Performance evaluation of Portuguese mutual fund portfolios using the Value-Based DEA method

Maria do Castelo Gouveia
IPC-ISCAC Coimbra Business School, Quinta Agrícola, Bencanta, 3040-316 Coimbra
INESC Coimbra, Rua Sílvio Lima, Pólo II, 3030-290 Coimbra
mgouveia@iscac.pt

Elisabete Duarte Neves
IPC-ISCAC Coimbra Business School, Quinta Agrícola, Bencanta, 3040-316 Coimbra
CETRAD - Centro de Estudos Transdisciplinares para o Desenvolvimento, Universidade de Trás-os-Montes e Alto Douro
mneves@iscac.pt

Luís Cândido Dias
CeBER and Faculdade de Economia, Universidade de Coimbra, Av. Dias da Silva 165, 3004-512 Coimbra
INESC Coimbra, Rua Sílvio Lima, Pólo II, 3030-290 Coimbra
lmcdias@fe.uc.pt

Carlos Henggeler Antunes
DEEC-FCT Universidade de Coimbra, Pólo II, 3030 Coimbra
INESC Coimbra, Rua Sílvio Lima, Pólo II, 3030-290 Coimbra
ch@deec.uc.pt

ABSTRACT. The increased volatility in capital markets since the outbreak of the 2008 global financial crisis and the investor´s lack of confidence in the banking sector represented significant challenges to portfolio fund managers. The current study assesses the performance of Portuguese mutual fund portfolios considering the period 2007-2014 using the Value-Based DEA method. This approach combines Data Envelopment Analysis (DEA) with Multiple Criteria Decision Aiding (MCDA). A dynamic evaluation including value judgements is carried out using data from 15 Portuguese equity funds. The results unveil the impact of the global crisis in the Portuguese investment funds industry. They show that Portuguese investment funds performed better between 2011 and 2013; this suggests that equity funds investors became more confident in these vehicles due to political measures reinforcing financial markets. The methodology followed in this study contributes to help investors in the identification of the funds with the best practices according to their judgments.

KEYWORDS. Data Envelopment Analysis; Multicriteria Decision Analysis; Finance; Equity Funds; Uncertainty.

1. Introduction

The importance of mutual funds in stock markets has grown intensely in recent decades. Mutual funds became a popular option for investors because they offer the possibility of accessing professional management with minimum initial capital and efficient risk diversification. Khorana *et al*. (2005) provide background on the mutual fund industry worldwide. They document that at the end of 2001, the global fund industry represented $11.7 trillion in assets, forty per cent of which were domiciled outside the United States, with a significant portion concentrated in Luxembourg, France, Italy and Japan. Professional mutual fund managers use their management skills to pursue positive risk-adjusted excess returns (Gregoriou, 2007). Investors are concerned with the selection of the funds with the best performance among the set of alternative investment funds. The performance of actively managed mutual funds has been of long-standing interest to financial economists and researchers. Mutual fund performance is traditionally evaluated by returns, such as the Treynor ratios (1965) and Sharpe index (1966), or taking into consideration several risk factors, such as the models proposed by Treynor and Mazuy (1966), Jensen (1968) and Carhart (1997). Nevertheless, more recently, many studies have considered a significant number of fund attributes as potential determinants of fund performance, besides risk-return characteristics. Some of these attributes explaining mutual fund portfolios performance include past returns (Ippolito, 1989) or size and past return (Yan, 2008); liquidity (Chen *et al.*, 2004); skill and persistence (Cremers and Petajisto, 2009 or Berk and Binsbergen, 2016); luck and no persistence (Busse, Goyal and Wahal, 2010 or Fama and French, 2010); age (Pástor *et al.*, 2015); fees (Wermers, 2000); industry concentration (Kacperczyk, Sialm and Zheng, 2005); flows (Lou, 2012), among others.

Data envelopment analysis (DEA) was originally designed for production theory, but it has been increasingly applied across several areas. It is a quantitative, empirical and non-parametric method based on linear programming to measure the relative efficiency of observations that represent the performances of organizational units (Decision Making Units - DMUs), operating in a similar technological environment and allowing the consideration of multiple inputs and multiple outputs in global performance evaluation. DEA constructs an empirical efficiency frontier, an "envelopment surface" of maximum performance (Charnes *et al.*, 1978). Efficiency scores take into account the multiple inputs consumed and multiple outputs produced by each DMU, without the need to specify a priori their relative weights (Sherman and Zhu, 2006). DEA also enables to identify reference DMUs on the efficient frontier whose performance scores serve as a benchmark for the inefficient DMUs, i.e. the ones that are enveloped by the efficient frontier. Each DMU chooses its best feasible weights for inputs and outputs in order to be classified as well as possible relatively to the set of all DMUs. However, this complete flexibility in the choice of weights allows disregarding important factors from the evaluation.

According to Glawischnig and Sommersguter-Reichmann (2010), a zero input (output) weight indicates a potential source of inefficiency.

A recent survey of DEA applications by Liu *et al.* (2013) revealed that finance, as well as energy and environment, are the areas in which the use of DEA is growing at a faster pace than in other application areas. Since the seminal work of Murthi *et al.* (1997), who proposed a DEA portfolio efficiency index (DPEI), DEA has been widely used to evaluate the performance of funds. Several authors used the classical DEA models in their studies. The CCR model (assuming constant returns-to-scale - CRS) was used, for instance, by Murthi *et al.* (1997), Basso and Funari (2001, 2003). McMullen and Strong (1998) and Galagedera and Silvapulle (2002), among others, chose the BCC model (assuming variable returns-to-scale - VRS) to evaluate the performance of mutual funds. Choi and Murthi (2001) applied both CCR and BCC models. Extended versions of classical models, including cross and super-efficiency models were used in the studies conducted by Gregoriou *et al.* (2005) and Pätäri *et al.* (2012). Daraio and Simar (2006) compared the efficiency scores of performance of US mutual funds obtained through DEA CCR and BCC models. In these past applications, no constraints on the weights were considered to reflect the judgment of decision makers (DMs).

The inclusion of weight restrictions in the performance evaluation of investment funds is not usually found in the literature and the few authors who incorporated them did not have in consideration the presence of value judgements elicited from DMs. In fact, DMs may judge some factors as being more important than others, and hence restrictions on weights should incorporate expert opinion (Joro and Viitala, 2004). McMullen and Strong (1998) assessed mutual fund performance through the BCC model (Banker *et al*, 1984) with weight restrictions. Glawischnig and Sommersguter-Reichmann (2010) used relative weight restrictions for inputs and outputs and they argue that the inclusion of value judgements has the advantage of avoiding zero weights. However, these authors also pointed out the disadvantage of the challenging and subjective specification of weight restrictions.

Traditionally, the main idea of DEA models is to evaluate the performance of production units (DMUs), where the DEA efficient frontier can be considered as an empirically derived production frontier. DEA is generally used for performance evaluation and benchmarking with regard to best-practice, as a Multiple Criteria Decision Aiding (MCDA) tool. In this work, DEA is used in this spirit as a multi-criteria decision support tool, in which "*the inputs are usually the “less-the-better” type of performance measures and the outputs are usually the “more-the-better” type of performance measures*" (Cook *et al.*, 2014) and where the identification of a production process is meaningless.

Only a few research studies of portfolios performance combine DEA with MCDA, as a way of incorporating the preference system of a stakeholder (investor, portfolio manager) into the analysis (for a comprehensive review see Zopounidis *et al.*, 2015). Among other studies that combine DEA with MCDA approaches for mutual fund performance evaluation, the closest to the present study is the one conducted by Babalos *et al.* (2012), which uses an additive multi-criteria evaluation model applied to the assessment of Greek equity funds. In that study, the authors construct a value function in the framework of SMAA-2 (stochastic multi-criteria acceptability analysis) (Lahdelma and Salminen, 2001) to obtain a multi-criteria performance evaluation and ranking of the mutual funds for different evaluation scenarios. Later, Babalos *et al.* (2015) enhanced the results of DEA through the development of a global multi-criteria evaluation model. The authors relaxed the assumption of a linear aggregation model, which is common in prior studies on the development of ranking techniques using DEA, considering a more general additive (nonlinear) value function.

Another work loosely related with the one proposed in the present study was carried out by Khedmatgozar *et al.* (2013), which consists in evaluating mutual fund performances using the VEA - Value efficiency analysis method (Halme *et al.*, 1999). The preference information is incorporated via the most preferred solution, i.e., a virtual or existing fund on the efficient frontier having the most desirable values of inputs and outputs over the set consisting of all convex combinations of existing mutual funds.

The present study consists in a dynamic assessment of the performance of 15 Portuguese Equity Funds over 2007-2014. Portugal is a country with a small number of listed companies, with low capitalization and the Portuguese capital market is characterized by the existence of a large number of inter-corporate shareholdings and a high level of concentration in corporate shareholdings. The Portuguese stock and mutual fund markets are small, as detailed by Alves and Mendes (2010). In fact, the Portuguese financial system is dominated by a few large banking groups, which also control the main fund management companies of the mutual fund market. Alves and Mendes (2010) point out that the Portuguese market exhibits two relevant characteristics. Firstly, in general, each company only manages one equity fund. Secondly, the distribution of funds throughout channels other than banks is virtually inexistent: banks are the primary promoters and distributors of funds. These banks are simultaneously the head of the conglomerate, the depositary institutions and the fund distributors. In general, they are also listed companies. According to Cabrita and Bontis (2008), the Portuguese banking industry has moved away from traditional ‘spread-based’ revenue generation (e.g. deposits and loans) towards higher added-value ‘fee-based’ business models (e.g. mutual funds and estate management).

In a recent paper, Ferreira *et al.* (2013) showed that the country´s characteristics such as economic development, financial development, familiarity and investor protection explain the fund performance. The economic indicators vary between countries and so does the viability of investment.

The methodology proposed for the performance evaluation of the 15 Portuguese Equity Funds over 2007-2014 is the Value-Based DEA method (Gouveia *et al.*, 2008), which builds on Multi-Attribute Utility Theory (MAUT) and where the DMUs (mutual funds) play the role of alternatives. Although the Value-Based DEA method is grounded on DEA, the input and output factors are converted into value functions, in the spirit of MCDA. Therefore, this means that it is not, necessary to identify which factors are outputs or inputs but rather which factors are to be maximized or minimized.

The Value-Based DEA method allows assessing the performance of the mutual funds (DMUs) with negative data (negative returns, for instance), which is a problematical issue in classical DEA (CCR and BCC) models.

In line with Tarnaud and Hervé (2017), this kind of approach (DEA combined with MCDA) to evaluate financial assets is not limited to a risk-return analysis but can rather be seen as a cost-benefit approach regarding the DMs' preferences for the attributes of the funds. Therefore, as the present study is conducted from the investor's viewpoint, the factors (criteria) under evaluation should be those that would be considered relevant by a typical investor wishing to measure the performance of his portfolio.

As stated by Glawischnig and Sommersguter-Reichmann (2010), "*in the investment fund industry, an input can be any characteristic the investor is interested in minimizing (e.g. risk measures) while an output is any characteristic the investor wishes to maximize (e.g. return measures)*". Thus, outputs (factors to maximize) are defined as the benefits derived by the investor from having the investment, e.g. the gross return, and the inputs (factors to minimize) are defined as the resources expended by the investor (loads, like sales charges, redemption fees and other expenses of the fund that are passed on to the investor and included in the expense ratio) and the various risk measures, e.g. standard deviation or beta. In this perspective, with the integration of risks as undesirable features of funds, it is assumed that investors' preferences for risks are restricted to risk aversion or mixed risk aversion (Tarnaud and Hervé, 2017).

The purpose of this study is to assess the impact of the global crisis in the Portuguese investment funds industry by means of a dynamic evaluation, comparing the mutual fund performances in the different years from 2007 to 2014. The Value-Based DEA method is used to compare the performance of DMUs with the best one observed in the 8-year period and unveil variations in performance across years. This means that possible technological changes are not taken into account, assuming that in this particular sector and period the main drivers of efficiency change are exogenous events (namely the financial crisis) and the quality of the funds management.

The question raised is a pertinent issue in a country severely hit by the economic recession and with the banking system largely affected by the global financial and sovereign debt crises. Leite *et al.* (2016) studied what they called a poorly exploited country in terms of the fund market. They point out some reasons for their difference with other European countries such as volatility and liquidity, sustaining that Portugal was heavily punished by the sovereign debt crisis that led to a request for a bailout program. Those authors also emphasise that one of the specific characteristics of the Portuguese mutual funds market is that fund management companies are usually dominated by the banking industry. This fact can condition investors' behaviour towards a close involvement with the bank/fund company group (Cortez *et al.*, 1999). Mutual fund managers are expected to perform according to investors' expectations, but the economic environment could affect the fund performances. Therefore, the conclusions of this work are potentially useful both for fund managers and investors.

This introduction provided the motivation and purpose of the study. Section 2 presents the process of data selection. Section 3 explains the methodology, in particular the Value-Based DEA method, the construction of value functions and the setting of weight restrictions to include preference information into the analysis. In section 4 the analysis of results is presented. Concluding remarks are drawn in section 5.

2. Data selection

The data selected includes 15 open-end actively managed Portuguese Equity Funds over 2007-2014. According to the classification given by Portuguese Association of Investment Funds, Pensions and Wealth (APFIPP), these Domestic Equity Funds invest 100% in securities issued by Portuguese companies (100% investment in Euros). The purpose of selecting this time interval is to assess the behaviour of investment funds in a small market affected by a deep global economic and financial crisis. The range 2007-2014 covers the crisis period, after the Lehman Brothers collapse on 15th September 2008. The increased volatility in capital markets during this crisis and the collapse of the banking system increased investor uncertainty and led to a problem of lack of confidence in the markets and substantial losses, also resulting in difficulties in accessing credit and higher cost of capital during this period. Additionally, the Portuguese sovereign debt crisis worsened problems requiring the intervention of the Troika[1] in 2011.

The selection of inputs and outputs for performance evaluation of investment funds is a matter that has been extensively explored in the literature. For this work the choice of factors to be minimized (inputs or undesirable outputs) and factors to be maximized (outputs) is based on

[1] The Troika included the European Central Bank (ECB), the European Commission (EC), and the International Monetary Fund (IMF).

the evaluation perspective, i.e. taking into account the investor's (DMs) point of view, the available data as well as the fact that they are also often considered in this type of DEA-based studies (see, for example McMullen and Strong, 1998; Choi and Murthi, 2001; Wilkens and Zhu, 2001; Chang, 2004; Daraio and Simar, 2006).

Table 1. Factors.

Factors to minimize	**Factors to maximize**
$x_{PropNeg}$: Proportion of negative monthly returns during the year x_{ER}: Expense ratio x_{SD}: Standard deviation x_{Beta}: Beta	y_{GR}: Gross return

Among the factors to minimize, Table 1 displays the proportion of negative monthly returns during the year, which can be seen as an indicator of a good yearly performance if this value is low. In a short-term perspective, it is more likely that a fund that presents several months with negative returns has a poor overall year performance. This factor was also considered, among others, by Wilkens and Zhu (2001) using DEA for analysing nonlinear returns generated by Commodity Trading Advisors strategies over mutual funds management.

The expense ratio, as defined by the Centre for Research and Security Prices (CRSP), is the ratio of the fund's operating expenses paid by shareholders to the total investment. This amount includes many operational expenses such as custodial service, management fees, marketing expenses and other. The factor x_{ER}, which represents an important share of the cost, was used, for example, by Pástor *et al*. (2015) to analyse active mutual fund management.

Standard deviation measures the volatility of the fund's returns in relation to its average. It specifies how much the fund's return deviates from the historical mean return. This is an absolute risk measure since the volatility refers to the magnitude of mutual fund's movements, which may be important for not well-diversified small funds (Chang, 2004).

Beta measures a fund's volatility relative to PSI20, the Lisbon stock exchange index (benchmark) and it was estimated using Jensen's (1968) version of the capital asset pricing model (CAPM). The Beta coefficient is a relative measure of risk and points out how much a fund's performance fluctuates compared to a benchmark. Beta equal to 1 can be seen as an indication that, in terms of volatility, the fund has the same risk as the Portuguese market. As a market risk measure Beta indirectly accounts for diversification (Lam and Tee, 2012). According to Frazzini and Pedersen (2014) and Hong and Sraer (2016), high Beta stocks persistently underperform when compared with low beta stocks.

The inclusion of both risk measures as factors to be minimized, one that is relative (Beta) and the other one that is absolute (Standard Deviation), allows a more comprehensive assessment of the performance of the Portuguese investment funds.

A single output is considered: the gross return is the annualized average returns. Considering gross instead of net returns avoids a double counting of fees (already accounted for in the expense ratio, to be minimized).

The empirical study uses data from the Portuguese Association of Investment Funds, Pensions and Wealth (APFIPP), Portuguese Securities Market Commission (CMVM), Bank of Portugal (BPstat) and Morningstar. Specifically, BPstat was used to extract factor data included in CAPM measure. Additionally, the monthly values of the equity funds were obtained through a compilation of two separate sources, CMVM and APFIPP.

3. Methodology

3.1. The Value-Based DEA method

The Value-Based DEA method proposed by Gouveia *et al* (2008) explores links between DEA and MCDA. This novel perspective uses the additive DEA model with oriented projections (Ali *et al*, 1995), in order to overcome some of its shortcomings by applying concepts from MAUT with imprecise information on weights. In Value-Based DEA the DMUs are analogous to alternatives of a multi-criteria evaluation model. Each criterion corresponds to a factor to be minimized (input or undesirable output in the DEA model) or to a factor to be maximized (output in the DEA model).

A set of n DMUs $\{DMU_j: j = 1, \dots, n\}$ is to be evaluated. Each DMU_j is evaluated on m different factors to be minimized and p different factors to be maximized. Thus, for DMU_j this is represented by an m-dimensional "inputs" vector $x_{ij} = \{x_{1j}, \dots, x_{mj}\}$ and p-dimensional "outputs" vector $y_{rj} = \{y_{1j}, \dots, y_{pj}\}$.

For each alternative (DMU j), $v_c(DMU_j)$ is the measure of performance of DMU_j on criterion c based on a value function (or utility function – the difference is not relevant here) $v_c(.)$ defined by the DMs ($c=1,\dots,q$, with $q=m+p$). The value functions must be defined such that the worst level has value 0 and the best level has value 1, which overcomes the scale-dependence problem of the additive DEA model.

In a preparatory phase the performance measures of DEA factors are converted into value functions to be maximized. These are then aggregated using the additive MAUT model. According to this model, the value obtained is $V(DMU_j) = \sum_{c=1}^{q} w_c v_c\,(DMU_j)$, where $w_c \geq 0$,

$\forall c = 1,\ldots,q$ and $\sum_{c=1}^{q} w_c = 1$ (by convention). The scale coefficients $w_1, \ldots, w_q$ are the weights of the value functions.

The scale coefficients $w_1, \ldots, w_q$ are established in the Value-Based DEA such that each alternative minimizes the value difference to the best alternative, according to the min-max regret rule (Bell, 1982). This provides an intuitive meaning (the loss of value) to the efficiency score assigned to each DMU. But instead of letting each DMU freely choosing the weights associated with these functions, they can be constrained according to the DMs' preferences. Then restrictions on weights may be incorporated into the efficiency assessment process, enabling to cope with the fact that otherwise important factors could be ignored in the analysis.

The Value-Based DEA formulation considering the super-efficiency concept (Andersen and Petersen, 1993) is the following when assessing the k-th DMU (Gouveia *et al.*, 2013):

$$
\begin{aligned}
&\min_{d_k, w} d_k \\
&s.t. \sum_{c=1}^{q} w_c v_c\left(DMU_j\right) - \sum_{c=1}^{q} w_c v_c(DMU_k) \leq d_k, j = 1, \ldots, n; j \neq k \\
&\quad \sum_{c=1}^{q} w_c = 1 \\
&\quad w_c \geq 0, \forall c = 1, \ldots, q
\end{aligned}
\tag{1}
$$

The efficiency measure, d_k^* , for each DMU k ($k = 1,\ldots,n$) and the corresponding weighting vector is computed via formulation (1). The score d_k^* is the distance defined by the value difference to the best of all DMUs (note that the best DMU will also depend on w), excluding itself from the reference set. If the optimal value d_k^* of the objective function in (1) is not positive, then the DMU k under evaluation is efficient, otherwise it is inefficient. The introduction of the super-efficiency concept into the original method allows the discrimination of the efficient units.

3.2. Value functions

The evaluation of the 15 Equity Funds using the Value-Based DEA is done considering the period that starts in 01/01/2007 and ends in 31/12/2014.

Assuming that the DMU_j, $j = 1,\ldots,15$ are observed in $t = 1,\ldots,8$ consecutive years, the sample used has 8x15 DMUs (DMU_j^t). The matrices of inputs and outputs of the 120 DMUs in evaluation are $X = \left(x_1^1, x_2^1, \ldots, x_{15}^1, x_1^2, x_2^2, \ldots, x_{15}^2, \ldots, x_1^8, x_2^8, \ldots, x_{15}^8\right)$ and

$Y = \left(y_1^1, y_2^1, \ldots, y_{15}^1, y_1^2, y_2^2, \ldots, y_{15}^2, \ldots, y_1^8, y_2^8, \ldots, y_{15}^8\right)$, respectively.

Considering that the value p_{cj}^t is the performance of DMU j in factor c, for the year t, the factors to minimize performances and the factors to maximize performances are converted into values in a linear way. Two limits, M_c^L and M_c^U, were defined for each factor, such that $M_c^L < min\{p_{cj}^t, j = 1, \ldots, 15; t = 1, \ldots, 8\}$ and $M_c^U > max\{p_{cj}^t, j = 1, \ldots, 15; t = 1, \ldots, 8\}$, for each $c = 1, \ldots, 5$. The values for each DMU were computed using:

$$v_c^t(DMU_j) = \begin{cases} \dfrac{p_{cj}^t - M_c^L}{M_c^U - M_c^L}, & if\ the\ factor\ c\ is\ to\ maximize \\ \dfrac{M_c^U - p_{cj}^t}{M_c^U - M_c^L}, & if\ the\ factor\ c\ is\ to\ minimize \end{cases}, j = 1, \ldots, 15; t = 1, \ldots, 8; c = 1, \ldots, 5 \quad (2)$$

The M_c^L and M_c^U values of the factors to minimize and the factor to maximize that were considered for all DMUs and for the interval 2007-2014 are displayed in Table 2.

Table 2. The M_c^L and M_c^U values.

	Factors to minimize				**Factor to maximize**
	x_{PropNeg}	x_{ER}	x_{SD}	x_{Beta}	y_{GR}
M_c^L	100%	3.5%	45%	2	61%
M_c^U	20%	0.3%	7%	0	-68%

In many applications of DEA, it is very common to find factors that have negative or zero values. For radial measures of efficiency, as the CCR and BCC models, the presence of negative data is a problematical issue. The Valued-based DEA overcomes this problem by converting the performances on each factor into a value scale. Hence after being converted into value functions all factors are to maximize.

The process was applied to all factors considering the period 2007-2014. Table 3 shows the performances data in the original scale and converted into value, for years 2013 and 2014 only.

Table 3. Performances converted into value scales for 2013-2014.

	Factors in original scales					Factors in value scale				
2013	$x_{PropNeg}$	x_{ER}	x_{SD}	x_{Beta}	y_{GR}	$v_{PropNeg}$	v_{ER}	v_{SD}	v_{Beta}	v_{GR}
Fund 1	41.67%	0.84%	21.07%	1.109	32.76%	0.729	0.831	0.630	0.446	0.781
Fund 2	33.33%	2.14%	18.61%	1.002	24.57%	0.833	0.425	0.694	0.499	0.718
Fund 3	33.33%	1.29%	18.09%	0.973	25.21%	0.833	0.691	0.708	0.513	0.723
Fund 4	33.33%	2.03%	18.19%	0.973	23.53%	0.833	0.459	0.705	0.514	0.710
Fund 5	33.33%	2.01%	20.20%	1.068	32.01%	0.833	0.466	0.653	0.466	0.775
Fund 6	41.67%	2.24%	20.44%	1.040	21.74%	0.729	0.394	0.646	0.480	0.696
Fund 7	25.00%	1.05%	12.73%	0.652	18.14%	0.938	0.766	0.849	0.674	0.668
Fund 8	41.67%	2.14%	11.76%	0.589	20.17%	0.729	0.425	0.875	0.706	0.683
Fund 9	33.33%	2.27%	17.37%	0.924	22.73%	0.833	0.383	0.727	0.538	0.703
Fund 10	33.33%	0.56%	16.36%	0.942	19.07%	0.833	0.919	0.754	0.529	0.675
Fund 11	33.33%	2.12%	19.98%	1.098	31.06%	0.833	0.431	0.658	0.451	0.768
Fund 12	41.67%	1.88%	19.51%	1.066	34.00%	0.729	0.507	0.671	0.467	0.791
Fund 13	33.33%	2.05%	22.57%	1.221	41.23%	0.833	0.453	0.590	0.389	0.847
Fund 14	33.33%	2.08%	19.32%	1.049	31.70%	0.833	0.444	0.676	0.475	0.773
Fund 15	33.33%	2.03%	20.50%	1.117	31.43%	0.833	0.459	0.645	0.442	0.771
2014										
Fund 1	66.67%	1.11%	20.77%	0.833	-17.68%	0.417	0.747	0.638	0.583	0.390
Fund 2	66.67%	2.05%	21.24%	0.824	-13.46%	0.417	0.453	0.625	0.588	0.423
Fund 3	58.33%	1.30%	17.64%	0.764	11.78%	0.521	0.688	0.720	0.618	0.618
Fund 4	66.67%	2.03%	18.45%	0.682	-13.68%	0.417	0.459	0.699	0.659	0.421
Fund 5	66.67%	2.02%	19.92%	0.757	-12.00%	0.417	0.463	0.660	0.622	0.434
Fund 6	66.67%	2.30%	20.15%	0.790	-13.72%	0.417	0.375	0.654	0.605	0.421
Fund 7	50.00%	1.04%	1014%	0.356	-5.85%	0.625	0.769	0.917	0.822	0.482
Fund 8	58.33%	2.12%	11.17%	0.355	-8.25%	0.521	0.431	0.890	0.822	0.463
Fund 9	58.33%	2.28%	17.42%	0.720	-9.26%	0.521	0.382	0.726	0.640	0.455
Fund 10	75.00%	0.54%	20.20%	0.979	-26.16%	0.313	0.925	0.653	0.511	0.324
Fund 11	66.67%	2.13%	21.95%	0.903	-20.17%	0.417	0.428	0.607	0.548	0.371
Fund 12	58.33%	1.99%	22.06%	0.960	-11.08%	0.521	0.472	0.604	0.520	0.441
Fund 13	66.67%	2.03%	24.39%	0.970	-15.78%	0.417	0.459	0.542	0.515	0.405
Fund 14	66.67%	2.08%	21.54%	0.957	-15.27%	0.417	0.444	0.617	0.521	0.409
Fund 15	58.33%	2.05%	22.95%	1.028	-12.02%	0.521	0.453	0.580	0.486	0.434

It is also possible to derive value functions from the DMs' preferences leading to nonlinear value functions (see, for instance, Almeida and Dias, 2012 and Gouveia *et al.*, 2015, 2016). The value function proposed by Tversky and Kahneman (1992) will be further presented for illustrative purposes, to model y_{GR} maintaining all the other factors translated into values in a linear way.

The value function in prospect theory is defined based on deviations from a reference point and it is normally concave for gains (implying risk aversion), convex for losses (risk seeking) and steeper for losses than for gains (loss aversion) (see figure 1). The main idea is that DMs derive utility from "gains" and "losses" measured relatively to a reference point; however, prospect theory does not specify how to determine this reference point.

The literature shows that prospect theory has been applied in different contexts in the financial field (Cornell, 1999; Barberis *et al*, 2001; Barberis, 2013). According to Cornell (1999), prospect theory assumes that the investor' utility function depends on changes in the value of the portfolios rather than the absolute value of the portfolio. In other words, utility comes from returns not from the value of assets. Thus, for the illustrative case, a "gain" simply means that the return on the stock market was positive.

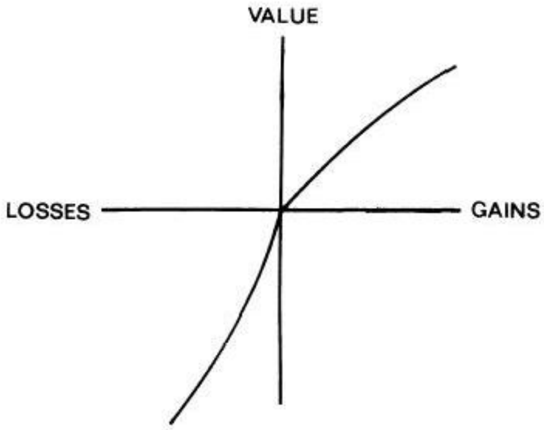

Figure 1. Hypothetical value function (Kahneman and Tversky (1979), p. 279).

The value function for the output y_{GR} was constructed according to:

$$v_{GR}^{t}\left(DMU_j\right) = \begin{cases} \left(p_{GRj}^{t}\right)^{\alpha}, & if\ p_{GRj}^{t} \geq 0 \\ -\lambda\left(-p_{GRj}^{t}\right)^{\alpha}, & if\ p_{GRj}^{t} < 0 \end{cases}, j = 1, \dots, 15; t = 1, \dots, 8 \tag{3}$$

Tversky and Kahneman (1992) estimated α = 0.88 and λ = 2.25 from experimental data and those were the values used for the parameters. Then $v_{GR}^{t}\left(DMU_j\right),\ j = 1, \dots, 15;\ t = 1, \dots, 8$, were converted into the range [0,1], using the affine transformation (2).

Table 4 shows the performances of factor y_{GR} for 2013 and 2014 in the final value scale.

Table 4. Performances of y_{GR} converted into value scales for 2013-2014.

Factor y_{GR} in value scales		
	v_{GR} **(2013)**	v_{GR} **(2014)**
Fund 1	0.879	0.559
Fund 2	0.848	0.598
Fund 3	0.851	0.797
Fund 4	0.844	0.596
Fund 5	0.877	0.612
Fund 6	0.837	0.596
Fund 7	0.823	0.672
Fund 8	0.831	0.648
Fund 9	0.841	0.638
Fund 10	0.827	0.485
Fund 11	0.873	0.537
Fund 12	0.884	0.621
Fund 13	0.911	0.577
Fund 14	0.876	0.581
Fund 15	0.874	0.612

3.3. Weight restrictions

The mathematical structure of classical DEA models allows flexibility in the choice of input and output weights, in a way that each DMU can be seen under “best possible light”. However, this advantage of DEA allows a DMU assigning a zero weight to a factor that is crucial for the DM or that is clearly more important than some other factor. This problem can be circumvented by the introduction of weight restrictions on the relative importance of the inputs and outputs capturing the DM´s preferences (Dyson and Thanassoulis, 1988; Dyson *et al.*, 2001).

Several techniques are available in MCDA, which may help to elicit the suitable weight restrictions for the Value-Based DEA model that reflect a DM’s preferences (von Winterfeldt and Edwards, 1986; Goodwin and Wright, 1998). Among these techniques the trade-offs method consists in asking the DM to specify which improvement on one factor would compensate a given worsening on another factor (or vice-versa), a question that is repeated for different pairs of factors.

The trade-offs method was used in this study. The procedure consisted in asking a panel of twenty-five experts, who are familiar with investment funds, to play the role of investors who care about the quality of fund management. The same type of question was repeated six times for six different pairs of factors (Table 5). For example, the first question was: "What is the (past) gross return of Fund 1 which would make it globally as attractive as Fund 2, for future investments?". This provides a trade-off between the first and the last factors.

Table 5. Questions made to experts.

Question 1	x_{PropNeg}	x_{ER}	x_{SD}	x_{Beta}	y_{GR}
Fund 1	6/12				?
Fund 2	4/12				11%
Question 2					
Fund 1		2.3%			?
Fund 2		0.9%			45%
Question 3					
Fund 1			21%		?
Fund 2			12%		17%
Question 4					
Fund 1				1.2	?
Fund 2				0.5	14%
Question 5					
Fund 1	9/12		?		
Fund 2	7/12		28%		
Question 6					
Fund 1		2.5%		?	
Fund 2		1.3%		1.5	

For each question, 25 answers were obtained. Rather than aggregating these answers (e.g. by averaging them), the minimum and maximum values indicated by the respondents were used to derive two inequalities they would all agree with. For example, for question 1:

$$w_{\text{PropNeg}}v_{\text{PropNeg}}(6/12) + w_{\text{GR}}v_{\text{GR}}(\min_j p_{\text{GR}j}) \leq w_{\text{PropNeg}}v_{\text{PropNeg}}(4/12) + w_{\text{GR}}v_{\text{GR}}(11\%) \quad (4)$$

$$w_{\text{PropNeg}}v_{\text{PropNeg}}(6/12) + w_{\text{GR}}v_{\text{GR}}(\max_j p_{\text{GR}j}) \geq w_{\text{PropNeg}}v_{\text{PropNeg}}(4/12) + w_{\text{GR}}v_{\text{GR}}(11\%) \quad (5)$$

Substituting $\min_j p_{\text{GR}j}$ in expression (4) and $\max_j p_{\text{GR}j}$ in expression (5), and after the performance values are translated into values, yields:

$$w_{\text{GR}} \leq 13.44\, w_{\text{PropNeg}} \text{ and } w_{\text{GR}} \geq 4.48\, w_{\text{PropNeg}}. \quad (6)$$

Questions 2, 3, 4, 5 and 6 led to the following inequalities, using an identical procedure:

$$w_{\text{GR}} \leq 28.33\, w_{\text{ER}} \text{ and } w_{\text{GR}} \geq 3.60\, w_{\text{ER}}. \quad (7)$$

$$w_{\text{GR}} \leq 10.18\, w_{\text{SD}} \text{ and } w_{\text{GR}} \geq 1.09\, w_{\text{SD}}. \quad (8)$$

$$w_{\text{GR}} \leq 2.05\, w_{\text{Beta}} \text{ and } w_{\text{GR}} \geq 1.37\, w_{\text{Beta}}. \quad (9)$$

$$w_{\text{SD}} \leq 2.64\, w_{\text{PropNeg}} \text{ and } w_{\text{SD}} \geq 0.99\, w_{\text{PropNeg}}. \quad (10)$$

$$w_{\text{Beta}} \leq 2.42\, w_{\text{ER}} \text{ and } w_{\text{Beta}} \geq 1.45\, w_{\text{ER}}. \quad (11)$$

The set W of the weight vectors satisfying these twelve weight restrictions are added to problem (1), which leads to a new formulation including $(w_1, \dots, w_5) \in W$.

4. Results

4.1 Dynamic evaluation using Value-Based DEA

For the purpose of this study it is important to analyse the variation of mutual fund performance in the period 01/01/2007 to 31/12/2014. A unifying reference set for the whole period was considered, and then the optimal value difference d_k^* has been computed for each mutual fund, in each year, to compare their variation.

This subsection presents results for the time interval 2007-2014 obtained with the Value-Based DEA method, considering that all criteria are translated into value by formulation (2) including weight restrictions (6)-(11) in the analysis. Then, the results are presented for the same years but with the value function (3) applied to factor y_{GR}.

4.1.1. Dynamic evaluation without weight restrictions

The evaluation of DMU's efficiency across the eight years without weight restrictions is depicted in Table 6. The lower the value of d^* is the better, and if d^* is negative then the DMU under analysis is efficient (highlighted in bold). The DMUs that have $d^* = 0$ are weakly efficient and the ones that have $d^* > 0$ are inefficient (Gouveia *et al.*, 2013).

The year 2009 is the one that shows more efficient DMUs, also displaying the lowest average optimal d^*. The year with the highest average (worst values) is 2008, accompanying the world financial crisis on the Lisbon stock exchange. DMU 10 (Fund 10) is the only one that maintains the efficiency status for every year (except 2007 and 2014). DMU 7 (Fund 7), the best one in 2014, is efficient in 2007, but loses efficiency in 2008, and starts to recover in 2012.

Table 6. d* for the 120 Funds (2007-2014).

	d^* (2007)	d^* (2008)	d^* (2009)	d^* (2010)	d^* (2011)	d^* (2012)	d^* (2013)	d^*(2014)
Fund 1	0.0861	0.2048	**-0.0496**	0.094	0.0929	0.0824	0.0078	0.1021
Fund 2	0.1382	0.2927	0.0294	0.2363	0.1384	0.0928	0.0635	0.1670
Fund 3	0.1234	0.1737	**-0.0222**	0.1555	0.1202	0.0732	0.0463	0.0543
Fund 4	0.1279	0.3139	0.0768	0.2271	0.1949	0.116	0.0614	0.1255
Fund 5	0.1042	0.2115	**-0.0214**	0.2789	0.1874	0.0983	0.0541	0.1443
Fund 6	0.1183	0.2920	0.0187	0.2338	0.1614	0.0816	0.0938	0.1600
Fund 7	**-0.0634**	0.0967	0.0396	0.0825	0.1173	0.0000	**-0.0254**	**-0.0806**
Fund 8	0.0764	0.2667	0.0971	0.2234	0.2041	0.0000	**-0.0245**	**-0.0004**
Fund 9	0.0982	0.2902	0.0215	0.2548	0.1608	0.0933	0.0535	0.1252
Fund 10	0.0294	**-0.0031**	**-0.0009**	**-0.0161**	**-0.0505**	**-0.0086**	**-0.0505**	0.0137
Fund 11	0.1107	0.3405	0.013	0.2413	0.2275	0.0935	0.0594	0.2108
Fund 12	0.0993	0.2737	**-0.0146**	0.251	0.1669	0.0872	0.0461	0.1934
Fund 13	0.1376	0.1729	0.0000	0.2913	0.1799	0.0906	0.0496	0.2121
Fund 14	0.1042	0.2798	0.0677	0.2151	0.1371	0.1261	0.0488	0.2081
Fund 15	0.1136	0.3021	0.0095	0.2173	0.1419	0.0886	0.0646	0.2154
Average	0.0936	0.2339	0.0176	0.1991	0.1454	0.0743	0.0366	0.1234

Figure 2 shows the evolution of performance variation of funds in Table 6 that were classified as efficient at least once in the period 2007-2014. The efficiency measure d* improved only for DMU 10 (Fund 10) from 2007 to 2008, moving from inefficient to efficient. Considering the next two years (2008 and 2009), only DMU 10 worsened d*, keeping the efficiency status. From 2009 to 2010, solely DMU 10 improved the efficiency score. DMU 7 (Fund 7) is the only one that worsened its performance from 2010 to 2011. Again, for 2011 and 2012, DMU10 worsened its performance but still being efficient. From 2012 to 2013 all funds improved their efficiency score. In 2014 only DMU 7 improved its efficiency score.

From the joint analysis of Table 6 and Figure 2, it can be inferred that nearly all funds improved their efficiency score from 2011 to 2013: Before 2011, the cautions that investors had regarding fund profitability, due to taxation or suspicion of the financial system, reflected in weak mutual fund performance. Later, in June 2011 with the presence of Troika in Portugal, there was a slight recover of credibility of the institutions. Several audits were conducted and financial improvement recommendations were made, including recapitalization.

Contrary to expectations, almost all funds have a poor performance in 2014, and all except DMU 7 worsened its efficiency measure. This may be due mainly to the fact that the European authorities predicted a weak economic growth for Portugal in the coming years. The effect of constant speculations about Euro exit, level of economic growth and the implicit pressure on the markets also justify the poor performance in 2014. Additionally, in accordance with APFIPP, it is necessary to go back to 2011, the year of the request for financial assistance, to obtain such a high amount of negative subscriptions in the industry after the collapse of one of the largest banks.

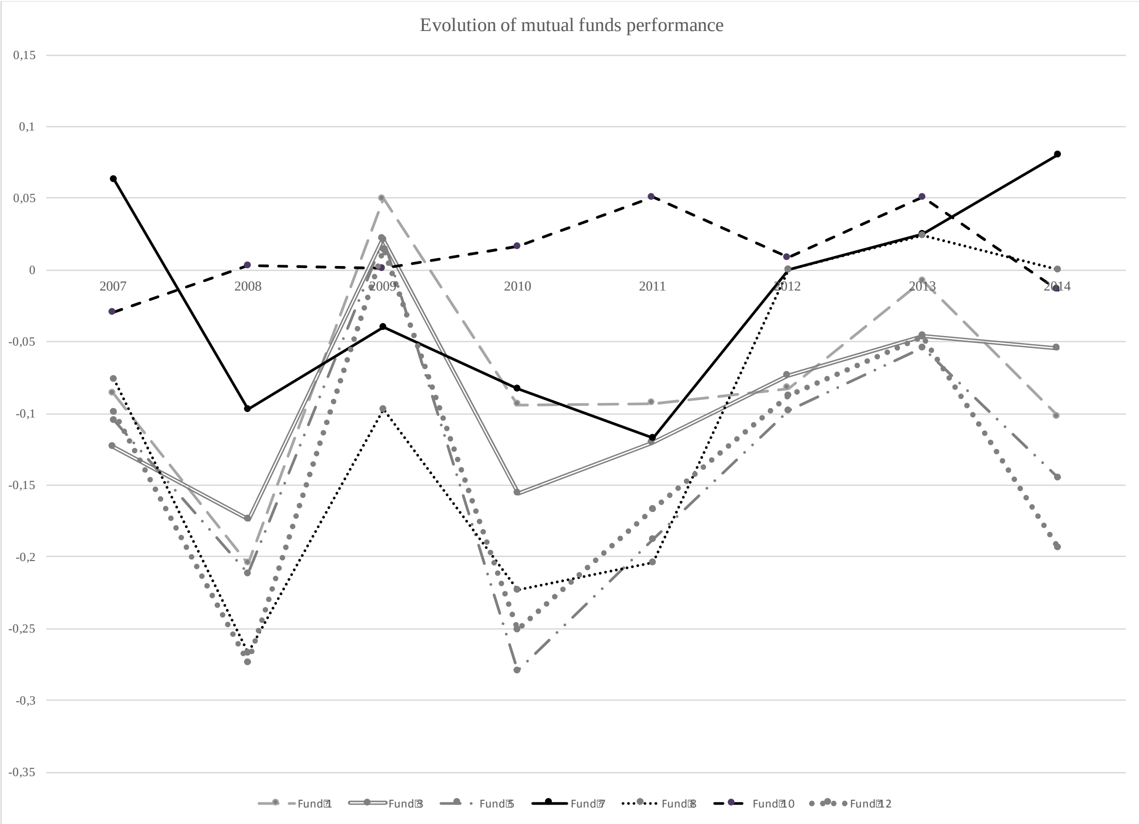

Figure 2. Evolution of $-d^*$ of mutual funds with at least one efficient score in 2007-2014.

Table 7 exhibits the results of Value-Based DEA, problem (1), only for the efficient units. The efficiency scores were obtained by allowing DMUs to ignore some factors from the assessment, because there are no restrictions on the weights. For example, DMU 10 in year 2008 (t=2) is efficient but only one weight is different from zero, hence the vector of weights that favoured it more disregards the other four factors. Zero weights assigned to some factors can be prevented with the incorporation of weight restrictions derived from preference information elicited from DMs concerning the efficiency assessment of DMUs.

Table 7. Results of Phase 1 for efficient units without weight restrictions.

DMUs	d^*	$w^*_{PropNeg}$	w^*_{ER}	w^*_{SD}	w^*_{Beta}	w^*_{GR}
DMU_1^3	**-0.0496**	0.0000	0.277	0.0000	0.0000	0.7230
DMU_3^3	**-0.0222**	0.0000	0.0760	0.4362	0.0000	0.4878
DMU_5^3	**-0.0214**	0.1134	0.0000	0.3287	0.0000	0.5579
DMU_7^1	**-0.0634**	0.1045	0.0000	0.7834	0.0000	0.1121
DMU_7^7	**-0.0254**	0.1316	0.0507	0.6594	0.0000	0.1583
DMU_7^8	**-0.0806**	0.0000	0.2339	0.0000	0.666	0.1002
DMU_8^7	**-0.0245**	0.0000	0.0000	0.0000	0.5571	0.4429
DMU_8^8	**-0.0806**	0.0000	0.2339	0.0000	0.6660	0.1002
DMU_{10}^2	**-0.0031**	0.0000	1.0000	0.0000	0.0000	0.0000
DMU_{10}^3	**-0.0009**	0.0000	0.2545	0.323	0.0000	0.4225
DMU_{10}^4	**-0.0161**	0.0458	0.9542	0.0000	0.0000	0.0000
DMU_{10}^5	**-0.0505**	0.0000	0.5702	0.4298	0.0000	0.0000
DMU_{10}^6	**-0.0086**	0.0000	0.6054	0.0000	0.3435	0.0512
DMU_{10}^7	**-0.0505**	0.1594	0.5274	0.1548	0.0000	0.1584
DMU_{12}^3	**-0.0146**	0.0000	0.0842	0.0000	0.0000	0.9158

4.1.2. Dynamic evaluation with weight restrictions

The set W of weight restrictions presented in section 3.3 was introduced into problem (1), which led to the results from the Value-Based DEA depicted in Table 8, only for previously efficient units (those in Table 7). There are no longer null weights.

Comparing the results without and with weight restrictions, the score of efficiency d^* is necessarily higher (i.e., worse) for all units when the set of weight restrictions is included. Only three DMUs maintain the efficiency status when the weight restrictions are considered. The best fund (DMU_7^8) without weight restrictions is now inefficient. The best fund considering the weight restrictions is DMU_7^1, which was in second position without considering such restrictions. In addition to this one, one more fund of 2009 and one of 2013 were classified as efficient. The DMU 7, considering weight restrictions, was classified as efficient in 2007 and in 2013. DMU 10, which was efficient for 6 years, appears in Table 8 always classified as inefficient.

Table 8. Results of Value-Based DEA considering weight restrictions.

DMUs	d^*	$w^*_{PropNeg}$	w^*_{ER}	w^*_{SD}	w^*_{Beta}	w^*_{GR}
DMU_1^3	0.0059	0.0506	0.1413	0.0501	0.2488	0.5092
DMU_3^3	**-0.0165**	0.0368	0.1208	0.0972	0.2506	0.4946
DMU_5^3	0.0043	0.1046	0.0947	0.1035	0.2289	0.4684
DMU_7^1	**-0.0193**	0.0809	0.1005	0.2135	0.2429	0.3622
DMU_7^7	**-0.0160**	0.0847	0.0913	0.2237	0.2207	0.3795
DMU_7^8	0.0418	0.0809	0.1005	0.2135	0.2429	0.3622
DMU_8^7	0.0267	0.0727	0.0879	0.192	0.2125	0.4349
DMU_8^8	0.0966	0.0809	0.1005	0.2135	0.2429	0.3622
DMU_{10}^2	0.3277	0.0371	0.1232	0.0981	0.2977	0.4439
DMU_{10}^3	0.0155	0.0506	0.1413	0.0501	0.2488	0.5092
DMU_{10}^4	0.1359	0.0371	0.1232	0.0981	0.2977	0.4439
DMU_{10}^5	0.2007	0.0809	0.1005	0.2135	0.2429	0.3622
DMU_{10}^6	0.0741	0.0371	0.1232	0.0981	0.2977	0.4439
DMU_{10}^7	0.0327	0.066	0.1194	0.1742	0.2102	0.4302
DMU_{12}^3	0.0183	0.0527	0.1070	0.0521	0.2587	0.5295

In order to perform a sensitivity analysis on the preference information elicited, weight restrictions (6)-(11) were modified by the introduction of the tolerances values $\delta = 5\%$, $\delta = 10\%$ and $\delta = 20\%$. For each one we computed a new (more relaxed) range: $L \times (1 - \delta) \leq w_c \leq U \times (1 + \delta)$. As a result of these relaxations, the efficiency scores improve (are lower). When $\delta = 5\%$, DMU_1^3 and DMU_5^3 (fund 1 and fund 5 in 2009), which were very close to efficiency are still inefficient, but they become efficient when $\delta = 10\%$. When a tolerance of 20% is considered, there are no further changes regarding the status of funds. Therefore, the main conclusions are fairly robust with regard to the preference information.

4.1.3. Dynamic evaluation with the Kahneman and Tversky value function

When the value function (3) is applied to the factor y_{GR}, the results, without weight restrictions, are slightly different. Comparing Table 9 with Table 6 in 4.1.1., the year 2008 shows no efficient funds and the number of efficient funds in 2009 decreased from 6 to 4. The average of d^* in 2009 improves, when compared with the average of the same year in Table 6, as well as in the years 2007, 2012 and 2013. For the remaining years, the average values are worse (see Table 9).

Almost all funds change their position in the ranking when the value function of the factor y_{GR} is modified. For example, there is an exchange of the first position with the second one. The DMU_{10}^4 rises from 10th position to 6th position and DMU_8^7 falls from 7th position to 12th position. These changes are only due to the shape of the curve derived from the value associated with “gains” and “losses”.

Table 9. $d*$ for the 120 Funds (2007-2014), with the value function of Kahneman and Tversky applied to the factor $y_{GR,}$ without weight restrictions.

DMUs	d^* (2007)	d^* (2008)	d^* (2009)	d^* (2010)	d^* (2011)	d^* (2012)	d^* (2013)	d^*(2014)
Fund 1	0.0628	0.2048	**-0.0282**	0.094	0.0962	0.0616	0.0056	0.1021
Fund 2	0.0915	0.2947	0.0178	0.2525	0.1657	0.0677	0.0446	0.176
Fund 3	0.0868	0.1737	**-0.0120**	0.1567	0.1355	0.0544	0.0316	0.0445
Fund 4	0.0851	0.3139	0.0475	0.229	0.2306	0.0887	0.0431	0.1315
Fund 5	0.0885	0.2115	**-0.0129**	0.277	0.2297	0.0688	0.0345	0.1497
Fund 6	0.0751	0.292	0.0116	0.2382	0.1952	0.0560	0.0590	0.1662
Fund 7	**-0.0631**	0.0967	0.0279	0.079	0.1173	0.0000	**-0.0148**	**-0.0617**
Fund 8	0.0689	0.2684	0.0608	0.2072	0.229	0.0000	**-0.0055**	**-0.0004**
Fund 9	0.0727	0.2933	0.0109	0.2751	0.1895	0.0622	0.0380	0.1286
Fund 10	0.0276	0.0000	0.0000	**-0.0161**	**-0.0505**	**-0.0100**	**-0.0504**	0.0137
Fund 11	0.0793	0.3405	0.0066	0.2487	0.2632	0.0627	0.0406	0.2235
Fund 12	0.0721	0.2737	**-0.0070**	0.2656	0.1963	0.0585	0.0284	0.1993
Fund 13	0.0855	0.1729	0.0000	0.2952	0.2120	0.0631	0.0281	0.2303
Fund 14	0.0797	0.2798	0.0413	0.2255	0.1646	0.0909	0.0324	0.2247
Fund 15	0.0846	0.3067	0.0068	0.2346	0.1710	0.0585	0.0427	0.2156
Average	0.0665	0.2348	0.0114	0.2041	0.1697	0.0522	0.0239	0.1296

5. Concluding remarks

This study aimed at offering a better understanding of the performance and variations of open-end actively managed Portuguese Equity Funds in the period 2007-2014. The Value-Based DEA method enabled to capture the determinants of funds' performance and observe the different behaviours in that period, which comprise the economic crisis, recognizing that some funds have been more efficient than others across those years.

This work enabled to conclude that the Portuguese fund industry in 2009 reached its best annual performance according to the comprehensive set of factors considered. Whereas many equity funds finished 2008 in the red, resulting in a decline of the Net Asset Value, in 2009 financial markets recovered markedly since March when the financial stress began to ease and market conditions started to improve. At the same time the liquidity profile of the industry improved significantly with the rate of recovery outpacing many expectations and clearly attracting the investors to new investment vehicles. Corroborating this, 2009 presents the highest number of efficient funds. Fund 10 is the one that performed better, except for the year 2007 and 2014 when fund 7 was the most efficient one. This could be explained by its composition, since fund 7 presents a small percentage of stocks of financial services (much less than the other funds) and those two years have been quite dramatic for the banking sector. In the year 2007 there was a need for recapitalization since the onset of the crisis with investors withdrawing money from banks. The announcement of Troika, at beginning of 2014, that some vulnerability in Portuguese banking sector persisted is the main reason for a new decline of the financial sector.

The results obtained also indicate that Portuguese investment funds performed better between 2011-2013; this may suggest that equity funds investors were more confident in these vehicles due to measures reinforcing financial markets.

The fifteen funds classified as efficient in the eight years considered attain that status ignoring important criteria of evaluation. The inclusion of weight restrictions elicited from experts allowed all criteria to be considered in the assessment.

One of the main contributions of the study is to assist investors and fund managers in the identification of funds with the best performance according to their judgments. Without considering the preferences expressed as weight constraints or non-linear value functions, two of the funds (DMUs 7 and 10) appear to be the most interesting to invest in. The possibility to incorporate the preferences of an investor using weight constraints and/or non-linear value functions enable to refine the analysis and lead to more appropriate choices for a specific investor.

Acknowledgments

This work has been supported by the Portuguese Foundation for Science and Technology (FCT) under project grant UID/MULTI/00308/2013

References

Ali AI, Lerme CS, Seiford L (1995). Components of efficiency evaluation in Data Envelopment Analysis. *European Journal of Operational Research* **80**(3): 462-473.

Almeida PN and Dias LC (2012). Value-based DEA models: application-driven developments. *Journal of the Operational Research Society* **63**(1): 16-27.

Alves C and Mendes V (2010). Mutual funds biased preference for the parent's stock: evidence and explanation. *Applied Financial Economics*, **20**(16): 1309-1320.

Andersen P and Petersen NC (1993). A procedure for ranking efficient units in data envelopment analysis. *Management Science* **39**(10) :1261-1264.

Babalos V, Philippas N, Doumpos M and Zopounidis C (2012). Mutual funds performance appraisal using stochastic multicriteria acceptability analysis. *Applied Mathematics and Computation* **218**(9): 5693-5703.

Babalos V, Doumpos M, Philippas N and Zopounidis C (2015). Towards a Holistic Approach for Mutual Fund Performance Appraisal. *Computational Economics* **46**(1): 35–53.

Banker RD, Charnes A, Cooper WW (1984). Some models for estimating technical and scale efficiencies in data envelopment analysis. *Management Science* **30**(9): 1078–1092.

Barberis N, Huan M and Santos T (2001). Prospect Theory and Asset Prices. *The Quarterly Journal of Economics* **116**(1): 1–53.

Barberis N (2013). Thirty Years of Prospect Theory in Economics: A Review and Assessment. *Journal of Economic Perspectives* **27**(1): 173–196.

Basso A, Funari S (2001). A data envelopment analysis approach to measure the mutual fund performance. *European Journal of Operational Research* **135** (3): 477-492.

Basso A, Funari S (2003). Measuring the performance of ethical mutual funds: A DEA approach. *Journal of the Operational Research Society* **54**(5): 521–531.

Bell DE (1982). Regret in Decision Making under Uncertainty. *Operations Research* **30**(2): 961-981.

Berk JB and Binsbergen JH (2016). Assessing asset pricing models using revealed preference. *Journal of Financial Economics* **119**(1): 1–23.

Busse JA, Goyal A and Wahal S (2010). Performance and Persistence in Institutional Investment Management. *Journal of Finance* **65**(2): 765-790.

Cabrita MDR and Bontis N (2008). Intellectual capital and business performance in the Portuguese banking industry. *International Journal of Technology Management*, **43**(1-3): 212-237.

Carhart M (1997). On persistence in mutual fund performance. *Journal of Finance* **52**(1): 57–82.

Chang KP (2004). Evaluating mutual fund performance: An application of minimum convex input requirement set approach. *Computers & Operations Research* **31**(6): 929–940.

Charnes A, Cooper WW and Rhodes E (1978). Measuring the efficiency of decision making units. *European Journal of Operational Research* **2**(6): 429-444.

Chen J, Hong H, Huang M and Kubik JD (2004). Does fund size erode mutual fund performance? The role of liquidity and organization. *The American Economic Review* **94**(5): 1276-1302.

Choi YK, Murthi BPS (2001). Relative performance evaluation of mutual funds: A non-parametric approach. *Journal of Business Finance and Accounting* **28**(7-8): 853–876.

Cortez MDCR, Paxson DA and Armada MJDR (1999). Persistence in Portuguese mutual fund performance. *The European Journal of Finance* **5**(4): 342-365.

Cook WD, Tone K and Zhu J (2014). Data envelopment analysis: Prior to choosing a model. *Omega* **44**: 1–4.

Cornell B (1999). *The Equity Risk Premium: The Long-Run Future of the Stock Market*. New York: Wiley.

Cremers KJ M and Petajisto A (2009). How active is your fund manager? A new measure that predicts performance. *Review of Financial Studies* **22**(9): 3329–3365.

Daraio C, Simar L (2006). A robust nonparametric approach to evaluate and explain the performance of mutual funds. *European Journal of Operational Research* **175**(1): 516–542.

Dyson RG and Thanassoulis E (1988). Reducing weight flexibility in DEA. *Journal of the Operations Research Society* **39**(6): 563–576.

Dyson RG, Allen R, Camanho AS, Podinovski VV, Sarrico CS, Shale EA (2001). Pitfalls and protocols in DEA. *European Journal of Operational Research* **132**(2): 245-259.

Fama EF and French KR (2010). Luck versus skill in the cross section of mutual fund returns. *Journal of Finance* **65**(5): 1915–1947.

Ferreira MA, Keswani A, Miguel AF and Ramos S (2013). The determinants of mutual fund performance: a cross-country study. *Review of Finance* **17**(3): 483–525.

Frazzini A and Pedersen LH (2014). Betting against beta. *Journal of Financial Economic*s **111**(1): 1-25.

Galagedera DUA, Silvapulle P (2002). Australian mutual fund performance appraisal using data envelopment analysis. *Managerial Finance* **28**(9): 60–73.

Glawischnig M, Sommersguter-Reichmann M (2010). Assessing the performance of alternative investments using non-parametric efficiency measurement approaches: Is it convincing? *Journal of Banking & Finance* **34**(2): 295–303

Goodwin P and Wright G (1998). *Decision analysis for management judgment*. Wiley, Chichester.

Gouveia MC, Dias LC, Antunes CH (2008). Additive DEA based on MCDA with imprecise information. *Journal of the Operational Research Society* **59**(1): 54-63.

Gouveia MC, Dias LC, Antunes CH (2013). Super-efficiency and stability intervals in additive DEA. *Journal of the Operational Research Society* **64**(1): 86-96.

Gouveia MC, Dias LC, Antunes CH, Boucinha J, Inácio CF (2015). Benchmarking of maintenance and outage repair in an electricity distribution company using the Value-Based DEA method. *Omega* **53**: 104-114.

Gouveia MC, Dias LC, Antunes CH, Mota MA, Duarte EM, Tenreiro EM (2016). An application of an additive DEA model to identify best practices in primary health care. *OR Spectrum* **38**(3): 743–767.

Gregoriou, GN, Sedzro K and Zhu J (2005). Hedge fund performance appraisal using data envelopment analysis. *European Journal of Operational Research* **164**(2): 555–571.

Gregoriou GN (2007). *Diversification and Portfolio Management on Mutual Funds*. Palgrave Macmillan.

Halme M, Joro T, Korhonen P, Salo SE, Wallenius J (1999). A value efficiency approach to incorporating preference information in Data Envelopment Analysis. *Management Science* **45**(1):103-15.

Hong H and Sraer DA (2016). Speculative betas. *The Journal of Finance* **71**(5): 2095-2144.

Ippolito R (1989). Efficiency with costly information: A study of mutual fund performance. *Journal of Economics* **104**(1): 1-23.

Jensen M (1968). The Performance of Mutual Funds in The Period 1945-1964. *Journal of Finance* **23**(2): 389-416.

Joro T, Viitala EJ (2004). Weight-restricted DEA in action: From expert opinions to mathematical models. *Journal of the Operational Research Society* **55**(1): 814–821.

Kacperczyk MT, Sialm C and Zheng L (2005). On Industry Concentration of Actively Managed Equity Mutual Funds. *Journal of Finance* **60**(4):1983–2011.

Kahneman D and Tversky A (1979). Prospect Theory: An Analysis of Decision under Risk. *Econometrica* **47**(2): 263–292.

Khedmatgozar HR, Kazemi A and Hanafizadeh P (2013). Mutual fund performance evaluation: a value efficiency analysis approach. *International Journal of Electronic Finance* **7**(3/4): 263 – 280.

Khorana A, Servaes H and Tufano P (2005). Explaining the Size of the Mutual Fund Industry Around the World. *Journal of Financial Economics* **78**(1):145-185.

Lahdelma R, Salminen P (2001). SMAA-2: stochastic multicriteria acceptability analysis for group decision making. *Operations Research* **49**(3): 444–454.

Lam JD and Tee K (2012). Data envelopment analysis models of investment funds. *European Journal of Operational Research* **216**(3): 687–696.

Leite P, Faria O and Armada MR (2016). The impact of the Eurozone sovereign debt crisis on bond fund performance persistence: Evidence from a small market. *Investment Analysts Journal* **45**(sup1): S32-S45.

Liu JS, Lu LYY, Lu WM and Lin BJY (2013). A survey of DEA applications. *Omega* **41**: 893–902.

Lou D (2012). A flow-based explanation for return predictability. *Review of Financial Studies* **25**(12): 3457–3489.

McMullen PR, Strong RA (1998). Selection of mutual funds using data envelopment analysis. *Journal of Business and Economic Studies* **4**(1): 1–14.

Murthi BPS, Choi KY and Desai P (1997). Efficiency of mutual funds and portfolio performance measurement: a non-parametric approach. *European Journal of Operational Research* **98**(2): 408-418.

Pástor L, Stambaugh RF and Taylor LA (2015). Scale and skill in active management. *Journal of Financial Economics* **116**(1): 23-45.

Pätäri E, Leivo T, Honkapuro S (2012). Enhancement of equity portfolio performance using data envelopment analysis. *European Journal of Operational Research* **220**(3): 786–797.

Sherman HD and Zhu J (2006). Service Productivity Management: Improving Service Performance using Data Envelopment Analysis (DEA). Springer.

Tarnaud AC and Hervé L (2017). Portfolio analysis with DEA: Prior to choosing a model. *Omega* (forthcoming) https://doi.org/10.1016/j.omega.2017.02.003

Treynor J (1965). How to rate management of investment funds. *Harvard Business Review* **43**: 63–75.

Treynor J, Mazuy K (1966). Can mutual funds outguess the market? *Harvard Business Review* **44**:131–136

Tversky A and Kahneman D (1992). Advances in Prospect Theory: Cumulative Representation of Uncertainty. *Journal of Risk and Uncertainty* **5**(4): 297–323.

von Winterfeldt D and Edwards W (1986). *Decision analysis behavioral research*. Cambridge University Press, New York.

Wilkens K and Zhu J (2001). Portfolio evaluation and benchmark selection: A mathematical programming approach. *The Journal of Alternative Investments* **4**(1): 9-19.

Wermers R (2000). Mutual fund performance: an empirical decomposition into stock-picking talent, style, transactions costs, and expenses. *Journal of Finance* **55**(4):1655–1695.

Yan XS (2008). Liquidity, Investment Style, and the Relation between Fund Size and Fund Performance. *Journal of Financial and Quantitative Analysis* **43**(3): 741-767.

Zopounidis C, Galariotis E, Doumpos M, Sarri S and Andriosopoulos K (2015). Multiple criteria decision aiding for finance: An updated bibliographic survey. *European Journal of Operational Research* **247**(1): 339–348.