data envelopment analysis (DEA). DEA is a non-parametric tool widely used in the public sector. Data envelopment analysis was invented in 1978 by Charnes, Cooper and Rhodes (CCR) [5]. Later, in 1984, another model was developed by Banker, Charnes, and Cooper (BCC) [2]. It has been extended and broadly employed to assess organizations performance in private sectors, such as schools, hospitals, banks, etc. After [5] and [2], Sengupta's work was significant because it combined portfolio selection techniques based on quadratic optimization with the efficiency analysis approach of Data Envelopment Analysis (DEA), a methodology commonly used in operations research [11], but it took until Murthi, Choi, and Desai [10] to identify DEA as an "advantageous technique for measuring efficiency" of mutual funds.

The production units are widely used to measure their efficiency using a large number of inputs and outputs [15]. CCR and BCC models are input- and output-oriented models. The purpose of input-oriented models is to reduce the inputs of inactive units and also aims to reach the efficiency limit [13]. DEA models implemented for organizations' evaluating efficiencies which combines several activities simultaneously have been studied by Beasley [3] and authors such as Murthi et al. [10] and Gregoriou and Zhu [7] observe the following analogy. The advantage of applying the DEA approach is the ability to account different investor attitudes to risk and return. The published literature on DEA for investment funds is not theoretically justified. The analogy between output–input ratios (used in Data Envelopment Analysis - DEA) and return–risk ratios (used in finance) can be misleading for several reasons when applied to investment funds. It usually makes an implicit assumption that fund returns are perfectly correlated. And it often ignores the need for comparable measures of risk and return.

The present paper is organized as follows: Section 2 provides a theoretical framework. In section 3, we represent the methodology for mutual funds with two types of returns. In section 4, we discuss the results, and in section 5, we delineate the conclusion.

2. A review of some models used to obtain efficient portfolio in mean-variance space

This section reviews the models proposed by Markowitz [9] and Morey and Morey [8] to obtain an efficient portfolio.

Definition 2.1 The efficient portfolio frontier is a set of efficient portfolios that offer the highest expected return for a defined level of risk or the lowest risk for a given level of expected return. Portfolios that lie below the efficient frontier are not efficient portfolios as they do not provide sufficient return for the desired risk.

The following model is related to the degree of risk aversion of the investor, when the investor considers the amount of risk that he or she can accept in investment, therefore, according to this amount of risk, the maximum possible return is achieved. As a result, the model was proposed by Markowitz [9], which maximizes the return rate with respect to the degree of riskiness of the investor. This model is as follows:

$$\begin{aligned} \max \quad & \sum_{i=1}^{n} \lambda_i \mu_i \\ \text{s.t.} \quad & \sum_{i=1}^{n}\sum_{j=1}^{n} \lambda_i \lambda_j \sigma_{ij} \le \sigma_o^2 \\ & \sum_{i=1}^{n} \lambda_i = 1 \\ & \lambda_i \ge 0, \ i = 1,\ldots,n, \end{aligned} \tag{1}$$

where

$n =$ The number of assets in the portfolio,

$\mu_i =$ The expected return of asset i,

$\sigma_o^2 =$ The variance of the portfolio,

$\sigma_{ij} =$ The covariance of the returns between asset i and asset j,

$\lambda_i =$ The proportion of the portfolio's initial value invested in asset i.

If λ^* is the optimum solution of model (1), then $(\sum_{i=1}^{n}\sum_{j=1}^{n}\lambda_i^*\lambda_j^*\sigma_{ij}, \sum_{i=1}^{n}\lambda_i^*\mu_i)$ is the efficient portfolio.

Model (1) is related to the expected return on the investment when the investor considers the lowest return on investment, so given the return, the minimum possible risk is achieved. As a result, the model has been proposed by Markowitz [9], which minimizes the risk with respect to the expected return on investment:

$$\begin{aligned} \min \quad & \sum_{i=1}^{n}\sum_{j=1}^{n} \lambda_i \lambda_j \sigma_{ij} \\ \text{s.t.} \quad & \sum_{i=1}^{n} \lambda_i \mu_i \ge \mu_o \\ & \sum_{i=1}^{n} \lambda_i = 1 \\ & \lambda_i \ge 0, \ i = 1,\ldots,n, \end{aligned} \tag{2}$$

where $\mu_o$is the expected return of the portfolio.

If λ^* be to an optimum solution of model (2), then $(\sum_{i=1}^{n}\sum_{j=1}^{n}\lambda_i^*\lambda_j^*\sigma_{ij}, \sum_{i=1}^{n}\lambda_i^*\mu_i)$ is the efficient portfolio.

Model (3) and (4) evaluate the performance of a portfolio by Morey and Morey [8]. In these models, the risk is considered as input, and return is considered as output. Similar to data envelopment analysis models, these models also have input-oriented and output-oriented. These models are as follows:

$$\begin{aligned} \max \quad & \varphi \\ \text{s.t.} \quad & \sum_{i=1}^{n}\sum_{j=1}^{n} \lambda_i \lambda_j \sigma_{ij} + s^- = \sigma_o^2 \\ & \sum_{i=1}^{n} \lambda_i \mu_i = \varphi \mu_o \\ & \sum_{i=1}^{n} \lambda_i = 1 \\ & \lambda_i \ge 0, \ i = 1,\ldots,n \\ & s^- \ge 0, \end{aligned} \tag{3}$$

where $s^-$is the input slack.

If $(\lambda^*, s^{-*}, \varphi^*)$ is the optimum solution of model (3), then

$$\sum_{i=1}^{n}\sum_{j=1}^{n}\lambda_i^*\lambda_j^*\sigma_{ij}, \sum_{i=1}^{n}\lambda_i^*\mu_i \ = \ \sigma_o^2 - s^{-*}, \ \varphi^*\mu_o$$

is an efficient portfolio. Science $(\sigma_o^2 - s^{-*}, \varphi^*\mu_o)$ is on the efficient portfolio frontier, therefore according to definition 1, it is an efficient portfolio.

$$
\begin{aligned}
\min \quad & \theta \\
\text{s.t.} \quad & \sum_{i=1}^{n}\sum_{j=1}^{n}\lambda_i\lambda_j\sigma_{ij} = \theta\sigma_o^2 \\
& \sum_{i=1}^{n}\lambda_i\mu_i - s^+ = \mu_o \\
& \sum_{i=1}^{n}\lambda_i = 1 \\
& \lambda_i \geq 0, \ i = 1,\dots,n \\
& s^+ \geq 0,
\end{aligned} \tag{4}
$$

where $s^+$is the output slack.

If $(\lambda^*, s^{+*}, \varphi^*)$ is the optimum solution of model (4), then

$$\sum_{i=1}^{n}\sum_{j=1}^{n}\lambda_i^*\lambda_j^*\sigma_{ij}, \sum_{i=1}^{n}\lambda_i^*\mu_i \ = \ \theta^*\sigma_o^2, \ \mu_o + s^{+*}$$

is an efficient portfolio. Science $(\theta^*\sigma_o^2, \mu_o + s^{+*})$ is on the efficient portfolio frontier; so, according to definition 1, it is an efficient portfolio.

3. An Evaluation on performance of mutual funds with fixed income

3.1 *Data and input and output variable*

The input-outputs variables on 15 Iranian mutual funds with fix income used in this study were collected from Financial Information Processing of IRAN (FIPIRAN), including the nine-years period from 2011 to 2019. This webpage provides information on qualitative as well as quantitative variables associated with a large number of mutual funds. The quantitative variables are mainly historical information such as cash inflow, growth, income, size, asset allocation and beta coefficient. We assess the sensitivity of the DEA efficiencies to different sets of outputs variable combinations on output variables measured across the estimated earning rate and year return. The reason for considering only 16 funds in this study is the availability of historical data from 2011 because these funds are new in Iranian financial market. This market is referred to as Financial Information Processing of Iran (FIPIRAN) is a subsidiary of Tehran Securities Exchange Technology Management Company (TSETMC). FIPIRAN mission is to provide data and processed information related to the Iranian financial market to everyone.

In mutual funds with fixed income in Iranian market, there are several portfolio types: Shares and priority, bonds, bank account, other assets. A bit part of portfolio is dedicated on bonds and stocks. So, high ratio of portfolio is invested in free risk market and this reason helps to Iranian mutual funds which pay fix income to investors. This income type has close return to banking deposit rate in Iran. In fact, there is high inflation rate in Iran and Iranian central bank allows to all Iranian banks to determine high rate income for deposits. To summarize, we have two types returns in mutual funds: Estimated Earning Rate and exceed revenue. In addition, mutual funds demonstrate all part of returns as below:

Year Revenue = Estimated Earning Rate +Exceed Revenue

In the context of fixed income in Iran, we examine expected return and excess return, influenced by the challenging economic environment of high inflation and varying economic growth. **Inflation** is the rate at which the general price level of goods and services rises, reducing purchasing power, while **economic growth** signifies an increase in the inflation-adjusted value of goods and services produced. **Expected return** is the anticipated baseline return compensating for time value, inflation, and basic risk, while **excess return** is the additional return above this expectation, sought for wealth preservation. High inflation erodes real investment value, necessitating higher expected returns that include an inflation premium and making the generation of positive *real* excess returns particularly challenging. Economic growth has a nuanced impact, potentially leading to higher interest rates that can negatively affect expected returns, and achieving excess returns is more difficult during periods of low growth or stagflation. Therefore, fixed income analysis in Iran requires models that differentiate between real and nominal returns and are sensitive to economic indicators.

3.2 *Modeling*

A cornerstone of financial decision-making is the concept of expected return: the total return an investor anticipates over a one-year horizon. This expectation, which should be consistent with their investment policy statement, is inherently linked to the investor's risk appetite. Investors utilize a range of methodologies to quantify the expected return of a specific security, reflecting this risk-return trade-off.

An expected return is what the mutual funds expect to pay to an investment. It is based on the potential outcome will be realized bank deposit interest or yield of bonds. Other expected return refers to profits from allocation of a small part of the portfolio on stock market. We apply mean-variance model; we use risk as input and returns and skewness as outputs. For input we calculate variance of returns as risk measure. For outputs, expected return and estimated earning rates are concerned.

In our proposal model, an output-oriented model is applied. As investors can be risk-averse, so investors prefer to use mutual funds. Risk-averse investors are the ones who choose more stable returns, even if lower, over volatility. So, mutual funds by fixed income pay return close to annual interested rate that is determined by Iranian central bank which means they are risk-free and offer a steady rate of return. Therefore, the investors averse from risk essentially and it is not being logical to decrease risk. In fact, the propose model should be focus on other side which is return. As a result, we apply an output-oriented model to increase return for risk averse investors.

The propose model is for evaluating the portfolio of stocks that have special conditions. These conditions are such that each asset includes unforeseen earning that are given to the investor as year revenue. On the other hand, a part of return has guaranteed by mutual funds. This part of the profit in these funds is defined as the "Estimated Earning Rate". In applications, we often have situations in which some of the inputs or some of the outputs are uncontrollable, at least in the short run or using the discretionary power of the firm or unit that we tend to evaluate. A very simple but useful way to handle such situations is to only look for improvements in the controllable dimensions [4]. In this manuscript, the output model is of two types: controllable and non-controllable. Our output is controllable, which is referred stocks return and other investments which are not free risk. Non-controllable output is referred to fixed income in mutual funds which is named expected returns. The capacity to earn returns in risk-free markets is limited by central bank policy on deposit rate and risk-free bonds for each year. Based on the optimal allocation of part of the portfolio to this sector, the total capacity of the risk-free market can be used. In other words, a percentage of the portfolio was allocated to the risk-free market; it can be useful in achieving the expected returns as well as optimizing the estimated earning rate.

Eventually, in this model, non-controllable output is not fixed. But it can be restricted between two numbers close to annual free-risk return. So, maximum free-risk return demonstrates the ability of mutual funds to utilize the risk-free market and optimize portfolio management.

The outputs, including controllable (C) and None-controllable (NC) dedicated as in:

$$(x, y) = (x, y_C, y_{NC}).$$

We define the output efficiency for an input-output combination (x, y) as the most significant factor φ by which we can multiply the output y so that φy can still produce the input x. If one wants to try a greater output φy, it would be impossible to produce y. Hence

$$f(x,y) = \max \ \varphi \mid x \text{ can produce } \varphi y \ .$$

The *technology set T* is the set of combinations of input and output such that the input can produce the output [4].

$$T = \ (\sigma, \mu) \mid \sigma \text{ can produce } \mu$$

As a result, on the output side, we similarly measure the efficiency of firm o as the output efficiency applying:

$$f((\sigma^o, \mu_C^o, \mu_{NC}^o); T) = \max \ \varphi \mid (\sigma^o, \varphi\mu_C^o, \mu_{NC}^o)$$

and inserting the formulation of *T* by Morey and Morey model, we get the following linear programming problem

$$\begin{aligned}
\max \quad & \varphi \\
\text{s.t.} \quad & \sum_{j=1}^{n} \lambda_j \mu_C^j \geq \varphi \mu_C^o && (5.1) \\
& \sum_{j=1}^{n} \lambda_j \mu_{NC}^j \geq \mu_{NC}^o && (5.2) \\
& \sum_{j=1}^{n} \sum_{i}^{m} \sigma_{ij} \leq \sigma_o && (5.3) \\
& \sum_{j=1}^{n} \sum_{i}^{m} \sum_{k}^{K} \lambda_i \lambda_j \lambda_k s_{ijk} \geq \varphi s_0 && (5.4) \\
& \sum_{j=1}^{n} \lambda_j = 1 && (5.5) \\
& \lambda_j \geq 0, \ j = 1, \ldots, n,
\end{aligned} \qquad (5)$$

where

$\mu_{NC}^j =$ The excess return of asset j,

$\mu_C^j =$ The expected return of asset j,

$s_{ijk} =$ Skewness between asset i, asset j, and asset k.

$s_0 =$ Skewness of portfolio.

Constraint (5.2) demonstrates free risk-return in all mutual funds. Slack for this constraint is shown by $\sum_{j=1}^{n} \lambda_j \mu_j - S^+ = \mu_o$. When shortfall in output $S^+ = 0$, as a result, $\sum_{j=1}^{n} \lambda_j \mu_j = \mu_o$ it can be clear that $\mu_0$belong to DMU_o is high free risk-return, a non-controllable value.

So, in this model, the first constraint represents controllable output, which usually involves the return of a small part of the fund's portfolio in the stock market. The second restriction, which provides fixed returns, is to invest funds in party securities and bank deposits. The third constraint is the maximum risk that investors consider. Given that there is no symmetry in most investment issues. Distribution is not a normal distribution; as a result, variance alone cannot represent the risk of an investment. This problem can be resolved by considering the mean, variance, and skewness (representing a curve's deviation from the symmetry state).

4. Numerical illustrations and results

For each of the 15 mutual funds, we calculated with MATLAB 2015a:

(i) Covariance.

(ii) Returns.

(iii) Skewness

These values were calculated using yearly return data from FIPIRAN's Mutual. Table 1, shows 9-year expected returns for funds. Table 2, shows the estimated earning rate in 9 years.

Table1. Expected returns –output1.

MUTUAL FUND	2019	2018	2017	2016	2015	2014	2013	2012	2011
A	17	16	17	19	20	20	20	19.5	19.5
B	15	15	15	19	20	19	19	20	19
C	20	20	20	20	20	20	20	20	20
D	17	17	17	19	20	20	20	20	20
E	20	20	20	20	20	20	20	20	20
F	17	16	17	18	20	20	20	20	20
G	20	20	20	20	22	16	20	20	20
H	16	16	16	16	20	16	20	20	20
I	17.2	17	17.2	20	22	20	20	20	20
J	20	20	20	20	20	17	20	20	20
K	16	16	16	18	20	15	20	20	20
L	16	17	16	18	20	15	20	20	20
A	17	16	17	19	20	20	20	19.5	19.5
B	15	15	15	19	20	19	19	20	19
C	20	20	20	20	20	20	20	20	20

Table2. Estimated earning rate –output2.

MUTUAL FUND	2019	2018	2017	2016	2015	2014	2013	2012	2011
A	22.1	20.5	20.1	20.0	23.8	23.2	21.6	21.6	21.6
B	20.3	19.6	28.8	31.0	22.1	22.3	21.1	22.0	21.9
C	21.6	20.8	21.0	21.0	23.5	16.4	27.7	19.5	19.5
D	22.0	20.7	21.7	22.0	24.1	24.3	22.7	21.6	21.6
E	21.2	21.8	26.8	28.6	23.9	17.4	48.2	31.3	31.3
F	22.6	22.3	17.6	18.2	18.7	14.9	27.6	21.1	21.1
G	26.0	23.0	21.8	21.8	24.7	16.2	22.8	20.4	20.4
H	20.0	18.4	19.6	20.1	20.8	16.9	22.7	19.0	19.0
I	22.6	21.1	21.5	21.9	22.5	20.5	22.6	20.9	20.9
J	22.0	22.8	21.2	21.1	21.6	18.5	20.6	20.4	20.4
K	20.8	20.7	26.3	28.7	20.6	16.1	39.3	44.8	44.8
L	18.4	18.3	19.7	20.3	24.6	15.7	22.8	22.2	22.2
A	25.2	22.9	22.0	21.5	18.1	19.0	18.9	20.2	20.9
B	23.8	20.3	20.1	20.3	23.9	15.4	20.0	21.1	20.5
C	21.6	19.0	21.4	22.2	23.2	22.8	22.1	22.9	20.0

Table 3, represents the percentage of expected return that we guarantee for investors to pay them.

Finally, GAMS programming is applied to calculate efficiency scores for all mutual funds by risk/return perspective. This result is presented in Table 4.

The maximum free-risk return between mutual funds demonstrate the ability of mutual funds to utilize the risk-free market and optimize portfolio management.

Table 4, represents the efficiency values of each evaluated 15 mutual funds, which are calculated by the new method. This result demonstrates E, F, and G units are efficient. So, portfolio management is efficient, especially when risk-averse customers are concerned.

Table3. expected returns for 2020.

Mutual Fund	2020
A	16.0
B	14.0
C	16.0
D	14.0
E	18.0
F	19.0
G	15.0
H	14.0
I	15.0
J	17.0
K	16.0
L	17.0
M	19.0
N	16.0
O	16.0

Table 4. Efficiency scores.

Mutual Fund	Efficiency Score
A	1.073
B	1.059
C	1.029
D	1.031
E	1.000
F	1.000
G	1.000
H	1.158
I	1.021
J	1.098
K	1.008
L	1.185
M	1.048
N	1.165
O	1.057

5. Conclusion

We apply general deviation measures as the inputs and return measures as the outputs. The objective of this study is to establish a new approach based on quadratic model to examine mutual funds' performance based on optimal using of risk to make returns for risk averse investors key goal of this study is to critically review. We applied approaches and discussions available in the literature to determine new constraint based on real problem in Iranian finance market. In fact, what has been addressed here is to provide a how-to-use low risk to cover inflation effect on investments when they are loss value. In this regard, we have proposed a method which optimize return as output.

This study uses financial data from mutual funds to test the proposed model. The modeling offers we also find the maximum return. A comparison between the new model and available models shows that the efficiency score of each DMU in this model based on trade off risk and return for risk averse investors. To summarize, the new method can be utilized to achieve more realistic results for efficiency scores of mutual funds with fixed income in high inflation environment.

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