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Mutual funds performance evaluation based on endogenous benchmarks

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ABSTRACT

This paper proposes two quadratic-constrained DEA models for evaluation of mutual funds performance, from a perspective of evaluation based on endogenous benchmarks. In comparison to previous studies, this paper decomposes two vital factors for mutual funds performance, i.e. risk and return, in order to define mutual funds' endogenous benchmarks and give insights and suggestions for managements. Of the two quadratic-constrained DEA models, one is a partly controllable quadratic-constrained programming. The approach is illustrated by a sample of twenty-five actual mutual funds operating in the Chinese market. It identifies the root reasons of inefficiency and ways for improving performance. The results show that although the market environment in year 2006 was much better than that in 2005, average efficiency score declines in year 2006 due to relaxing of system risk control. The majority of mutual funds do not show persistence in efficiency ranking. The most important conclusion is that the ranking of mutual funds in China depends mostly on system risk control.

1. Introduction

Mutual funds have become one of the most important investment tools for common people as they enable small investors to take part in diversified investments. Assets managed by mutual funds are increasing as demand is growing and funds are getting diversified. Therefore, how to evaluate funds' performances has become a question of consequence. Since the important work of Markowitz (1952), Sharpe (1964, 1966), Treynor (1965) and Jensen (1968, 1969), numerous studies have been conducted for measuring performance in respect of risk and return, mainly based on the mean-variance (MV) framework. Evaluation results of these studies appear to depend, to a large extent, on exterior benchmarks used (1978).

In the most recent decade, some studies have been based on data envelopment analysis (DEA) methodologies to evaluate mutual funds' performance. Introduced by Charnes, Cooper, and Rhodes (1978), DEA is a mathematical programming method for measuring relative efficiencies of decision making units (DMUs). Since it is a non-parametric method capable of comparative evaluation, it is able to give assessments based on multi-inputs and multi-outputs, and enables managements to benchmark the best-practices of mutual funds by calculating scores denoting their efficiencies.

In order to assess 11 funds engaged in finance and metal industries in International Bargainers Research Database, Wilkens and Zhu (2001) chose standard deviation of returns and the proportion of negative monthly return in the year as inputs, and monthly return, skewness of return distribution and the minimum return in the year as outputs. Murthi, Choi, and Desai (1997) put forward a portfolio performance measurement method based on DEA in 1997, called DEA portfolio efficiency index (DPEI), with standard deviation and transaction loads as inputs, and excess return as output, to investigate performance of 2083 mutual funds in the third quarter of 1993. Choi and Murthi (2001) used the same inputs and outputs but with a different DEA formulation. McMullen and Strong (1998) analyzed and compared the comparative effectiveness of 135 American stock funds with data of the past 1 year, past 3 years and past 5 years, based on the DPEI index. Sedzro and Sardano (1999), on the other hand, analyzed performance of 58 US equity funds in Canada using DEA with annual return, expense ratio, minimum initial investment and a proxy for risk as factors associated with fund performance. Galagedera and Silvapulle (2002) analyzed and measured comparative effectiveness of 257 Australian mutual funds during the years 1995–1999 with different combinations of inputs and outputs. Basso and Funari (2001) used several risk measures (standard deviation, standard semi-deviation and beta) and subscription and redemption costs as inputs, and the mean return and the fraction of periods in which the mutual fund was non-dominated as outputs. Basso and Funari (2003), for assessing ethical funds, substituted the fraction of non-dominated periods for an ethical score of the mutual fund. Luo, Wang, and Tian (2003) used the integrated DEA index to evaluate the comparative performance of 33 closed-end funds which en-

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tered the Chinese market before 2001. He found that the ranking differed much from than that of the Jessen index, which indicates that index selection is very important in funds' performance evaluation. Chang (2004) used a non-standard DEA formulation (based on minimum convex input requirement set) with mean return as output, and standard deviation, beta, total assets and load as inputs. Zhao, Zhang, Lai, and Wang (2007) evaluated Chinese mutual funds in DEA model with value-at-risk (VaR) under asymmetric Laplace distribution, cost and total return, and also investigated their scale efficiencies. Furthermore, Han and Liu (2003), Ma, Wu, and Cheng (2003) also studied the performance of closed-end funds in the Chinese market with an improved DEA model. Chen (2003) summed up DEA models applied in mutual funds performance evaluation.

Most of these researches were based on conventional linear envelopment model; the major differences between them were related to consideration of variables and data samples. As is known to all, DEA approaches provide each inefficient DMU's endogenous benchmark and estimates of the potential improvement that can be made. In mutual funds' evaluation with DEA models, the endogenous benchmarks are portfolios of funds. It is one of the advantages of DEA approaches. However, conventional DEA approaches in the above references do not compute correctly the risk of the target portfolios. These approaches compute the risk measure of the benchmark against which the mutual fund is compared as a linear combination of risk measures of the intervening mutual funds. This does not take into account diversification effects, and the resulting overestimation of the risk measure that usually leads to underestimation of efficiency scores. To make up for this consideration, Morey and Morey (1999) proposed quadratic-constrained DEA models that use a MV approach with variance as input and mean return as output. But there is still space to improve. Their input is total risk and output is total return. This makes sense, but is still not explicit enough in management. A good evaluation should be able to tell the root reason for different performances.

This paper digs the problem deeper and gives two quadratic-constrained envelopment models with information of system risk, non-system risk, excess return from timing and excess return from selecting. Our purpose is to investigate the root reason of each mutual fund's relative efficiency, present its endogenous benchmark, and to give performance improvement suggestions. Considering that the two kinds of risk are a little different from each other, system risk cannot be lowered with diversification, while non-system risk can be, we give a quadratic constraint for non-system risk in the envelopment evaluation model. Constraints of system risk and excess returns then be handled as linear. In addition, since the system risk is an uncontrollable factor, we incorporate the uncontrollable technology factor in our quadratic-constrained DEA models. The two models proposed in this paper are from the perspectives of input and output orientations. With this approach, investors will be able to assess mutual funds better, and shall be able to design better funds portfolios, with their own endogenous benchmarks.

The rest of this paper is organized as follows. Section 2 describes measures of risk and excess return. Section 3 presents the two quadratic-constrained envelopment evaluation models for mutual funds' endogenous benchmarks. Section 4 makes an empirical study of mutual funds in China and Section 5 draws some insightful conclusions.

2. Measures for risk and excess return

2.1. Excess return

Different mutual funds have different proportions allocated to different types of assets. Most existing quantitative researches of asset allocation are based on the framework of Brinson, Hood, and Beebower (1986). Actual allocation is dependent on timing and equity selection, which ultimately defines the original and extended strategic structure of a fund. Then funds adjust proportions of different kinds of assets, including stock, bond and money, dynamically. Asset allocation is the principal step of investment decisions. Decomposing and measuring excess return from differences in asset allocation can help managers find the reasons for performance differences on a running basis, and identify potential for performance improvement in the future.

According to BHB, suppose that there is a market benchmark M with g kinds of assets, and a mutual fund P with the same g kinds of assets. g is a positive integrity. These g kinds may be stock, bond or money, etc. The return of the ith asset in P is denoted as R_{pi} and that in 9i is denoted as R_{mi} ($i = 1,2,\ldots,$ g). The ith asset's proportion in P is denoted as W_{pi} and in M it is denoted as W_{mi}. Then mutual fund P's excess return from timing R_{PT} can be represented as:

$$R_{PT} = \sum_{i=1}^{g} R_{mi} \times (W_{Pi} - W_{mi}). \tag{1}$$

Mutual fund P's excess return from timing R_{PS} can be represented as:

$$R_{PS} = \sum_{i=1}^{g} (R_{pi} - R_{mi}) \times W_{pi}. \tag{2}$$

For practical convenience, the original assets allocation of mutual fund P at the beginning of some given time horizon is regarded as benchmark M's collation proportion. And we assume that the benchmark will not change its asset allocation during this horizon. Therefore, we can investigate mutual fund P's excess return from asset collation adjustment, or we can say, timing, during the given period, via formula (1). However, since it is very hard for us to get the actual return R_{pi}, excess return from selection cannot be computed directly. Here we get a substitute in an indirect way, for selection, by excluding timing, as follows:

$$R_{PQ} = R_P - R_M - R_{PT}, \tag{3}$$

where R_P is mutual fund P's actual total return, and R_M is the benchmark's total return. R_{PQ} can be regarded as the approximate excess return from selection during the given period.

2.2. Risks

Risk is a vital factor affecting return. As a professionally designed financial instrument, one of mutual funds' basic functions is to manage its portfolio's risk. According to the Capital Asset Pricing Model (CAPM), investment risk can be decomposed into system risk and non-system risk. System risk is from market's integral changing, impossible to be controlled by diversification of the portfolio. Non-system risk is the risk that only affects some industry or some company, and which can be countered by diversification of investment. System risk can be computed as follows, according to CAPM:

$$R_P = \alpha_P + \beta_P R_M + \varepsilon_P, \tag{4}$$

where R_P denotes the mutual fund's total return and R_M denotes the benchmark's total return. β_P is a measure of system risk. The bigger the value of β_P is, the higher is the system risk this mutual fund is exposed to. Eq. (4) can be solved by the Least-Squares Method. Standard deviation $\sigma(\varepsilon_P)$ of stochastic error series ε_P is regarded as non-system risk.

Though transaction load is also what investors are concerned about, and it is a necessary payout in mutual fund operations, high initial commission and redemption charges also constitute severe erosions of investment return. Therefore, the transaction load needs not to be considered solely, because it has been deducted during returns calculation.

In summary, in our programming model for evaluation of mutual funds, we consider system risk indicator β_P, non-system risk indicator $\sigma(\varepsilon_P)$, excess return from timing, and excess return from selecting.

3. Modeling

3.1. Related models

The conventional DEA models employed in previous studies are Charnes et al. (1978) and Banker, Charnes, and Cooper (1984) models, which are both linear DEA models, and are illustrated as follows. Suppose there are n mutual funds. Each one has m inputs and s outputs. $\mathbf{x}_j$ is the input vector and $\mathbf{y}_j$ is the output vector of the jth mutual fund, $\mathbf{x}_j = (x_{1j}, x_{2j}, \ldots, x_{mj})$, $\mathbf{y}_j = (y_{1j}, y_{2j}, \ldots, y_{sj})$. The state possibility set, made of inputs and outputs, is: $T = \{(\mathbf{x}, \mathbf{y}) | \mathbf{x} \geqslant \sum_{j=1}^{n} \lambda_j \mathbf{x}_j, \mathbf{y} \leqslant \sum_{j=1}^{n} \lambda_j \mathbf{y}_j,\ j = 1, 2, \ldots, n\}$. Then the comparative efficiency of mutual fund $j_0 (1 \leqslant j_0 \leqslant n)$ can be defined as:

$$\begin{aligned} \theta^* = \min \quad & \theta \\ \text{subject to} \quad & \sum_{j=1}^{n} \lambda_j x_{ij} \leqslant \theta x_{ij_0}, \quad i = 1, 2, \ldots, m, \\ & \sum_{j=1}^{n} \lambda_j y_{rj} \geqslant y_{rj_0}, \quad r = 1, 2, \ldots, s, \\ & \sum_{j=1}^{n} \lambda_j = 1, \\ & \lambda_j \geqslant 0. \end{aligned} \tag{5}$$

It is evident that the linear model provides a subsection production surface, which denotes a production frontier in economics: the most outputs from given inputs, or the least inputs for given outputs. Projection of inefficient units (funds) actually provides a feasible scenario to improve performance, since it points out the reason and the extent of inefficiency, and it is also one of DEA model's advantages. Here, the projection of an inefficient point $(\mathbf{x}_{j_0}, \mathbf{y}_{j_0})$ is:

$$\begin{cases} \hat{\mathbf{x}}_{j_0} = \theta^* \mathbf{x}_{j_0} - \mathbf{s}^{*+} = \sum_{j=1}^{n} \lambda_j^* \mathbf{x}_j, \\ \hat{\mathbf{y}}_{j_0} = \mathbf{y}_{j_0} + \mathbf{s}^{*-} = \sum_{j=1}^{n} \lambda_j^* \mathbf{y}_j, \end{cases} \tag{6}$$

where $\mathbf{s}^{*+}$,$\mathbf{s}^{*-}$ are the corresponding optimal relax and optimal surplus for constraints of model (5). $(\hat{\mathbf{x}}_{j_0}, \hat{\mathbf{y}}_{j_0})$ denotes a new, comparatively DEA efficient fund, against the original n funds.

Apparently, DEA models provide endogenous benchmarks for each inefficient mutual fund, and estimates of the potential improvement that can be made. The endogenous benchmarks are portfolios of mutual funds used in the evaluation. Inputs of the benchmark against which the mutual fund is compared are a linear combination of inputs of the intervening mutual funds, and so are the outputs. However, when risk measure is one of the inputs, the linear DEA model cannot compute correctly the risk of the target portfolios, as in the related references. It does not take into account the diversification and its effects; the resulting overestimation of the risk measure usually leads to underestimation of efficiency scores. To make up for this consideration, Morey and Morey (1999) and Briec, Kerstens, and Lesourd (2004) proposed quadratic-constrained DEA models that use a MV approach with variance as input and mean return as output. Suppose there is only risk as an input, and total return as an output, determine $\omega_j \geqslant 0$ $(j = 1, 2, \ldots, j_0, \ldots, n)$ and $\theta \geqslant 1$, so that:

$$\begin{aligned} \theta^* = \max \quad & \theta \\ \text{subject to} \quad & \sum_{j=1}^{n} \omega_j^2 \sigma_j^2 + \sum_{\substack{k=1 \\ k \neq j}}^{n} \sum_{j=1}^{n} \omega_k \omega_j Cov(R_k, R_j) \leqslant \sigma_{j_0}^2, \\ & \sum_{j=1}^{n} \omega_j E(R_j) \geqslant \theta E(R_{j_0}), \\ & \sum_{j=1}^{n} \omega_j = 1, \\ & \omega_j \geqslant 0 \end{aligned} \tag{7}$$

where σ_j^2 is the jth mutual fund's return deviation variance for measuring the total risk, $\sigma_{j_0}^2$ is fund j_0's return deviation variance, $Cov(R_k, R_j)$ is the covariance between the ith mutual fund and the jth mutual fund, and $E(R_j)$ and $E(R_{j_0})$ are the expectations of the ith and the jth mutual fund's return, respectively.

3.2. Proposed model

Model (7) is more scientific and accords with reality, concerning about funds' risk and return. It takes the diversification effect for risk into consideration. On the other hand, since only total risk and total return measures are considered, even though the model can provide much insightful information to improve performance, its results are still not clear enough and practical enough. For example, if a relatively inefficient fund has a target portfolio of mutual funds as an endogenous benchmark, and the model says it needs to lower its total risk to some extent to be relatively efficient, say 10%, compared to its original level, then how should we realize it? Both the fund's risk measure and the target portfolio's risk measure are total risk, wherein, actually, non-system risk is avoidable by diversification and system risk is unavoidable.

A similar situation prevails in respect of return measure. Investors care about the excess return of mutual funds more than the total return, as a matter of fact. The excess return is the substantial reason that they invest in mutual funds. Even if we take excess return as an output in model (7), and model (7) gives us suggestions on how much to improve on excess return to get better performance, it does not provide any ultimate help in mutual funds management. Because it can only tell the extent of improvement needed, not the specific way to achieve improvement. That is why we are going to describe our quadratic-constrained enveloping model as follows.

It is also based on model (7).

$$\begin{aligned} \theta^* = \max \quad & (\theta_1 + \theta_2)/2 \\ \text{subject to} \quad & \sum_{j=1}^{n} \omega_j^2 \sigma^2(\varepsilon_j) + \sum_{\substack{k=1 \\ k \neq j}}^{n} \sum_{j=1}^{n} \omega_k \omega_j Cov(\varepsilon_k, \varepsilon_j) \leqslant \sigma^2(\varepsilon_{j_0}), \\ & \sum_{j=1}^{n} \omega_j \beta_j \leqslant \beta_{j_0}, \\ & \sum_{j=1}^{n} \omega_j R_{jT} \geqslant \theta_1 R_{j_0 T}, \\ & \sum_{j=1}^{n} \omega_j R_{jQ} \geqslant \theta_2 R_{j_0 Q}, \\ & \sum_{j=1}^{n} \omega_j = 1, \\ & \omega_j \geqslant 1 \end{aligned} \tag{8}$$

where $\sigma^2(\varepsilon_j)$ $(j = 1, 2, \ldots, j_0, \ldots, n)$ is the variance of ε_j and $\beta_j (j = 1, 2, \ldots, j_0, , \ldots, n)$ denotes the jth mutual fund's system risk level. Both ε_j and β_j come form the following Eq. (9). $Cov(\varepsilon_k, \varepsilon_j)$ is the covariance between ε_k and ε_j.

$$R_j = \alpha_j + \beta_j R_M + \varepsilon_j, \quad j = 1, 2, \ldots, j_0, \ldots, n. \tag{9}$$

And R_{jT} ($j = 1,2,\ldots,j_0,\ldots,n$) in Eq. (8) comes from the following Eq. (10) and R_{jQ} ($j = 1,2,\ldots,j_0,\ldots,n$) in Eq. (8) comes from the following Eq. (11).

$$R_{jT} = \sum_{i=1}^{g} R_{mi} \times (W_{ji} - W_{mi}), \quad j = 1,2,\ldots,j_0,\ldots,n, \tag{10}$$

$$R_{jQ} = R_j - R_M - R_{jT}, \quad j = 1,2,\ldots,j_0,\ldots,n. \tag{11}$$

R_j is the jth mutual fund's return and R_M is the return of the market benchmark.

Model (8) considers the problem from an output perspective. It tries to keep the fund's risk level and increases its excess returns as much as possible. θ^* represents the relative performance. According to classical data envelopment analysis methodology, θ^* in output forms will be larger than or equal to 1, which means the larger θ^* is, the poorer is the performance of the fund.

On the contrary, when it comes to input perspective, we could constitute another quadratic-constrained envelopment model, as follows, to settle the same problem.

$$\begin{aligned}
\varphi^* = \min \quad & \varphi \\
\text{subject to } & \sum_{j=1}^{n} \omega_j^2 \sigma^2(\varepsilon_j) + \sum_{\substack{k=1 \\ k\neq j}}^{n} \sum_{j=1}^{n} \omega_k \omega_j Cov(\varepsilon_k, \varepsilon_j) \leqslant \varphi \sigma^2(\varepsilon_{j_0}), \\
& \sum_{j=1}^{n} \omega_j \beta_j \leqslant \beta_{j_0}, \\
& \sum_{j=1}^{n} \omega_j R_{jT} \geqslant R_{j_0 T}, \\
& \sum_{j=1}^{n} \omega_j R_{jQ} \geqslant R_{j_0 Q}, \\
& \sum_{j=1}^{n} \omega_j = 1, \\
& \omega_j \geqslant 1.
\end{aligned} \tag{12}$$

Considering that one of inputs, system risk, cannot be addressed by a diversified portfolio, we are not able to change the system risk level unless we change volumes, which means system risk is uncontrollable. Therefore, improvement indicator φ is not multiplied to the right side of the system risk constraint. Only non-system risk is controllable in model (12). Model (12) actually describes a scene that decreases non-system risk as much as possible, without lowering excess return, by constituting a new portfolio of mutual funds. Apparently, φ^* is less than 1, and the lower the value of φ^*, poorer the performance.

Model (8) and model (12) can be converted into their equivalents as model (13) and (14), respectively.

$$\begin{aligned}
\theta^* = \max \quad & (\theta_1 + \theta_2)/2 \\
\text{subject to } & \sum_{j=1}^{n} \omega_j^2 \sigma^2(\varepsilon_j) + \sum_{\substack{k=1 \\ k\neq j}}^{n} \sum_{j=1}^{n} \omega_k \omega_j Cov(\varepsilon_k, \varepsilon_j) + s_1^+ = \sigma^2(\varepsilon_{j_0}), \\
& \sum_{j=1}^{n} \omega_j \beta_j + s_2^+ = \beta_{j_0}, \\
& \sum_{j=1}^{n} \omega_j R_{jT} - s_1^- = \theta_1 R_{j_0 T}, \\
& \sum_{j=1}^{n} \omega_j R_{jQ} - s_2^- = \theta_2 R_{j_0 Q}, \\
& \sum_{j=1}^{n} \omega_j = 1, \\
& \omega_j \geqslant 1,
\end{aligned} \tag{13}$$

$$\begin{aligned}
\varphi^* = \min \quad & \varphi \\
\text{subject to } & \sum_{j=1}^{n} \omega_j^2 \sigma^2(\varepsilon_j) + \sum_{\substack{k=1 \\ k\neq j}}^{n} \sum_{j=1}^{n} \omega_k \omega_j Cov(\varepsilon_k, \varepsilon_j) + s_1^+ = \varphi \sigma^2(\varepsilon_{j_0}), \\
& \sum_{j=1}^{n} \omega_j \beta_j + s_2^+ = \beta_{j_0}, \\
& \sum_{j=1}^{n} \omega_j R_{jT} - s_1^- = R_{j_0 T}, \\
& \sum_{j=1}^{n} \omega_j R_{jQ} - s_2^- = R_{j_0 Q}, \\
& \sum_{j=1}^{n} \omega_j = 1, \\
& \omega_j \geqslant 1.
\end{aligned} \tag{14}$$

where $s_1^+, s_2^+, s_1^-, s_2^-$ are the corresponding relax and optimal surplus for the constraints.

The projection of an inefficient mutual fund can be attained by the following equations:

$$\begin{cases}
\hat{\sigma}^2(\varepsilon_{j_0}) = \varphi \sigma^2(\varepsilon_{j_0}) - s_1^{*+} = \sum_{j=1}^{n} (\omega_j^*)^2 \sigma^2(\varepsilon_j) + \sum_{\substack{k=1 \\ k\neq j}}^{n} \sum_{j=1}^{n} \omega_k^* \omega_j^* Cov(\varepsilon_k, \varepsilon_j), \\
\hat{\beta}_{j_0} = \beta_{j_0} - s_2^{*+} = \sum_{j=1}^{n} \omega_j^* \beta_j, \\
\widehat{R}_{j_0 T} = R_{j_0 T} + s_1^{*-} = \sum_{j=1}^{n} \omega_j^* R_{jT}, \\
\widehat{R}_{j_0 Q} = R_{j_0 Q} + s_2^{*-} = \sum_{j=1}^{n} \omega_j^* R_{jQ},
\end{cases} \tag{15}$$

where $s_1^{*+}, s_2^{*+}, s_1^{*-}, s_2^{*-}$ are the corresponding optimal relax and optimal surplus for the constraints. ω_j^* ($j = 1,2,\ldots,n$) are the optimal weights for each unit. $\hat{\sigma}^2(\varepsilon_{j_0}), \hat{\beta}_{j_0}, \widehat{R}_{j_0 T}$ and $\widehat{R}_{j_0 Q}$ actually constitute a new target portfolio for mutual fund j_0. With these parameters, mutual fund j_0 is able to identify the essential reason for its poor performance, and later, ways to improve it.

$$\begin{cases}
\Delta\sigma^2(\varepsilon_{j_0}) = \sigma^2(\varepsilon_{j_0}) - \hat{\sigma}^2(\varepsilon_{j_0}) = (1-\varphi)\sigma^2(\varepsilon_{j_0}) + s_1^{*+}, \\
\Delta\beta_{j_0} = \beta_{j_0} - \hat{\beta}_{j_0} = s_2^{*+}, \\
\Delta R_{j_0 T} = \widehat{R}_{j_0 T} - R_{j_0 T} = s_1^{*-}, \\
\Delta R_{j_0 Q} = R_{j_0 Q} - \widehat{R}_{j_0 Q} = s_2^{*-}.
\end{cases} \tag{16}$$

4. Empirical study and discussion

4.1. Data

With financial markets' liberalization and globalization, foreign investors' interest in the Chinese financial market is growing considerably. Therefore, ranking in the Chinese mutual fund industry would be of international interest.

Since open-ended mutual funds in China were required to publish their asset allocation data only from year 2004 onwards, asset data are available only for 2005 to 2007. In order to ensure that all evaluated funds are in the same market environment and operate in a similar policy environment, 25 open-end mutual funds of stock type, for which the required data for years 2005 and 2006 are avail-

Table 1
Inputs and outputs of 25 mutual funds.

Fund name	β_P		$\sigma^2(\varepsilon_P)$		R_{PT}		R_{PQ}	
	2005	2006	2005	2006	2005	2006	2005	2006
Huaanchuangxin	0.6098	0.7208	0.006	0.0074	0.500877	−8.84208	−0.4173	8.888619
Huaxiachengzhang	0.5932	0.7634	0.0048	0.0071	0.727706	0.796419	−0.58849	−0.76601
Guotaijinying	0.5571	0.797	0.0056	0.0072	−2.55794	19.83804	2.682034	−19.6411
Xinlanchou	0.6132	0.7853	0.0056	0.0067	0.852928	−2.82101	−0.76504	2.805617
Changshengchengzhang	0.5789	0.6946	0.0047	0.0052	0.544688	−6.6933	−0.44124	6.477621
Baoyinghongli	0.5982	0.7694	0.0048	0.0089	0.025801	−18.3518	0.025952	18.68587
Dachengjiazhi	0.5653	0.7673	0.0044	0.0068	−0.53951	−7.68092	0.654394	7.714403
Jiashichengzhang	0.5665	0.7071	0.0058	0.0083	0.37455	−17.5095	−0.25179	17.63945
Huaan MSCI	0.7537	0.8949	0.0029	0.0047	−3.93021	−1.60627	3.949763	1.749488
Wanjia 180	0.7144	0.9021	0.0019	0.0046	−3.40292	3.961437	3.41861	−3.80676
Zhaoshanggupiao	0.5836	0.7154	0.0047	0.0062	0.018714	−0.72987	0.109939	0.727443
Hefengchengzhang	0.6113	0.7316	0.0049	0.008	0.573651	18.12505	−0.30043	−18.3777
Hefengzhouqi	0.6625	0.7284	0.0056	0.0084	−0.86473	11.03235	1.004541	−10.7496
Hefengwending	0.5919	0.6844	0.0053	0.0075	1.15508	15.99596	−1.03283	−15.7377
Jinyingyouxuan	0.6714	0.7143	0.0043	0.0087	0.502953	−5.32444	−0.44693	5.018644
Penghuashouyi	0.5818	0.6203	0.0049	0.0095	−1.02203	−20.0305	1.132801	20.08416
Jiashiwenjian	0.5241	0.6881	0.005	0.0058	−1.05893	−2.01028	1.185118	1.794744
Jiashizengzhang	0.5458	0.6695	0.0056	0.0073	−1.37267	−14.4914	1.627866	14.53621
Baokangxiaofeipin	0.5492	0.6205	0.004	0.0054	−1.01097	5.69089	1.19733	−5.715
Yinhewenjian	0.6817	0.7278	0.0048	0.008	1.651603	−4.5717	−1.63975	4.812023
Haifutongjingxuan	0.6136	0.7083	0.0043	0.0054	−1.0157	−8.32626	1.162452	8.350115
Rongtongshen 100	0.8154	0.9586	0.0032	0.0073	−3.31979	−1.38137	3.3554	1.386394
Rongtongchengzhang	0.6862	0.5429	0.0048	0.0066	1.374613	24.78204	−1.26444	−25.0454
Jingshenyouxuan	0.5579	0.6873	0.0053	0.0074	−0.26128	5.480109	0.441939	−5.24595
Guotaijingxuan	0.5507	0.6253	0.0053	0.0053	−0.2968	−7.49238	0.396312	7.508311

Table 2
Outcome of stock-type funds evaluation in 2005–2006.

	Efficiency in 2005	Ranking in 2005	Efficiency in 2006	Ranking in 2006
Huaanchuangxin	0.810648	29	0.823323	24
Huaxiachengzhang	1.000000	1	0.777108	33
Guotaijinying	0.925428	10	0.772355	34
Xinlanchou	0.806414	30	0.678474	45
Changshengchengzhang	0.853918	18	0.894465	14
Baoyinghongli	0.82955	21	0.989521	7
Dachengjiazhi	0.905965	12	0.791685	31
Jiashichengzhang	0.87261	17	1.000000	1
Huaan MSCI	0.905724	13	0.664417	46
Wanjia 180	1.000000	1	0.688776	43
Zhaoshanggupiao	0.851633	19	0.699035	42
Hefengchengzhang	0.812159	28	0.702294	41
Hefengzhouqi	0.760803	35	0.687915	44
Hefengwending	0.835763	20	0.736832	38
Jinyingyouxuan	0.814566	27	0.747648	37
Penghuashouyi	0.815283	26	1.000000	1
Jiashiwenjian	0.961097	8	0.752677	36
Jiashizengzhang	0.929304	9	0.995191	6
Baokangxiaofeipin	0.783887	32	0.66361	47
Yinhewenjian	0.52611	49	0.5055	50
Haifutongjingxuan	0.877733	16	0.918385	11
Rongtongshen 100	0.818806	25	0.55146	48
Rongtongchengzhang	0.826961	22	1.000000	1
Jingshenyouxuan	0.892329	15	0.723826	39
Guotaijingxuan	0.723811	40	0.825624	23

able, have been selected for the empirical study. All of these were launched before the year 2004.

According to the prescription for stock-type mutual funds by CERC,[1] we construct a virtual exterior benchmark, i.e. market benchmark. Here we assume the fund has allocated 80% to contemporary stock market, 15% to contemporary bond market, and 5% to money markets. Contemporary stock market return is worked out by adding 50% of ISA[2] return and 50% of ISIA[3] return, and contemporary bond market return refers to CBI[4] return. The virtual benchmark is designed to reflect the Chinese security market comprehensively and accurately. All data have come from Tianxiang Investment Analysis System.

[1] Asset in stocks not less than 60% and not more than 95%, regulated by Management Methods of Equity Investment Funds Operation, 29th June, 2004.

[2] Index of Shanghai A-shares, that is, the signal index of the Shanghai Stock Exchange.

[3] Index of Shenzhen Ingredients A-shares, that is, the signal index of the Shenzhen Stock Exchange.

[4] The Chinese Bond Index, that is, the signal index of the Chinese bond market.

Table 3
Changes needed for inputs and outputs.

	2005				2006			
	$\Delta\beta_{j_0}$ (%)	$\Delta\sigma^2(\varepsilon_{j_0})$ (%)	ΔR_{j_0T} (%)	ΔR_{j_0Q} (%)	$\Delta\beta_{j_0}$ (%)	$\Delta\sigma^2(\varepsilon_{j_0})$ (%)	ΔR_{j_0T} (%)	ΔR_{j_0Q} (%)
Huaanchuangxin	−18.94%	0.00	21.07	0.00	−17.67	0.00	999.90	0.00
Huaxiachengzhang	0.00	0.00	0.00	0.00	−22.29	0.00	0.00	0.00
Guotaijinying	−7.46	0.00	999.90	0.00	−32.37	0.00	0.00	999.90
Xinlanchou	−19.36	0.00	0.00	0.00	−32.15	0.00	999.90	0.00
Changshengchengzhang	−14.61	0.00	11.33	0.00	−10.55	0.00	999.90	0.00
Baoyinghongli	−17.05	0.00	999.90	0.00	−9.59	0.00	0.00	0.00
Dachengjiazhi	−9.40	0.00	999.90	0.00	−20.83	0.00	999.90	0.00
Jiashichengzhang	−12.74	0.00	61.91	0.00	0.00	0.00	0.00	0.00
Huaan MSCI	−9.43	0.00	999.90	0.00	−33.56	0.00	999.90	0.00
Wanjia 180	0.00	0.00	0.00	0.00	−31.12	0.00	0.00	999.90
Zhaoshanggupiao	−14.84	0.00	999.90	0.00	−30.10	0.00	999.90	0.00
Hefengchengzhang	−18.78	0.00	4.68	999.90	−29.77	0.00	0.00	999.90
Hefengzhouqi	−23.92	0.00	999.90	0.00	−31.21	0.00	0.00	0.00
Hefengwending	−16.42	0.00	0.00	0.00	−26.32	0.00	0.00	0.00
Jinyingyouxuan	−18.54	0.00	0.00	999.90	−25.24	0.00	999.90	0.00
Penghuashouyi	−18.47	0.00	999.90	0.00	0.00	0.00	0.00	0.00
Jiashiwenjian	−3.89	0.00	999.90	0.00	−24.73	0.00	999.90	0.00
Jiashizengzhang	−7.07	0.00	999.90	0.00	0.00	0.00	999.90	0.00
Baokangxiaofeipin	−21.61	0.00	999.90	0.00	−33.64	0.00	0.00	999.90
Yinhewenjian	−47.39	0.00	0.00	999.90	−49.45	0.00	999.90	0.00
Haifutongjingxuan	−12.23	0.00	999.90	0.00	−8.16	0.00	999.90	0.00
Rongtongshen 100	−18.12	0.00	999.90	0.00	−44.85	0.00	999.90	0.00
Rongtongchengzhang	−17.30	0.00	0.00	999.90	0.00	0.00	0.00	0.00
Jingshenyouxuan	−10.77	0.00	999.90	0.00	−27.62	0.00	0.00	0.00
Guotaijingxuan	−27.62	0.00	999.90	0.00	−17.44	0.00	999.90	0.00

Data used is shown in Table 1.

The stock market in year 2005 was still in vale, when most funds were cautious to control their risk and restricted β_j $(1 \leqslant j \leqslant 25)$ to less than 1, to avoid losses in the event of market declining. That is why Chinese mutual funds' system risks were lower than the benchmark. In the year 2006, when the bull market came, funds' risk control slackened as they were keen to share benefits of rising markets; therefore, β_js went up.

4.2. Results

On evaluation of 25 mutual funds' performance in years 2005 and 2006, with model (14), the outcomes were as shown in Table 2.

Evaluation of individual funds' comparative performance reveals funds settled on the production frontier, and puts in perspective changes in each fund's performance over the given time horizon, besides their comparative rankings and changes therein.

As Table 2 shows, among 25 mutual funds, 2 were comparatively efficient in year 2005, namely, Huaxiachengzhang and Wanjia 180, and 3 were efficient in year 2006, namely, Jiashichengzhang, Penghuashouyi and Rongtongchengzhang. 16 funds' investment efficiency scores were lower in year 2006 than in 2005, and 9 funds' efficiency scores were higher 2006 than in 2005. Obviously, the average efficiency of the 25 open-end funds declined in 2006. Yinhewenjian had the worst performance; its efficiency scores were almost the same in both the years.

4.3. Discussion

Information of each fund's projections on DEA comparative efficient frontier provides further useful information to improve performance. Generally, the greater the number of times a fund stands on the efficient frontier, the more predominant and more competitive it is as the target fund. Therefore, funds constituting efficient frontier are ideal for the evaluated fund. That is to say, they are the powerful competitors on the relationship of inputs and outputs this paper suggests. Take Huanchuangxin as example. Huaxiachengzhang was its powerful competitor in year 2005, while Xinlanchou, Dachengjiazhi and Yinhewenjian were its competitors in 2006. Huaxiachengzhang figured as other funds' frontier 44 times, as the most competitive fund. However, its efficiency score dropped to 78% in year 2006. Similarly, Wanjia 180 performed well to constitute other funds' efficient frontier 29 times in 2005, while its efficiency score in year 2006 was only 69%. On the contrary, Penghuashouyi's efficiency score in year 2005 was 81%, but it constituted other funds' efficient frontier 28 times in year 2006, with an efficiency score of 100%. Similarly, Rongtongchengzhan, having efficiency scores of 83% in 2005 and 100% in 2006, constituted other funds' efficient frontiers many times.

By calculating the difference between inefficient funds and their projections on the efficient frontier made by formula (16), we can get the quantum of potential improvement for inefficient funds and find out the reason of inefficiency.

Table 3 lists each fund's inadequacy or excess in inputs and outputs, according to formula (16). It shows that system risk is all that needs to be reduced. At the same time, reduction of system risk will bring large increase in excess returns; some funds' excess return would increase even 10 times. As seen from Table 3, non-system risk is far from being as important as system risk. Therefore, it can be concluded that differences of comparative efficiency mainly result from system risk controls.

Table 3 also indicates that many funds' efficiency changes in year 2006 resulted from risk control. For example, Jiashiwenjian ranked 8th among 25 funds in year 2005 and needed to cut 3.89% of its system risk to attain comparative effectiveness. While its rank dropped to 36 in year 2006, it needed to cut system risk 24.73% to be efficient. Huaxiachengzhang, Wanjia 180, Penghuashouyi, Rongtongchengzhang, etc. were all similar to fund Jiashiwenjian, with much changes in their comparative efficiency scores in the two years, resulting from the controlling of system risk not being persistent.

4.4. Comparison with other methods

We then compare efficiency ranking of these 25 open-ended funds in years 2005 and 2006 with rankings of their Sharp ratios,

Table 4
Correlation test of different indexes rankings.

	Treynor ratio	Sharpe ratio	Jensen Alpha	IR	M-2	RAC
Comparative efficiency	−0.153595	−0.208934	0.203713	0.178612	0.230667	0.254441
Treynor ratio	1.000000	0.986394	0.444335	−0.569889	−0.339328	-0.576269
Sharpe ratio	0.986394	1.000000	0.379945	−0.593425	−0.341626	-0.558684
Jensen Alpha	0.444335	0.379945	1.000000	0.388877	0.612123	0.155704
IR	−0.569889	−0.593425	0.388877	1.000000	0.821699	0.615461
M-2	−0.339328	−0.341626	0.612123	0.821699	1.000000	0.729650
RAC	−0.576269	−0.558684	0.155704	0.615461	0.729650	1.000000

Treynor ratios, Jensen Alphas, information ratios (IR), M-2s and risk adjustment capacity (RAC), which are classical mutual funds evaluation measures in correlation test. The results are shown in Table 4.

After regressing comparative efficiency rankings on the other 6 series, the coefficients are not significant. Therefore, it is concluded that comparative efficiency scores do not necessarily have a relationship with the traditional fund performance index. Traditional indexes only consider the difference between the average market return and the fund portfolio's return adjusted by risk, without weighing other factors such as loads, that also affect performance in the course of investment. DEA approach, on the other hand, considers these two or more factors. DEA based on multiple inputs and multiple outputs is much different in terms of computing principles, from the single factor ratio index, under the hypothesis of CAPM. There is no surprise in their outcomes' deviation. Besides, Sharp ratio, Treynor ratio, Jensen Alpha, IC, M-2,[5] and RAC do not always have significant positive or negative relations among themselves.

5. Conclusions

Data envelopment analysis is a systematic analysis method and is usually applied for comparative performance evaluation. This paper proposes two quadratic-constrained DEA models for evaluation of mutual funds, based on endogenous benchmarks. In comparison to previous studies, this paper decomposes two vital factors affecting mutual funds performance, i.e. risk and return, in order to define mutual funds' endogenous benchmarks, and give insights and suggestions for managements. Of these two quadratic-constrained DEA models, one is a partly controllable quadratic-constrained programming. These two models with inputs of system (uncontrollable variable) and non-system risks, and outputs of excess returns emanating from timing and selection, are applied to evaluate 25 open-end mutual funds' performance during years 2005 and 2006. With weights and slack variables, we track down the reason of bad performance, and the improvement orientation. Compared with traditional methods, data envelopment analysis in mutual fund performance evaluation can obtain more management information for regulators and fund management companies to take measures to boost funds' operations efficiency.

Empirical results show that although the Chinese financial market in year 2006 was much better than that in year 2005 for mutual funds, average efficiency scores in 2006 were lower than in 2005, because of poor system risk control. Most mutual funds relaxed their control on system risk in year 2006 and the comparative efficiency changed considerably. System risk control affects comparative effectiveness greatly. The difference of evaluation principles leads to no correlations between DEA rankings and traditional rankings, though it is logical.

[5] M-2 is a common index in fund evaluation, which is based on CAPM and APT theory, with risk-free equities' included, for adjusting portfolio's risk to equal the benchmark, and then comparing their returns with the same risk level.

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