SOCIALLY RESPONSIBLE INVESTMENT: MUTUAL FUNDS PORTFOLIO SELECTION USING FUZZY MULTIOBJECTIVE PROGRAMMING

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De conformidad con la base quinta de la convocatoria del Programa de Estímulo a la Investigación, este trabajo ha sido sometido a evaluación externa anónima de especialistas cualificados a fin de contrastar su nivel técnico.

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Title: Socially Responsible Investment: Mutual Funds Portfolio Selection using Fuzzy Multiobjective Programming[1].

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Abstract

This paper proposes a three-stage decision making model for mutual funds portfolio selection taking into account, not only classical criteria (risk and return), but also socially responsible ones.

Portfolio selection is, due to its specific characteristics, a multicriteria decision making problem. Nevertheless, portfolio selection's classical theory only takes into account criteria related to the portfolio's return and risk and does not include environmental, ethical or social criteria which due to their nature are usually expressed by the investor in a qualitative, linguistic and/or imprecise way. In this context, Fuzzy Multicriteria Decision Making techniques seem to be suitable techniques for solving the portfolio selection problem including several criteria such as return, risk and socially responsible criteria, among other.

This work aims to be a contribution to the resolution of that problem. In order to select an optimal portfolio composed by ethical and non ethical mutual funds, a fuzzy multi-criteria model has been proposed which takes into account, not only the classical portfolio selection criteria but also other criteria as the ethical profile of the portfolio obtained from the definition of an ethical index which is built for each investor taking into account his/her individual ethical preferences. The proposed model allows then the consideration of non-standard investors.

Key words: Multi-Objective Decision Making, Compromise Programming, Portfolio selection, Fuzzy Sets and Systems, Ethical investment

JEL code: C00, C6, D81, G11.

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1. Introduction.

Ethical Investing, or its US equivalent, *Socially Responsible Investment* (SRI) in mutual funds invest in companies that are concerned with ethical issues or they avoid investing in companies that produce certain products or follow certain policies as discrimination against minorities…The total amount of SRI assets in Europe last decade grew by more than 40%, from €24.1 billions to €34.0 billions at the end of the second quarter 2006. By countries, France has presented a remarkable growth, with more than 100% increase in the asset under management and now is the second country in Europe with about 20% of market share. UK remains by far the largest manager of SRI retail asset with a share of about 28%. On the opposite, Italian funds did not increase (Avanzi [1]). By types, it is interesting to notice the predominance of equity and balanced funds (77.9% of total assets) as opposed to fixed-income funds (only 19.6% of total SRI assets).

The field of ethical mutual funds arises then, more and more interesting in modern financial field. Several recently works investigate the performance of ethical funds by taking into account not only their returns and risks but also their ethical profile. In order to evaluate the performance of ethical mutual funds we need an ethical measure which can be used as an output variable to be taken into account together with the return and risk indicators [2]. Therefore, several consultant agencies and research institutes analyze the ethical nature of mutual funds. The *Eurosif* (European Social Investment Forum), a pan-European group whose mission is to address sustainability through financial markets together with *Avanzi* rating agency and Morningstar, provide, by means of the “SRI Fund Service”, basic information regarding the socially responsible profile of European ethical mutual funds. One of the most important activities of these consultant agencies is the *ethical screening*. Ethical screening allows selection of the assets to be included in the mutual fund portfolios on the basis of social and environmental grounds. The selection can be carried out either with a negative feature, by excluding from the portfolios the assets of the companies with a profile that is bad for socially responsible criteria, or with a positive feature, by including in the portfolio investments in companies which are selected on the ground of their ethically and socially behaviour.

The most important information on the ethical screening takes into consideration a set of features which can be either present or absent in the ethical profile of each fund such as: firearms, tobacco, gambling, human rights…

In this work an ethical measure is proposed and incorporated in the portfolio selection model as an additional criterion.

Previous works can be found related to the definition of ethical measures. Basso and Funari [2], for example, used the information provided by the "SRI Fund Service" in order to define an ethical measure. In their work, these authors assign to each ethical feature a weight and then they compute their weighted sum taking into account also the presence of an ethical committee with the task of defining the guidelines of the socially responsible investment.

Barracchini [3] proposed the construction of an ethical index as evaluation of the coherence of the ethical principles of the investor in comparison with the ethical principles respected in the investment.

The proposed ethical measure in this paper, which will be designed as "*ethical component*", will allow us to define different investor profiles and will be defined as follows:

$$e_i = \sum_{j=1}^{l} w_j z_{ij} \tag{1}$$

Where l is the number of social features to be taken into account and w_j are non-negative weights assigned by the investor depending on his/her ethical preferences and

$$z_{ij} = \begin{cases} 1 & \text{if fund } i \text{ presents feature } j \\ 0 & \text{if fund } i \text{ does not present feature } j \end{cases} \tag{2}$$

By construction, fund i has a zero ethical measure if and only if it has no ethical profile, so that $e_i = 0$ for non ethical funds. This new ethical measure allows investors to select among feature issues for portfolio selection.

We will distinguish between four types of socially responsible investors depending on their profile:

1. Investor with a social profile: he/she prefers investing in those ethical mutual funds verifying positive and negative features related to the first group of socially responsible features (see table 1 with group screening for investor's profile). For this kind of investor the ethical component will be denoted as e_i^{soc}.

2. Investor with an ecological profile: he/she prefers investing in those ethical mutual funds verifying positive and negative features related to the second group of socially responsible features (see table 1 with group screening for investor's profile). For this kind of investor the ethical component will be denoted as e_i^{eco}.

3. Investor with an ethical profile: he/she prefers investing in those ethical mutual funds verifying positive and negative features related to the third group of socially responsible features (see table 1 with group screening for investor's profile). For this kind of investor the ethical component will be denoted as e_i^{ethi}.

4. Investor socially responsible: he/she wants to invest in ethical mutual funds but has not a specific social responsible profile, so, he/she aims to invest in funds verifying positive and negative features related to all the groups of socially responsible features (see table 1 with group screening for investor's profile). For this kind of investor the ethical component will be denoted as e_i.

Few empirical studies can be found related to ethical mutual funds portfolio selection (see [3]).

In this work a fuzzy three stage-multiindex model is proposed to help an investor to find an optimal portfolio taking into account not only financial but also ethical personal investor's criteria.

In the first stage of the model, a multifactor model has been proposed in order to select an optimal portfolio. Principal factors affecting mutual funds returns are identified by Principal Component Analysis. Once they have been obtained, a regression model is proposed in order to determine sensitivity of mutual funds to changes in the considered underlying factors. To this end, a regression technique based on non Euclidean distance is used (e.g. Least Absolute Value) which can be more suitable under certain conditions usual in the financial field.

A fuzzy multiobjective linear program has been proposed in order to obtain optimal portfolio. Three groups of objectives have been considered: maximization of the fuzzy expected return of the portfolio, minimization of the portfolio's risk and maximization of the ethical component of the portfolio. The proposed model will allow us to define different investor's profiles depending on the degree of interest of the investor in ethical investing and moreover, depending on his/her personal and particular interests: ecology, labour policies, non-armament…or all of them, which will define his/her ethical profile.

Two groups of constraints have been considered: the classical budget constraint and bounds on the investment in ethical assets.

In order to solve the problem of portfolio selection funds we have use Compromise Programming (CP). CP is a well-known Multicriteria Decision Making approach developed by Yu [4] and Zeleny [5] and [6]. The basic idea in CP is the identification of an ideal solution as a point where each criteria under consideration achieves its optimum value. Zeleny states that alternatives that are closer to the ideal are preferred to those that are farther from it, because being as close as possible to the perceived ideal is the rationale of human choice. This technique is especially suitable for those real applications where there exists conflicting objectives which is our case: the investor has to face conflicting objectives, maximization of expected return while minimization of risk maximizing the ethical component of the portfolio.

From what the authors know, no papers can be found relating portfolio selection with multiple criteria and fuzzy data on ethical and non ethical criteria.

2. Database construction.

We have constructed a database containing 110 UK domiciled ethical mutual funds and 90 UK domiciled traditional funds (see tables in the appendix for more details). From this large database we have selected 44 ethical mutual funds (E) and 81 traditional mutual funds (T) all denoted in local currency. Criteria used for this final funds selection was availability of data which have been kindly provided by *Morningstar*.

Once mutual funds have been selected, weekly returns from January 2001 to January 2006 have been calculated for a final number of 125 mutual funds (ethical and traditional).

In the following table we present ethical selected funds and their ethical screening. All the data related to positive and negative features have been obtained from their Facts Sheets provided by the Fund Service from *Avanzi* in www.avanzi_sri.org.

We have classified ethical criteria into three groups in order to define socially responsible investment profiles: social, ecological and ethical without taking into account if the feature is positive or negative.

If the fund present a certain feature (positive or negative) we have assigned to it in the table value 1 and if it not, value 0.

Table 1.Group Screening for Investor's Profile.

I/ GROUP: Social	II/ GROUP: Environmental	III/ GROUP: Ethical
1.Access to Medicines	13. Air & Water Pollution	27.Alcohol
2.Bribery & corruption	14.Biodiversity	28.Animal Testing & Fur
3.Child Labour	15.Climate Change	29.Gambling
4.Community Giving	16.Energy	30.Genetic Engineering
5.Community Initiatives	17.Environmental Management	31.Military

6.Conflict	18.Mining & Quarrying	32.Nuclear Power
7.Corporate Governance	19.Nuclear power	33.Pornography & Adult Entertainment
8.Equal Opportunities	20.Ozone-Depleting Chemicals	34.Repressive Regimes
9.Health & Safety	21.Pesticides	35.Tobacco
10.Human Rights	22.Resource Productivity	36.Firearms
11.Labour Standards	23.Transport	37.Animal derived products
12.Supply Chain Management	24.Tropical Hardwood	38.Animal food related Issues
	25.Waste & Toxic Chemical Management	
	26.Water Management	

3. Markowitz's Portfolio selection classical model.

Modern portfolio theory is based on pioneering works of Markowitz (see [7] and [8]) and Sharpe [9]. Markowitz's portfolio optimization model, contrary to its theoretical reputation, has not been used extensively from its original form to construct a large-scale portfolio [10]. The first reason behind this is the nature of the input required for portfolio analysis. If accurate expectations about future mean returns for each asset and the correlation of returns between each pair of stocks could be obtained, then the Markowitz model would produce optimum portfolios. The problem lies in obtaining accurate expectations of the input needed for this model. This difficulty is particularly acute with respect to the matrix of covariance between assets [11]. Another of the most significant reasons for this is the computational difficulty related to the resolution of large-scale quadratic programming problem with a dense covariance matrix. Several authors have tried to solve these problems by using various approximation schemes ([12], [13], [14], [15] and [10] among others) to obtain linear problems.

The use of the index or factor models enables one to reduce the amount of computation by introducing the notion of "factors" influencing stock prices ([16], [9]). Yet, these efforts have been largely discounted because of the popularity of equilibrium models such as the capital asset pricing model (CAMP), developed by Sharpe ([17], [18]) and Lintner [19], and the multifactor arbitrage pricing theory (APT) formulated by Ross [20] and extended by Huberman [21] and Connor [22], which are computationally less demanding. In a factor model, the random return of each asset is a linear combination of a small number of common factors, plus an asset-specific random variable (see [23]).

Multifactor model is a general form of factor model and is the most popular model for the return generating process. Let a portfolio, *P*, made up of a set of *n* assets, mutual funds, be vector $P = \left(x_1, x_2, ..., x_n\right)$, where each x_i represents the proportion of the total budget invested in mutual fund *i*. The standard formulation of a multiindex model is:

$$R_i = \alpha_i + \sum_{f=1}^{m} \beta_{if} F_f + c_i, \qquad i = 1, 2, ..., n \tag{3}$$

where R_i represents the random return of mutual fund s_i, α_i is the expected value of the returns not related to any index, c_i is the random component not related to any index satisfying $E\left(c_i\right) = 0$, F_f is factor *f* affecting the returns of mutual fund *i*, assumed to be pair wise independent and β_{if} is the sensitivity of R_i to factor F_f.

Finding the factors for the model is a challenge but not an easy task to researchers. Investigators use different approaches in factor models ([24], [25]). The first one assumes some known fundamental factors are the factors that influence the security and β's are evaluated accordingly. The second approach assumes the sensitivities to factors are known, and the factors are estimated from the security returns [26]. The third approach is factor analysis. This one assumes neither factor values nor the security sensitivities are known.

In this work approaches first and third are used jointly by means of applying Principal Component Analysis to reduce the dimensionality and to find sensitivities of the returns to changes in the extracted factors ([27], [28]).

Thus, here we propose to consider several economic, financial and social indexes as measures of the macroeconomic, financial and social responsible environment in the construction of return and risk prediction models and Principal Component Analysis

(PCA) is used in order to reduce the initial dimension of the problem of determining the existence of underlying dimensions, that is, factors that are common to indexes variations. In next section a PCA will be apply in order to determine principal factors affecting mutual funds' returns.

4. First stage: Principal Component Analysis (PCA).

We have calculated weekly returns for the considered initial indexes for the period 2002-2006. The economic, financial and ethical indexes which possibly influence mutual fund returns are displayed in the following table:

Table 2. Economic, Market and Social Indexes.

Index		Source
Financial		
DJ Eurostoxx50	I_1	www.stoxx.com
FTSE 100	I_2	www.ftse.com
DAX	I_3	www.yahoo.com
Dow Jones Global Titan Index	I_4	www.djindexes.com
Morgan & Stanley Capital Index Europa	I_5	www.mscibarra.com (Morgan&Stanley)
Ethical		
Domini 400 Social Index	I_6	www.kld.com/indexes/ds400index/index.html
FTSE4Good Europe	I_7	www.ftse.com/ftse4good
Dow Jones Stoxx Sustainability Index	I_8	http://www.sustainability-index.com
Dow Jones Sustainability World Index	I_9	http://www.sustainability-index.com
Economic		
UK Govern Bonds	I_{10}	www.yieldbook.com (Citigroup)
Euro BIG	I_{11}	www.yieldbook.com (Citigroup)
World BIG	I_{12}	www.yieldbook.com (Citigroup)
3 month UK Treasure Bills	I_{13}	www.bankofengland.co.uk
3 months euro bills	I_{14}	www.bankofengland.co.uk

The following tables show the results obtained from the PCA using SPSS. For the Kaiser-Meyer-Olkin Measure of Sampling Adequacy the statistic is 0.884, so the factor analysis seems to be appropriated.

Table 3. KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling		.884
Bartlett's Test of Sphericity	Aprox. Chi-square	5530.647
	Df	105
	Sig.	.000

The variance explained by the initial solution, extracted components and rotated components is displayed in the following tables.

Table 4. Total Explained Variance

Component	Inicial Eigenvals		
	Total	% of variance	% cumutative
1	8.864	59.096	59.096
2	1.461	9.742	68.838
3	1.107	7.383	76.221

Extraction Method: Principal Component Analysis.

We have requested that 3 factors be extracted, so the first three principal components form the extracted solutions. The second section of the table shows the extracted components. They explained nearly 76.22 % of the variability in the original 15 variables, so the complexity of the data set can be considerably reduced by using these three components.

Table 5. Component Store Coefficient Matrix.

	Component		
	1	2	3
DJ Eurostoxx50	.121	.045	.000
FTSE 100	.109	.009	-.008
DAX	.108	.005	.000
D Jones Global Titan Index	.115	.035	-.106
MSCI Europa	.100	.015	.010
Domini 400 Social Index	.120	.044	-.113
FTSE4Good UK50	.109	.014	-.008
FTSE4Good Europe	.119	.042	.012
DJ Stoxx Sustainability Index	.107	.007	.026
DJ Sustainabil World Index	.117	.051	.038
UK Govern Bonds	.051	.480	-.071
Euro BIG	.058	.525	-.099
World BIG	.065	.392	.181
uk t-bills	-.063	-.012	.693
euro bills	.034	-.005	-.578

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser normalization.
Component Scores.

5. Second stage: Prediction by Least Absolute Value Regression (LAV).

The input data of the classical portfolio selection model (see [7]) are the expected returns and covariance matrix of expected returns of the assets. There are different methods for obtaining these data. In this work, as we have established in previous sections, we are going to use a revised version of a multiindex model ([29]) to identify some of the financial market and non-financial market influence.

Under the assumption that return is a linear function of the obtained factors, we wish to develop a return predictive equation, of the following form:

$$R_i = A_i + \sum_{f=1}^{3} \beta_{if} F_f \tag{4}$$

where R_i is the predicted return for a given asset i, F_1, F_2 and F_3 are the previously obtained factors and $A_i, \beta_{i1}, \beta_{i2}$ and β_{i3} are unknown constants. One very powerful alternative for this task is that of a Goal Programming based on regression approach.

Following Ignizio and Cavalier [30], sensitivity for each individual fund ($i = 1,...,125$) for the $t = 1,...,264$ considered periods, ($A_i, \beta_{i1}, \beta_{i2}, \beta_{i3}$), is given by the solution to the following Weighted Goal Programming model (WGP) which aims to minimize the absolute values of the residuals defined as the difference between actual return values and predicted ones:

$$
\begin{aligned}
& Min \;\; z = \sum_{t=1}^{264} (n_t + p_t) \\
& s.t. \;\; A_i + \sum_{f=1}^{3} \beta_{if} F_{tf} + n_t - p_t = R_{it} \quad t = 1,...,264 \\
& A_i, \; \beta_{if} \quad free \\
& n_t, p_t \geq 0
\end{aligned}
\tag{5}
$$

where n_t, p_t represent the negative and positive deviations from the target value R_{it}, historical return, for the t'th period. β_{if} are the regression coefficients, which minimize the distance between the values predicted from the equation (5) and the values obtained by measurement. Model (5) is solved for each of the 125 mutual funds. Each set of outcomes ($\beta_{i1}, \beta_{i2}, \beta_{i3}$) obtained for each asset $i = 1, 2,...,125$ is stored in a sensitivity matrix used in the second stage model.

The minimization in (5) uses a L_1 (least absolute value, LAV) distance metric instead of the usual L_2 (least squares). As stated by Ignizio and Cavalier [30], conventional regression of any form is a parametric tool. That is, it is assumed that we have a normal population with equal variances (or multivariate population with equal correlation matrix)-an assumption that may not be true and/or defendable always. Further, if such an assumption is incorrect, then any sensitivity analysis performed on the resulting predictive function is likely to be in error. There are further reasons for using Least Absolute Values (LAV) regression techniques. Conventional regression focuses solely on the minimization of the sum of the squares of all the residuals but it must be realized that the minimization of the sum of the squares of the residuals is not necessarily the optimal measure of predictive performance. Further, as has been well documented, “outliers” can have a hard impact on the predictive function formed when one minimizes the sum of the squares of the residual (see [31]). The estimations derived from the used of LAV regression techniques are less sensitive to problems of multicollinearity, more stable in presence of outliers, perform better in problems with a small number of observations, and does not require assumptions regarding the structure of the data (e.g., normal distribution of errors).

Thus, in this work we have used a LAV approach in order to determine sensitivities of mutual funds to changes in the considered factors and those changes that are independent from variations on the factors:

Table 6. Estimated coefficients by means of a LAV regression.

i	A_i	β_{i1}	β_{i2}	β_{i3}	i	A_i	β_{i1}	β_{i2}	β_{i3}
1	0.002272	0.011817	-0.0022	0.002079	64	-0.00037	0.015368	-0.00151	0.001855
2	0.002073	0.011404	-0.00133	0.002286	65	0.002617	0.007851	-0.00159	0.001486
3	0.002541	0.011863	-0.00258	0.001931	66	0.000407	0.016383	-0.00299	-0.00033
4	0.002337	0.011362	-0.0014	0.002266	67	0.005704	0.013736	-0.0026	0.003594
5	0.001274	-0.00142	0.002996	-0.00029	68	0.003984	0.010508	-0.00096	4.35E-05
6	0.000886	-0.00121	0.003047	-0.00011	69	0.002822	0.010253	-0.00101	0.001454
7	0.002357	0.010323	-0.00145	0.002889	70	0.000582	0.014177	-0.00171	0.001374
8	0.002196	0.010359	-0.00147	0.002874	71	0.003989	0.010523	-0.00053	0.002361
9	0.001776	0.009277	-0.00067	0.001247	72	0.003588	0.008821	-0.00136	0.000782
10	0.001701	0.009321	-0.00067	0.001152	73	0.001499	0.013777	-0.00323	0.002002
11	0.002082	0.009466	-0.00082	0.001312	74	0.001303	0.01399	-0.0031	0.001861
12	0.001399	0.012381	-0.00247	0.002143	75	0.002484	0.012477	-0.00187	-0.00047
13	0.001436	0.012435	-0.00264	0.002106	76	0.002337	0.012549	-0.00182	-0.00046
14	0.001517	0.010536	-0.00172	0.001419	77	0.00057	0.011024	-0.00131	0.001443
15	0.00065	0.010827	-0.0016	0.002352	78	0.000573	0.011023	-0.00131	0.001442
16	0.00068	0.010825	-0.00161	0.002359	79	0.0024	0.013571	-0.00172	0.000152
17	0.000746	0.010405	-0.00163	0.002495	80	0.002207	0.013467	-0.00183	0.000112
18	0.000453	0.012908	-0.00101	0.00247	81	0.002344	0.012185	-0.00183	0.002425
19	0.000331	0.012795	-0.00131	0.002202	82	0.001404	0.019406	-0.00462	-0.00062
20	0.000626	0.010677	-0.0023	0.001794	83	0.00217	0.012935	-0.00132	0.001659
21	0.000811	0.010683	-0.00232	0.001753	84	0.000502	0.01287	-0.00196	0.001384
22	0.001144	0.013506	-0.00149	0.002166	85	0.001579	0.018505	-0.00332	-0.00024
23	0.001151	0.013359	-0.00163	0.002065	86	0.000386	0.012879	-0.00273	0.000593
24	0.000979	0.013249	-0.00155	0.002165	87	0.000659	0.016164	-0.00211	0.001416
25	0.001282	0.013175	-0.00154	0.001927	88	0.001132	0.014994	-0.00175	0.000292
26	0.001909	0.010004	-0.00161	0.00167	89	0.00111	0.010553	-0.00105	0.000611
27	0.002105	0.009868	-0.00166	0.001738	90	0.001976	0.013884	-0.00213	0.00156
28	0.002033	0.01138	-0.00242	0.002073	91	0.001333	0.015386	-0.00259	4.39E-05

29	0.002017	0.011387	-0.00235	0.002038	**92**	0.004145	0.007502	-0.00077	0.000968
30	0.001275	0.010941	-0.00246	0.003401	**93**	0.000387	0.015499	-0.00084	0.001557
31	0.001145	0.011438	-0.00241	0.003496	**94**	0.000679	0.017096	-0.00083	0.001128
32	0.003211	0.008873	-0.00146	0.001143	**95**	0.000678	0.017095	-0.00084	0.001126
33	0.00299	0.009246	-0.00148	0.001273	**96**	0.001055	0.018297	-0.00377	0.000228
34	0.001294	0.011045	-0.0016	0.002622	**97**	0.001053	0.018293	-0.00377	0.000233
35	0.00124	-0.00079	0.002163	-0.00014	**98**	0.001964	0.015451	-0.00047	0.002877
36	0.001309	-0.00071	0.002102	-1.76E-05	**99**	0.00196	0.018043	-0.0034	0.000689
37	0.002474	0.010585	-0.00307	0.000991	**100**	0.001761	0.017976	-0.00337	0.000566
38	0.002027	0.010171	-0.00224	0.001478	**101**	0.000657	0.0152	-0.00189	0.002951
39	0.000599	0.011174	-0.00134	0.002328	**102**	0.000433	0.015109	-0.00199	0.002897
40	0.000574	0.010366	-0.00163	0.002719	**103**	0.003379	0.00931	-0.00183	6.56E-05
41	0.001267	0.009528	-0.00171	0.001988	**104**	0.003118	0.009068	-0.00164	0.000224
42	0.001366	0.00952	-0.00181	0.001961	**105**	0.000291	0.010391	-0.00197	0.00102
43	0.00111	0.010484	-0.00214	0.002346	**106**	0.001497	0.016203	-0.00394	-0.00012
44	0.000948	0.010049	-0.00199	0.002458	**107**	0.002262	0.013447	-0.00221	-0.00012
45	0.001922	0.018267	-0.00442	-0.00051	**108**	0.000338	0.013354	-0.00208	0.001274
46	0.000183	0.013861	-0.00219	0.0029	**109**	-0.00018	-0.00165	0.002712	-0.00014
47	-0.00215	0.020274	-0.00095	0.004863	**110**	0.001127	0.014722	-0.00198	0.001064
48	0.001257	0.014357	-0.00222	0.002522	**111**	0.000185	0.013317	-0.00068	-0.00121
49	0.00142	0.016069	-0.00397	0.000873	**112**	0.001599	0.013118	-0.00219	0.000393
50	0.001118	0.013811	-0.00191	0.001419	**113**	0.003053	0.010856	-0.00266	0.001277
51	0.000374	0.014553	-0.00191	0.000947	**114**	0.00064	0.004799	0.001318	0.000587
52	0.004007	0.008489	-0.00085	0.001398	**115**	0.003505	0.011342	-0.00117	0.003433
53	0.000795	0.013964	-0.00193	0.001926	**116**	0.000445	0.015031	-0.00173	0.002031
54	0.002023	0.011804	-0.00183	0.000475	**117**	0.002475	0.014518	-0.00361	0.000938
55	0.002167	0.010255	-0.00126	0.001359	**118**	0.002472	0.014696	-0.00345	0.000822
56	0.001484	0.016302	-0.00143	0.000661	**119**	0.00222	0.019068	-0.00391	0.001538
57	0.00071	0.014372	-0.00068	0.001228	**120**	0.001707	0.019548	-0.00381	0.001756
58	0.00243	0.016857	-0.00377	0.000347	**121**	0.004474	0.012503	-0.00312	0.003262
59	0.003756	0.012067	-0.00273	-0.00078	**122**	0.004269	0.012527	-0.00311	0.003124
60	0.00155	0.014113	-0.00171	0.00201	**123**	0.001309	0.015629	-0.00108	0.001502
61	0.00114	0.012381	-0.00184	0.001892	**124**	0.002723	0.007031	-0.00023	0.001846
62	-0.00091	-0.00022	0.002712	-0.00076	**125**	0.003398	0.011209	-0.00112	0.00349
63	0.000345	0.014736	-0.00228	0.002184					

6. Third Stage: Fuzzy Multiobjective Linear Programming Model for Portfolio Selection.

Parameters of the portfolio selection model are usually fixed by the Decision Maker (DM) from financial market and taking into account his/her expert knowledge so, some degree of subjective imprecision is included in the decision making process. In this kind of situations Fuzzy Sets Theory and Possibility Theory may be helpful as allow quantifying imprecise information and to reason and make decisions based on vague and or incomplete data ([32], [33]).

If X denote a universal set, a fuzzy set $\tilde{A}$ of X can be characterized as a set of ordered pairs of element x and the grade of membership of x in $\tilde{A}$, $\mu_{\tilde{A}}(x)$ which is a value between zero and one, being often written: $\tilde{A} = \{(x, \mu_{\tilde{A}}(x)) / x \in X\}$.

A fuzzy number is one of the most common forms of fuzzy set application [34]; it is defined as fuzzy set defined on the real line IR with a convex, continuous membership function. Based on the properties of convexity and normality, the α-level set of a continuous fuzzy number is an interval represented by $\lfloor L_{\tilde{A}}(\alpha), \; R_{\tilde{A}}(\alpha) \rfloor$ consisting of all the elements where the grade of membership is at least α. The α – level set of a fuzzy number is defined as:

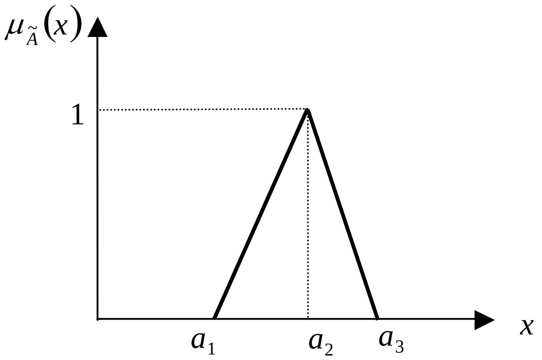
$$A_{\alpha} = \{ x / \mu_{\tilde{A}}(x) \geq \alpha \} \quad \alpha \in [0,1] \tag{6}$$

There are different types of fuzzy numbers, but the triangular fuzzy numbers and the trapezoidal fuzzy numbers are the most commonly applied to economical decision-making problems. Let $\tilde{A}$ be a triangular fuzzy number characterized by the triplet(a^1, a^2, a^3). The membership function $\tilde{A}$ is represented as:

$$\mu_{\tilde{A}}(x) = \begin{cases} 0 & x < a^1 \\ \dfrac{x - a^1}{a^2 - a^1} & a^1 \leq x \leq a^2 \\ 1 & x = a^2 \\ \dfrac{a^3 - x}{a^3 - a^2} & a^2 \leq x \leq a^3 \\ 0 & x > a^3 \end{cases} \tag{7}$$

Figure 1 shows the representation of the triangular fuzzy number:

Figure 1. Triangular fuzzy number membership.



Fuzziness must be considered in decision making where human estimation is influential. Possibility theory has been proposed by Zadeh [35] and advanced by Dubois and Prade [36]; since then the fuzziness of several decision making problems has been handled by possibility distributions. A possibility distribution can be defined in the following way. Let $\tilde{A}$ be a fuzzy set of a universe of discourse X characterized by its membership function $\mu_{\tilde{A}}$. Let x be a variable of X. Then $\mu_{\tilde{A}}(x)$ can be interpreted as the degree of possibility of the proposition "x is $\tilde{A}$". So the possibility distribution (π_x) of x is defined to be numerically equal to the membership function of $\tilde{A}$, i.e. $\pi_x = \mu_{\tilde{A}}$. So, fuzzy numbers can also be considered as possibility distributions [36].

In figure 1, $\mu_{\tilde{A}}(x)$, with $0 \le \mu_{\tilde{A}}(x) \le 1$, represents the possibility degree of occurrence of x taking the value of parameter $\tilde{A}$. Thus, the value with a higher possibility degree of occurrence is the central value of the fuzzy triangular number, a_2, which has $\mu_{\tilde{A}} = 1$. As well, we can observe, that values of x being lower or greater than a_1 and a_3 respectively, have no possibility of occurring, so $\mu_{\tilde{A}} = 0$ for these values. Remaining values have intermediate possibility degrees of occurrence.

Fuzzy triangular number can be easily handled by means of their expected value. Heilpern [37] defined the expected value of a fuzzy triangular number as follows:

$$EV\left(\tilde{A}\right)=\frac{a_1+2a_2+a_3}{4} \tag{8}$$

6.2 Mathematical formulation.

In this work we have considered three objectives which should be kept in mind when choosing the best portfolio:

a) Maximization of the fuzzy expected return of the portfolio P, ($\tilde{E}_P$):

$$Max\ \ \tilde{E}_P=\sum_{i=1}^{125}\tilde{E}\left(R_i\right)x_i \tag{9}$$

Where $\tilde{E}\left(R_i\right)$ is the fuzzy expected return of each mutual fund i which has been established taking into account historical information on the returns of the assets as well as the expertise knowledge of the investor (see table 7 and 2A in the appendix). Fuzzy expected returns in our model are represented by fuzzy triangular numbers which will be handled by means of their expected values, as explained above ([37]).

Table 7. Expected values of fuzzy mutual funds' returns.

Fund	$EV\left(\tilde{E}\left(R_i\right)\right)$	Fund	$EV\left(\tilde{E}\left(R_i\right)\right)$	Fund	$EV\left(\tilde{E}\left(R_i\right)\right)$	Fund	$EV\left(\tilde{E}\left(R_i\right)\right)$	Fund	$EV\left(\tilde{E}\left(R_i\right)\right)$
1	0.001669	26	0.003412	51	0.000858	76	0.001437	101	0.002016
2	0.001239	27	0.003542	52	0.004365	77	-0.00189	102	0.001760
3	0.001825	28	0.003151	53	0.002233	78	-0.00189	103	0.000823
4	0.001381	29	0.003200	54	-0.00277	79	0.002498	104	0.000736
5	-0.00027	30	0.003396	55	0.003681	80	0.002301	105	0.000556
6	-0.00083	31	0.003139	56	-0.00273	81	0.003376	106	0.001791
7	0.004022	32	0.003950	57	-0.00108	82	0.002052	107	0.001666
8	0.003877	33	0.003816	58	0.002293	83	0.001705	108	0.001262
9	0.002650	34	0.000596	59	0.001914	84	0.00143	109	-0.00224
10	0.002656	35	-0.00041	60	0.001464	85	0.001963	110	-0.00055
11	0.003035	36	-0.0004	61	0.001434	86	0.000757	111	-0.00322
12	0.003826	37	0.002331	62	-0.00217	87	0.000919	112	0.001123
13	0.003726	38	0.002457	63	0.000994	88	-0.00121	113	0.002069
14	0.002994	39	0.000444	64	-0.00011	89	0.001665	114	-0.00023
15	0.002659	40	0.000593	65	-0.00666	90	0.002029	115	0.003244
16	0.002730	41	0.001322	66	-0.00211	91	0.001458	116	0.000932
17	0.002671	42	0.001383	67	0.002654	92	0.004014	117	0.002670
18	0.000307	43	0.002423	68	0.002141	93	-0.00054	118	0.002657
19	0.000434	44	0.002569	69	0.002161	94	0.001207	119	0.002379
20	0.002830	45	0.002219	70	0.000861	95	0.001207	120	0.002085
21	0.002990	46	0.002553	71	0.003620	96	0.002317	121	0.003690

22	0.000434	**47**	-0.00159	**72**	0.002945	**97**	0.002127	**122**	0.003431
23	0.000427	**48**	0.002540	**73**	0.003645	**98**	0.001995	**123**	0.000228
24	0.000261	**49**	0.002416	**74**	0.003630	**99**	0.001706	**124**	-0.00503
25	0.000355	**50**	0.002469	**75**	0.001587	**100**	0.001371	**125**	0.002785

b) Minimization of the portfolios' risk measured by the portfolio's Betas, β_P^f associated to each factor, $f = 1,2,3$:

$$Min \quad \beta_P^f = \sum_{i=1}^{125} \beta_{if} x_i \tag{10}$$

where β_{if} are the sensitivities of each asset to changes on each factor.

c) Maximization of the *ethical component* of the portfolio:

$$ET_P = \sum_{i=1}^{125} e_i x_i \tag{11}$$

Where $e_i = \sum_{j=1}^{38} w_j z_{ij}$ is the ethical general component of mutual fund i defined in section 1. In this paper we will not distinguish within the internal features of a specific screening group. Thus, for a social investor $w_j = \frac{1}{12}$ for $j = 1,...,12$; for a ecological investor $w_j = \frac{1}{14}$ for $j = 13,...,26$; for a ethical investor $w_j = \frac{1}{12}$ for $j = 27,...,38$ and finally, for a social responsibly investor $w_j = \frac{1}{38}$ for $j = 1,...,38$.

Table 8. Ethical component for each investor's profile.

	Investor's Profile			
	Social	**Ecological**	**Ethical**	**Social Responsible**
Fund	e_i^{soc}	e_i^{eco}	e_i^{eth}	e_i
1…4	0.5	0.5	0.583333	0.526316
5…8	0.166667	0.071429	1	0.394737
9…11	0.833333	0.928571	0.75	0.842105
12,13	0.083333	0.571429	0.75	0.473684
14	0.416667	0.142857	0.75	0.421053
15…17	0.666667	0.714286	0.75	0.710526

18, 19	1	1	1	1
20,21	1	1	0.916667	0.973684
22…25	1	1	0.916667	0.973684
26, 27	0.25	0.857143	0.75	0.631579
28, 29	0.666667	0.857143	0.833333	0.789474
30, 31	0.75	0.642857	0.583333	0.657895
32, 33	0.666667	1	0.916667	0.868421
34…44	0.666667	0.857143	0.833333	0.789474

Three groups of constraints have been considered:

d) Budget constraint: $\sum_{i=1}^{125} x_i = 1$.

e) Bounds related to the investment in ethical mutual funds: the investor shall decide to invest a certain, minimum or maximum amount of his/her budget in ethical assets. If ethical mutual funds correspond with the range $i = 1,\ldots,44$ the following constraint could be added to the model:

$$\sum_{i=1}^{44} x_i * k \quad \textit{for} \quad i = 1,\ldots,44 \quad \textit{where} \quad * = \begin{cases} \leq \\ \geq \end{cases} \tag{12}$$

In this work we are going to suppose that socially responsible investors want to invest at least 40% of their budget in ethical funds.

f) Short sales are not allowed; therefore a non-negative condition is verified:

$$x_i \geq 0 \tag{13}$$

Therefore the Fuzzy Multiobjective Linear Programming problem to be solved for a general social responsible investor is the following:

$$\begin{aligned}
&Max \;\; E_P = \sum_{i=1}^{125} \tilde{E}\left(R_i\right) x_i \\
&Min \quad \beta_P^f = \sum_{i=1}^{125} \beta_{if} x_i, \quad f = 1,2,3 \\
&Max \quad ET_P = \sum_{i=1}^{125} e_i x_i = \sum_{i=1}^{125}\sum_{j=1}^{38} w_j z_{ij} x_i \\
&s.t. \quad \sum_{i=1}^{125} x_i = 1 \\
&\qquad \sum_{i=1}^{44} x_i \geq 0.4 \\
&\qquad x_i \geq 0
\end{aligned} \tag{14}$$

The handle of fuzzy expected returns by means of their expected values, $EV\left(\tilde{E}\left(R_i\right)\right)$, gives rise to a crisp problem which is possible to solve using traditional Compromise Programming.

6.2 Resolution of the portfolio selection problem through Compromise Programming.

Compromise Programming (CP) is a mathematical programming technique with the capability of handling multiple objectives in those situations where existence of a high level of conflict between criteria does not allow the simultaneous optimization of all the considered objectives. In those situations it seems rational to find compromise solutions between objectives. The pioneering applications of CP for portfolio selection are due to Ballestero and Romero [38]. In this section we shall present the portfolio selection model proposed in this work and we shall solve it by means of a Compromise Programming approach.

The basic structure of a Compromise Programming problem (CP) model is the following:

$$\begin{aligned} &Min \quad L_p = \left[\sum_{s=1}^{q} \left(\varpi_s \frac{\left| f_s^* - f_s(x) \right|}{\left| f_s^* - f_{s*} \right|} \right)^p \right]^{\frac{1}{p}} = \left[\sum_{s=1}^{q} (\varpi_s d_s)^p \right]^{1/p} \qquad \text{(CP)} \\ &s.t. \quad x \in F \end{aligned}$$

Where x is the vector of decision variables; $f_s(x)$ is the mathematical expression for the $s-th$ criterion $(s \in \{1,...,q\})$; $(f_1^*,..., f_q^*)$ represents the ideal point, i.e., the optimum value for each attribute, without considering the achievement of the other attributes and $(f_{1*},..., f_{q*})$ represents the anti-ideal point, i.e., the worst value of each criterion when the others are optimized; d_s stands for the degree of discrepancy for the $s-th$ criterion (i.e., the normalized difference between the anchor value and the actual achievement of the $s-th$ criterion); ϖ_s is the weight or relative importance attached to the $s-th$ criterion; F is the feasible set and p is the topological metric; i.e., a real number belonging to interval $[0,\infty)$ and $p=\infty$.

Compromise solutions corresponding to metrics $p=1$ and $p=\infty$ have an interesting economic interpretation (see [39]). For metric $p=1$ the objective function in (CP) can be interpreted as a linear and additive utility function. Compromise solution corresponding to this metric, L_1, implies a point of maximum efficiency where the sum of the achievements of the considered objectives are maximized.

For metric $p=\infty$ the objective function in (CP) can be interpreted as a Rawlsian utility function as the maximum deviation with respect to the ideals is minimized. These kind of utility functions are called Rawlsian because of the connexions between them and the principles of justice introduced by Rawls [40]. These principles within an economics context mean that the welfare of society only depends on the utility of the worst-off individual. Hence this solution, L_∞, implies a point of maximum equity.

The L_∞ compromise solution implies a very strong condition: the equilibrated character of the solutions obtained by the considered objectives.

In this work, due to their interest from an economic point of view we have obtained both compromise solutions, L_1 and L_∞ for the five different types of investor defined in section 1.

The next tables display the payoff-matrixes, with the ideal and anti-ideal values and the obtained optimal portfolios corresponding to both compromise solutions, for each of the considered investors.

The following weights have been considered for the investors with a social profile $\varpi_1 = \varpi_5 = 1$ and $\varpi_2 = \varpi_3 = \varpi_4 = 1/3$ and for the non social investor $\varpi_1 = 1$ and $\varpi_2 = \varpi_3 = \varpi_4 = 1/3$.

Table 9. Payoff-matrix for investor with a social profile.

	Return	Risk 1 (β_1)	Risk 2 (β_2)	Risk 3 (β_3)	Ethical component
Return	0.0042277	0.0092226	-0.00109	0.0019944	0.066667
Risk 1 (β_1)	-0.001456	-0.001558	0.0028256	-0.0002	0.066667
Risk 2 (β_2)	0.0021185	0.01895	-0.00454	-0.000576	1.04E-10
Risk 3 (β_3)	-0.0010428	0.015297	-0.002176	-0.00093	3.94E-12
Ethical compon	0.0010047	0.012544	-0.0016437	0.0020677	1

Table 10. Optimal portfolios for investor with a social profile.

	Fund	***Investment***
L_1	**21**	**1**
L_∞	**10**	0.646
	32	0.31511
	35	0.038691

The obtained portfolio for an investor with a social profile will be characterized by the following optimal values:

Table 11. Optimal solution for investor with a social profile.

	Return	Risk 1	Risk 2	Risk 3	Ethical component
L_1	0.0029898	0.010683	-0.00232	0.001753	1
L_∞	0.0029453	0.0087886	-0.00080932	0.0010992	0.77437

Table 12. Payoff-matrix (ideal solutions) for investor with an ecological profile.

	Return	Risk 1 (β_1)	Risk 2 (β_2)	Risk 3 (β_3)	Ethical component
Return	0.0042277	0.0092226	-0.00109	0.0019944	0.028572
Risk 1 (β_1)	-0.001456	-0.001558	0.0028256	-0.0002	0.028571
Risk 2 (β_2)	0.0021185	0.01895	-0.00454	-0.000576	0
Risk 3 (β_3)	-0.001043	0.015297	-0.002176	-0.00093	0
Ethical compon	0.0015804	0.011847	-0.001609	0.0018958	1

Table 13. Optimal portfolios for investor with an ecological profile.

	Fund	*Investment*
L_1	**32**	1
L_∞	**32**	0.732
	35	0.097223
	59	0.17075

The obtained portfolio for an investor with a ecological profile will be characterized by the following optimal values:

Table 14. Optimal solution for investor with an ecological profile.

	Return	Risk 1	Risk 2	Risk 3	Ethical component
L_1	0.0039503	0.008873	-0.00146	0.001143	1
L_∞	0.0031783	0.0084789	-0.0013246	0.0006899	0.81536

Table 15. Payoff-matrix for investor with an ethical profile.

	Return	Risk 1 (β_1)	Risk 2 (β_2)	Risk 3 (β_3)	Ethical component
Return	0.0042277	0.0092226	-0.00109	0.0019944	0.4
Risk 1 (β_1)	-0.001456	-0.001558	0.0028256	-0.0002	0.4
Risk 2 (β_2)	0.0021185	0.01895	-0.00454	-0.000576	0
Risk 3 (β_3)	-0.0010428	0.015297	-0.002176	-0.00093	0
Ethical compon	0.001255	0.0072925	0.00013383	0.0016725	1

Table 16. Optimal portfolios for investor with an ethical profile.

	Fund	*Investment*
L_1	**32**	1
L_∞	**5**	0.127
	32	0.748
	59	0.12574

The obtained portfolio for an investor with an ethical profile will be characterized by the following optimal values:

Table 17. Optimal solution for investor with an ethical profile.

	Return	Risk 1	Risk 2	Risk 3	Ethical component
L_1	0.0039503	0.008873	-0.00146	0.001143	0.91667
L_∞	0.0028887	0.0074302	-0.0013119	0.00035168	0.56838

Table 18. Payoff-matrix for a socially responsible investor.

	Return	Risk 1 (β_1)	Risk 2 (β_2)	Risk 3 (β_3)	Ethical component
Return	0.0042277	0.0092226	-0.00109	0.0019944	0.15789
Risk 1 (β_1)	-0.001456	-0.001558	0.0028256	-0.0002	0.15789
Risk 2 (β_2)	0.0021185	0.01895	-0.00454	-0.000576	1.20E-10
Risk 3 (β_3)	-0.0010428	0.015297	-0.002176	-0.00093	4.82E-12
Ethical compon	0.00037044	0.012851	-0.00116	0.002336	1

Table 19. Optimal portfolios for a socially responsible investor.

	Fund	*Investment*
L_1	**32**	1
L_∞	**32**	0.80172
	35	0.15339
	59	0.044896

The obtained portfolio for an investor with a general social profile will be characterized by the following optimal values:

Table 20. Optimal solution for investor with a socially responsible profile.

	Return	Risk 1	Risk 2	Risk 3	Ethical component
L_1	0.0039503	0.008873	-0.00146	0.001143	0.86842
L_∞	0.0031894	0.0075342	-0.00096129	0.00085987	0.81732

Table 21. Payoff-matrix for an investor not socially responsible.

	Return	Risk 1 (β_1)	Risk 2 (β_2)	Risk 3 (β_3)
Return	0,0043649	0,008489	-0,00085	0,001398
Risk 1 (β_1)	-0,0022415	-0,00165	0,002712	-0,00014
Risk 2 (β_2)	0,0020516	0,019406	-0,00462	-0,00062
Risk 3 (β_3)	-0,0032173	0,013317	-0,00068	-0,00121

Table 22. Optimal portfolios for an investor not socially responsible.

	Fund	*Investment*
L_1	**92**	**1**
L_∞	**5**	0,040112
	59	0,34295
	92	0,61694

The obtained portfolio for an investor with a not social profile will be characterized by the following optimal values:

Table 23. Optimal solution for investor with a not socially responsible profile.

	Return	Risk 1	Risk 2	Risk 3
L_1	0.0040137	0.007502	-0.00077	0.000968
L_∞	0.0031214	0.0087097	-0.0012911	0.00031807

As it can be observed from the above information in every case compromise solution L_1 implies investing in only one mutual fund. The investment depends on the profile of the investor although investors with an ecological, ethical and general socially responsible profiles, may invest their budget in the same fund, fund 32 which verifies the three profiles.

Portfolios corresponding to compromise solution L_∞ are more diversified and include more than one mutual fund.

7. Conclusions.

This work aims to be a contribution to the resolution a portfolio selection problem for a non *standard investor*. In order to select an optimal portfolio composed by ethical and non ethical mutual funds, a fuzzy multi-criteria model has been proposed which takes into account, not only the classical portfolio selection criteria but also other criteria as the ethical profile of the portfolio obtained from the definition of an ethical index which is built for each investor taking into account his/her individual ethical preferences.

A multifactor model has been proposed in order to study mutual funds performance. Principal factors affecting mutual funds returns are identified in the first stage of the model by Principal Component Analysis on both, economic and socially indexes. Once they have been obtained a regression model is proposed in order to determine sensitivity of mutual funds to changes in the considered underlying factors. To this end, a regression technique based on non Euclidean distance is used (e.g. Least Absolute Value) which can be more suitable under certain conditions usual in financial models.

A fuzzy multiobjective linear program has been proposed in order to obtain optimal portfolio. Three different types of objectives have been considered: maximization of fuzzy expected return of the portfolio, minimization of the portfolio's risk measured by the portfolio's Betas and maximization of the ethical component of the portfolio by the building of an ethical index . This last objective, allows us to define different investor's profiles depending on the degree of interest of the investor in ethical investing and moreover, depending on his/her personal and particular interests: ecology, labour policies, non-armament…or all of them, which will define his/her ethical profile.

Three groups of constraints have been considered: the classical budget constraint, bounds on the investment in ethical assets and the non-negativity conditions.

In order to solve the problem we have use Compromise Programming (CP). This technique is especially suitable for those real applications where exist conflicting objectives which is our case: the investor has to face conflicting objectives, maximization of expected return while minimization of risk and maximizing the ethical component of the portfolio.

The proposed model allows portfolio selection taking into account not only the classical criteria: return and risk, but also new criteria as the ethical component.

The model permits considering different investor profiles which includes in the model some kind of subjectivity. Two different efficient solutions are presented to each type of investor: a maximum efficient solution (compromise solution L_1) and a solution characterized by maximum equilibrium among the objectives (compromise solution L_∞).

This is only an example of a possible investor. In future works the authors aim to develop an interactive system with investors in order to define their investment particular profiles.

The interest of this kind of research is important due to the novelty for the general public of this kind of products in Europe.

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Appendix

Table 1A. Survivor Mutual Funds (ethical and tradicional).

i	Fund	Mutual Fund	*i*	Fund	Mutual Fund
1	E1	Aberdeen Ethical World Fd A Acc	64	T27	Fidelity Inv Fds(OEIC) Mngd Intern Acc
2	E2	Aberdeen Ethical World Fd A Inc	65	T28	Fidelity Jap Spcl Sit Acc
3	E3	Aberdeen Ethical World Fd C Acc	66	T29	Fidelity Japan Acc
4	E4	Aberdeen Ethical World Fd C Inc	67	T30	Fidelity South East Asia Acc
5	E5	Aegon Ethical Corp Bd Fund A Acc	68	T31	Fidelity Special Situations Acc
6	E6	Aegon Ethical Corp Bd Fund A Inc	69	T32	Fidelity UK Aggressive GBP Acc
7	E7	Aegon Ethical Eq B Inc Instl Nav B Acc	70	T33	Fidelity UK Growth Acc
8	E10	Aegon Ethical Equity	71	T34	First State Asia Pac A EUR Acc
9	E11	Allchurches Amity Fund A Inc	72	T35	First State Asia Pacific
10	E12	Allchurches Amity Fund B Inc	73	T36	First State British Opps A Acc
11	E13	Allchurches Amity Fund C Acc	74	T37	First State British Opps A GBP Inc
12	E20	AXA Ethical I Acc	75	T38	GAM Global Diversified Acc
13	E21	AXA Ethical R Acc	76	T39	GAM Global Diversified Inc
14	E22	Banner Real Fd A Acc	77	T40	GAM North American Growth Acc
15	E26	Credit Suisse Fellowship A Inc	78	T41	GAM North American Growth Inc
16	E27	Credit Suisse Fellowship I Inc	79	T42	GAM UK Diversified Acc
17	E28	Credit Suisse Fellowship R Inc	80	T43	GAM UK Diversified Inc
18	E49	Henderson Glb Care Growth Inc	81	T44	Henderson UK Cap Gr A Acc
19	E50	Henderson Glb Care Growth Instl Inc	82	T45	HSBC European Gwth Fd Retail Inc
20	E51	Henderson Glb CareIncome Inc	83	T46	Insight Inv Asia Pacific Eq A Acc
21	E52	Henderson Glb CareIncome Inst Inc	84	T47	Insight Inv Eq Hi Income Retail Inc
22	E54	Henderson Ind of the Ftre I Acc	85	T48	Insight Inv European Eq A Acc
23	E55	Henderson Ind of the Ftre I Inc	86	T49	Insight Inv Evergreen Retail Acc
24	E56	Henderson Ind of the Ftre X Inc	87	T50	Insight Inv Glb Eq A Acc
25	E57	Henderson Ind of the Ftre	88	T51	Insight Inv Japan Eq A Acc
26	E58	Insight Inv European Ethical A Acc	89	T52	Insight Inv Monthly Inc A Acc
27	E59	Insight Inv European Ethical I Acc	90	T53	JP Morgan UK Equity Income Class A Acc
28	E69	Norwich UK Ethical Fd 1 Acc	91	T54	Lazard European Alpha R Inc
29	E70	Norwich UK Ethical Fd 2 Acc	92	T55	Lazard UK Sm Cos R Inc
30	E72	Old Mutual Ethical Fd A Acc	93	T56	Lincoln North America Trust Inc
31	E73	Old Mutual Ethical Fd A Inc	94	T57	M&G American Fd A GBP Acc
32	E85	Standard Life UK Ethical Fd Instl Acc	95	T58	M&G American Fd A Inc
33	E86	Standard Life UK Ethical R Acc	96	T59	M&G European Fd A GBP Acc
34	E87	Sustainable Fut Abslte Gr 1 Acc	97	T60	M&G European Fd A Inc
35	E91	Sustainable Fut Corp Bond 1 Inc	98	T61	M&G Intl Growth A EUR Acc
36	E92	Sustainable Fut Corp Bond 2 Inc	99	T62	M&G Pan European Fd A GBP Acc

37	E94	Sustainable Fut Europn Gr 1 Acc	100	T63	M&G Pan European Fd A Inc
38	E95	Sustainable Fut Europn Gr 2 Acc	101	T64	M&G UK Select A Acc
39	E97	Sustainable Fut Global Gr 1 Acc	102	T65	M&G UK Select A Inc
40	E98	Sustainable Fut Global Gr 2 Acc	103	T66	New Star Balanced Portfolio B Acc
41	E100	Sustainable Fut Managed 1 Inc	104	T67	New Star Balanced Portfolio Class A Acc
42	E101	Sustainable Fut Managed 2 Inc	105	T69	Newton Balanced Inc
43	E103	Sustainable Fut UK Gr 1 Acc	106	T70	Newton Continental European Inc
44	E104	Sustainable Fut UK Gr 2 Acc	107	T71	Newton Higher Income Inc
45	T1	Aberdeen European Growth A Acc	108	T72	Newton Income Inc
46	T2	Aberdeen UK Growth Fund Inc	109	T73	Newton International Bond Inc
47	T3	AEGON Technology B Acc	110	T74	Newton International Growth Inc
48	T4	AEGON UK Equity Fund B Acc	111	T75	Newton Japan Fd Inc
49	T10	Cazenove European Fund B Acc	112	T76	Newton Managed
50	T11	Cazenove UK Opportunities Fd B Acc	113	T77	Newton Oriental Inc
51	T12	Credit S Wldwd Gr A Inc	114	T78	Norwich Distribution-Fund 1 Inc
52	T14	Credit Suisse Small Companies I Inc	115	T79	Schroder Instl Pacific Inst
53	T15	F&C FTSE All-Share Tracker Fd 1 Acc	116	T81	Scottish Widows Global Sel Gr B Acc
54	T16	F&C Japan Gr Fd 1 Acc	117	T82	Singer & Friedlander Euro Gr Inst I Inc
55	T17	F&C Stewardship Gr Fd 1 Acc	118	T83	Singer & Friedlander Euro Gr Inst R Inc
56	T18	Fidelity Amer Spec Situations AC Acc	119	T84	The Schroder Instl Europ Fd Acc
57	T19	Fidelity American	120	T85	The Schroder Instl Europ Fd Inc
58	T21	Fidelity Euro Opps GBP Acc	121	T86	The Schroder Instl Europ Sm Comp Fd Acc
59	T22	Fidelity European	122	T87	The Schroder Instl Europ Sm Comp Fd Inc
60	T23	Fidelity Growth & Income Inc	123	T88	The Schroder Instl Glb Eq Inc
61	T24	Fidelity Income Plus Inc	124	T89	The Schroder Instl Jap Sm Cos Instl Inc
62	T25	Fidelity Inst OEIC IntlBd A Inc	125	T90	The Schroder Instl Pacific Fd Inc
63	T26	Fidelity International Acc			

Table 2A (a). Fuzzy expected mutual funds' returns.

Fund	$\tilde{R}_i$			Fund	$\tilde{R}_i$		
	R_1	R_2	R_3		R_1	R_2	R_3
1	-0.038330547	0.011669453	0.021669453	26	-0.036588313	0.013411687	0.023411687
2	-0.038761017	0.011238983	0.021238983	27	-0.036458429	0.013541571	0.023541571
3	-0.038174734	0.011825266	0.021825266	28	-0.036849493	0.013150507	0.023150507
4	-0.03861904	0.01138096	0.02138096	29	-0.036799827	0.013200173	0.023200173
5	-0.040277784	0.009722216	0.019722216	30	-0.036603727	0.013396273	0.023396273
6	-0.040832432	0.009167568	0.019167568	31	-0.036861092	0.013138908	0.023138908
7	-0.035978071	0.014021929	0.024021929	32	-0.036049682	0.013950318	0.023950318
8	-0.036122702	0.013877298	0.023877298	33	-0.036184324	0.013815676	0.023815676
9	-0.037349999	0.012650001	0.022650001	34	-0.039403893	0.010596107	0.020596107
10	-0.037343659	0.012656341	0.022656341	35	-0.040414172	0.009585828	0.019585828
11	-0.036965159	0.013034841	0.023034841	36	-0.040401249	0.009598751	0.019598751
12	-0.036174193	0.013825807	0.023825807	37	-0.037668869	0.012331131	0.022331131
13	-0.036273917	0.013726083	0.023726083	38	-0.037543054	0.012456946	0.022456946
14	-0.03700588	0.01299412	0.02299412	39	-0.03955615	0.01044385	0.02044385
15	-0.037341201	0.012658799	0.022658799	40	-0.039407031	0.010592969	0.020592969
16	-0.03726978	0.01273022	0.02273022	41	-0.038677644	0.011322356	0.021322356
17	-0.037329056	0.012670944	0.022670944	42	-0.038616699	0.011383301	0.021383301
18	-0.039692865	0.010307135	0.020307135	43	-0.037576784	0.012423216	0.022423216
19	-0.039566255	0.010433745	0.020433745	44	-0.037430783	0.012569217	0.022569217
20	-0.037169575	0.012830425	0.022830425	45	-0.03778101	0.01221899	0.02221899
21	-0.037010199	0.012989801	0.022989801	46	-0.037446977	0.012553023	0.022553023
22	-0.039566457	0.010433543	0.020433543	47	-0.041597484	0.008402516	0.018402516
23	-0.039572963	0.010427037	0.020427037	48	-0.037459931	0.012540069	0.022540069
24	-0.039739432	0.010260568	0.020260568	49	-0.037583508	0.012416492	0.022416492
25	-0.039644553	0.010355447	0.020355447	50	-0.037530752	0.012469248	0.022469248

Table 2A(b). Fuzzy expected mutual funds' returns.

Fund	$\tilde{R}_i$			Fund	$\tilde{R}_i$		
	R_1	R_2	R_3		R_1	R_2	R_3
51	-0.039141817	0.010858183	0.020858183	76	-0.038563233	0.011436767	0.021436767
52	-0.035635085	0.014364915	0.024364915	77	-0.041899172	0.008100828	0.018100828
53	-0.037767391	0.012232609	0.022232609	78	-0.041899248	0.008100752	0.018100752
54	-0.042776491	0.007223509	0.017223509	79	-0.037502227	0.012497773	0.022497773
55	-0.036318576	0.013681424	0.023681424	80	-0.03769936	0.01230064	0.02230064
56	-0.042732187	0.007267813	0.017267813	81	-0.036624403	0.013375597	0.023375597
57	-0.041084359	0.008915641	0.018915641	82	-0.037948424	0.012051576	0.022051576
58	-0.037707012	0.012292988	0.022292988	83	-0.038295193	0.011704807	0.021704807
59	-0.03808611	0.01191389	0.02191389	84	-0.038567718	0.011432282	0.021432282
60	-0.038535681	0.011464319	0.021464319	85	-0.03803714	0.01196286	0.02196286
61	-0.038565871	0.011434129	0.021434129	86	-0.039242925	0.010757075	0.020757075
62	-0.042167106	0.007832894	0.017832894	87	-0.03908122	0.01091878	0.02091878
63	-0.039005751	0.010994249	0.020994249	88	-0.041211904	0.008788096	0.018788096
64	-0.040110383	0.009889617	0.019889617	89	-0.03833472	0.01166528	0.02166528
65	-0.046658634	0.003341366	0.013341366	90	-0.037970712	0.012029288	0.022029288
66	-0.042105181	0.007894819	0.017894819	91	-0.038541703	0.011458297	0.021458297
67	-0.037346391	0.012653609	0.022653609	92	-0.035986341	0.014013659	0.024013659
68	-0.037858554	0.012141446	0.022141446	93	-0.040540879	0.009459121	0.019459121
69	-0.037839087	0.012160913	0.022160913	94	-0.038793347	0.011206653	0.021206653
70	-0.039139036	0.010860964	0.020860964	95	-0.038793265	0.011206735	0.021206735
71	-0.036380415	0.013619585	0.023619585	96	-0.037683118	0.012316882	0.022316882
72	-0.037055097	0.012944903	0.022944903	97	-0.037872671	0.012127329	0.022127329
73	-0.036355252	0.013644748	0.023644748	98	-0.038004595	0.011995405	0.021995405
74	-0.036369747	0.013630253	0.023630253	99	-0.038293542	0.011706458	0.021706458
75	-0.038413037	0.011586963	0.021586963	100	-0.038628817	0.011371183	0.021371183

Table 2A(c). Fuzzy expected mutual funds' returns.

Fund	$\tilde{R}_i$		
	R_1	R_2	R_3
101	-0.037983998	0.012016002	0.022016002
102	-0.038239675	0.011760325	0.021760325
103	-0.039176786	0.010823214	0.020823214
104	-0.039263742	0.010736258	0.020736258
105	-0.039443539	0.010556461	0.020556461
106	-0.038208596	0.011791404	0.021791404
107	-0.038334103	0.011665897	0.021665897
108	-0.038738419	0.011261581	0.021261581
109	-0.042241514	0.007758486	0.017758486
110	-0.040547096	0.009452904	0.019452904
111	-0.043217307	0.006782693	0.016782693
112	-0.038876911	0.011123089	0.021123089
113	-0.037931376	0.012068624	0.022068624
114	-0.040233885	0.009766115	0.019766115
115	-0.036755646	0.013244354	0.023244354
116	-0.039068274	0.010931726	0.020931726
117	-0.037330319	0.012669681	0.022669681
118	-0.037342539	0.012657461	0.022657461
119	-0.037620758	0.012379242	0.022379242
120	-0.037914672	0.012085328	0.022085328
121	-0.036309892	0.013690108	0.023690108
122	-0.036569124	0.013430876	0.023430876
123	-0.039771577	0.010228423	0.020228423
124	-0.045024853	0.004975147	0.014975147
125	-0.037214847	0.012785153	0.022785153

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