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A novel approach to improve the bank ranking process: an empirical study in Spain

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Abstract. In this paper, a novel approach to the bank ranking process based on the possibilistic theory is proposed. Through this new method, the sensitivity of the results can be improved. Several methods are applied in order to rank the financial performance of Spanish Banks. Methods such as the Fuzzy Analytic Hierarchy Process (FAHP) and fuzzy TOPSIS are integrated in the proposed model. Criteria and sub-criteria weights are computed based on the judgments of experts using FAHP. These weights and financial indicators are inputs of the fuzzy TOPSIS methods for ranking the banks. The financial ratios are based on the CAMEL rating system criteria. Moreover, the results from the application of several distance measurements (Vertex, Hamming and Euclidean) in fuzzy TOPSIS as well as a new measure based on the possibilistic theory are compared. Finally, the results obtained applying fuzzy TOPSIS show that they vary depending on the separate measure, so it is necessary to have different measures to be able to correct decision making.

Keywords: Financial performance, fuzzy numbers, fuzzy AHP, fuzzy TOPSIS, CAMELS rating system

1. Introduction

Financial performance is central to the survival of businesses, especially in the banking sector, which is characterized by rising competition, reduced net income margins and a high level of impaired loans. This study specifically focuses on the evaluation of the financial performance in leading companies from this sector in Spain. It particularly concentrates on the seven largest banks in the sector that are listed on the IBEX 35, the main indicator of the Spanish Stock Exchange. The analysed period spans 3 years from 2013 to 2015.

There are a large number of studies that evaluate banking performance and apply different parametric and non-parametric methods [42]. The most widely used parametric method is known as the stochastic frontier approach. Meanwhile, in the field of nonparametric methods, the most common approach is the analysis of ratios and DEA [19]. Below are some of the most recent studies. The research by Lampe and Hilgers [16] evaluates the efficiency of banking offices in Canada by applying DEA. In their study Barros et al. [8] analyse the technical efficiency of Japanese banks in the period 2000–2007. Wanke and Barros [41] apply Fuzzy DEA and Bootstrapping to evaluate productive efficiency in the case of Mozambican banks. Barros et al. [7] studied the technical efficiency of Angolan banks from 2005 to 2012 using a Bayesian stochastic frontier model. Gil-Alana et al. [25] analyse the technical efficiency of Mozambican banks from 2005 to 2014 with a Bayesian stochastic frontier mode. Wanke et al. [40] present a strategic fit assessment of mergers and acquisitions (M & A) in South African banks.

A new trend in the evaluation of banking performance is related to the use of multi-criteria decision-making (MCDM) methods such as the analytic hierarchy process (AHP) and the technique for order of preference by similarity to ideal solution

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(TOPSIS) for criteria weighting and efficiency ranking, respectively [30]. There are many AHP and TOPSIS-based studies on performance evaluation in banking, but even so there are fewer than those based on other methods.

Over the last few years, the Analytic Hierarchy Process (AHP), developed by Saaty [50], has become one of the most widely used MCDM tools in the resolution of complex decision-making problems. All the pairwise comparisons generated by the relative weights of the criteria, which appear in the intermediate stages of the AHP, represent judgments made by decision makers (DMs). These are based on knowledge and information that DMs have about the problem, which means that the pairwise comparisons are imbued with subjectivity in the interpretation and assessment of the problem. Therefore, DMs personal viewpoints can profoundly affect the final results [20].

The uncertainty arising from the subjectivity and imprecision of the evaluation process renders the conventional AHP an inappropriate tool in situations involving vagueness in linguistic assessment [34]. However, this limitation disappears when fuzzy logic is incorporated into the AHP methodology, thus giving rise to the Fuzzy Analytic Hierarchy Process (FAHP).

The Fuzzy Analytic Hierarchy Process (FAHP) has been proposed by various authors [12, 22, 27, 37]. It represents a systematic approach to selecting alternatives and solving problems using fuzzy set theory to express the uncertain comparison of opinions using fuzzy numbers and the AHP method. Van Laarhoven and Pedrcyz [37] and Buckley [22] derive fuzzy priorities and, after aggregating, the final scores of the alternatives are also represented as fuzzy numbers or fuzzy sets. In contrast, Chang [12] and Mikhailov [27] derive crisp priorities from fuzzy comparison judgments.

A large number of studies support the efficiency and applicability of the FAHP methodology alone or in conjunction with other techniques. Specifically, 103 papers have used the FAHP from 1994 to 2014 [3]. These papers deal with different applications of the FAHP to numerous fields of knowledge. In particular, for evaluating banking performance: Seçme et al. [35] in Turky, Shaverdi et al. [33] in Iran, Wanke et al. [42] in ASEAN banks, Mandic et al. [23] in Serbia and Chatterjee [9] in India.

Once the weights have been determined through the FAHP method and the financial ratios have been calculated, the ranking for the companies using fuzzy TOPSIS will be established [15, 48, 52]. This method is a generalization of TOPSIS in a fuzzy environment.

According to Mardani et al. [3], 79 papers applying the Fuzzy TOPSIS method alone or combined with other methods were published between the years 1994 and 2014.

It is worth mentioning the following recent studies combining FAHP techniques and Fuzzy TOPSIS. Asghari et al. [28] apply these methods to measure the impact of heat stress in surface mining. Lee et al. [54] analyse the performance evaluation of medical device manufacturers. Mardani et al. [4] evaluate energy saving technologies and solutions in hotels. Buyukozkan and Guleryuz [14] examine product development partner selection. Zyoud et al. [47] address water loss management in developing countries. Lee et al. [51] evaluate the Commercial Potential of Original Technologies in Universities. Ozdagoglu and Guler [5] analyse e-service quality of internet-based banking. Shaverdi et al. [33] develop a new financial performance evaluation framework to rank the companies from the Iranian petrochemical industry. It should be noted that the combined application of both methods, the FAHP and fuzzy TOPSIS, in the field of banking is almost non-existent. To date, the only one is by Jaksic et al. [31], who develop an application for Serbian banks.

The financial indicators used in this paper come from the Annual Financial Reports of banks. In fact, these indicators are usually classified into some categories, since accounting experts claim that financial instruments within a cluster are partially similar [53]. Although there is no universal set of indicators used across previous studies, the CAMELS rating system criteria appear to have a significant capacity to detect distress [42].

The CAMELS rating system, which was originally developed in the US, includes the following criteria: capital adequacy (C), asset quality (A), management efficiency (M), earnings (E), liquidity (L), and sensitivity to market risk (S). In recent decades, several studies have reported on the use of these variables in risk measurement and monitoring. Examples can be found in Cole and Gunther [43], DeYoung [44], Oshinsky and Olin [46], Ravi-Kumar and Ravi [38], Poghosyan and Cihák [6], and Ravisankar et al. [39]. More recently, Wanke et al. [41, 42].

The CAMELS rating system is based on a ratio analysis of financial statements. As the financial indicators that integrate the CAMELS criteria are not public [21], it was decided to use the financial

Table 1
CAMELS. Financial indicators proposed

Criteria		Subcriteria	Reference
Capital adequacy (C)	C1	Growth to Assets Ratio	[42]
	C2	Regulatory Capital Ratio (BASEL III)	[2][13][29][35][42][43]
	C3	Equity to Total Assets Ratio	[2][13][17][35][42][43]
	C4	Equity to Liabilities Ratio	[42]
Assets quality (A)	A1	Impaired Loans/Gross Loan	[17][35][42][43]
	A2	Loan Loss Reserve/Impaired Loan	[17][29][35][42][43]
	A3	Loan Loss Provision/Net Interest Revenue	[2][13][17][35][42][43]
	A4	Tier 1 Ratio	[7]
Management efficiency (M)	M1	Net Interest Revenue to Average Assets Ratio	[13][17][29][35][42][43]
	M2	Other Operational Income to Average Assets Ratio	[13][29][42][43]
	M3	Non-Interest Expenses to Average Assets Ratio	[29][42]
Earning quality (E)	E1	Return on Equity (ROE)	[2][13][17][29][42][43]
	E2	Return on Tangible Equity (ROTE)	
	E3	Return on Asset (ROA)	[2][13][17][29][35][42][43]
	E4	Return on Risk-Weighted Assets (RORWA)	
	E5	Efficiency Ratio	[13][17][35][42][43]
Liquidity (L)	L1	Net Loan/Deposits	[13][35][42][43]
	L2	Net Loan to Asset	[29][42][43]
	L3	Liquid Assets to Deposits	[2][13][17][29][35][42]
Sensitivity of market risk (S)	S1	Risk-Weighted Assets to Assets Ratio	
	S2	Net Income to Risk-Weighted Assets Ratio	[42]
	S3	Rating	

indicators from previous studies and those used in different applications.

The main objective of this paper is to simplify processes, increase efficiency and improve the sensitivity of results in the bank ranking process.

Together with the proposed model based on the combination of the FAHP and fuzzy TOPSIS to establish the ranking of banks according to the CAMELS rating system, a new Fuzzy TOPSIS resolution methodology is developed. This is done through the application of the possibilistic theory that simplifies the operation against other separate measures such as Vertex, Hamming distance or Euclidean distance. In order to analyse the validity of the proposed methodology, a practical application for Spanish banks is developed. Finally, the main conclusions are presented.

2. Methodology

This section details the different stages of an original model that improves the bank ranking process. The steps for the methodological process are as follows:

2.1. Camel rating system

Table 1 shows the selected financial indicators classified according to the CAMELS rating system, where the general objective is the evaluation of financial performance. It is structured into 22 financial indicators classified into six categories: four (C) capital adequacy indicators, four (A) asset quality indicators, three (M) management efficiency indicators, five (E) earnings indicators, three (L) liquidity indicators and three (S) sensitivity to market risk. These indicators have been selected on the basis of their use in previous scientific research.

2.2. Elicit the weights of each ratio. Application of the FAHP

2.2.1. Determine the weight of each category over the total

a) Evaluation by experts. With the help of questionnaires, a group of K decision makers from different areas are asked to assess the relevance of each of the categories of the CAMELS rating systems (F) and the indicators included in each of the categories. Considering that different stakeholders (inside and outside the bank) have different objectives and expectations and bearing in mind that the financial analysis must represent the different perspectives [45], the financial indicators have to have different levels of relevance for the different users [18]. For instance, company managers are especially interested in growth and activity indicators, investors and shareholders focus on profitability ratios, and creditors focus more on financial leverage ratios [32].

Table 2
The linguistic scale and underlying triangular number

Fuzzy number	Linguistic scales	Scale of fuzzy numbers
$\tilde{1}$	Equally important	(1, 1, 1)
$\tilde{3}$	Weakly important	(2, 3, 4)
$\tilde{5}$	Essentially important	(4, 5, 6)
$\tilde{7}$	Highly important	(6, 7, 8)
$\tilde{9}$	Absolutely important	(8, 9, 10)
$\tilde{2}, \tilde{4}, \tilde{6}, \tilde{8}$	Intermediate values ($\tilde{x}$)	$(x-1, x, x+1)$
$\tilde{x}^{-1}$	Between two adjacent judgments	$\left((x+1)^{-1}, x^{-1}, (x-1)^{-1}\right)$

In this way, a square matrix of order F (ratios o categories) will be available to each of the K experts.

$$\tilde{A} = \{\tilde{a}_{ij}\} = \begin{pmatrix} \tilde{a}_{11} & \cdots & \tilde{a}_{1F} \\ \vdots & \ddots & \vdots \\ \tilde{a}_{F1} & \cdots & \tilde{a}_{FF} \end{pmatrix} \quad (1)$$

The element $\tilde{a}_{ij}$ represents the relative importance of category i with respect to j. The elements of matrix, $\tilde{a}_{ij} = \left(a_{ij}^1, a_{ij}^2, a_{ij}^3\right)$, are triangular fuzzy numbers.

b) Representation of expert opinions. In order to decide the importance of category i over j, each expert selects an element according to the semantic correspondence shown in Table 2 [1, 24, 49]. When category i is highly compared to category j, the expert chooses the fuzzy number $\tilde{7}$. In this way, there are K opinions on each pair of elements to be compared. The opinion of the kth expert is represented by $\tilde{a}_{ijk} = \left(a_{ijk}^1, a_{ijk}^2, a_{ijk}^3\right)$ and indicates the relative importance of category i over category j assigned by expert k, $k = 1, \ldots, K$.

c) Aggregation of expert priorities. The information provided by the experts is aggregated according to the following expression

$$\tilde{a}_{ij} = \left(a_{ij}^1, a_{ij}^2, a_{ij}^3\right) = \left(\min_k a_{ijk}^1, \left(\prod_k a_{ijk}^2\right)^{\frac{1}{K}}, \max_k a_{ijk}^3\right), k = 1, .., K \quad (2)$$

This information is summarized in the matrix $\tilde{A}(1)$ in which each element $\tilde{a}_{ij}$ represents the importance that the group of experts assign to category j with respect to category i.

d) Elicit the weights of each category implementing the FAHP. The FAHP is applied to improve the decision process by reducing the uncertainty and vagueness of the decision maker's subjective judgment.

The nonlinear program developed by Mikhailov [27] is applied to obtain the final weight of each criterion (3).

Mikhailov and Tsvetinov [26] proposed Fuzzy Preference Programming (FPP) to derive priorities from the fuzzy comparison judgments that eliminate some of the inconveniences of existing fuzzy prioritization methods [34], where $\omega = (\omega_1, \omega_2, \ldots, \omega_F)^T$ is the vector of crisp priorities.

$$\begin{aligned} & Max\lambda \\ & \text{s.t.} \\ & \left(a_{ij}^2 - a_{ij}^1\right)\lambda\omega_j - \omega_i + a_{ij}^1\omega_j \le 0 \\ & \left(a_{ij}^3 - a_{ij}^2\right)\lambda\omega_j + \omega_i - a_{ij}^3\omega_j \le 0 \quad (3) \\ & \sum_j \omega_j = 1; \omega_j > 0 \\ & i = 1, 2, \ldots, F-1; \mathrm{j} = 1, 2, \ldots, F; j > i \end{aligned}$$

The optimal value λ^* is "the consistency index". This value is used to measure the level of satisfaction of the optimal priority vector

$$\omega^* = \left(\omega_1^*, \ldots, \omega_F^*\right)^T \quad (4)$$

When λ^* is positive, all the solution coefficients fully satisfy fuzzy opinions, which means that the initial set of fuzzy judgments is quite consistent. A negative value of λ^* shows that the fuzzy judgments are highly inconsistent; that is to say, the optimal value of λ^* can be used as a measure of the consistency of the initial set of fuzzy judgments. Thereby, the weights of each category are obtained.

In the practical case the optimal priority vector is given by

$$\omega^* = \left(\omega_C^*, \omega_A^*, \omega_M^*, \omega_E^*, \omega_L^*, \omega_S^*\right)$$

2.2.2. Determination of the weights that each ratio has in each category

On determining the final weight, the ratios for each category will have $j,\ j = 1, \ldots, F$

$$\omega_j^* = \left(\omega_{j1}^*, \ldots, \omega_{jH_j}^*\right)^T \tag{5}$$

where ω_{jh}^* is the weight of ratio h in category j, with $h = 1, \ldots, H_j$ and H_j is the total number of ratios belonging to category j, being $\sum_h \omega_{jh}^* = 1$. To do this, the procedure described in section 2.2.1. is repeated for each of the F categories for the ratios considered.

In the case study, the weights that each ratio have in each category, will be determined by the following formulation.

$$\omega_j^* = \left(\omega_{j1}^*, \ldots, \omega_{jH_j}^*\right),$$
$$\text{j = C,A,M,E,L,Sh} = 1, \ldots, H_j$$

2.2.3. Calculation of the final weights

The weight of ratio h in category j (ϖ_{jh}^*) is obtained by multiplying the weight calculated for each category j in (4) (ω_j^*) by the weighting that corresponds to ratio h in category j (ω_{jh}^*) obtained in (5) with $h = 1, \ldots, H_j$. By aggregating them, a matrix that represents all the weights can be obtained. This could be simplified as,

$$\varpi^* = \left(\varpi_1^*, \ldots, \varpi_Q^*\right)^T \tag{6}$$

where $\sum_q \varpi_q = 1$ and $Q = H_1 + \ldots + H_F$

Thereby, the matrix corresponding to the weights of each subcategory is obtained, where Q refers to the total of the criteria used (financial indicators). For example, for the first element in the case study, the following would be obtained,

$$\varpi_{C1}^* = \omega_C^* \cdot \omega_{C1}^*$$

2.3. Ranking Alternatives Based on Fuzzy TOPSIS

After determining the weight of each criterion, the ranking is established through the application of the MCDM fuzzy TOPSIS method [15, 48, 52]. This allows us to perform a sensitivity analysis of the results obtained by evaluating the different methodologies. The algorithm of the fuzzy TOPSIS method has seven main steps, as follows:

Step 1. The criteria for each alternative are quantified. The set of crisp criteria represented by v_{qst}.

where,
$s = 1, \ldots, S$(Alternative)
$q = 1, \ldots, Q$ (Criteria)
$t = 1, \ldots, T$ (Years)

Step 2. Decision matrix normalized by using this equation:

$$w_{qst} = \frac{v_{qst}}{\sqrt{\sum_s v_{qst}^2}} \tag{7}$$

Step 3. Construction of the order matrix SxQ $W = \left\{\tilde{w}_{sq}\right\}$ whose elements are TFN:

$$\tilde{w}_{qs} = \left(w_{qs}^1, w_{qs}^2, w_{qs}^3\right) = \left(\min_t w_{qst}, \frac{1}{t}\sum_t w_{qst}, \max_t w_{qst}\right) \tag{8}$$

Step 4. Weighted normalized fuzzy decision matrix $R = \left\{\tilde{r}_{qs}\right\}$ from matrix W and from the weights ϖ defined in (6)

$$\tilde{r}_{qs} = \left(r_{qs}^1, r_{qs}^2, r_{qs}^3,\right) = \tilde{w}_{qs} \cdot \varpi_q \tag{9}$$

Step 5. Calculate the ideal solution $\tilde{R}^+$ and anti-ideal solution $\tilde{R}^-$ of the Q criteria.

$$\tilde{R}^- = \left[\tilde{R}_1^-, \tilde{R}_2^-, \ldots, \tilde{R}_Q^-\right] \tag{10}$$

$$\tilde{R}^+ = \left[\tilde{R}_1^+, \tilde{R}_2^+, \ldots, \tilde{R}_Q^+\right] \tag{11}$$

Where

$$\tilde{R}_q^- = \left(r_q^{1-}, r_q^{2-}, r_q^{3-}\right) = \left(\min_s r_q^1, \min_s r_q^2, \min_s r_q^3\right) \tag{12}$$

$$\tilde{R}_q^+ = \left(r_q^{1+}, r_q^{2+}, r_q^{3+}\right) = \left(\max_s r_q^1, \max_s r_q^2, \max_s r_q^3\right) \tag{13}$$

Step 6. The distance d_i^- and d_i^+ of each alternative from $\tilde{R}_{qs}$ to $\tilde{R}^-$ and $\tilde{R}^+$ are computed. In this case, and in order to evaluate the applicability and effectiveness of the proposed method based on the possibilistic measure Magnitude, different separation measures are used. The Vertex Method [10, 11, 31], Extensions of Euclidean and Hamming distance based on the Hausdorff metric are widely recognized in the scientific community and have been developed and applied in fuzzy TOPSIS [31, 36].

In this paper, a novel methodology is proposed to compute the distance between two triangular fuzzy numbers, based on the possibilistic measure denominated Magnitude (Mag). It is calculated by the Magnitude (Mag) operation for $\tilde{R}_{sq}$, anti-ideal solution $\tilde{R}^{-}$ and ideal solution $\tilde{R}^{+}$, of the Q criteria. For the fuzzy number $\tilde{R}$, the magnitude of $\tilde{R}$ is defined as,

$$Mag\left(\tilde{R}\right) = M\left(\tilde{R}\right) + \sigma\left(\tilde{R}\right) \tag{14}$$

Where $M\left(\tilde{R}\right)$ is the possibilistic mean value and $\sigma\left(\tilde{R}\right)$ is the degree of deviation (Carlsson and Fuller, 2001). The $M\left(\tilde{R}\right)$ for the TFN $\tilde{R} = \left(r^1, r^2, r^3\right)$ is

$$M\left(\tilde{R}\right) = \frac{1}{6}\left(r^1 + 4r^2 + r^3\right) \tag{15}$$

The possibilistic standard deviation value for the TFN $\tilde{R} = \left(r^1, r^2, r^3\right)$ is:

$$\sigma\left(\tilde{R}\right) = \frac{1}{\sqrt{24}}\left(r^3 - r^1\right) \tag{16}$$

There by, the $Mag()$ for $\tilde{R}_q^{-}$, $\tilde{R}_q^{+}$ and $\tilde{R}_{sq}$ is obtained.

$$Mag\left(\tilde{R}_{sq}\right) = \frac{1}{6}\left(r_{sq}^1 + 4r_{sq}^2 + r_{sq}^3\right) + \frac{1}{\sqrt{24}}\left(r_{sq}^3 - r_{sq}^1\right) \tag{17}$$

$$Mag\left(\tilde{R}_q^{-}\right) = \frac{1}{6}\left(r_q^{1-} + 4r_q^{2-} + r_q^{3-}\right) + \frac{1}{\sqrt{24}}\left(r_q^{3-} - r_q^{1-}\right) \tag{18}$$

$$Mag\left(\tilde{R}_q^{+}\right) = \frac{1}{6}\left(r_q^{1+} + 4r_q^{2+} + r_q^{3+}\right) + \frac{1}{\sqrt{24}}\left(r_q^{3+} - r_q^{1+}\right) \tag{19}$$

The separation between d_s^- and d_s^+ of each alternative from $\tilde{R}_{sq}$ to $\tilde{R}_q^{-}$ and $\tilde{R}_q^{-}$ are computed from the operator difference between Magnitudes (Mag). From equations, (17) to (19) the following is obtained.

$$d_s^- = \sum_q \left[Mag\left(\tilde{R}_{sq}\right) - Mag\left(\tilde{R}_q^{-}\right)\right] \tag{20}$$

$$d_s^+ = \sum_q \left[Mag\left(\tilde{R}_q^{+}\right) - Mag\left(\tilde{R}_{sq}\right)\right] \tag{21}$$

Table 3
Name of bank and net interest income (2015)

Name of bank	2015 (million €)
Banco Santander S.A.	32.189
Banco Bilbao Vizcaya Argentaria, S.A.	16.426
CaixaBank, S.A.	4.353
Bankia, S.A.	2.740
Banco Sabadell, S.A.	2.260
Banco Popular, S.A.	2.251
Bankinter, S.A.	869

Step 7: Finally, closeness coefficient CC_s of each bank is defined as:

$$CC_s = \frac{d_s^-}{d_s^- + d_s^+} \tag{22}$$

For $s = 1, 2, \ldots, n$. Obviously, $0 \leq CC_s \leq 1$, where $s = 1, 2, \ldots, n$. If $CC_s = 1$ alternative s is the ideal solution. To the contrary, if $CC_s = 0$ denotes that alternative s is the anti-ideal solution. Therefore, alternatives are ranked according to the closeness coefficients of alternatives and then the best alternative is determined.

3. Case study

As a complement to the research, this paper develops an application of both the well-known and novel methodologies proposed to evaluate the financial performance of the main Spanish banks (Table 3). Companies are subject to evaluation by using the data sets for the years 2013 to 2015. The financial data used in this analysis is extracted from the banks' Annual Reports.

Following the proposed methodology in section 2.1, financial indicators are computed for each Bank (Table 3). According to section 2.2, three decision makers from different areas are asked to assess the relevance of each of the categories of the CAMELS rating systems and the indicators included in each of the categories with the help of questionnaires. By applying the FAHP criteria, weights are obtained according to (3). All weights obtained are shown in Table 4.

According to section 2.3, the closeness coefficients (Cci) for each of the proposed methods in the fuzzy TOPSIS are obtained for the seven analysed banks (Table 5).

As shown in Table 5, comparing the results obtained from applying the different separate measures in the fuzzy TOPSIS, different bank rankings

Table 4
Local weights, global weights and consistency index (λ) for each criterion (financial indicators)

	λ^*	ω_j^*		λ^*	ω_{jh}^*	ϖ_{jh}^*
C	0,426	0,306017	C1	0,589789832	0,20955958	0,06412879
			C2		0,42003496	0,12853784
			C3		0,1318159	0,04033791
			C4		0,23858956	0,07301246
A		0,18100359	A1	0,659797151	0,27745447	0,05022026
			A2		0,39450871	0,07140749
			A3		0,19064295	0,03450706
			A4		0,13739386	0,02486878
M		0,10706036	M1	0,762559154	0,56943372	0,06096378
			M2		0,2546762	0,02726573
			M3		0,17589008	0,01883086
E		0,10706036	E1	0,637406727	0,33321576	0,0356742
			E2		0,18289615	0,01958093
			E3		0,27947762	0,02992098
			E4		0,13307215	0,01424675
			E5		0,07133832	0,00763751
L		0,08562656	L1	0,730392693	0,5580109	0,04778055
			L2		0,18646359	0,01596623
			L3		0,25552552	0,02187977
S		0,21323212	S1	0,638978728	0,2957989	0,06307383
			S2		0,21507382	0,04586065
			S3		0,48912728	0,10429765

Table 5
CC_i and rank for the period 2013-2015 for the fuzzy TOPSIS

	Vetex Method		Hamming distance		Euclidean distance		Possibilistic method	
	CCi	Rank	CCi	Rank	CCi	Rank	CCi	Rank
Santander	0,800	1	0,793	1	0,938	1	0,819	1
Bbva	0,771	2	0,774	2	0,956	2	0,780	2
Caixabank	0,411	5	0,415	5	0,750	6	0,372	5
Bankinter	0,535	3	0,532	3	0,761	4	0,528	3
Bankia	0,240	7	0,237	7	0,610	7	0,248	7
Popular	0,365	6	0,377	6	0,7564	5	0,365	6
Sabadell	0,513	4	0,517	4	0,870	3	0,516	4

are obtained. The results show that with the new proposed method, the ranking coincides with that obtained by applying the Vertex Method and the Hamming distance extension.

Applying this new methodology permits an increase in the range of techniques for calculating the separate measure between two fuzzy numbers when implementing the fuzzy TOPSIS. Thus, it has a greater number of alternative rankings that allow decision makers to make more accurate decisions. On the other hand, the simplicity in its application compared to other measures already discussed (Vertex Method, Hamming distance extension or Euclidean distance extension), which require the use of more complex operators to obtain the same ranking, as demonstrated in the case study, justifies its use.

4. Conclusions

In today's global economy, a firm's competitive advantages in financial terms are generally evaluated through financial indicators. They usually provide quantitative financial information for investors and shareholders which allows a company's operational management to be evaluated and its position within a sector to be analysed over time. The increasing uncertainty and complexity of the global market has led to a rise in the flow of information, making the measurement of efficiency more difficult. In today's context, the soundness of classical measures has diminished, and new approaches are needed. This study proposes a novel fuzzy MCDM approach to increase the information available to analysts. It applies several methodologies together with our novel approach to evaluate the financial performance of the seven largest banks in the Spanish banking sector in the period 2013–2015. The fuzzy MCDM approach proposed in this paper has been proven successful in other contexts and case studies. In our combination of the FAHP with fuzzy TOPSIS, this paper applies the Mikhailov methodology leading to crisp weights, which provide advantages over fuzzy weights. Crisp weights allow the analyst to easily check the consistency of the expert's opinions through index λ^*.

This study shows the need to use different computational techniques in the separation measure of the fuzzy TOPSIS, since the results may vary according to the technique selected. Therefore, different alternatives should be available to improve the sensitivity of the analysis of the final result. In this case, the results obtained have shown their predictive efficiency. For instance, because of the financial difficulties they presented, Bankia, ranked last in the ranking, was intervened by the Spanish government in 2012; and Popular, sixth in the ranking, was acquired for a symbolic valued of one euro by Santander in 2017.

The case study has shown the advantages and applicability of our proposed method and has provided effective fuzzy MCDM tools which could be further applied to numerous problems in different fields of study. Further research includes (1) extending the model to nonfinancial performance and efficiency; (2) using other MCDM ranking methods such as PROMETHEE or ELECTRE to analyse soundness; (3) developing and applying new fuzzy versions of the TOPSIS or other MCDM ranking methods.

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