Appraisal of Mutual Equity Fund Performance Using Data Envelopment Analysis*

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This paper employs Data Envelopment Analysis to measure for the first time the performance of Greek domestic equity mutual funds over four different one-year horizons and for the whole four-year period. In particular, the model used examines whether fund managers employ inputs (i.e. assets, loads, and risk) efficiently to produce output (returns). The results demonstrate that the efficient funds form the smaller part of the examined sample of funds, the average efficiency rises over time, and that the mean-variance efficiency hypothesis holds for the inefficient funds over the whole period. Moreover, the evidence from the identified sources of inefficiency suggests that fund managers should put more emphasis on the management of assets and the specification of front-end and back-end loads. (JEL: G20, G23)

Keywords: Mutual funds, equity funds, efficiency, data envelopment analysis

I. Introduction

The measurement and comparison of performance of mutual funds have become an important issue for both fund managers and investors while the empirical literature is rich on mutual fund performance evaluation. The pioneering works of Sharpe (1964, 1966), Treynor (1965) and Jensen (1968, 1969) were followed by studies using the Capital Asset Pricing Model (CAPM) or the Arbitrage Pricing Theory (APT) model

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(Galagedera and Silvapulle, 2002; Murthi, Choi, and Desai, 1997) in their conditional or unconditional versions (Demos and Parissi, 1998). However, the results of these studies which have mainly concentrated on measuring performance in two dimensions, risk and return, appear to largely depend on the benchmark portfolio used and on the risk measurement, as well as on the validity of the underlying assumptions of the model (Galagedera and Silvapulle, 2002; Sengupta and Zohar, 2001). They take into account the expected excess return of the portfolio and a risk measure without considering the costs (i.e. initial and final investment costs) which contribute to the overall return of the investment.

Since the work of Murthi, Choi, and Desai (1997) there is a growing body of research applying an operations research technique, called Data Envelopment Analysis (DEA), on mutual fund performance evaluation (Charnes, Cooper, and Rhodes, 1978; Norman and Stoker, 1991; Thanassoulis, 2001). DEA being a non-parametric approach does not employ any particular function to measure efficiency and therefore no assumptions are made concerning the underlying production technology. It has been applied in finance for the derivation of performance measures of financial institutions (see e.g. Sathye, 2005) and also as an alternative to traditional measures of mutual fund performance; see section II for a literature review.

Based on Farrell's method of efficiency measurement (Farrell, 1957), DEA permits to appraise and rank Greek domestic equity mutual funds in a risk-return framework using also other variables, such as loads and net assets. It has the ability to deal with several inputs and outputs without demanding a precise relation between input and output variables (Gregoriou, Sendro, and Zhu, 2005). A DEA based performance measure is important because it enables investors to potentially pinpoint the reasons behind poor performance of funds. In addition, it assists fund managers not only to appraise the performance of their funds in terms of self appraisal and peer group appraisal, but also to derive possible ways to control risk with respect to certain other criteria (i.e. other input variables).

The mutual funds industry was established in Greece in 1972 with the introduction of one equity and one balanced fund. Over the next fifteen years no other mutual fund was introduced due to a series of economic and political events that caused a recession in the stock market. In 1989, investors turned their attention to the mutual fund industry due to institutional changes in the Greek capital market and the positive behavior of the Athens Exchange. During the following years the mutual funds industry expanded rapidly (Philippas, 2003). In 2006, there were 28 mutual fund companies and 262 funds of different categories; the total assets managed by the fund companies approximated 30 billion euros according to the Association of Greek Institutional Investors.

This study complements existing research in three ways: Firstly, it has an explicit focus on constructing a consolidated measure of relative performance of 55 Greek equity mutual funds for different 1-year horizons (2001; 2002; 2003; and 2004) and for the 4-year period (2001-04) using the DEA framework, in order to capture the multidimensional aspect of mutual fund performance and alleviate some of the problems associated with the traditional two-dimension performance measures (i.e. risk-return measures). Secondly, the study uses two semi-parametric tests and one non-parametric test to identify the nature of global returns to scale of the funds studied and as a result to support the selection of DEA model applied; and thirdly, it provides evidence from the Greek mutual fund industry not only identifying the sources of inefficiency for non-efficient funds, but also testing whether the mean-variance efficiency hypothesis holds for the inefficient funds.

The rest of the paper is organized as follows: Section II presents some background information on funds performance. Section III discusses the DEA method and the models used. Section IV presents the data and empirical results. Section V draws the conclusions and some policy implications.

II. Background

The bulk of the relevant literature on the use of the DEA framework to measure the performance of mutual funds is growing since the end of the 1990s. DEA applications are based on and have extended the Murthi, Choi, and Desai (1997) pioneering work. They presented a DEA application for appraising the performance of mutual funds using costs (inputs) and returns (output) for each one of a sample of mutual funds in order to derive a performance measure. They modified the basic idea employed in the Sharpe index (Sharpe, 1966) by incorporating transaction costs. The motivation of Murthi, Choi, and Desai (1997) to use DEA was to overcome a number of shortcomings of traditional two-dimensional (risk – return) performance measures. DEA offers a multi-dimensional performance analysis compared to traditional two-dimensional performance measures and their extensions such as higher-moments of the CAPM (Hwang and Satchel, 1999) and the generalized version of the CAPM (Leland, 1999). It does not require any theoretical model as a benchmark such as the CAPM or the APT model. Instead, it measures how well a fund performs relative to the best funds. Furthermore, it can address the problem of endogeneity of transaction costs in the analysis by simultaneously considering expense ratios, turnover, and loads, as well as returns.

The common point of the majority of DEA applications undertaken in measuring mutual fund performance is that the obtained performance is a combination of multiple fund attributes such as mean returns (outputs), risk (total or systematic), expenses, i.e. transaction costs and administration fees, loads (subscription and/or redemption costs) and minimum initial investment (inputs); Sedzro and Sardano (1999), Morey and Morey (1999), Choi and Murthi (2001), Sengupta and Zohar (2001), Anderson et al. (2004), Basso and Funari (2005). The analysis has been extended introducing other variables such as a stochastic dominance indicator to the output side of DEA (Basso and Funari, 2001), an ethical indicator to the input side of DEA (Basso and Funari, 2003) and value-at-risk (VaR) and conditional value-at-risk (CVaR) measures into the input side of DEA (Chen and Lin, 2006).

Employing essentially basic DEA models like CCR (Charnes, Cooper, and Rhodes, 1978) or BCC (Banker, Charnes, and Cooper, 1984), directional distance function DEA models (Chambers, Chung, and Färe, 1998) or DEA weight restricted algorithms (McMullen and Strong, 1998), the efficiency of funds is compared within a category or between several categories. Other approaches that have appeared in the literature are the minimum convex input requirement set (MCIRS) approach (Chang, 2004), the concept of order m frontier (Daraio and Simar, 2006), the concept of a quantile efficiency scores (Daouia and Simar, 2007) and also DEA modeling based on the mean-variance (Briec, Kerstens, and Lesourd, 2004) and mean–variance–skewness framework (Joro and Na, 2006; Briec, Kerstens, and Jokung, 2007). Moreover, the combined use of DEA with other techniques such as stochastic dominance criteria (Sengupta, 2003; Kuosmanen, 2007; Lozano and Gutiırrez, 2007) and regression (Sengupta, 2003; Galagedera and Silvapulle, 2002; Margaritis, Otten, and Tourani-Rad, 2006; Hsu and Lin, 2007) have also been applied.

It is worth noting that the bulk of the empirical literature on mutual funds performance appraisal by means of DEA has been concentrated on US funds; exceptions are the study for Australian funds (Galagedera and Silvapulle, 2002), Italian funds (Basso and Funari, 2001, 2005), Chinese funds (Chen and Lin, 2006), Taiwanese funds (Hsu and Lin, 2007) and New Zealand funds (Margaritis, Otten, and Tourani-Rad, 2006).

Studies on Greek mutual fund performance are based on the traditional risk-return framework, see Milonas (1999), Philippas (1999), Artikis (2001a, 2001b, 2002, 2003a, 2003b, 2004a, 2004b), and Sorros (2003). Moreover, Pendaraki, Doumpos, and Zopounidis (2003) and Pendaraki, Zopounidis, and Doumpos (2005) have used multicriteria methodologies to assess the performance of funds.

III. Methodology of Data Envelopment Analysis

The methods on efficiency measurement use either a parametric or a non-parametric or linear programming approach (Førsund, Lovell, and Schmidt, 1980).[1] The DEA methodology first proposed by Charnes, Cooper, and Rhodes (1978) to evaluate the relative efficiency of production units which are often referred as Decision Making Units (DMUs). It is a non-parametric method based on Farrell's method of efficiency measurement (Farrell, 1957). Also, it does not require assumptions regarding the shape of the production frontier using simultaneously multiple inputs and outputs.

In this analysis, the use of mutual funds as DMUs may raise some questions about the homogeneity of DMUs. It is worth noting that the objective of DEA is to measure relative efficiency among similar units that share the same technology (procedure) for similar goals (outputs, i.e. returns), by using similar resources (inputs). DEA maps a piecewise linear convex isoquant (i.e., a non-parametric efficient frontier) over data points to determine the efficiency of each of the DMUs relative to the isoquant. DEA accomplishes this by constructing the efficient frontier from a linear combination of the perfectly efficient funds and determines fund deviations from that frontier which represent performance inefficiencies. The efficiency scores of DMUs are bounded between zero and one, with fully efficient funds having an efficiency score of one.

1. For a comparison between DEA and other parametric methods, see appendix A.

A DEA model can be formulated in two versions: an input orientation and an output orientation. An input orientation analysis determines the proportional reduction of the inputs without changing the output level for an inefficient fund to become DEA-efficient. An output orientation analysis provides information on the proportional expansion of output levels of an inefficient fund which is necessary, along with the maintenance of current input levels, for the fund to become DEA-efficient. However, the latter version is of little significance because output augmentation is beyond the control of the fund managers and therefore the input orientation analysis is most cited in the relevant literature. The DEA input orientation analysis defines an efficiency measure of a fund by its position relative to the frontier of the best fund performance established mathematically by the ratio of the weighted sum of outputs to the weighted sum of inputs. The estimated frontier of best performance characterizes the efficiency of funds and identifies inefficiencies.

Charnes, Cooper, and Rhodes (1978) specified a fractional linear program that computes the relative efficiency of each DMU by comparing it to all DMUs in the sample, known as the CCR model. The dual form of CCR model (i.e. 'CCR envelopment model') for determining the relative efficiency, θ, of a designated fund ‘0’ is given by:

$$Min\ \theta - \varepsilon\left(\sum_{r=1}^{k} s_r^+ + \sum_{i=1}^{m} s_i^-\right) \tag{1}$$

s.t.

$$\sum_{j=1}^{n} \lambda_j x_{ij} + s_i^- = \theta\, x_{ij_0}$$

$$\sum_{j=1}^{n} \lambda_j y_{rj} - s_r^+ = y_{rj_0}$$

$$\lambda_j, s_r^+, s_i^- \geq 0,\ j = 1,2,...,n, i = 1,2,...,m, r = 1,2,...,k$$

where

$y_{r,j}$ = output level of fund j, r =1,2,…, k where, k is the number of outputs

$x_{i,j}$ = input level of fund j, i =1,2,…,m where m is the number of inputs

n = total number of funds

λ_j = intensity factor showing the contribution of fund j in the derivation of efficiency of fund '0'

s_r^+ = slack variable accounting for extra gains in output r

s_i^- = slack variable accounting for extra savings in input i

$\varepsilon > 0$, a convenient small positive number (non-Archimedean), see also Charnes et al. (1994).

In practice, the non-Archimedean constant ε is handled by a two stage routine in most DEA computer codes by optimizing θ in the above envelopment model (1). With the value of θ fixed, a second stage is then used to maximize the slacks s_r^+ and s_i^- (Murthi, Choi, and Desai, 1997).

Another version of DEA that is in common use is the BCC model (Banker, Charnes, and Cooper, 1984). The primary difference between this and the CCR model is the treatment of returns to scale. The CCR version is based on the assumption of constant returns to scale (CRS), while the BCC version is more flexible and allows for variable returns to scale (VRS). Using the same notation as above, the BCC formulation is model (2).

$$Min\ \theta - \varepsilon\left(\sum_{r=1}^{k} s_r^+ + \sum_{i=1}^{m} s_i^-\right) \tag{2}$$

s.t.

$$\sum_{j=1}^{n} \lambda_j x_{ij} + s_i^- = \theta\, x_{ij_0}$$

$$\sum_{j=1}^{n} \lambda_j y_{rj} - s_r^+ = y_{rj_0}$$

$$\sum_{j=1}^{n} \lambda_j = 1$$

$$\lambda_j, s_r^+, s_i^- \geq 0, j = 1,2,...,n, i = 1,2,...,m, r = 1,2,...,k$$

The relative efficiency of a fund under evaluation compared to the other funds in the sample is 1 (i.e. optimum value) for efficient funds and less than 1 for inefficient funds. Thus, a DEA model run produces a relative efficiency score for each fund in the sample and a set of λ_j, j = 1, 2,..., n, values for each fund. The set of λ_j values (intensity variables) are used to calculate the slacks of inputs and outputs.

The relative efficiency score obtained for a designated fund under CRS is a measure of overall technical efficiency of the fund, although the relative efficiency score obtained under VRS is a measure of pure technical efficiency. The difference in overall and pure technical efficiencies is attributed to scale efficiency that is measured as the ratio of overall (CRS) and pure (VRS) technical efficiencies (Byrnes, Färe, and Grosskopf, 1984; Galagedera and Silvapulle, 2002).

IV. Data and empirical results

The main source of the data is the 'Association of Greek Institutional Investors' a non-profit organization whose members are Greek Portfolio Investment Companies and Mutual Fund Management Companies.[2] The universe of Greek domestic equity mutual funds (i.e. 55 funds) for the period 2001-04 is drawn. The selection of variables is based on variables chosen in earlier DEA studies mentioned in section II. This choice is aimed at comparing the results of this study with those of previous studies.

The traditional output in the DEA framework is the return of the funds, while the traditional inputs are risk (the standard deviation of return or beta coefficient)[3] and other inputs which include the

2. Abbreviated name of 'The Association of Greek Investment Trust and Mutual Fund Management Companies'.

3. By using the risk measures of the return of a mutual fund as an input factor, one can also determine whether the investment is efficient from a risk perspective. Moreover, a risk measure such as the standard deviation of the returns can be used as an additional input, since an investment's risk is a vital input consideration for investors and an essential factor when interpreting returns (Anderson et al., 2004).

transaction costs (expense ratio, loads[4] and turnover ratio, Daraio and Simar, 2006) and fund size (net assets value, Anderson et al., 2004).[5] The total net assets of the funds can reflect the effect of economies of scale associated with the management of larger funds (for more see Chang, 2004, and the references cited there).[6] Other characteristics of funds may also be considered as determinants of fund performance. For example, fund age (period since inception) may be significant to the extent that economies of experience are important. A positive relation between age and performance may indicate an experience effect but it may also indicate survivorship bias (Annaert, Van den Broeck, and Vennet, 2003).[7]

The variables used in the input minimization analysis are fund returns (i.e. annualized daily arithmetic returns) as outputs and standard deviation, beta coefficient, assets and sales commissions or charges (loads) as inputs.[8] The BCC model is used to examine whether the fund managers have employed inputs (assets, risk and loads) efficiently to produce output (returns). Fund returns (i.e. annualized daily arithmetic returns) are net of expenses but gross of any sales charges. Standard deviation, the dispersion of return, represents the funds total risk which may be important for the not-well-diversified small funds.

The beta coefficient, a measure of a fund's volatility relative to the Athens Exchange General Index, is estimated from Jensen's market model over the whole period studied (2001-04). Beta measures the systematic risk that cannot be further reduced through diversification. Fund managers may time the market, for example by adjusting portfolio

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4. An interesting empirical result is that front-end loads for Denmark have the greatest contribution on total cost (Benchmann and Rangvid, 2005).

5. On the relation of fund size to performance, see Annaert, Van den Broeck, and Vennet (2003) and the references cited there.

6. In the case of mutual fund companies, when the scale of activity expands a less than proportional increase in costs may be recorded both in the area of portfolio management (information technology and security turnover) and in shareholder servicing (record, keeping and distribution) (Daraio and Simar, 2006).

7. The empirical literature has devoted little attention on this issue (Annaert, Van den Broeck, and Vennet, 2003) and the relationship between efficiency and size will not be investigated further in this paper.

8. In case of negative returns, the actual return r can be transformed to $R = 1 + r$ in order to get positive returns. This transformation does not affect the input oriented analysis (see also Annaert, Van den Broeck, and Vennet, 2003; Daraio and Simar, 2006).

TABLE 1. Descriptive statistics of mutual funds in the 1- and 4-year periods.

		Returns*	Standard deviation*	Beta*	Assets (euros)	Frond-end load	Back-end load
Four year period:							
2001-4	Min	–21.00%	0.16	0.50	924200.78	0.00	0.00
	Max	26.80%	0.99	1.10	626508081.18	0.05	0.05
	Mean	–4.51%	0.20	0.83	100134357.57	0.03	0.01
	Median	–4.58%	0.18	0.84	26068399.85	0.04	0.01
	Standard deviation	6.40%	0.11	0.09	168849397.77	0.02	0.01
	Number of funds: 55						
2001	Min	–44.59%	0.22	0.50	924200.78	0.00	0.01
	Max	96.45%	1.96	1.10	626508081.18	0.05	0.04
	Mean	–21.37%	0.30	0.83	100134357.57	0.03	0.01
	Median	–23.42%	0.27	0.84	26068399.85	0.04	0.01
	Standard deviation	17.60%	0.23	0.09	168849397.77	0.02	0.01
	Number of funds: 55						
2002	Min	–48.11%	0.11	0.50	770074.73	0.00	0.00
	Max	–7.59%	0.18	1.10	434054350.01	0.05	0.03
	Mean	–30.69%	0.14	0.83	72310179.58	0.03	0.01
	Median	–30.16%	0.14	0.84	18257851.92	0.03	0.01
	Standard deviation	8.45%	0.02	0.09	118742406.61	0.02	0.01
	Number of funds: 55						

(*Continued*)

TABLE 1. (Continued)

Four year period:		Returns*	Standard deviation*	Beta*	Assets (euros)	Frond-end load	Back-end load
2003	Min	3.93%	0.13	0.50	577814.15	0.00	0.00
	Max	40.72%	0.20	1.10	378945291.57	0.05	0.05
	Mean	23.69%	0.16	0.83	53680617.44	0.03	0.01
	Median	23.64%	0.16	0.84	11533250.72	0.04	0.01
	Standard deviation	7.18%	0.02	0.09	92896511.92	0.02	0.01
	Number of funds: 55						
2004	Min	–6.74%	0.10	0.50	668901.41	0.00	0.00
	Max	23.62%	0.16	1.10	474273856.77	0.05	0.05
	Mean	10.49%	0.13	0.83	69057097.40	0.03	0.01
	Median	12.52%	0.13	0.84	16331367.26	0.03	0.01
	Standard deviation	7.74%	0.01	0.09	115928838.81	0.02	0.01
	Number of funds: 55						

Note: Source: *Own calculations. Association of Greek Institutional Investors (www.agii.gr), and institutional investors.

weights, to increase (decrease) funds' betas if they expect the market return to be high (low) (Chang, 2004). Assets in euros are the total net assets of the funds as the previous year-end. Sales commissions or charges (loads) as a percentage of investment are the entry fee paid by the investors at the time of purchasing shares of mutual funds (front-end load) and the fee paid when selling the shares of mutual fund (back-end load).

Table 1 reports the descriptive statistics for the variables used. On average, over the 2001-04 period, the size of a fund in terms of its assets is about 100 million euros. The average return over the 4-year period is about –4.5 percent. Furthermore, the average return, the standard deviation, and the betas of the funds are calculated, all based on a daily return over different 1-year periods (2001, 2002, 2003, 2004) and the 4-year period; assets, frond-end load and back-end load are also provided. As it can be seen, average assets (except for 2004) decrease as well as standard deviations (except for 2003) while the average front-end and back-end loads remain constant, during the period under review.

It should be noted that it can only make sense to use the BCC model if the underlying technology is one of non-constant returns to scale. Based on the consistency property estimator (Banker, 1993), two semi-parametric statistical tests and one Kolmogorov-Smirnov test (non-parametric) were conducted to test the null hypothesis of CRS versus the alternative hypothesis of VRS (Banker, 1996; Giokas, 2001).[9] These tests are described in greater detail in appendix B. The results of the returns to scale tests (table 2) indicate that the null hypothesis of CRS is rejected at the 5% significance level, firstly, by the two semi-parametric tests and the non-parametric test for the 1-year periods and for the whole period 2001-4 when the standard deviation is used as the measure of risk, and, secondly, by the two semi-parametric tests over the 1-year periods when both the standard deviation and the beta coefficient are used as measures of risk. The estimated efficiency scores of equity mutual funds derived by the BCC model for the 1- and 4-year periods are summarized in table 3.

The results indicate that, out of the universe of 55 equity funds 15 funds in the 2001-04 period, 16 funds in 2001, 16 funds in 2002, 18 funds in 2003, and 23 funds in 2004 are the most efficient having a score of 1, with a combination of return, standard deviation, beta,

9. The results of the CCR model used are available on request.

TABLE 2. DEA- based returns to scale tests under three different inefficiency distribution specifications

			Semi-parametric statistical tests		Non-parametric test	
Period	Null hypothesis	Alternative hypothesis	Exponential distribution assumption, $F_{2n,2n}$	Half-normal distribution assumption, $F_{n,n}$	No assumption about the inefficiency distribution, K	Result
2001	CRS	VRS	1.72	2.81	0.29	Reject CRS
2001 (no beta)*	CRS	VRS	1.62	2.48	0.29	Reject CRS
2002	CRS	VRS	2.11	3.98	0.40	Reject CRS
2002 (no beta)*	CRS	VRS	1.83	2.94	0.35	Reject CRS
2003	CRS	VRS	5.91	24.16	0.67	Reject CRS
2003 (no beta)*	CRS	VRS	4.90	16.20	0.69	Reject CRS
2004	CRS	VRS	1.63	2.28	0.42	Reject CRS
2004 (no beta)*	CRS	VRS	1.46	1.87	0.38	Reject CRS
2001-4	CRS	VRS	1.45	2.08	0.27	Reject CRS
2001-4 (no beta)*	CRS	VRS	1.45	2.11	0.25	Reject CRS according to semi-parametric tests
Critical values at the 5% level of significance			1.37	1.56	0.26	

Note: CRS=constant returns to scale; VRS=variable returns to scale. $F_{2n,2n}$, $F_{n,n}$= Banker's (1996) first and second statistic, respectively, K= Banker's (1996) third statistic (i.e. Kolmogorov-Smirnov Test). *The standard deviation, only, is used as the measure for risk while both the standard deviation and the beta coefficient are used in the other cases.

TABLE 3. Summary of efficiency scores of mutual funds.

	2001-04	2001-04 (no beta)	2001	2001 (no beta)	2002	2002 (no beta)	2003	2003 (no beta)	2004	2004 (no beta)
Min	0.77	0.77	0.73	0.69	0.75	0.67	0.81	0.75	0.84	0.77
Max	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Mean	0.93	0.93	0.91	0.90	0.92	0.89	0.95	0.93	0.96	0.95
Median	0.94	0.93	0.91	0.89	0.93	0.91	0.97	0.93	0.99	0.95
Standard deviation	0.07	0.07	0.08	0.09	0.08	0.10	0.06	0.07	0.05	0.06
Number of funds	55	55	55	55	55	55	55	55	55	55
Number of efficient funds	15	14	16	13	16	12	18	16	23	21
Number of efficient funds (% number of funds)	27%	25%	29%	24%	29%	22%	33%	29%	42%	38%

frond-end load and back-end load that dominate all other funds.[10] They are on the efficiency frontier where there is no need for input reduction. Furthermore, the analysis of these 55 funds over different 1-year periods and for the whole 4-year period using standard deviation and beta coefficient as measures of risk indicates significant differences in their performances, ranging from perfectly efficient funds scoring 1 to the least efficient fund which scored 0.77 in 2001-04 period, 0.73 in 2001, 0.75 in 2002, 0.81 in 2003, and 0.84 in 2004. The average efficiency score for the sample was 0.93 in 2001-04 period, 0.91 in 2001, 0.92 in 2002, 0.95 in 2003, and 0.96 in 2004. When using only standard deviation as a risk measure there are 14 funds in the 2001-04 period, 13 funds in 2001, 12 funds in 2002, 16 funds in 2003, and 21 funds in 2004 that have a score of 1, with a combination of return, standard deviation, frond-end load and back-end load that dominate all other funds. Also, the analysis seems to derive significant differences in the performance of the funds, ranging from perfect efficient funds scoring 1 to the least efficient fund, which scored 0.77 in 2001-04 period, 0.69 in 2001, 0.67 in 2002, 0.75 in 2003, and 0.77 in 2004. The average efficiency score for the sample in this case was 0.93 in the 2001-04 period, 0.90 in 2001, 0.89 in 2002, 0.93 in 2003, and 0.95 in 2004.

When both the standard deviation and the beta are used as measures of risk the lowest average efficiency score is for 2001 and the highest for 2004 while when the standard deviation is used only as the measure of risk the lowest is for 2002 and the highest is also for 2004. In both cases, the average efficiency seems to improve over time from 2002 to 2004 while the number of efficient funds is also increasing, albeit by a small rate, during the same period. However, it should be noted that the inefficient funds form the greatest part of the funds under analysis. Furthermore, the average efficiency score for all funds over the 2001-04 period is 93%, which indicates a 7% required proportional reduction of their input levels.

In addition, the sources of inefficiency for the non-efficient funds can be identified by examining the slacks of the input variables. Table 4 depicts the relative mean slacks (absolute mean slack of an input divided by mean value of the input) of the input variables (Murthi, Choi, and Desai, 1997). Using the relative slacks the marginal impact of

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10. It is worth noting that the DEA models do not allow ranking of the efficient DMUs themselves. However, there are methodologies for ranking the efficient DMUs such as the so-called super-efficiency model introduced by Andersen and Petersen (1993), and the cross-efficiency model (see also Gregoriou, Sendro, and Zhu, 2005).

TABLE 4. Mean slacks in inputs* (standard deviation, beta, assets, and commissions).

	Standard deviation of returns	Beta coefficient	Assets	Front-end loads	Back-end loads
2001	0.39%	0.79%	36.67%	21.26%	4.72%
2001 (no beta)	0.06%		27.25%	34.59%	6.23%
2002	1.69%	0.32%	50.38%	7.24%	8.56%
2002 (no beta)	1.24%		46.64%	7.99%	13.87%
2003	1.66%	0.43%	2.86%	18.58%	18.71%
2003 (no beta)	0.49%		2.87%	18.41%	22.55%
2004	0.18%	1.53%	8.37%	5.85%	10.06%
2004 (no beta)	0.00%		5.83%	4.72%	14.05%
2001-4	0.25%	2.15%	37.79%	13.04%	6.33%
2001-4 (no beta)	0.00%		37.79%	13.90%	7.79%

Note: * Mean slack: absolute mean slack of an input all over funds/mean value of the input all over funds.

inputs on the return of a fund across the set of funds can be compared as these slacks identify the inputs of the funds which are utilized inefficiently. A striking result derived is that when risk is measured by the standard deviation alone, it has virtually no slacks throughout all funds for the whole time period (2001-04). In other words, by lengthening the time period (i.e. 2001-04) the risk is reduced considerably. This is consistent with the notion that mutual funds are on average mean-variance efficient (Murthi, Choi, and Desai, 1997). Moreover, it is evident that the slacks for risk are decreasing over time during the 2002-04 period when measured by either standard deviation or by both standard deviation and beta.

With respect to the other input variables, assets, front-end loads and back-end loads, they have larger slacks indicating that fund management seems to be inefficient on these three dimensions. Moreover, the slacks for assets are the largest indicating that this direction may be of higher priority for the Greek equity mutual fund managers.

In a multinational context, similar evidence demonstrating that the mean-variance efficiency hypothesis holds for the inefficient funds has also been provided by studies concerning different categories of US mutual funds (Murthi, Choi, and Desai, 1997; Sengupta and Zohar, 2001; and Sengupta, 2003). Furthermore, the findings of this paper indicating the dimensions that reduce the efficiency of asset management for the funds under review, are rather remarkable to both managers and individual investors as empirical research suggests that smaller funds, especially those within more aggressive investment objectives, tend to outperform larger funds (Ciccotello and Grant, 1996). Finally, concerning the derived fund inefficiency related to front-end and back-end loads one should take into account evidence from other markets which conclude that the use of load fees is not a way to offer a different fund pricing mix but a strategy to reduce investor turnover (Geranio and Zanotti, 2005).

V. Concluding remarks and policy implications

Mutual funds have proved able to disperse investment risks to the lowest possible degree and are among the popular products for the diversity of investments. Therefore, performance measurement in the mutual fund industry is receiving an increasing interest from both a theoretical and an applied perspective. Recent used performance evaluation techniques for mutual fund appraisal are based not only on traditional financial literature but also on frontier analysis. This paper has employed DEA as a tool of frontier analysis, to monitor the performance of the Greek mutual fund industry concentrating on the class of equity mutual funds. DEA is a non-parametric methodology and therefore does not need to assume a particular functional form for the return generating process. In contrast to traditional methods which estimate efficiency relative to the average performance, the applied methodology provides an efficiency index for each mutual fund under evaluation relative to the best set of funds. Moreover, this methodology provides the possibility to address simultaneously the problem of endogeneity of transaction costs and returns and identify the sources of inefficiency of the funds. DEA is applied under the assumption of VRS having rejected the null hypothesis of CRS, to evaluate the performance of the Greek equity mutual funds over 1-year periods and over the whole period, 2001-2004, under review.

Four main reasons motivated this analysis, namely, the absence of prior DEA research on this topic in Greece, the growing importance of other fund characteristics than return and risk for investors' investment decisions, the importance of identifying sources of inefficiencies for Greek fund management, and finally, the level of mutual fund fees in view of increasing competition.

In appraising Greek mutual funds, the past performance of funds (return), the risk, i.e. the dispersion of return (standard deviation) and the beta coefficient play a central role in their evaluation, as well as other characteristics such as total net assets (size) and sales commissions or charges (loads or fees).

This form of empirical analysis applied for the Greek mutual fund industry comes with findings that are comparable to those of DEA studies undertaken elsewhere. Furthermore, the empirical results indicate that the Greek equity mutual funds attain the maximum relative efficiency only in year 2004 of the 1-year periods, while the efficient funds form the smaller part of the funds under review. The results over the whole period under review provide evidence that the mean-variance efficiency hypothesis holds for the inefficient funds, implying that these mutual funds had the highest expected return at their given level of risk. Furthermore, the sources of inefficiency are assets, front-end loads and back-end loads, meaning that the fund management seems to be inefficient on these dimensions. Therefore all these should be of higher priority for the Greek equity mutual fund managers.

The results have practical implications for fund management in mutual fund companies including issues of interest such as diversification of risk, fund size, and fund pricing policies. In addition, this research allows mutual fund companies, regulators, and investors to establish a benchmark for fund performance taking also into account fund fees and fund size. In view of the findings of this paper fund managers in Greece should put more emphasis on the management of assets and the specification of front-end and back-end loads. In this way they could improve the efficiency of their funds under management and formulate their strategy on investor turnover level.

Although the analysis conducted in this paper focuses only on equity mutual funds, future research on the Greek market can be extended to consider other classes of mutual funds such as balanced mutual funds and bond mutual funds, among others.

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Appendix A

A. DEA and parametric methods

The main difference between DEA and other parametric methods (e.g.

stochastic frontier method (Meeusen and Van den Broeck, 1977; Aigner, Lovell, and Schmidt, 1977), Bayesian frontier approach (Van den Broeck et al., 1994)) is that the former is non-parametric and does not account for noise, whereas the latter are parametric and account for noise around the estimated efficient frontier.

Models developed using parametric methods are not able to cope satisfactorily with multi-output DMUs. DEA on the other hand does not need the pre-specification of the functional form for the association between output and input variables. DEA can cope with multiple outputs and inputs; it constructs a non-parametric frontier over observations (i.e. data points) so that they may lie below or above the frontier (Charnes, Cooper, and Rhodes, 1978; Färe, Grosskopf, and Lovell, 1994). Unlike the stochastic frontier method, DEA makes no assumption of the distribution of the observed data, and all deviations are assumed to be due to inefficiency (Banker et al., 1989).

In addition, DEA produces detailed information on the efficiency of the DMU under evaluation not only relative to the efficient frontier but also to specific efficient DMUs (i.e. the peers) and moreover, sources of inefficiency can be identified and analysed further.

Appendix B

A. Tests for returns to scale

Banker (1996) proposed three statistics for testing the null hypothesis of CRS against the VRS. The first statistic is given by:

$$\hat{F}_{1n}^{crs} = \sum_{j=1}^{n}(h^{crs} - 1) / \sum_{j=1}^{n}(h^{vrs} - 1) \tag{3}$$

where h^{crs} are the efficiency scores derived using the CCR model and h^{vrs} are the efficiency scores derived using the BCC model.

Banker's second statistic is given by:

$$\hat{F}_{2n}^{crs} = \sum_{j=1}^{n}(h^{crs} - 1)^2 / \sum_{j=1}^{n}(h^{vrs} - 1)^2 \tag{4}$$

Banker argued that if one assumes that h ~ exponential, then:

$$\hat{F}_{1n}^{crs} \xrightarrow{d} F_{2n,2n}$$

Alternatively, if one assumes that h ~ half-normal then:

$$\hat{F}_{2n}^{crs} \xrightarrow{d} F_{n,n}$$

Banker's third statistic is the Kolmogorov-Smirnov test statistic which is given by:

$$\hat{K}_n^{crs} = \max[h^{crs} - h^{vrs} \mid j = 1,...,n] \quad (5)$$

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