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Using ELECTRE to analyse the behaviour of economic agents

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Abstract

According to behavioural finance, economic agents display cognitive bias, heuristics and emotional factors that generate preferences which systematically violate the rationality assumptions of the normative model of classical decision theory. Rather than maximizing the expected utility, representing the optimal choice, they attempt to accept a satisfactory solution. Morton and Fasolo (J Oper Res Soc 60:268–275, 2009) outlined some behavioural findings relevant to the practice of multicriteria approach. In this paper, we propose a multicriteria model for analysing some experiments proposed by Kahneman and Tversky (Econometrica 47:263–29 l, 1979). Our aim is to verify whether a multicriteria tool reduces or minimizes cognitive biases. We focus on ELECTRE due to its main features: it accepts the violation of some mathematical axioms. By a simulation study, we represent a set of prospects by means of decision matrices: the prospects are considered as alternatives, the events as criteria, the probabilities of events as the weights assigned to criteria. Then, we apply ELECTRE to verify whether the preference ranking among the alternatives confirms the results obtained by Kahneman–Tversky, that is, whether it is able to describe the emotional behaviours of economic agents.

Keywords MCDM · ELECTRE · Rationality · Prospect theory · Behavioural finance

1 Introduction

Experimental evidence shows that human choice behaviour deviates in systematic ways axioms of expected utility theory (EUT), as captured originally in two classical demonstrations referred to as the Allais and Ellsberg paradoxes. The human mind is subject to biological and physiological limits that force it to simplify the surrounding reality through an approximation of the information obtained or the use of heuristics and cognitive filters. Kahneman and Tversky (1986) pointed out that errors induced by the use of heuristics often represent a violation of the logical assumptions of the EUT. In particular, they showed how these cognitive errors violate the four fundamental assumptions referred to by the expected utility theory: cancellation, dominance, transitivity and invariance. The cancellation principle establishes that a decision maker should choose among several alternatives based on what differentiates them and not on what they have in common. This notion has been absorbed by different formal assumptions, such as the substitution axiom of von Neumann and Morgenstern (1947), the extension of the principle of the certainty of Savage (1954) and the independence condition of Luce and Krantz (1971).

The dominance principle states that if one alternative is better than another in one state and at least as good in all other states, then the dominant alternative should be chosen. As regards the transitivity principle, it means that if alternative *A* is better than alternative B, which in turn is better than alternative *C*, then *A* is better than *C*. For the invariance principle, the preference between alternatives should be independent of their description; in other words, different representations of the same problem should provide the same preference (Kahneman and Tversky 1986).

In real contexts, economic agents act based on emotional and instinctive components: the flow of emotions and feelings leads the decision makers to commit

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evaluative errors that can result in irrational choices (not optimal at all). Behavioural finance studies the influence of psychology on the behaviour of economic agents.

Starting from some behavioural findings relevant to the practice of multicriteria approaches highlighted by Morton and Fasolo (2009), in this paper, we propose to use a multicriteria decision-making (MCDM) method in order to verify that the judgments expressed by the decision maker are not as coherent as he/she may have thought; furthermore, it may be useful to identify the weights to apply to criteria and explain clashes between the model and intuitive judgment.

We consider some experiments proposed in the behavioural economics literature. It is expected that evidence of decision biases such as the framing effect, the escalation of commitment and the overconfidence would be present during the decision process. Through a simulation study, we analyse by means of a multicriteria approach some decision problems proposed in behavioural finance. The purpose is to determine whether using a multicriteria decision tool reduces or minimizes these biases. To the best of our knowledge, no paper deals with the use of multicriteria methods to describe the emotional behaviour of economic agents.

At first, we represent prospects by means of multicriteria decision matrices, and then we apply ELECTRE and verify whether the preference ranking among the alternatives confirms the results obtained by Kahneman and Tversky in their experiments. Among different methods, we use ELECTRE because of its main features: as well as behavioural finance, it admits that the actual behaviour of economic agents violates some rationality assumptions (i.e. the transitivity).

The rest of the paper is structured as follows: Sect. 2 reviews the literature related to choice under risk (focusing on prospect theory and behavioural finance); Sect. 3 describes the phases of ELECTRE I; Sect. 4 illustrates some prospects by means of multicriteria matrices, applies ELECTRE to these prospects and discusses the results; and finally, Sect. 5 provides some concluding remarks.

2 Literature review

Expected utility theory (EUT), based on the rationality of economic agents, represents the normative model for decision-making under risk conditions. von Neumann and Morgenstern (1947) established a set of axioms for the EUT, specifying conditions on an individual's preference over pairs of risky prospects.

In economics, a rational agent is an ideal agent characterized by the following characteristics: he/she is selfish, fully informed and able to act constantly following his/her personal interests, independently of what other economic agents do.

Empirical studies showed that many people make choices that are inconsistent with the EUT. Allais (1953) criticized the independence axiom. Savage (1954) stated that, when the subjective probability assessments are ambiguous or inaccurate, economic agents take a pessimistic position against the possible outcomes (ambiguity aversion). Another celebrated experiment, underlying that human choice behaviour deviates in systematic ways axioms of the EUT, has been proposed by Ellsberg (1961). The psychological justification of the behaviour described by Ellsberg lies in the erroneous assessment of the probability: agents apply a logical process to assess the probability something occur and a different perspective for assessing the probability that something does not occur (Anscombe and Aumann 1963).

Studies conducted in the field of psychology confirmed that EU model may be considered as a normative model, allowing to describe what the economic agent should act, but it is not able to describe the way in which he/she acts (Tversky and Kahneman 1974, 1991; Simon 1990; Shefrin 2002; Zweig 2007). In other words, economic agents do not act rationally.

Simon (1990) showed that people are characterized by a "bounded rationality": they have a limited cognitive capacity that allows them to perform only certain tasks whose difficulty does not force them to use all their cognitive resources.

Kahneman and Tversky (1979) showed that agents assume behaviours guided by the instinct, the perception of events and his/her sensitivity. The emotional agent represents the core of the prospect theory (PT).

The PT involves two phases about the selection process: the editing phase and the evaluation phase.

The purpose of the editing phase is to organize and reformulate the statements in the simplest way. It is structured in the following operations (Kahneman and Tversky 1979; Ferretti et al. 2011):

- *Coding* the results offered are coded as regards a reference point (individuals represent the outcomes as losses or gains in relation to the conditions in which they are at the time of the decision or the type of benchmark);
- *Combination* simplification implemented through the combination of identical results that have, however, different probabilities of occurrence;
- *Separation* consists of separating risk-free elements from risky ones within the statements.
- *Cancellation* elimination of the components common to all statements;

- *Simplification* elimination of results with extremely low probabilities;
- *Recognition of dominance* decision makers discard alternatives dominated by other alternatives.

For each simplification procedure in the editing phase, the decision maker always chooses the second simplified prospectus. The simplification operations can be applied without a precise order depending on the information on which each decision maker is concentrated (it creates a problem for the predictability of the evaluations, and consequent choices, of the agents).

The evaluation phase is based on two functions that people use to assess, in a subjective way, the outcomes and the probabilities associated with them: the probability weighting function and the value function. The weighting function highlights two fundamental aspects related to the subjective perception of probabilities: the lowest probabilities are overestimated; average and high probabilities are underestimated.

It is evident that the unlikely results are overrated with respect to the certainty of not obtaining them. Likewise, very probable outcomes are undervalued as regards the certainty of obtaining them (certainty effect). The value function proposed by Tversky and Kahneman (1991) is characterized by three properties: it is defined on variations with respect to a reference point (which is not zero, but the status quo or another starting point, defined by the agent himself); it is concave in the area of earnings (the impact of the variation on the emotional apparatus is always positive, but increases at a decreasing rate) and convex in the area of losses (the marginal value of the loss is always smaller, with the increase in the loss); it decreases faster in the area of losses than it increases in the area of earnings.

People value gains and losses asymmetrically, as they suffer the loss aversion. In fact, Kahneman and Tversky stated that the suffering in losing a sum of money is greater than the pleasure for the gain of the same sum; more precisely, the suffering caused by a loss is about twice the pleasure produced by a gain of equal amount.

Behavioural finance studies the influence of psychology on the behaviour of economic agents. It focuses on the fact that economic agents are not always rational, have limits to their self-control, and are influenced by their own biases (Shefrin 2002). By taking into account cognitive errors and the non-observance of the rationality of preferences, the BF allows to overcome some limits of EUT in describing behavioural anomalies.

Prospect theory, originally developed for single criterion problems, has been extended to multiple criteria choice problem (Korhonen et al. 1990). Salminen (1994) proposed a method for identifying the best alternative based on pairwise comparisons among the alternatives.

Multicriteria methods, based on pairwise comparisons to evaluate the alternatives, can be used in prospect theory to manage complexity by not excluding the decision makers' emotions, allowing them to face decision problems even when the information framework is insufficient, the number of decision makers is high, their interests are different and variable over time, the number of action alternatives is also high.

Among the various multicriteria methods proposed in the literature (Ishizaka and Nemery 2013), we focus on ELECTRE methods because they accept the violation of both the axiom of comparability (in some cases it is impossible to establish a preference or indifference relationship between two alternatives), and the capacity for discrimination. These two features imply that the principle of transitivity no longer holds.

There exist many contact points between ELECTRE and BF: they both admit economic agent is not rational and makes sub-optimal choices (Roy 1991; Kahneman and Tversky 1979); they violate the axioms of rationality (Roy and Mousseau 1996; Kahneman and Tversky 1979; Slovic and Lichtenstein 1971), independence (Roy and Mousseau 1996), comparability (Roy and Mousseau 1996; Slovic and Lichtenstein 1971) and transitivity (Roy and Mousseau 1996; Kahneman and Tversky 1979).

Morton and Fasolo (2009) outlined some behavioural findings relevant to the practice of multicriteria approach: structuring, value elicitation and weighting phases of the analysis.

Starting from these findings and considering that, on the one hand, economic agents naturally make choices without decision analytic assistance, and, on the other hand, multicriteria methods represent a powerful analytical tool to deal with complex decision problems, our aim is to verify whether using a multicriteria decision tool is able to reduce or minimize some biases. To the best of our knowledge, no scholars used multicriteria methods to describe the emotional behaviour of economic agents.

3 Methodology

ELimination Et Choix Traduisant la RealitÈ (ELECTRE) methods, proposed by Roy (1991), belong to the family of outranking methods. An outranking method is based on pairwise comparisons of the alternatives. This means that every alternative is compared to all other options. For a disclosure of ELECTRE methods, see (Roy 1991; Roy and Mousseau 1996; Figueira and Roy 2002; Figueira et al. 2009; Ishizaka and Nemery 2013).

Given a set of alternatives, the decision maker selects the smallest subset containing the best options. An outranking relation aSb is a binary relation *S*, defined on a set of alternatives (A). Given the preferences of a decision maker, the quality of the assessments of the actions and the nature of the problem, there are enough arguments to decide that a is at least as good as b, while there are no valid reasons to say otherwise (Roy 1990).

ELECTRE methods have the advantage that they avoid compensation between criteria (Ishizaka and Nemery 2013).

These methods arise from the idea that rigorous mathematical axioms cannot describe a complex problem characterized by many contradictions. The aim is to have a decision-making method closer to reality, on the one hand, supporting the irrationality of the decision maker and, on the other, refusing the completeness theorem which states that the decision maker, faced with two alternatives, is always able to express its preference or indifference.

ELECTRE I chooses alternatives that are preferred by the majority of the criteria and which do not cause an unacceptable level of discontentment on other criteria.

Given a decision matrix A composed by m rows, representing the alternatives, and n columns representing the criteria, the use of ELECTRE involves the following steps (Roy 1991):

1. Calculation of the normalized matrix (X)
2. Calculation of the weighted normalized matrix (V)
3. Calculation of concordance and discordance sets ($C_{p,q}$; $D_{p,q}$)
4. Construction of net concordance and discordance matrices (C and D)
5. Calculation of advantage averages of concordance and discordance values (C(average) and D(average))
6. Calculation of net concordance and discordance values (C_p and D_p)

Once the matrix A has been constructed, one proceeds to its normalization taking into account whether the parameters considered in the problem represent cost parameters or beneficial parameters. In the case of cost parameters, the formula to calculate the entries of matrix X is the following (Yücel and Görener 2016):

$$x_{ij} = \frac{a_{ij}}{\sqrt{\sum_{i=1}^{m} a_{ij}^2}} \quad i = 1, 2, \ldots, m \quad j = 1, 2, \ldots, n \tag{1}$$

In the case of benefit parameters, we use:

$$x_{ij} = \frac{\frac{1}{a_{ij}}}{\sqrt{\sum_{i=1}^{m} \left(\frac{1}{a_{ij}}\right)^2}} \quad i = 1, 2, \ldots, m \quad j = 1, 2, \ldots, n \tag{2}$$

Each column of matrix A is normalized with respect to the Euclidean norm defined in R^m. Let a be a column vector of matrix A, its Euclidean norm, $\|a\|$, is equal to 1.

Fixing the weights of criteria, we construct the weights matrix:

$$W = \begin{bmatrix} w_1 & \ldots & 0 \\ \ldots & w_2 & \ldots \\ 0 & \ldots & w_n \end{bmatrix} \tag{3}$$

If the weights are not given, they could be derived by applying a method, such as the Analytic Hierarchy Process (Saaty 1980, 1986). In order to construct the normalized weight matrix (V), we multiply the weights matrix by the normalized matrix, as follows:

$$V = WX \tag{4}$$

Then, we calculate the concordance sets $C_{p,q}$ and discordance sets $D_{p,q}$:

$$C_{p,q} = \{j, v_{pj} \geq v_{qj}\} \tag{5}$$

$$D_{p,q} = \{j, v_{pj} < v_{qj}\} \tag{6}$$

For every pair of alternatives p and q with respect to all criteria: if alternative p is better than or equal to alternative q, there is concordance; if alternative p is worse than q, there is discordance.

The next step is the calculation of the matrix with the index of concordance C(p,q) and discordance D(p,q):

$$C(p, q) = \sum_{j \in Cp,q} w_j \tag{7}$$

$$D(p, q) = \frac{\sum_{j \in Dp,q} |v_{pj} - v_{qj}|}{\sum_{j=1}^{n} |v_{pj} - v_{qj}|} \tag{8}$$

Each entry of matrix C (c(i,j)) represents the sum of the weights of criteria for which a_i is preferred to a_j, that is concordance matrix is the matrix generated by adding the values of weights of concordance set elements. Discordance matrix is prepared by dividing discordance set members values to total value of whole set.

Then, we calculate the advantage averages of concordance and discordance values (C(average) and D(average)).

Finally, the net concordance and discordance values are calculated:

$$C_p = \sum_{\substack{k=1 \\ k \neq p}}^{m} C(p, k) - \sum_{\substack{k=1 \\ k \neq p}}^{m} C(k, p) \tag{9}$$

$$D_p = \sum_{\substack{k=1 \\ k \neq p}}^{m} D(p, k) - \sum_{\substack{k=1 \\ k \neq p}}^{m} D(k, p) \tag{10}$$

They provide the ranking of alternatives by decreasing (C_p) or increasing (D_p) order of the values, respectively.

4 Simulation study

In this section, we propose to apply ELECTRE method to some prospects well known in the literature. Prospects are combinations of possible outcomes of an alternative and the probabilities associated with them (replacing the economic meaning of a lottery).

In the actual experiment by Kahneman and Tversky (1979), subjects were asked to evaluate a pair of prospects and to choose one of the options:

Problem 1 Choose between the following two prospects.
Prospect A: 33% chance to win 2500; 66% chance to win 2400; 1% chance to win nothing
Prospect B: 2400 for sure
Problem 2 Choose between the following two prospects.
Prospect C: 33% chance to win 2500; 67% chance to win nothing;
Prospect D: 34% chance to win 2400; 66% chance to win nothing.

For problem 1, Kahneman and Tversky report that 82% of respondents choose prospect B: it has a higher expected value compared to prospect A. In problem 2, 83% of respondents choose prospect C. This behaviour represents a violation of EUT.

Indeed, assuming that $u(0) = 0$, the preference of prospect B on A, in problem 1, implies

$$u(2400) > 0.33u(2500) + 0.66u(2400) \text{ or } 0.34u(2400) > 0.33u(2500) \quad (11)$$

while the preference of prospect C on D, in problem 2, implies the reverse inequality.

Considering that problem 2 derives from problem 1 by eliminating a 66% chance of winning 2400 from both prospects, the choice of prospect B, in problem 1, and prospect C, in problem 2, means that the above change produces a greater reduction in desirability when the prospect changes from a sure gain to a probable one, than when both the original and the reduced prospects are uncertain (Kahneman and Tversky 1979).

First of all, in order to apply ELECTRE method, we have to present the above problems (prospects) in a different way. In particular, we consider each prospect as an alternative (A_i, $i = 1,\ldots,m$), the events as criteria (C_j, $j = 1,\ldots n$), the probability assigned to a certain event as the weight (p_i) assigned to that criterium. In this way, problems 1 and 2 can be represented as matrices, as shown in Tables 1 and 2.

The above matrix is the classical representation of a multicriteria problem, where the weights (p_i) of criteria are prefixed. We may apply ELECTRE for ranking the alternatives.

Then, we consider some other problems proposed in the literature. In particular, we have analysed the statements relating to the cancellation.

Problem 3 Choose between the following two prospects.
Prospect A: 1000 with probability 0.25; − 100 with probability 0.75
Prospect B: 1000 with probability 0.10; 500 with probability 0.40; − 200 with probability 0.50
Problem 4 Choose between the following two prospects.
Prospect C: 1000 with probability 0.15; − 100 with probability 0.75;
Prospect D: 500 with probability 0.40; − 200 with probability 0.50.

The respondents prefer prospects B and D. That choice violates the EUT. Indeed, the preference of prospect B on A, in problem 3, implies

$$0.25u(1000) + 0.75u(-100) > 0.10u(1000) + 0.40u(500) + 0.50u(-200) \text{or } 0.15u(1000) + 0.75u(-100) > 0.40u(500) + 0.50u(-200) \quad (12)$$

while the preference of prospect C on D, in problem 4, implies the reverse inequality.

Problems 3 and 4 are represented in Tables 3 and 4.

We apply the ELECTRE method to all the above decision matrices (Tables 1, 2, 3, 4).

For each problem, we comply with the following steps:

- Calculation of the normalized matrix (X);
- Calculation of the weighted normalized matrix (V);
- Construction of net concordance and discordance matrices (C and D);
- Calculation of advantage averages (C(average) and D(average));
- Calculation of net concordance and discordance values (C_p and D_p).

In the following, we describe three experiments.

Experiment no. 1 concerns the problem 3. Tables 5, 6, 7 and 8 show the normalized decision matrix [calculated by using Eq. (2)], weighted normalized matrix, concordance and discordance sets, matrices and values.

Table 1 Representation of problem 1

,	Criterium 1 $p_1 = 0.33$	Criterium 2 $p_2 = 0.66$	Criterium 3 $p_1 = 0.01$
Alternative $A1$	2500	2400	0.001[a]
Alternative $A2$	2400	2400	2400

[a]We consider the amount 0.001 instead of 0.000 in order to calculate the normalized matrix (see formula no. 2 in Sect. 3)

Table 2 Representation of problem 2

	Criterium 1 $p_1 = 0.33$	Criterium 2 $p_2 = 0.66$	Criterium 3 $p_1 = 0.01$
Alternative *A*3	2500	0.001[a]	0.001[a]
Alternative *A*4	2400	0.001[a]	2400

[a]We consider the amount 0.001 instead of 0.000 in order to calculate the normalized matrix (see formula no. 2 in Sect. 3)

Table 3 Representation of problem 3

	Criterium 1 $p_1 = 0.10$	Criterium 2 $p_2 = 0.15$	Criterium 3 $p_3 = 0.40$	Criterium 4 $p_4 = 0.35$
*A*1	1000	1000	− 100	− 100
*A*2	1000	− 200	500	− 200

Table 4 Representation of problem 4

	Criterium 1 $p_1 = 0.10$	Criterium 2 $p_2 = 0.15$	Criterium 3 $p_3 = 0.25$	Criterium 4 $p_4 = 0.50$
*A*3	0.001[a]	1000	− 100	− 100
*A*4	0.001[a]	500	500	− 200

[a]We consider the amount 0.001 instead of 0.000 in order to calculate the normalized matrix

Each entry (c_{ij}) of matrix *C* represents the sum of weights of criteria for which the *i*th alternative is preferred to the *j*th alternative; each entry (d_{ij}) of matrix *D* is calculated following formula (8).

Once the net concordance and discordance matrices are constructed, concordance and discordance values (Table 8) are calculated following formulas 9 and 10 introduced in the previous section.

These values provide the final ranking of the alternatives regarding concordance and discordance. Both concordance and discordance values of the experiment no. 1 show that the alternative *A*2 is preferred to *A*1.

Experiment no. 2 concerns the problem 4. Tables 9, 10, 11 and 12 show the normalized decision matrix, weighted

Table 5 Normalized decision matrix (*X*)—experiment 1

(x_{ij})	Criterium 1	Criterium 2	Criterium 3	Criterium 4
*A*1	0.707	0.196	− 0.981	− 0.894
*A*2	0.707	− 0.981	0.196	− 0.447

Table 6 Weighted normalized matrix (*V*)—experiment 1

(v_{ij})	Criterium 1	Criterium 2	Criterium 3	Criterium 4
*A*1	0.0707	0.029	− 0.392	− 0.313
*A*2	0.0707	− 0.147	0.078	− 0.157

Table 7 Net concordance and discordance matrices—experiment 1

$C(i,j)$		$D(i,j)$	
	0.250		0.780
0.750		0.220	

normalized matrix, the concordance and discordance sets, matrices and values, providing the ranking of the alternatives.

The concordance and discordance values of experiment no. 2 show that the alternative *A*4 is preferred to *A*3.

Experiment no. 3 We simultaneously consider the alternatives of problems 3 and 4 (Table 13).

Applying formulas 7 and 8, at first, we construct the matrices in Tables 14 and 15.

Each entry $c(i,j)$ represents the sum of the weights of criteria for which a_i is preferred to a_j.

Then, we calculate two threshold values, *C*(average) and *D*(average), and individuate $C(p,q)$ and $D(p,q)$ such that $C(p,q)$ is greater than the concordance threshold—*C*(average)—and $D(p,q)$ is lesser than the discordance threshold—*D*(average). Then, for each entry of matrices *C* and *D*, if $C(p,q) \geq C(\text{ave})$ or $D(p,q) \leq D(\text{ave})$, we stated as Yes, otherwise No. Table 16 shows the thresholds and the outranking relation among the alternatives. We stress that the computation of the above thresholds is not necessary to obtain the ranking.

Once the net concordance and discordance matrices are constructed, net concordance and discordance values are calculated following formulas 9 and 10.

Concordance and discordance values provide the ranking of alternatives, respectively, by decreasing (C_p) or increasing (D_p) order of the values, as shown in Tables 17 and 18.

Both concordance and discordance values of the experiment no. 3 confirm the results of experiments 1 and 2, that is, the alternative *A*2 (resp. *A*4) is preferred to *A*1 (resp. *A*3).

We use the graph relation to identify good alternatives. Figure 1 shows the outranking graph related to the alternatives of Experiment no. 3. As we can see, the alternative *A*4 has no incoming arrows and states to be the best alternative among others: *A*4 is better than the alternatives *A*3, *A*2 and *A*1; *A*2 is better than *A*1 and *A*3; *A*3 is better than *A*1.

Table 8 Concordance and discordance values and preferences ranking—experiment 1

C_p	Concordance value	Ranking	D_p	Discordance value	Ranking
$C1$	− 0.7	2	$D1$	0.561	2
$C2$	0.7	1	$D2$	− 0.561	1

Table 9 Normalized decision matrix (X)—experiment 2

(x_{ij})	Criterium 1	Criterium 2	Criterium 3	Criterium 4
$A3$	0.707	0.447	− 0.981	− 0.894
$A4$	0.707	0.894	0.196	− 0.447

Table 10 Weighted normalized matrix (V)—experiment 2

(v_{ij})	Criterium 1	Criterium 2	Criterium 3	Criterium 4
$A3$	0.0707	0.067	− 0.245	− 0.447
$A4$	0.0707	0.134	0.049	− 0.224

Table 11 Concordance and discordance matrices—experiment 2

$C(i,j)$		$D(i,j)$	
	0.150		1.00
0.850		0.00	

It is interesting to note that ELECTRE provides the same results obtained by Kahneman and Tversky in their experiments: therefore, it allows describing the emotionality of economic agents.

5 Concluding remarks

Kahneman and Tversky showed that the human behaviour does not necessarily conform to what is predicted by the rationality axioms underlying expected utility theory. They highlighted that cognitive errors violate some fundamental assumptions referred to the above model.

Table 14 Concordance matrix C—experiment 3

	0.25	0.9	0.0
0.85		0.75	0.5
1.0	0.25		0.1
1.0	0.6	1.0	

Table 15 Discordance matrix D—experiment 3

	0.73	1.0	1.0
0.27		0.35	0.67
0.0	0.65		1.0
0.0	0.33	0.0	

Starting from some behavioural findings relevant to the practice of multicriteria approaches, highlighted by Morton and Fasolo (2009), we propose to apply a multicriteria method to verify that judgments expressed by a decision maker are not as coherent as he/she may have thought.

Due to some similarities between the behavioural finance axioms and the theoretical foundation of ELECTRE methods, among the various multicriteria methods, we use ELECTRE I. We consider some experiments proposed by Kahneman and Tversky: a modified version of the Allais paradox and some prospects defined in the editing phase, in particular those related to cancellation (Kahneman and Tversky 1979). At first, we represent the prospects by means of decision matrices and, then, we apply ELECTRE to these prospects.

Table 12 Concordance and discordance values and preferences ranking—experiment 2

C_p	Concordance value	Ranking	D_p	Discordance value	Ranking
$C1$	− 0.7	2	$D1$	1.00	2
$C2$	0.7	1	$D2$	− 1.00	1

Table 13 The unified representation of problems 3 and 4—experiment 3

	Criterium 1 $p_1 = 0.10$	Criterium 2 $p_2 = 0.15$	Criterium 3 $p_3 = 0.25$	Criterium 4 $p_4 = 0.10$	Criterium 5 $p_4 = 0.40$
$A1$	1000	1000	− 100	− 100	− 100
$A2$	1000	− 200	− 200	− 200	500
$A3$	0.001	1000	− 100	− 100	− 100
$A4$	0.001	500	500	− 200	− 200

Table 16 Threshold values [C(ave) and D(ave)] and comparisons with concordance and discordance values—experiment 3

$C(p,q)$	$C_{p,q}$	$C(p,q) \geq C$(ave)	$D(p,q)$	$D_{p,q}$	$D(p,q) \leq D$(ave)	Outranking relation Ap → Aq
C(1,2)	0.25	No	D(1,2)	0.727	No	
C(1,3)	0.9	Yes	D(1,3)	1	No	
C(1,4)	0	No	D(1,4)	1	No	
C(2,1)	0.85	Yes	D(2,1)	0.273	Yes	2 → 1
C(2,3)	0.75	Yes	D(2,3)	0.350	Yes	2 → 3
C(2,4)	0.5	No	D(2,4)	0.670	No	
C(3,1)	1	Yes	D(3,1)	0	Yes	3 → 1
C(3,2)	0.25	No	D(3,2)	0.650	No	
C(3,4)	0.1	No	D(3,4)	1	No	
C(4,1)	1	Yes	D(4,1)	0	Yes	4 → 1
C(4,2)	0.6	Yes	D(4,2)	0.330	Yes	4 → 2
C(4,3)	1	Yes	D(4,3)	0	Yes	4 → 3
C(ave)	0.6		D(ave)	0.5		

Table 17 Concordance values and preferences ranking—experiment 3

C_p	Concordance value	Ranking
C_1	− 1.7	4
C_2	1.0	2
C_3	− 1.3	3
C_4	2.0	1

Table 18 Discordance values and preferences ranking—experiment 3

D_p	Discordance value	Ranking
D_1	2.455	4
D_2	− 0.416	2
D_3	0.300	3
D_4	− 2.399	1

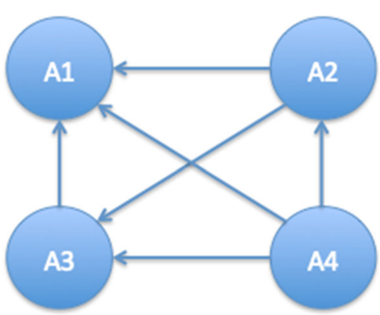

Fig. 1 Outranking graph—experiment 3

We observe that ELECTRE provides the same results obtained in the literature: therefore, it is able to describe the emotional behaviour of economic agents, that is, it could be used in choices characterized by emotionality.

Our future aim is to apply ELECTRE to a real case study and to consider other steps of the decision-making process. Furthermore, it would be interesting to verify the possibility to apply some other multicriteria methods.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Research involving human participants and/or animals This article does not contain any studies with human participants or animals performed by any of the authors.

Informed consent Informed consent was obtained from all individual participants included in the study.

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