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METHODOLOGIES AND APPLICATION

The evaluation performance for commercial banks by intuitionistic fuzzy numbers: the case of Spain

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Abstract

In a globalized world, the banking sector has been forced to advance not only in financial performance, but also in non-financial performance, especially in sustainability criteria. For this purpose, multicriteria decision methods are especially suited to evaluate efficiency and to make a stable ranking of the most outstanding banks in the Spanish financial system. However, we are aware of the difficulties involved due to the inherent uncertainty and subjectivity of this process. For this reason, the use of fuzzy models is proposed, especially intuitionistic fuzzy numbers combined with the Analytic Hierarchy Process and the TOPSIS. The combination of financial criteria based on the CAMELS rating system with non-financial sustainability criteria makes it possible to order the Spanish banking system based on global efficiency. The most relevant contributions are: first, the use of intuitionistic fuzzy numbers in the performance evaluation process, whereby the quality of the information available can be quantified; and the most important one, a simplification of the process in the implementation of the intuitionistic fuzzy TOPSIS. Finally, through a sensibility analysis, it is possible to isolate the relevance of the sustainability process to obtain the global performance evaluation.

Keywords Fuzzy sets · Intuitionistic fuzzy numbers · Performance · Banks

1 Introduccion

Financial and non-financial performance is central to the survival of businesses. This is especially true of the European banking sector, which is characterized by a low interest-rate and reduced net income margins, which will be maintained while the European Central Bank maintains a low interest-rate policy.

As financial accounts do not quite meet the needs of shareholders, additional means of financial reporting have been established, such as intellectual capital statements, value reporting, and sustainability reports (Wulf et al. 2014). However, there is a notable absence of sustainable discourse, which could be a tool for enhancing performance. The resource-based perspective of firms suggests that they attain a higher performance when they disclose financial and non-financial resources (Buallay 2019). These resources help firms develop capabilities and competencies that are essential for achieving a sustainable competitive advantage (Gaur et al. 2011). Banks are particularly interested in ESG disclosure (Nizam et al. 2019), and serving social needs as a means of building a strong local base for a future sustainable business. According to Nobanee and Hellili (2016), the compliance of banks with the best practices of sustainability disclosure and the integration of environmental and ecological dimensions in their annual reports indicate their assurance of increasing transparency and reducing information asymmetry and costs related to debt financing.

A new trend in the evaluation of banking performance is related to the use of multicriteria decision-making (MCDM) methods, such as the analytic hierarchy process (AHP) and the technique for order of preference by similarity to ideal solution (TOPSIS) for criteria weighting and efficiency ranking, respectively (Hemmati et al. 2013). There are many AHP and TOPSIS-based studies on performance evaluation in banking, but even so, there are fewer based on other methods.

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Over the last few years, the AHP, developed by Saaty (1980), has become one of the most widely used MCDM tools in the resolution of complex decision-making problems. 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 (Tavana et al. 2016). However, this limitation disappears when fuzzy logic is incorporated into the AHP methodology. The combination of fuzzy logic with AHP is called Fuzzy AHP, and it represents a systematic approach to selecting alternatives and solving problems using fuzzy set theory to express the uncertain comparison of opinions.

Several authors have proposed this methodology, such as Van Laarhoven and Pedrcyz (1983) and Buckley (1985). They derive fuzzy priorities, and after the aggregation process, the final scores of the alternatives are also represented as fuzzy numbers or fuzzy sets. In contrast, Chang (1996) and Mikhailov and Tsvetinov (2004) derive crisp priorities from fuzzy comparison judgments. Sometimes, DMs do not clearly indicate the extent to which one alternative is better than the others (Herrera-Viedma et al. 2007), or they are unable to express their preferences accurately because of the lack of knowledge about the alternatives (Mitchell 2004).

It is possible that DMs are not sure about providing preferences from among the alternatives or providing an accurate and reliable degree of preference (Deschrijver and Kerre 2003). An Intuitionistic Fuzzy Set (IFS) is an extension of a fuzzy set, characterized by a membership function, a non-membership function, and a hesitancy function, and it is especially useful for solving this problem (Yu et al. 2018). The first research in this area was developed by Atanassov (1986).

On the other hand, intuitionistic AHP is an extension of the FAHP, which combines IFS and AHP. This methodology is applicable to a wide range of fields such as: environmental decision-making (Sadiq and Tesfamariam 2009), selection of vendor (Kaur 2014), ship system risk estimation (Nguyen 2016), determination of the balance scorecard, sheet metal industry (Rajaprakash and Ponnusamy 2017), the ranking of risk factors in transnational public–private partnership projects (Yu et al. 2018), and selecting hazardous waste carriers (Buyukozkan et al. 2019).

In order to evaluate the performance of Spanish Banks, a financial and non-financial indicator system is proposed. Financial indicators are usually classified into categories, since accounting experts claim that financial instruments within a cluster are partially similar (Wang 2014). 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 (Wanke et al. 2016b).

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 (1995), DeYoung (1998), Oshinsky and Olin (2006), Ravi-Kumar and Ravi (2007), Poghosyan and Cihák (2011), Ravisankar et al. (2010), Wanke et al. (2016a). 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 (Jin et al. 2011), the financial indicators from previous studies and those used in different applications are applied.

This study improves on previous studies by using non-financial indicators (CAMELS-ESG), particularly Environmental, Social and Governance (ESG) ratios, which permit the evaluation of banking policies related to corporate social responsibility (CSR). The main objective of this paper is to simplify processes, increase efficiency and improve the sensitivity of results in the bank ranking process.

In addition to the proposed model, based on a combination of the IFAHP and the IFTOPSIS to establish the ranking of banks according to the expanded CAMELS rating system (CAMELS-ESG), a new IFTOPSIS resolution methodology is developed. This methodology considers the application of the possibilistic theory, which simplifies the operation in contrast to other separate measures such as 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 Theoretical foundations of intuitionistic fuzzy sets

Since Zadeh (1965) proposed fuzzy set theory, it has been widely used in several research fields. Later, Atanassov (1986) generalized fuzzy sets and introduced the concept of the intuitionistic fuzzy set.

Definition 1 Let X be a non-empty set, the intuitionistic fuzzy set $\tilde{A}$ is expressed as (Atanassov 1986):

$$\tilde{A} = \left\{ \left\{ x, \mu_{\tilde{A}}(x), v_{\tilde{A}}(x) \right\} | x \in \mathbf{X} \right\}$$

In set $\mu_{\tilde{A}}(x)$ and $v_{\tilde{A}}(x)$ are the degree of membership and the degree of non-membership of element x to $\tilde{A}$, respectively. That is:

$\mu_{\tilde{A}} : X \to [0, 1], x \in X \to \mu_{\tilde{A}}(x) \in [0, 1]$

$v_{\tilde{A}} : X \to [0, 1], x \in X \to v_{\tilde{A}}(x) \in [0, 1]$

Which satisfies the condition:

$\pi_{\tilde{A}}(x) = 1 - \mu_{\tilde{A}}(x) - v_{\tilde{A}}(x), x \in X$

where $\pi_{\tilde{A}}(x)$ is the hesitancy degree or uncertainty degree of element x that belongs to $\tilde{A}$ in X. Logically:

$0 \leq \pi_{\tilde{A}}(x) \leq 1, x \in X$

In the case of the intuitionistic fuzzy sets, the presence of the second functional component, namely function $v_{\tilde{A}}$, gives rise to different possibilities for the definition of a norm (in the sense of a pseudo-norm) over the subsets and the elements of a given universe X (Szmidt 2014).

Definition 2 (*Atanassov* 1994) For every $x \in X$ with respect to a fixed set $A \subset X$, the first norm is defined as.

$$\sigma_{1,\tilde{A}}(x) = \mu_{\tilde{A}}(x) + v_{\tilde{A}}(x)$$

It represents a degree of *definiteness* of the element x.

Definition 3 (*Atanassov* 1994). For every $x \in X$ with respect to a fixed set $A \subset X$, the second norm is defined as.

$$\sigma_{2,\tilde{A}}(x) = \sqrt{\left(\mu_{\tilde{A}}(x)^2 + v_{\tilde{A}}(x)^2\right)}$$

The norms σ_1 and σ_2 are analogous to the basic classical types of norms.

Definition 4 (*Tanev* 1995). For every $x \in X$ with respect to a fixed set $A \subset X$, the third norm is defined as.

$$\sigma_{3,\tilde{A}}(x) = \frac{\mu_{\tilde{A}}(x) + 1 - v_{\tilde{A}}(x)}{2}$$

The properties of σ_3 are similar to the properties of the first norm σ_1, and the second one, σ_2.

Definition 5 According to Li (2010), a Triangular Intuitionistic Fuzzy Number (TIFN) is an IFS in $\tilde{A} = ((\underline{a}, a, \overline{a}); w_{\tilde{A}}, u_{\tilde{A}})$ the set of real numbers $\mathbb{R}$ where the membership function and the non-membership function are defined as:

$$\mu_{\tilde{A}}(x) = \begin{cases} \dfrac{x - \underline{a}}{a - \underline{a}} w_{\tilde{A}}, & \text{if } \underline{a} \leq x < a \\ w_{\tilde{A}}, & \text{if } x = a \\ \dfrac{\overline{a} - x}{\overline{a} - a} w_{\tilde{A}}, & \text{if } a < x \leq \overline{a} \\ 0, & \text{if } x < a \text{ or } x > \overline{a} \end{cases} \tag{1}$$

$$v_{\tilde{A}}(x) = \begin{cases} \dfrac{a - x + (x - \underline{a}) u_{\tilde{A}}}{a - \underline{a}}, & \text{if } \underline{a} \leq x < a \\ u_{\tilde{A}}, & \text{if } x = a \\ \dfrac{x - a + (\overline{a} - x) u_{\tilde{A}}}{\overline{a} - a}, & \text{if } a < x \leq \overline{a} \\ 1, & \text{if } x < a \text{ or } x > \overline{a} \end{cases} \tag{2}$$

Values $w_{\tilde{A}}$ and $u_{\tilde{A}}$ are the maximum degree of the membership function and the minimum degree of the non-membership function, so that they fulfill the following conditions:

$0 \leq w_{\tilde{A}} \leq 1,\ 0 \leq u_{\tilde{A}} \leq 1,\ 0 \leq w_{\tilde{A}} + u_{\tilde{A}} \leq 1$

A TIFN $\tilde{A}$ represents an unknown value "approximately equal to a", and it is expressed using any value between $\underline{a}$ and $\overline{a}$ with several degrees of membership and non-membership: a being the value with the highest possibility, with a degree of membership $w_{\tilde{A}}$ and a degree of non-belonging $u_{\tilde{A}}$. The pessimist value is $\underline{a}$, with a degree of membership 0 and a degree of non-membership 1. The optimistic value is $\overline{a}$, with a degree of membership 0 and non-membership 1. Other values $x \in (\underline{a}, \overline{a})$ have the membership function $\mu_{\tilde{A}}(x)$ and non-membership function $v_{\tilde{A}}(x)$ (Li 2010).

According to the TIFN definition, it is easy to observe that a TIFN is a generalization of a Triangular Fuzzy Number (TFN). If $w_{\tilde{A}} = 1$ and $u_{\tilde{A}} = 0$, then TIFN $\tilde{A}$ becomes a TFN (Dubois and Prade 1980). A TIFN can express more uncertainty than a TFN (Nan et al. 2010).

Definition 6 Let $\tilde{A} = ((\underline{a}, a, \overline{a});\ w_{\tilde{A}}, u_{\tilde{A}})$ and $\tilde{B} = ((\underline{b}, b, \overline{b});\ w_{\tilde{B}}, u_{\tilde{B}})$ be two TIFNs and λ a real number, then:

$$\tilde{A} + \tilde{B} = \left((\underline{a} + \underline{b}, a + b,\ \overline{a} + \overline{b}); \min\left[w_{\tilde{A}}, w_{\tilde{B}}\right], \max\left[u_{\tilde{A}}, u_{\tilde{B}}\right]\right) \tag{3}$$

$$\tilde{A} - \tilde{B} = \left((\underline{a} - \overline{b}, a - b,\ \overline{a} - \underline{b}); \min\left[w_{\tilde{A}}, w_{\tilde{B}}\right], \max\left[u_{\tilde{A}}, u_{\tilde{B}}\right]\right) \tag{4}$$

$$\tilde{A}\times\tilde{B}=\begin{cases}\left(\left(\underline{a}\times\underline{b},\ a\times b,\ \overline{a}\times\overline{b}\right);\ \min\left[w_{\tilde{A}},w_{\tilde{B}}\right],\max\left[u_{\tilde{A}},u_{\tilde{B}}\right]\right) \text{ if } \tilde{A}>0 \text{ and } \tilde{B}>0\\ \left(\left(\underline{a}\times\overline{b},\ a\times b,\ \overline{a}\times\underline{b}\right);\ \min\left[w_{\tilde{A}},w_{\tilde{B}}\right],\max\left[u_{\tilde{A}},u_{\tilde{B}}\right]\right) \text{ if } \tilde{A}<0 \text{ and } \tilde{B}>0\\ \left(\left(\overline{a}\times\overline{b},\ a\times b,\ \underline{a}\times\underline{b}\right);\ \min\left[w_{\tilde{A}},w_{\tilde{B}}\right],\max\left[u_{\tilde{A}},u_{\tilde{B}}\right]\right) \text{ if } \tilde{A}<0 \text{ and } \tilde{B}<0\end{cases} \tag{5}$$

$$\frac{\tilde{A}}{\tilde{B}}=\begin{cases}\left(\left(\frac{\underline{a}}{\overline{b}},\frac{a}{b},\frac{\overline{a}}{\underline{b}}\right);\min\left[w_{\tilde{A}},w_{\tilde{B}}\right],\max\left[u_{\tilde{A}},u_{\tilde{B}}\right]\right) \text{ if } \tilde{A}>0 \text{ and } \tilde{B}>0\\ \left(\left(\frac{\overline{a}}{\overline{b}},\frac{a}{b},\frac{\underline{a}}{\underline{b}}\right);\min\left[w_{\tilde{A}},w_{\tilde{B}}\right],\max\left[u_{\tilde{A}},u_{\tilde{B}}\right]\right) \text{ if } \tilde{A}<0 \text{ and } \tilde{B}>0\\ \left(\left(\frac{\overline{a}}{\underline{b}},\frac{a}{b},\frac{\underline{a}}{\overline{b}}\right);\min\left[w_{\tilde{A}},w_{\tilde{B}}\right],\max\left[u_{\tilde{A}},u_{\tilde{B}}\right]\right) \text{ if } \tilde{A}<0 \text{ and } \tilde{B}<0\end{cases} \tag{6}$$

$$\lambda\tilde{A}=\begin{cases}\left(\left(\lambda\underline{a},\ \lambda a,\ \lambda\overline{a}\right);\ w_{\tilde{A}},\ u_{\tilde{A}}\right) \text{ if } \lambda>0\\ \left(\left(\lambda\overline{a},\ \lambda a,\ \lambda\underline{a}\right);\ w_{\tilde{A}},\ u_{\tilde{A}}\right) \text{ if } \lambda<0\end{cases} \tag{7}$$

$$\tilde{A}^{-1}=\left(\left(\frac{1}{\overline{a}},\frac{1}{a},\frac{1}{\underline{a}}\right);\ w_{\tilde{A}},u_{\tilde{A}}\right) \tag{8}$$

As can be observed, the result of the multiplication and division of two TIFNs is not another TIFN, but these TIFNs are often used to express the approximate result of these operations.

Definition 7 For a TIFN $\tilde{A}=\left(\left(\underline{a},\ a,\ \overline{a}\right);\ w_{\tilde{A}},\ u_{\tilde{A}}\right)$, the possibility mean $M\left(\tilde{A}\right)$ is given by (Wan et al. 2013a):

$$M\left(\tilde{A}\right)=\frac{M_{\mu}\left(\tilde{A}\right)+M_{\nu}\left(\tilde{A}\right)}{2} \tag{9}$$

where $M_{\mu}\left(\tilde{A}\right)$ is the possibility mean of the membership function, and $M_{\nu}\left(\tilde{A}\right)$ is the possibility mean of the non-membership function:

$$M_{\mu}\left(\tilde{A}\right)=\frac{1}{6}\left(\underline{a}+4a+\overline{a}\right)w_{\tilde{A}} \tag{10}$$

$$M_{\nu}\left(\tilde{A}\right)=\frac{1}{6}\left(\underline{a}+4a+\overline{a}\right)\left(1-u_{\tilde{A}}\right) \tag{11}$$

Definition 8 For a TIFN $\tilde{A}=\left(\left(\underline{a},\ a,\ \overline{a}\right);\ w_{\tilde{A}},\ u_{\tilde{A}}\right)$, the possibility variance $V\left(\tilde{A}\right)$ is given by (Wan et al. 2013a):

$$V(\tilde{A})=\frac{V_{\mu}(\tilde{A})+V_{\nu}(\tilde{A})}{2} \tag{12}$$

where $V_{\mu}\left(\tilde{A}\right)$ is the possibility variance of the membership function, and $V_{\nu}\left(\tilde{A}\right)$ is the possibility variance of the non-membership function:

$$V_{\mu}\left(\tilde{A}\right)=\frac{1}{24}\left(\underline{a}-\overline{a}\right)^{2}w_{\tilde{A}} \tag{13}$$

$$V_{\nu}\left(\tilde{A}\right)=\frac{1}{24}\left(\underline{a}-\overline{a}\right)^{2}\left(1-u_{\tilde{A}}\right) \tag{14}$$

Definition 9 For a TIFN $\tilde{A}=\left(\left(\underline{a},a,\overline{a}\right);w_{\tilde{A}},u_{\tilde{A}}\right)$, the possibility standard deviation $D(\tilde{A})$ is given by (Wan et al. 2013a):

$$D\left(\tilde{A}\right)=\frac{D_{\mu}\left(\tilde{A}\right)+D_{\nu}\left(\tilde{A}\right)}{2} \tag{15}$$

where $D_{\mu}\left(\tilde{A}\right)$ is the possibility standard deviation of the membership function, and $D_{\nu}\left(\tilde{A}\right)$ is the possibility standard deviation of the non-membership function:

$$D_{\mu}\left(\tilde{A}\right)=\left(\underline{a}-\overline{a}\right)\sqrt{\frac{w_{\tilde{A}}}{24}} \tag{16}$$

$$D_{\nu}\left(\tilde{A}\right)=\left(\underline{a}-\overline{a}\right)\sqrt{\frac{\left(1-u_{\tilde{A}}\right)}{24}} \tag{17}$$

Definition 10 Let $\tilde{A}=\left(\left(\underline{a},\ a,\ \overline{a}\right);\ w_{\tilde{A}},\ u_{\tilde{A}}\right)$ and $\tilde{B}=\left(\left(\underline{b},\ b,\ \overline{b}\right);\ w_{\tilde{B}},\ u_{\tilde{B}}\right)$ be two TIFNs, the Hamming distance (Wan et al. 2013b) is:

$$d_h\left(\tilde{A},\tilde{B}\right)=\frac{1}{3}\left(\left|\underline{a}-\underline{b}\right|+\left|a-b\right|+\left|\overline{a}-\overline{b}\right|\right)+\max\left(\left|w_{\tilde{A}}-w_{\tilde{B}}\right|,\left|u_{\tilde{A}}-u_{\tilde{B}}\right|\right) \tag{18}$$

3 Intuitionistic fuzzy analitic hierarchy process (IFAHP)

The IFAHP is an extended version of the AHP and Fuzzy AHP methods. This methodology is commonly used to solve complex MCDM problems (Xu and Liao 2014). In recent years, the AHP developed by Saaty (1980) 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 judgements are based on the 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, the DMs' personal viewpoints can profoundly affect the final results (Chai et al. 2013).

The uncertainty arising from subjectivity and the imprecision from the evaluation process renders the conventional AHP an inappropriate tool in situations involving vagueness in linguistic assessment (Tavana et al. 2016). However, this limitation disappears by incorporating fuzzy logic into the AHP methodology, thus giving rise to the FAHP.

The FAHP has been suggested by various authors (van Laarhoven and Pedrycz 1983; Buckley 1985; Chang 1996; Mikhailov 2003). It represents a systematic approach to selecting alternatives and solving problems using fuzzy set theory to express the uncertain comparison of opinions through fuzzy numbers and the AHP method. Van Laarhoven and Pedrcyz (1983) and Buckley (1985) derive fuzzy priorities and, after aggregation, the final scores of the alternatives are also represented as fuzzy numbers or fuzzy sets. Unlike Chang (1996), Mikhailov (2003) derives crisp priorities from fuzzy comparison judgments.

The IFAHP improves the FAHP method by combining the advantages of the AHP method with the IFS. This method can be used to solve more complex problems, where DMs may have problems showing their preferences between alternatives (Xu and Liao 2014).

Step 1 Representation of expert opinions. In order to decide the preference of category i over j, each expert selects an element according to the semantic correspondence shown in Table 1 (Xu and Liao 2014; Yu et al. 2018). In this way, there are K opinions on each pair of elements to be compared. The opinion of the kth expert is represented by $\tilde{a}_{ijk} = \left(\mu_{\tilde{a}_{ijk}}, v_{\tilde{a}_{ijk}}\right)$ and indicates the relative preference of category i over j assigned by the expert k, $k = 1,\ldots,K$

Step 2 Aggregation of expert priorities: intuitionistic fuzzy ordered weighted average (IFOWA) is used.

Definition 11 (*Grabisch et al.* 2009). An aggregation function in R^n is a function $F^{(n)}: R^n \to R$ that (a) is non-decreasing (in each variable) and (b) fulfills the boundary conditions: $\inf_{x \in R^n} R^{(n)}(x) = \inf R$ and $\sup_{x \in R^n} R^{(n)}(x) = \sup R$.

The information provided by the experts can be aggregated according to the arithmetic mean

$$\tilde{r}_{ij} = \left(\frac{1}{K}\sum_{k=1}^{K}\mu_{\tilde{a}_{ijk}}, \frac{1}{K}\sum_{k=1}^{K}v_{\tilde{a}_{ijk}}\right), k = 1, \ldots, K \tag{19}$$

Definition 12 (*Yager* 1993, 1996): An ordered weighted average (OWA) is defined as a mapping of dimension n, $F: R^n \to R$ that has an associated weighting vector W of dimension n, $W^T = [w_1, w_2, \ldots w_n]$, such that $w_j \in [0, 1]$ and $\sum_{j=1}^{n} w_j = 1$, with.

$$f(a_1, a_2, \ldots, a_n) = \sum_{j=1}^{n} w_j \cdot b_j \tag{20}$$

where b_j is the jth largest of a_i.

Table 1 Intuitionistic preference matrix for categories

Scale	Linguistic scales
0.1	Extremely not preferred
0.2	Very strongly not preferred
0.3	Strongly not preferred
0.4	Moderately not preferred
0.5	Equally preferred
0.6	Moderately preferred
0.7	Strongly preferred
0.8	Very strongly preferred
0.9	Extremely preferred
Other values between 0 and 1	Intermediate values used to present compromise

Definition 13 (*Xu* 2006). Let $\tilde{a}_i = (\mu_i,\ v_i)(i = 1,\ 2, \ldots,\ n)$ be a collection of IFNs, an intuitionistic fuzzy ordered weighted average (IFOWA) operator of the OWA operator is a mapping of dimension n, IFOWA : $\Omega^n \rightarrow \Omega$ that has an associated weighting vector W of dimension n, $W^T = [w_1,\ w_2, \ldots w_n]$, such that $w_j \in [0,1]$ and $\sum_{j=1}^{n} w_j = 1$, with

$$\mathrm{IFOWA}(\tilde{a}_1, \tilde{a}_2, \ldots, \tilde{a}_n) = \sum_{j=1}^{n} \omega_j \beta_j = \left(1 - \prod_{j=1}^{n} (1 - \mu_j)^{\omega_j}, \prod_{j=1}^{n} v_j^{\omega_j}\right) \tag{21}$$

where $\tilde{a}_i$ is an intuitionistic fuzzy number, and β_j is the jth largest of $\tilde{a}_i$.

The information provided by the experts is aggregated according to the previous aggregation functions.

Step 3 Priority calculation. In this case, the linear programming model called Optima Priority Optimization (OPO) developed by Liao et al. (2018) has been chosen. This model allows the generation of exact priorities from the matrix of intuitionistic fuzzy preference relations (IFPR), which can be used in any software to quantify the consistency of each IFPR (Liao et al. 2018).

Definition 14 Let $\widetilde{R}$ be a consistent IFPR matrix, $\tilde{R} = (\tilde{r}_{ij})_{nxn},\ \tilde{r}_{ij} = (\mu_{ij}, v_{ij}),\ i,j = 1, \ldots n$

Then, there is a vector $\omega = (\omega_1,\ \omega_2, \ldots,\ \omega_n)^T$, such that

$$\mu_{ij} \le \frac{\omega_i}{\omega_i + \omega_j} \le 1 - v_{ij},\ i,\ j = 1,\ 2, \ldots n \tag{22}$$

where

$$\omega_i \ge 0,\ i = 1, 2, \ldots n$$

$$\sum_{i=1}^{n} \omega_i = 1$$

To obtain the priority vector $\omega = (\omega_1,\ \omega_2, \ldots,\ \omega_n)^T$, the OPO model is applied (Liao et al. 2018).

$$\text{Max } \tau$$

$$s.t.\begin{cases} 1 - \dfrac{P_l\omega}{t_l} \ge \tau,\ l = 1, 2, \ldots, m\ m = n(n-1) \\ 0 \le \omega_i \le 1,\ i = 1, 2, \ldots, n \\ \sum_{i=1}^{n} \omega_i = 1 \end{cases} \tag{23}$$

where

$$P\omega = \begin{cases} (\mu_{ij} - 1)\omega_i + \mu_{ij}\omega_j \le 0,\ i = 1, 2, \ldots, n j = 1, 2, \ldots, n-1 \\ v_{ij}\omega_i + (v_{ij} - 1)\omega_j \le 0,\ i = 1, 2, \ldots, n j = 1, 2, \ldots, n-1 \end{cases} \tag{24}$$

$P_l\omega$ represents the *lth* file of expression (24), τ is the value of the objective function which measures the degree of satisfaction of the fuzzy constraint, and t_1 is a parameter given by the DMs, showing the approximate satisfaction of inequality $P_l\omega \lesssim 0,\ l = 1, 2, \ldots m$.

The optimal value of the objective function $\tau*$ shows the maximum degree of satisfaction of the fuzzy constrains. This value can be used as an indicator of the inconsistency of the DMs' opinions. If IFPR is consistent, $\tau*$ should be close to 1, whereas if IFPR is inconsistent, IFPR should change between zero and one, depending on the degree of inconsistency and the value t_1 given by the DMs. Without loss of generality, the parameter can be configured to be equal to one if the DMs do not have preferences about the pairwise assessments (Mikhailov and Singh 2003).

Step 4 Consistency checking. In pairwise comparisons, consistency checking cannot be ignored because inconsistent preference relations can generate misleading results. To obtain a lower value of τ than the required value one, the experts should be asked again in order to repair the inconsistency of the preferences until an unacceptable τ is obtained. However, it is possible that the experts refuse to be re-checked. For this reason, the inconsistency must be repaired automatically, and the following algorithm is proposed (Xu and Liao 2014).

For $k > i + 1$, let $\tilde{r}_{ik} = (\tilde{\mu}_{ik}, \tilde{v}_{ik})$ where

$$\tilde{\mu}_{ik} = \frac{\sqrt[k-i-1]{\prod_{t=1+i}^{k-1} \mu_{it}\mu_{tk}}}{\sqrt[k-i-1]{\prod_{t=1+i}^{k-1} \mu_{it}\mu_{tk}} + \sqrt[k-i-1]{\prod_{t=i+1}^{k-1} (1-\mu_{it})(1-\mu_{tk})}},\ k > i + 1$$

$$\tilde{v}_{ik} = \frac{\sqrt[k-i-1]{\prod_{t=1+i}^{k-1} v_{it}v_{tk}}}{\sqrt[k-i-1]{\prod_{t=1+i}^{k-1} v_{it}v_{tk}} + \sqrt[k-i-1]{\prod_{t=i+1}^{k-1} (1-v_{it})(1-v_{tk})}},\ k > i + 1$$

For $k = i + 1$, let $\tilde{r}_{ik} = r_{ik}$.

For $k < i + 1$, let $\tilde{r}_{ik} = (\tilde{\mu}_{ik}, \tilde{v}_{ik})$.

Step 4: The repaired IFPR is obtained as $\tilde{R} = (\tilde{r}_{ik})_{mxm}$ where:

$$\tilde{\mu}_{ik} = \frac{(\mu_{ik})^{1-\sigma}(\overline{\mu})^{\sigma}}{(\mu_{ik})^{1-\sigma}(\overline{\mu})^{\sigma} + (1-\mu_{ik})^{1-\sigma}(1-\overline{\mu})^{\sigma}},\ i,k = 1, 2, \ldots, n$$

$$\tilde{v}_{ik} = \frac{(v_{ik})^{1-\sigma}(\overline{v})^{\sigma}}{(v_{ik})^{1-\sigma}(\overline{v})^{\sigma} + (1-v_{ik})^{1-\sigma}(1-\overline{v})^{\sigma}},\ i,k = 1, 2, \ldots, n$$

For the sake of consistency, $\sigma = 1$ is assumed.

Step 5 Global priority vector. In the practical case, the optimal priority vector for categories is given by

$$\omega^* = (\omega_1^*, \omega_2^*, .., \omega_N^*)^T \tag{25}$$

In this study, the weights that each indicator has in each category will be determined from the following formulation:

$$\omega_j^* = \left(\omega_{j1}^*, ..., \omega_{jH_i}^*\right)^T, j = C, A, M, E, L, S, ESG \tag{26}$$

where ω_{jh}^* is the weight of indicator h in category j, with $h = 1, ..., H_j$ and H_j is the total number of indicators belonging to category j, being $\sum_{h=1}^{H_j} \omega_{jh}^* = 1$. To do this, the procedure described is repeated for each of the seven categories of the indicators considered.

The global weight of indicator h in category j ($\overline{\omega}_{jh}$) is obtained by multiplying the weight calculated for each category in (25) (ω_j^*) by the weight corresponding to indicator h in category j (ω_{jh}^*) obtained in (26) with $h = 1, ..., H_j$. From this aggregation, we can obtain a matrix that represents all the weights. In a simplified way, it could be represented as,

$$\overline{\omega}^* = (\overline{\omega}_1^*, ..., \overline{\omega}_N^*)^T$$

where $\sum_{n=1}^{N} \overline{\omega}_n^* = 1$

In this way, the matrix corresponding to the weights of each subcategory is obtained, where N refers to the total number of criteria used (indicators).

4 Ranking alternatives based on intuitionistic fuzzy TOPSIS

The intuitionistic fuzzy TOPSIS is an extension of the fuzzy TOPSIS method (Liang 1999; Miyamoto 2003; Wang et al. 2003), which was first developed by Chen and Tsao (2008). The following algorithm of the intuitionistic fuzzy TOPSIS method is proposed in order to perform a commercial bank ranking from the performance evaluation of the financial and non-financial indicators.

Step 1 The set of crisp variables represented by c_{qst} are quantified, where, $q = 1, 2, ..., Q$ (criteria),$s = 1, 2, ..., S$ (alternative), and $t = 1, 2, ..., T$ (years).

Step 2 Construction of the order matrix $\tilde{R} = (\tilde{r}_{qs})$ whose elements are TIFN:

$$\tilde{r}_{qs} = \left(\left(\underline{r}_{qs}, r_{qs}, \overline{r}_{qs}\right);\ w_{\tilde{r}_q}, u_{\tilde{r}_q}\right) = \left(\left(\min_t c_{qst}, \frac{1}{t}\sum_t c_{qst}, \max_t c_{qst}\right); w_{\tilde{r}_q}, u_{\tilde{r}_q}\right) \tag{27}$$

Step 3 Decision matrix $\tilde{N} = (\tilde{n}_{qs})$ is normalized by using this equation (Chen and Li 2011; Wan and Xu 2017):

$$\begin{aligned} \tilde{n}_{qs} &= \left(\left(\frac{\underline{r}_{qs}}{r_q^+}, \frac{r_{qs}}{r_q^+}, \frac{\overline{r}_{qs}}{r_q^+}\right); w_{\tilde{n}_q}, u_{\tilde{n}_q}\right), q \in B \\ \tilde{n}_{qs} &= \left(\left(\frac{r_q^-}{\overline{r}_{qs}}, \frac{r_q^-}{r_{qs}}, \frac{r_q^-}{\underline{r}_{qs}}\right); w_{\tilde{n}_q}, u_{\tilde{n}_q}\right), q \in C \end{aligned} \tag{28}$$

where $r_q^+ = \max_s(\overline{r}_{qs})$, $r_q^- = \min_s(\underline{r}_{qs})$, $w_{\tilde{n}_q} = w_{\tilde{r}_q}$ y $u_{\tilde{n}_q} = u_{\tilde{r}_q}$. B and C are the revenue and the cost of the criteria set, respectively.

Step 4 Weighted normalized fuzzy decision matrix $\tilde{P} = (\tilde{p}_{qs})$ from the matrix ω and from the weights defined in (23).

$$\tilde{p}_{qs} = \omega_q * \tilde{n}_{qs} \tag{29}$$

Applying (29) in expression (7)

$$\tilde{p}_{qs} = \left(\left(\omega_q\, \underline{n}_{qs},\ \omega_q\, n_{qs},\ \omega_q\, \overline{n}_{qs}\right);\ w_{\tilde{n}_q},\ u_{\tilde{n}_q}\right) = \left(\left(\underline{p}_{qs},\ p_{qs},\ \overline{p}_{qs}\right);\ w_{\tilde{p}_q},\ u_{\tilde{p}_q}\right) \tag{30}$$

Step 5 Calculate the triangular intuitionistic fuzzy positive ideal solution γ^+ and the triangular intuitionistic fuzzy anti-ideal solution γ^- of the Q criteria. According to the weighted normalized fuzzy decision matrix $\tilde{P} = (\tilde{p}_{qs})$, we know that $\gamma^+ = ((1,\ 1,\ 1);\ 1,\ 0)$ is the highest TIFN, and $\gamma^- = ((0, 0, 0); 0, 1)$ is the lowest TIFN (Chen and Li 2011). According to (Wan and Xu 2017):

1. Since $\tilde{P}$ is a normalized decision matrix, it is easy to define γ^+ as the largest TIFN and γ^- as the smallest TIFN.
2. γ^+ and γ^- can be regarded as a unified bound for all individual decision matrices.

Step 6 The separation (d_i^- and d_i^+) from each alternative ($\tilde{p}_{qs}$) to γ^- and γ^+ is computed. Lastly, several authors, such as Chen and Li (2011), Wan et al. (2013b), Wan and Dong (2014) and Wan and Xu (2017), have proposed several distance measures between two TIFNs, basically based on the Haudorff metric proposed by Grzegorzewski (2004). A novel methodology to compute the separation between two TIFNs is proposed based on the possibilistic measure denominated Magnitude (Mag). The operator Magnitude (Mag) is obtained for $\tilde{p}_{qs}$ with respect to the anti-ideal solution γ^- and the ideal solution γ^+ for each Q criteria.

For the TIFNs, $\tilde{p}_{qs}$ is defined as

$$\mathrm{Mag}(\tilde{p}_{qs}) = M(\tilde{p}_{qs}) + D(\tilde{p}_{qs}) \tag{31}$$

where $M(\tilde{p}_{qs})$ is the possibilistic mean value, and $D(\tilde{p}_{qs})$ is the degree of deviation.

For a fuzzy number $(\tilde{A})$, the bigger the mean and the standard deviation are, the bigger the fuzzy number $(\tilde{A})$ is; furthermore, $D(\tilde{A})$ has the same dimension as $M(\tilde{A})$. Obviously, the magnitude of a generalized fuzzy number $\tilde{A}$, which is defined by (31), is synthetically reasonable. The resulting scalar value is used to rank the fuzzy numbers. The fuzzy number will be greater as Mag(*) grows greater (Gu and Xuan 2017).

According to expressions (9), (10) and (11), $M(\tilde{p}_{qs})$ for the TIFN $\tilde{p}_{qs} = \left(\left(\underline{p}_{qs}, p_{qs}, \overline{p}_{qs}\right);\ w_{\tilde{p}_q}, u_{\tilde{p}_q}\right)$ is

$$M(\tilde{p}_{qs}) = \frac{1}{12}\left(\underline{p}_{qs} + 4p_{qs} + \overline{p}_{qs}\right)\left(1 - u_{\tilde{p}_q} + w_{\tilde{p}_q}\right) \tag{32}$$

According to expressions (15), (16) and (17), the $D(\tilde{p}_{qs})$ for the TIFN $\tilde{p}_{qs} = \left(\left(\underline{p}_{qs}, p_{qs}, \overline{p}_{qs}\right); w_{\tilde{p}_q}, u_{\tilde{p}_q}\right)$ is

$$D\tilde{p}_{qs} = \frac{\left(\overline{p}_{qs} - \underline{p}_{qs}\right)}{2\sqrt{24}}\left(\sqrt{w_{\tilde{p}_q}} + \sqrt{1 - u_{\tilde{p}_q}}\right) \tag{33}$$

We can obtain the Magnitude (Mag) operation for $\tilde{p}_{qs}$, anti-ideal solution γ^-, and ideal solution γ^+ of the Q criteria. From expressions (32) and (33),

$$\mathrm{Mag}(\tilde{p}_{qs}) = \left(\frac{1}{12}\left(\underline{p}_{qs} + 4p_{qs} + \overline{p}_{qs}\right)\left(1 - u_{\tilde{p}_q} + w_{\tilde{p}_q}\right) + \frac{\left(\overline{p}_{qs} - \underline{p}_{qs}\right)}{2\sqrt{24}}\left(\sqrt{w_{\tilde{p}_q}} + \sqrt{1 - u_{\tilde{p}_q}}\right)\right) \tag{34}$$

The separation d_i^- and d_i^+ of each alternative from d_i^+ $\tilde{p}_{qs}$ to anti-ideal solution γ^- and ideal solution γ^+ is computed from the difference operator between Magnitudes (Mag). From (34),

$$d_i^- = \sum_q \left(\mathrm{Mag}(\tilde{p}_{qs}) - \mathrm{Mag}(\gamma^-)\right) \tag{35}$$

$$d_i^+ = \sum_q \left(\mathrm{Mag}(\gamma^+) - \mathrm{Mag}(\tilde{p}_{qs})\right) \tag{36}$$

Step 7 Closeness coefficient CC_s of each alternative s and final rank. From expressions (35) and (36), the closeness coefficient CC_s is defined as:

$$\mathrm{CC}_s = \frac{d_i^-}{d_i^- + d_i^+} \tag{37}$$

For $s = 1, 2, \ldots, S$, obviously $0 \le \mathrm{CC}_s \le 1$. The $\mathrm{CC}_s = 1$ alternative s is the ideal solution. Conversely, if $\mathrm{CC}_s = 0$, it denotes that alternative s is the anti-ideal solution. Therefore, we rank alternatives according to closeness coefficients of alternatives, and then the best alternative is determined.

5 Evaluation perfomance of Spanish commercial banks

Next, we are going to quantify the performance of the six main Spanish commercial Banks in the Ibex-35 index for the period 2015–2017 (Table 2). In this process, financial and non-financial criteria are considered using the expanded CAMELS-ESG rating system to quantify the efficiency of the model, since it introduces non-financial criteria (Sustainability, ESG).

5.1 Identifying the relevant criteria for evaluation

Table 3 shows the selected indicators classified according to the expanded CAMELS-ESG rating system, where the general objective is to evaluate the performance of the six Spanish commercial banks. It is structured into 26 indicators classified into seven categories: five capital adequacy indicators (C), four asset quality indicators (A), three management efficiency indicators (M), five earnings indicators (E), three liquidity indicators (L), three sensitivities to market risk (S), and three sustainability indicators (ESG). These indicators have been selected on the basis of their use in previous scientific works.

5.2 Determination of the criteria priority

Step 1 First, three banking specialists are invited to express their opinions regarding the criteria. The

Table 2 Name of bank. Commercial name and net interest income (2017)

Name of bank	2017 (Million €)
Banco Santander S. A	34,296
Banco Bilbao Vizcaya Argentaria. S. A	17,758
CaixaBank. S. A	4746
Banco Sabadell. S. A	3802
Bankia. S. A	1968
Bankinter. S. A	1062

Table 3 CAMELS-ESG rating systems. Indicators

Criteria	Subcriteria		References
Capital adequacy (C)	$C1$	CET1 capital ratio	
	$C2$	TIER1 capital ratio	[8]
	$C3$	Regulatory capital ratio (BASEL III)	[1] [2] [3] [4] [5] [6] [7] [8]
	$C4$	Regulatory leverage ratio	[8]
	$C5$	Equity to liabilities ratio	[7]
Assets quality (A)	$A1$	Impaired loans/gross loan	[1] [2] [3] [7]
	$A2$	Loan loss reserve/impaired loan	[1] [2] [3] [4] [7]
	$A3$	Loan loss provision/net interest revenue	[1] [2] [3] [4] [5] [6] [7]
	$A4$	Risk cost	
Management efficiency (M)	$M1$	Net interest revenue to average assets ratio	[1] [2] [3] [4] [5] [6] [7]
	$M2$	Other operational income to average assets ratio	[1] [4] [6] [7]
	$M3$	Non-interest expenses to average assets ratio	[4] [7]
Earning quality (E)	$E1$	Return on asset (ROA)	[1] [2] [3] [4] [5] [6] [7]
	$E2$	Return on equity (ROE)	[1, 3–7]
	$E3$	Return on tangible equity (ROTE)	
	$E4$	Return on risk-weighted assets (RORWA)	
	$E5$	Efficiency ratio	[1–7]
Liquidity (L)	$L1$	Net loan/deposits	[1,2,6,7]
	$L2$	Net loan to asset	[1,4,7]
	$L3$	Liquid assets to deposits	[2–7]
Sensitivity of market risk (S)	$S1$	Risk-weighted assets to assets ratio	
	$S2$	Net income to risk-weighted assets ratio	[7]
	$S3$	Rating	
Sustainability (ESG)	ESG1	Environmental	
	ESG2	Social	
	ESG3	Governance	

[1]: Cole and Gunther (1995), [2]: Seçme et al. (2009), [3]: Zhao et al. (2009), [4]: Doumpos and Zopounidis (2010), [5]: Maghyereh and Awartani (2012), [6]: Betz et al. (2014), [7]: Wanke et al. (2016b), [8]: Liu et al. (2018)

experts are going to express their opinions as intuitionistic fuzzy numbers $\tilde{r}_{ijk} = \left(\mu_{\tilde{r}_{ijk}}, \nu_{\tilde{r}_{ijk}}\right)$ according to the linguistic scales in Table 1. In this way, there are three opinions on each pair of elements to be compared. The opinion of the kth expert indicates the relative preference of category i over j assigned by expert k, $k = 1, .., 3$.

Step 2 Aggregation of expert priorities. The information provided by the experts is aggregated using the arithmetic mean, expression (19), and using IFOWAs (21) with weighting vectors: $\omega_1 = (0.5,\ 0.3,\ 0.2)$, $\omega_2 = (0.3,\ 0.5,\ 0.2)$ and $\omega_3 = (0.2,\ 0.3,\ 0.5)$. Tables 4 and 5 show the IFPR matrices corresponding to the criteria and the liquidity subcriteria. In this case, in matrix IFPR, the value (0.6, 0.4) shows the preference relation between Capital Adequacy (C) and Sustainability (ESG), and this means that the Capital Criteria (C) are «moderately preferred» to the Sustainability criteria (ESG), according to Table 1.

Step 3 Priority calculation through the application of the OPO model (Liao et al. 2018). In this case, for the Liquidity Subcriteria, applying expressions (23) and (24):

$$\text{Max } \tau$$
$$s.t.\begin{cases} 1-[(0.67-1)\omega_1+0.67\omega_2]\geq\tau \\ 1-[(0.53-1)\omega_1+0.53\omega_3]\geq\tau \\ 1-[(0.50-1)\omega_2+0.50\omega_3]\geq\tau \\ 1-[0.3\omega_1+(0.3-1)\omega_2]\geq\tau \\ 1-[0.42\omega_1+(0.42-1)\omega_3]\geq\tau \\ 1-[0.43\omega_2+(0.43-1)\omega_3]\geq\tau \\ 0\leq\omega_i\leq 1,\ i=1,\ldots,3 \\ \sum_{i=1}^{3}\omega_i=1 \end{cases}$$

Table 4 Intuitionistic fuzzy preference relations matrix among criteria (using arithmetic mean)

	C	*A*	*M*	*E*	*L*	*S*	ESG
C	(0.50, 0.50)	(0.67, 0.28)	(0.70, 0.30)	(0.70, 0.25)	(0.70, 0.23)	(0.57, 0.43)	(0.60, 0.40)
A	(0.28, 0.67)	(0.50, 0.50)	(0.67, 0.26)	(0.67, 0.32)	(0.67, 0.32)	(0.57, 0.40)	(0.50, 0.48)
M	(0.30, 0.70)	(0.26, 0.67)	(0.50, 0.50)	(0.50, 0.47)	(0.53, 0.43)	(0.37, 0.60)	(0.37, 0.60)
E	(0.25, 0.70)	(0.32, 0.67)	(0.47, 0.50)	(0.50, 0.50)	(0.57, 0.40)	(0.33, 0.62)	(0.37, 0.60)
L	(0.23, 0.70)	(0.32, 0.67)	(0.43, 0.53)	(0.40, 0.57)	(0.50, 0.50)	(0.43, 0.53)	(0.43, 0.52)
S	(0.43, 0.57)	(0.40, 0.57)	(0.60, 0.37)	(0.62, 0.33)	(0.53, 0.43)	(0.50, 0.50)	(0.50, 0.45)
ESG	(0.40, 0.60)	(0.48, 0.50)	(0.60, 0.37)	(0.60, 0.37)	(0.52, 0.43)	(0.50, 0.45)	(0.50, 0.50)

Table 5 Intuitionistic fuzzy preference relations matrix among liquidity subcriteria (using arithmetic mean)

	*L*1	*L*2	*L*3
*L*1	(0.50, 0.50)	(0.67, 0.30)	(0.53, 0.42)
*L*2	(0.30, 0.67)	(0.50, 0.50)	(0.50, 0.43)
*L*3	(0.42, 0.53)	(0.43, 0.50)	(0.50, 0.50)

On solving the optimization problem, the optimum solution is $\omega^* = (0.45, 0.26, 0.19)^T$, and the maximum value of the objective function is $\tau^* = 0.981 \approx 1$, which means that the IFRP matrix for the Liquidity Subcriteria reaches complete consistency. Columns ω^*_{jh} in Table 6 show the results obtained.

Step 4 Repair inconsistency. According to Table 6, consistency indexes τ^* *y* τ^*_j are close to 1, so it is not necessary to repair the inconsistency of the IFRP matrices.

Step 5 Calculate the global priority vector. Table 6 shows global priority vectors. According to the data obtained, the Capital Adequacy criteria ($\omega^*_j = 0.232$) are the most relevant as they present a higher weight, followed by the Sustainability criteria (ESG) ($\omega^*_j = 0.176$). For indicators, $C1$ ($\overline{\omega}^*_{jh} = 0.076$) presents the highest weight, followed by S3 ($\overline{\omega}^*_{jh} = 0.072$).

5.3 Ranking Spanish commercial banks

Once the weight of each indicator, as defined in the CAMELS-ESG rating systems structure, has been determined, the ranking of Spanish banks is established through the application of the Intuitionistic Fuzzy TOPSIS method, applying the algorithm in Sect. 4.

Step 1 The indicators are quantified. For this purpose, a study of three years (t) has been proposed, using the Banks in Table 2 alternatives (s) and the q criteria in Table 3.

Step 2 Construction of the order matrix $\tilde{R} = (\tilde{r}_{qs})$. The ESG Sustainability indicators have been obtained from the web. This information has been prepared by the firm *Sustainalytics,* which compiles information from an inner dashboard, whose results do not undergo any institutional auditing.

Despite the spread of Corporate Social Responsibility practices among firms, there is no commonly accepted method of measuring sustainability (Venturelli et al. 2017). Moreover, although Environmental Social Governance (ESG) rating agencies provide Corporate Social Responsibility evaluations (Olmedo et al. 2010; Chelli and Gendron 2013), their methods have certain weaknesses. Sometimes, higher scores for one domain may conceal very low scores in another domain (Escrig-Olmedo et al. 2014). Indeed, a major criticism of these rating agencies is the lack of transparency in their methods (Stubbs and Rogers 2013). So, considering that the quality of the information is not 100% guaranteed, these indicators take the values $w_{\tilde{r}_q} = 0.7$ and $u_{\tilde{r}_q} = 0.2$. If the information is 100% guaranteed, they will take the values $w_{\tilde{r}_q} = 1$ and $u_{\tilde{r}_q} = 0$.

The Rating indicator ($S3$) is the rating of the agency's credit rating (*S&P, Moodýs, Fitch* and *DBRS*). In this case, the problems are similar to those for the ESG indicator, but considering the average of the rating obtained for each of the commercial Banks, the assigned values are $w_{\tilde{r}_q} = 0.8$ and $u_{\tilde{r}_q} = 0.1$.

The remaining indicators have been taken from the financial information published by the commercial Banks. This information is under the supervision of the Spanish National Central Bank, European Central Bank and European Banking Authority. In addition, this information is audited by independent firms. Despite the strict control of the financial information published, there are situations of deficient quality information in Spain (Bankia in 2012 or Banco Popular in 2017). For this situation, the proposed values are $w_{\tilde{r}_q} = 0.9$ and $u_{\tilde{r}_q} = 0.05$.

Step 3 Normalized decision matrix $\tilde{N} = (\tilde{n}_{qs})$ (28).

Table 6 Local weights, global weights and consistency index (τ) of each criterion and indicator (using arithmetic mean)

Criteria	ω_j^*	τ^*	Subcriteria	ω_{jh}^*	τ_j^*	$\overline{\omega}_{jh}^*$
Capital adequacy (C)	0.232	0.981	$C1$	0.326	0.992	0.076
			$C2$	0.231		0.054
			$C3$	0.190		0.044
			$C4$	0.146		0.034
			$C5$	0.107		0.025
Assets quality (A)	0.145		$A1$	0.443	1	0.064
			$A2$	0.282		0.041
			$A3$	0.105		0.015
			$A4$	0.170		0.025
Management efficiency (M)	0.101		$M1$	0.630	1	0.064
			$M2$	0.225		0.023
			$M3$	0.145		0.015
Earning quality (E)	0.101		$E1$	0.289	1	0.029
			$E2$	0.221		0.022
			$E3$	0.189		0.019
			$E4$	0.184		0.019
			$E5$	0.117		0.012
Liquidity (L)	0.101		$L1$	0.453	0.981	0.046
			$L2$	0.255		0.026
			$L3$	0.292		0.029
Sensitivity of market risk (S)	0.144		$S1$	0.317	1	0.046
			$S2$	0.186		0.027
			$S3$	0.497		0.072
Sustainability (ESG)	0.176		SU1	0.341	1	0.060
			SU2	0.333		0.059
			SU3	0.326		0.057

Table 7 CC_s and rank (brackets) for the period 2015–2017 for IFTOPSIS, using arithmetic mean and weighting vector ω_1, ω_2 and ω_3

	$w_{\tilde{r}_q} \neq 1$ and $u_{\tilde{r}_q} \neq 0$				$w_{\tilde{r}_q} = 1$ and $u_{\tilde{r}_q} = 0$			
Aggregation vector	Arithmetic mean	ω_1	ω_2	ω_3	Arithmetic mean	ω_1	ω_2	ω_3
Santander	0.02866 (1)	0.02893 (1)	0.02888 (1)	0.02858 (1)	0.03223 (2)	0.03240 (1)	0.03240 (1)	0.03216 (1)
BBVA	0.02863 (2)	0.02884 (2)	0.02883 (2)	0.02854 (2)	0.03225 (1)	0.03234 (2)	0.03239 (2)	0.03216 (2)
Caixabank	0.02574 (3)	0.02571 (4)	0.02584 (3)	0.02567 (3)	0.02914 (3)	0.02896 (4)	0.02917 (3)	0.02908 (3)
Bankia	0.02544 (5)	0.02551 (5)	0.02556 (5)	0.02533 (5)	0.02867 (5)	0.02862 (5)	0.02873 (5)	0.02857 (5)
Bankinter	0.02558 (4)	0.02584 (3)	0.02577 (4)	0.02548 (4)	0.02882 (4)	0.02897 (3)	0.02895 (4)	0.02873 (4)
Sabadell	0.02518 (6)	0.02530 (6)	0.02530 (6)	0.02509 (6)	0.02837 (6)	0.02838 (6)	0.02843 (6)	0.02828 (6)

Step 4 Weighted normalized fuzzy decision matrix $\tilde{P} = (\tilde{p}_{qs})$.

Step 5 Calculate the triangular intuitionistic fuzzy positive ideal solution γ^+ and the triangular intuitionistic fuzzy anti-ideal solution γ^- of the Q criteria. The ideal solution considered is:

$$\gamma^+ = ((1, 1, 1); 1, 0)$$

$$\gamma^- = ((0, 0, 0); 0, 1)$$

Step 6 The separation d_i^- and d_i^+ of each alternative is computed applying expressions (35) and (36).

Step 7 Finally, the closeness coefficient CC_s of each Spanish Commercial Bank, from expression (37).

As shown in Table 7, if we compare the results obtained from applying the different $w_{\tilde{r}_q}$ and $u_{\tilde{r}_q}$ in the IFTOPSIS and the different aggregation functions, different bank rankings are obtained. Results show that the introduction of uncertainty about the quality of the information used, $w_{\tilde{r}_q} \neq 1$ and $u_{\tilde{r}_q} \neq 0$ through an ITFN, generates a different ranking because it considers $w_{\tilde{r}_q} = 1$ and $u_{\tilde{r}_q} = 0$, and it also works with a TFN. In general, Banco Santander ranks first in all cases, followed by BBVA, except for the arithemtic mean with $w_{\tilde{r}_q} = 1$ and $u_{\tilde{r}_q} = 0$, where their positions are inverted. On the other hand, Banco Sabadell is the worse valued in all cases.

Traditionally, the MCDM fuzzy models applied to evaluate banking performance were based on the use of this methodology to basically represent expert opinions; either in the process priority fixation process or in the determination of some indicators. The subjectivity and uncertainty of the obtained indicators were never considered, which should be done according to the origin of the information, as justified in step 2 for the case of the commercial banks in Spain. That is why the results obtained by applying this model are a better approach to banking performance in contrast to other models, which do not consider these aspects in the criteria.

Next, a sensibility analysis is proposed in order to evaluate the impact of the non-financial criteria of Sustainability on the process for ranking Spanish commercial banks. For this purpose, banking performance will be revaluated removing the Environmental, Social and Governance (ESG) criteria, and only the CAMELS rating system will be applied in the model (Table 8).

In this case, once the Sustainability indicators are excluded, on considering uncertainty ($w_{\tilde{r}_q} \neq 1$ and $u_{\tilde{r}_q} \neq 0$) or without considering it ($w_{\tilde{r}_q} = 1$ and $u_{\tilde{r}_q} = 0$), with the four aggregation vectors in the CAMELS system, results are similar. In this case, Santander and BBVA are in the first two positions of the ranking regardless of the $w_{\tilde{r}_q}$ and $u_{\tilde{r}_q}$ value or of the aggregation function used. In all cases the final ranking is the same, the first two positions for Santander and BBVA and the last two for Caixabank and Sabadell.

On another level, the aggregation process of the experts' opinion is carried out on the basis of different aggregation functions in order to compare the different methodologies. From the results obtained, hardly any diffferences are observed in the rankings with respect to the sustainability criteria (Table 7), and there is no difference when the sustainability criteria are not included (Table 8). The data generated imply that in this case, the use of either one or the other of the aggregation functions does not actually alter the final results. This situation is possibly justified by the consistency of the opinions of the expert consulted, since the consistency indicator τ^* of the matrix of intuitionistic fuzzy preferences relations (IFPR) is close to the value 1 in all cases.

6 Conclusions

In the current financial world, financial and non-financial performances are the key to a commercial bank's survival, especially in a low interest-rate environment. In this sense, banks are more and more interested in improving practices based on sustainability, that is to say: environmental, social and governance. A multicriteria decision-making method such as the AHP combined with the TOPSIS is a very useful tool to manage these objectives.

However, sometimes the DMs have to choose between somewhat unclear alternatives, where the use of the fuzzy mathematics is especially suitable. A better approximation can be obtained by using intuitionistic fuzzy numbers, which combine a membership with a non-membership

Table 8 CC_s and rank (brackets) for the period 2015–2017 for IFTOPSIS, without including the Sustainability criteria, using arithmetic mean and weighting vectors ω_1, ω_2 and ω_3

Aggregation vector	$w_{\tilde{r}_q} \neq 1$ and $u_{\tilde{r}_q} \neq 0$				$w_{\tilde{r}_q} = 1$ and $u_{\tilde{r}_q} = 0$			
	Arithmetic mean	ω_1	ω_2	ω_3	Arithmetic mean	ω_1	ω_2	ω_3
Santander	0.03335 (1)	0.03350 (1)	0.03352 (1)	0.03327 (1)	0.03619 (1)	0.03627 (1)	0.03634 (1)	0.03614 (1)
BBVA	0.03259 (2)	0.03264 (2)	0.03273 (2)	0.03252 (2)	0.03533 (2)	0.03532 (2)	0.03546 (2)	0.03529 (2)
Caixabank	0.02835 (5)	0.02821 (5)	0.02837 (5)	0.02835 (5)	0.03071 (5)	0.03049 (5)	0.03071 (5)	0.03074 (5)
Bankia	0.02860 (4)	0.02849 (4)	0.02858 (4)	0.02855 (4)	0.03098 (4)	0.03080 (4)	0.03093 (4)	0.03095 (4)
Bankinter	0.02913 (3)	0.02940 (3)	0.02926 (3)	0.02906 (3)	0.03157 (3)	0.03181 (3)	0.03169 (3)	0.03152 (3)
Sabadell	0.02822 (6)	0.02813 (6)	0.02821 (6)	0.02823 (6)	0.03055 (6)	0.03040 (6)	0.03052 (6)	0.03058 (6)

function. That is why a fuzzy AHP-TOPSIS model based on intuitionistic fuzzy numbers is proposed.

The global performance of Spanish banks has been analyzed according to a criteria rating system called CAMELS to which financial and non-financial indicators are added: environmental, social and governance ratios, which make it possible to evaluate bank policy regarding corporate social responsibility.

This model has led to the performance quantification of the six main Spanish commercial banks for the period 2015–2017. For this purpose, different aggregations of the opinions expressed by the experts were used to determine the relevance or weighting of the different evaluation criteria by applying the IFAHP, and to thereby analyse the sensibility of the resulting ranking.

In the real world, the information available and its reliability is limited. As can be verified, the use of intuitionistic fuzzy numbers deals with this problem appropriately, and thus the enhanced quality of the information leads to an improved ranking of Spanish banking performance. As can be observed, Banco de Santander is generally the first in this ranking followed by BBVA and finally, Banco Sabadell is the last in the ranking in all cases.

The sensibiltiy analysis of the application of the alternative aggregates of the experts' opinion in the table application of the IFAHP, in our particular case, leads us to the conclusion that the ranking positions obtained do not alter significantly due to the consistency in the opinions expressed by the experts.

From an operative point of view, this innovative formulation simplifies the process of calculating the distance between intuitionistic fuzzy numbers, based on possibility mean value and degree of deviation, in contrast to other operators that are more complex and are based on the concept of distance.

Declarations

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

Ethical approval 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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