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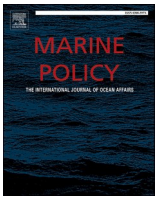

Assessing the label's mandatory information for fishery and aquaculture products in the EU28. A consumer approach based on a consistent fuzzy preference relation with geometric Bonferroni mean

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ABSTRACT

Fishery and aquaculture products (FAPs) are a very important source of the protein intake of the European Union (EU) citizens. Despite the importance, the knowledge on labelling is still scarce. Two important issues regarding the labelling preferences of 27732 EU residents (the criteria interrelationship as well as the relationship that exists at the country level) will be assessed through a method based on a modified Consistent Fuzzy Preference Relation (CFPR) that uses the Geometric Bonferroni Mean (GBM) operator. The results show that not all the EU countries are homogeneous, so the subsidiarity principle might have been applicable. Our results also contribute to the strand of the fishery and aquaculture market. Policy implications, as well as future research studies, are discussed.

1. Introduction

Food labelling can be analysed under a myriad of multiple perspectives that ranges from third-party or private own-label product differentiation to strict public legislation that reduces the existing asymmetrical information position that consumers have in the market [18]. The first practice can be considered anti-competitive if some firms are capable of exerting market power [51]. The author shows that some of the important food retailers in the EU sale an increasing proportion of own-label products. On the other hand, EU food labelling legislation was first introduced in 1978 as a way to guarantee food safety for European consumers [36]. Since then, some new directives and regulations have been signed until the provision of food information to consumers (EU Regulation No 1169/2011) that has the following main objectives: (1) to simplify the existing law; (2) to ensure legal certainty; (3) to reduce administrative burden; and (4) to benefit EU citizens by requiring clear, comprehensive and legible labelling of foods [28].

Under the consumers' perspective on fishery and aquaculture products (FAPs), the EU regulation 1379/2013 seeks to provide information to consumers, obliging the Member States to elaborate a list of the commercial name in each respective territory with the corresponding species scientific name. Tinacci et al. [74] analyse the Italian national lists since 2002 assessing the evolution and accuracy. The authors find that the list published in 2017 contains a total of 1003 records and conclude that there is a decreasing trend in terms of accuracy of the species scientific name in favour of the commercial name. In addition, D'Amico et al. [22] contend that the EU regulation 1379/2013 is the consequence of the application of the three main pillars that sustain the European Common Fisheries Policy envisaged in 1970 and reformed in 2013: traceability, sustainability and consumers' right to an informed purchase. The authors concluded that the regulation can also be seen as the evolutionary process of seventeen years of countries' negotiations on the creation of a common market in FAPs.

Article 35 of the EU regulation 1379/2013 establishes the following mandatory information to be declared in marks or labels on FAPs marketed within the Union: the commercial designation of the species and its scientific name; the production method as, for example, "caught", "caught in freshwater" or "farmed"; the area where the product was caught or farmed, and the category of fishing gear used to capture the products by fisheries; whether the product has been defrosted; and the date of minimum durability.

The regulation that assesses the mandatory information for FAPs (EU 1379/2013) has been analysed in the literature during the last years in which two main topics can be extracted: fraud and compliance. First, Mariani et al. [48] conclude that this regulation has marked a positive trend in getting a market with less fraud. D'Amico et al. [22] insist that

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the regulation should also be applied to all the prepared and processed products based on FAPs. Similarly, Giusti et al. [33] analyse the semi-preserved anchovies in Italy and conclude that marinated and oil anchovy products are difficult to trace as the information on scientific names and catching areas are only voluntarily made. Second, Tinacci et al. [76] analyse the compliance of the Bulgarian seafood wholesalers with the EU regulation using the labels of 97 seafood products. The authors find that 59% and 85% of the products were not included in the official list and do not include the catching area, respectively. Tinacci et al. [77] compare the commercial designations (CDs) with the correspondent scientific names (SNs) of the Bulgarian official seafood designation list. The authors find that 43 out of 110 different CDs that exist in the list do not have any SN associated.

As discussed by Alfnes et al. [2], many studies have analysed the preferences and willingness to pay for certain mandatory labels in the context of specific seafood products. For example, understanding the preferences for the origin label for German consumers of Salmon. However, according to our best knowledge, no previous investigation in the context of the EU has analysed the relative importance of the complete set of mandatory labels for all the FAPs, as a whole. As seen, the regulation that assesses the mandatory information for FAPs (EU 1379/2013) is an important regulation of the Common Fisheries Policy that can be analysed within the framework of decision analysis and decision makers (DMs) preferences.

The Consistent Fuzzy Preference Relation (CFPR) is often used to solve multi-criteria decision making (MCDM) problems due to its effectiveness in the representation of perceptions of people [3,35]. However, the majority of CFPR methods involve a traditional aggregation process that does not identify the interrelationship among decision-making criteria, which is something that should be addressed to obtain better results [3]. To cope with this, a model based on a CFPR that uses the Geometric Bonferroni Mean (GBM) operator is developed to analyse the mandatory scale proposed by the EU 1379/2013 according to the preference values related to 27732 EU residents, who will be considered as the main DMs. A final ranking of the criteria and the relationship concerning some interesting segments such as country of residence and age will be obtained. To the best of our knowledge, this is the first study that analyses the full scale proposed by the EU 1379/2013.

In sum, our paper develops a method based on a CFPR as a way to avoid the limitation of consistency that is normal in other decision-making methods. In this sense, we extend the method proposed by Alias et al. [3] in which not only the interrelationship of information on the criteria included in the labelling scheme is dealt with as the GBM operator is also applied to the respondents as a way to aggregate the information also considering their possible interrelationship. The extended modified approach is applied to our case study as a way to analyse the consumers' preferences on the EU FAPs mandatory labelling scheme dealing with two potential interactions at the level of criteria and respondents. Thus, as the GBM is also applied to the weights obtained for each of the respondents, we denominate our model as CFPR-GGBM method –Consistent Fuzzy Preference Relation with a Grand Geometric Bonferroni Mean.

An analysis of the scale related to the mandatory information for fishery and aquaculture products is also important considering that its crucial to determine which information is relevant for consumers, especially taking into account that excessive information on labels can be confusing, while too little information can be misleading [59]. Also, an analysis within the context of the EU is important, as Bradford [15] contends that the EU matters and this evident fact should not undermine the narrative for further integration if the EU's role in the world is going to be persistent and relevant. A further move to build an authentic European federation will boost the interests of the EU, both within and beyond its borders, through the Brussels Effect. Moreover, food labelling schemes of specific food products should be performed and evaluated with special attention and consideration of the cultural differences, because apart from the expectations generated by the information provided, which influence the choice of consumers and the product experience, consumers also have expectations derived by previous experiences and traditions [5].

The remainder of the paper is organized as follows: Section 2 offers some insights from the literature, Section 3 describes the data section, Section 4 details the methodology, Section 5 presents and discusses the results, Section 6 describes some policy implications, and Section 7 offers some concluding remarks.

2. Literature review

D'Amico et al. [22] analyse the regulation that assesses the mandatory information for FAPs (EU 1379/2013) in comparison with the previous legislative mandate regarding the labelling requirements for FAPs. The authors point out that besides the legislation advances in the right direction there are still at least two important drawbacks: the exclusion of prepared and processed derived seafood products and the existing void of the mass caterer operators. The authors suggest that these controversial problems that exist 15 years ago should be modified with new regulatory measures that extend the applicability to all the seafood products and all the economic agents of the FAPs logistic chain. As Pardo et al. [58] acknowledge the percentage of mislabelling is 30%, and, in general, the incidental rates are more numerous in restaurants and takeaways than in retailers and supermarkets. Also, the mislabelling rate can differ according to the presentation of the product, as Miller and Mariani [52] found that around 25% of all the products sampled were genetically different species from the indicated on the label, while it was more than 80% when the smoked fish samples were considered. According to Esposito and Meloni [26], the mislabelling can be due to different circumstances such as unintentional or accidental vs. those that can be considered fraud –less valued species are labelled as other more valued species. Reilly [61] contends that species mislabelling is one of the common illegal practices that affect FAPs and that FAPs are among the sectors in which food fraud is more common.

Asensio and Montero [10] contend that FAPs labelling is essential and almost the unique source of information that consumers have about the products they consume. The authors add that the information is relevant and demanded by consumers because FAPs are very perishable and have multiple origins. The authors provide an overview of the existing regulation regarding the mandatory information: commercial designation of the species; the area of catch; the production method; and fish presentation. The authors analyse the labelling of fresh, refrigerated and chilled fish in 285 and 155 fishmongers in food markets and supermarkets, respectively in Madrid, Spain or its surrounding area. Mercamadrid is the second world largest wholesale market for FAPs. The analysis is similar to the previously commented studies regarding the compliance of the labelling concerning the mandatory information, but there is not any particular investigation on the validity and integrity of the four criteria studied in the mandatory information scale. In this sense, there is only one mention of the traceability concept as the information gathered throughout the food supply chain as a way to guarantee the quality of the seafood product. The authors conclude that "consumers must demand a complete fish labelling with the designation of the fish species, the catch area, the production method and the fish presentation (p. 798)." Nevertheless, a critical assessment of the scale itself is missing.

Another interesting salient issue from the literature review is the scarcity of studies that analyse the economic causes of the mislabelling behaviour. Oceana [54] overviews more than 200 published studies from 55 countries and finds that, on average, 20% of seafood products were mislabelled, and most of the economic agents of the logistic chain such as fisheries, farms, processors, distributors, retailers or caterers were involved. The scale of the problem is outstanding in developed and developing countries, and Reilly [61] contends that the first step to combat the fraud in FAPs is to establish an agreed list of commercial

names with the respective scientific denomination –the first attribute of the mandatory information requested by regulation that assesses the mandatory information for FAPs (EU 1379/2013). According to the author, national governments need to provide the list before any fraud control program can be designed.

NOAA Fisheries' FishWatch, an American database on sustainable seafood, identified three types of seafood fraud: seafood substitution, seafood short-weighting and mislabeling seafood [32]. The first category is mostly related to the substitution of low-value species for more expensive ones, mostly on filleted and skinned presentation, in which

Table 1
Literature that included an analysis of the different types of mandatory information for FAPs.

Investigation	Species	Country	Type of mandatory information				
			Wild or farmed product	Area of catch or production	The fishing gear used to catch the product	Presentation of the product: frozen or not	The "use by" or "best before" date
Ankamah-Yeboah et al. [6]	Trout	Germany		X		X	
Ankamah-Yeboah et al. [7]	Trout	Germany		X		X	
Ariji [8]	Tuna	Japan	X	X			
Asche et al. [9]	Salmon	Scotland	X	X		X	
Banovic et al. [11]	Amberjack	Germany, France, Italy, Spain, UK		X			
Bi et al. [14]	Salmon, Mahi mahi, Grouper	US					
Bronnmann and Asche [16]	Salmon	Germany	X			X	
Bronnmann and Hoffmann [17]	Turbot	Germany	X			X	
Chen et al. [20]	Cod, Salmon, Monkfish, Pangasius	France	X	X			
Darko et al. [23]	Tilapia	Tanzania (Africa)	X			X	
Davidson et al. [24]	Salmon, Tuna, Tilapia, Moi	US	X	X		X	
Fernández-Polanco et al. [30]	Seabream	Spain	X	X			
Ferrer Llagostera et al. [31]	Seabream	Spain	X				
Heide and Olsen [34]	Cod	Norway					X
Hinkes and Schulze-Ehlers [37]	Pangasius, Tilapia	Germany		X			
Jaffry et al. [39]	Cod, Salmon, Tuna, Haddock, Prawns	UK	X	X		X	
Lim et al. [45]	Tuna	US		X			
Lucas et al. [47]	Seafood in general	France	X	X			
Mauracher et al. [49]	Seabass	Italy		X			
McClenachan et al. [50]	Seafood in general	US		X			
Miyata and Wakamatsu [53]	Cod, Whitebait	Japan		X			
Olesen et al. [56]	Salmon	Norway					
Olesen et al. [55]	Salmon	Norway					
Risius et al. [63]	Trout	Germany		X			
Risius et al. [62]	Trout	Germany		X			
Roheim et al. [64]	Salmon	US	X				
Rudd et al. [65]	Salmon	Canada		X			
Sogn-Grundvåg et al. [70]	Whitefish	Scotland		X		X	
Stefani et al. [71]	Seabream	Italy		X			
Thong et al. [73]	Salmon, Cod, Sole, Seabream, Saithe, Pangasius, Monkfish, Tuna	France	X	X		X	
Thong et al. [72]	Cod, Saithe, Pangasius, Monkfish, Salmon, Sea bream, Sole, Tuna	France	X	X		X	
Uchida et al. [78]	Salmon	Japan	X	X			
van Osch et al. [80]	Salmon	Ireland		X			
van Osch et al. [79]	Salmon, Seabream	Ireland, UK, Italy, Israel, Norway		X			
Wakamatsu and Miyata [81]	Cod, Whitebait	Japan		X			
Witkin et al. [83]	Pollock, Atlantic mackerel, Silver hake, Spiny dogfish, Haddock, Cod	US		X			
Yip et al. [86]	Atlantic Salmon, Sockeye Salmon, King Salmon	US	X	X			
Zander et al. [87]	Trout	Germany		X			

species are difficult to differentiate. The second is related to the misrepresentation of the net weight of the seafood by using practices such as using an excess of ice or additives. Finally, the last type of fraud is related to using not suitable labels on some products, to avoid regulations or fees. Moreover, Alfnes et al. [2] added that a more recent version of fraud is related to the misuse of sustainability labels.

Jacquet and Pauly [38] and Reilly [61] contend that fish fraud is mainly caused by the economic benefits obtained by the offenders. As commented, one of the most common examples is the substitution of low-quality-value species for high-quality-value varieties. This cause can be rooted in Akerlof [1], in which adverse selection is seen as one important cause of market failure. It is evident that the FAPs market is characterized by important information asymmetries in which some supply participants of the food logistic chain have much better information than other agents, especially consumers. This classic asymmetric information problem is known by his seminal work as Akerlof's market for lemons. Levin [43] revisits Akerlof's work to analyse to what extent greater information asymmetries reduce the gains from trade. The author concludes that trade gains depend on the net effects of two interaction forces: "the buyers' curse" and the shift supply effects. On the other hand, the author shows that improving buyers' information increases unambiguously trade gains. Thus, it can be concluded that the use of DNA sequencing for species identification can be considered a valid tool to improve FAPs' consumer information [40,61,75] and a key element of the assessment of the regulation that assesses the mandatory information for FAPs (EU 1379/2013) compliance.

As discussed, the previous literature has mainly analysed the compliance degree of the current legislation in the EU, and the main reasons that originate the fraud of mislabelling. The directive was seen as the derivative of seventeen years of Member States negotiations in which the labelling mandatory information pretended to protect consumers at the time of making purchases with better information. However, the current legislative labelling directive has been taken as a normative and valid regulatory status-quo that has not been critically analysed from the consumers' perspective, and as we will see in the current study, the consumers' preferences regarding the FAPs mandatory labelling are not homogeneous at country level, and this result should have had clear implications in the development of the FAPs common market in the EU. The next section will provide an overview of the mandatory information module included in the Special Eurobarometer 475 2018. Thus, the degree of importance given by consumers to each individual piece of information included in the directive will be analysed.

In addition, while other investigations have studied the importance of some of the elements of the mandatory information established for FAPs (EU 1379/2013), none of them has studied the full set, as can be noticed from Table 1. Most of these studies used Discrete Choice Experiments as their main methodology and focused on specific species and countries to develop their analysis. Regarding the mandatory information, the first element "the commercial designation of the species and its scientific name" is normally assumed to be something obvious to be given as part of the study, so the importance of its inclusion is never considered. From the rest of the different types of mandatory information, the importance of the harvest method (wild or farmed product) and the area of catch or production are commonly studied in the literature as shown in Table 1. Moreover, the information on the fishing gear used to catch the product has not been previously assessed in any of the studies listed, since most of them focus on farmed species, and this type of information is only applicable to captured species. Regarding the information about whether or not the product has been previously frozen, the studies rather focus on the preferences for product presentation and include the frozen presentation as a variable to identify differences to other types of presentations, such as fresh. Finally, the "use by" or "best before" date is assessed by only one of the investigations listed.

3. The questionnaire and data

The Special Eurobarometer 475 2018, for the second time, includes questions that analyse the "EU consumer habits regarding FAPs". The EU is the world largest market for FAPs in nominal terms, although the expenditure per capita on FAPs is higher in Japan. As said, the Common Fisheries Policy establishes a set of rules that "aim to secure a safe and stable supply of seafood, sustainable fisheries, healthy seas, and prosperous coastal communities for today's Europeans and future generations internal market for fishery and aquaculture products of the EU" (p. 3) [29].

The Special Eurobarometer 475 2018 [27] provides important insights to operators that can be used to be more competitive and to design the strategies and plans considering the EU consumers' voice. Especially relevant to the purpose of the study, it is the trust and mandatory information module that accompanies FAPs, as the labelling of the products was enforced in December 2014. The mandatory information pretends to protect consumers within the EU making a better-informed selection.

The main objectives of the questionnaire are to: (1) understand consumer habits regarding fishery and aquaculture: how frequently do consumers eat and/or buy these products? What types of products do they buy? Where do they buy them?; (2) find the factors that influence consumption; (3) explore the reasons for buying or eating FAPs, or not; (4) determine whether there is consumer preference for wild or farmed products, sea or freshwater products, processed or unprocessed products, or in terms of origin; (5) investigate what consumers think about the information accompanying FAPs and whether they trust the information provided by the government, by certified authorities or by the brand or seller; and (6) compare current figures with those from the June 2016 survey.

This survey was administered face-to-face at respondents' home and in their native language by the Kantar Public Brussels network in the 28 Member States of the European Union in the period 23rd of June and 6th of July. The total sample was 27,734 EU citizens from different social and demographic status (Table 2). The survey was carried out on behalf

Table 2
Sample features.

Country	Frequency	Percentage (%)
FR - France	1006	3,6
BE - Belgium	1055	3,8
NL - The Netherlands	1006	3,6
DE-W - Germany - West	1011	3,6
IT - Italy	1025	3,7
LU - Luxembourg	506	1,8
DK - Denmark	1020	3,7
IE - Ireland	1011	3,6
GB-UKM - Great Britain	1043	3,8
GR - Greece	1016	3,7
ES -Spain	1035	3,7
PT - Portugal	1082	3,9
DE-E Germany East	539	1,9
FI - Finland	1017	3,7
SE - Sweden	996	3,6
AT - Austria	1044	3,8
CY - Cyprus (Republic)	503	1,8
CZ - Czech Republic	1023	3,7
EE - Estonia	1004	3,6
HU - Hungary	1064	3,8
LV - Latvia	1007	3,6
LT - Lithuania	1015	3,7
MT - Malta	502	1,8
PL - Poland	1033	3,7
SK - Slovakia	1071	3,9
SI - Slovenia	1015	3,7
BG - Bulgaria	1031	3,7
RO - Romania	1021	3,7
HR - Croatia	1031	3,7
Total	27732	100,0

of the Directorate-General for Maritime Affairs and Fisheries.

Question 16 of section B (QB16) was worded as follows: From which sources do you get most of your information about fishery and aquaculture products? The respondents can choose up to three different sources among Friends and family; Television, books and magazines; The internet; Public institutions; Non-governmental organisations (NGOs); Store employee or fishmonger; Advertising and other commercial information; Other (SPONTANEOUS); None (SPONTANEOUS); Do not know. The results show that at the EU level, the three most cited sources of information are: Store employee or fishmonger (44%), Television, books and magazines (32%) and Friends and family (30%). Nevertheless, in 27 of the 28 Member States, the proportion of respondents who mentioned store employees and fishmongers has decreased in comparison with the data obtained in 2016.

Table 3 shows the criteria and the answer format scale included in question 13 of section B of the questionnaire. The wording of the question was as follows: How important or not is it to find the following information on labels of FAPs like fresh, frozen, smoked and dried products? It can be seen that the mandatory information scale has six criteria and that the answer format is based on a 4-point linguistic scale (Very important (4); Fairly important (3); Not very important (2) and Not at all important (1)).

4. Methodology

All the respondents to the survey are treated as the main DMs to represent the preferences of the mandatory information for FAPs in the EU. Some MCDM methods have been developed to select the best alternative or to rank the relative importance degree of a set of criteria like in the study. For example, in the seafood context, some of the main methods used are: the analytic hierarchy process (AHP) first introduced by Saaty [41,42]; the elimination and choice expressing reality (ELECTRE) [25]; Value of Information [12]; Multi-Attribute Utility Theory (MAUT) [69,86]; Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE) [66]; and Dominance Based Rough Set Approach (DRSA) [44,85]. All these methods are based on answers given by a group of DMs over a set of criteria that serves to approximate the concept under analysis. Instead of values, the information can be obtained through pairwise comparisons that determine somehow the DMs' preferences. Orlovsky [57] contends that the preference relation has usually a fuzzy nature and introduces the fuzzy logic as a way to handle the uncertainty associated with the preferences representation over criteria. Alias et al. [3] assess this method as a more "simple and effective model to construct a pairwise comparison with less information needed from the DMs" (p. 2672).

The Fuzzy Preference Relations (FPRs) approach has been previously successfully applied in different fields such as management [82], business [21] and education [19]. In our case, the study is applied to the analysis of consumers 'perceptions adapting the methods proposed by Alias et al. [3], Alonso et al. [4] and Herrera-Viedma et al. [35]. The adapted method resolves the inconsistency of FPRs as the decision matrix is constructed preserving the consistency of FPRs, as well as the missing preference values. Additionally, the method overcomes the limitations of some aggregated measures such as the average, using a geometric Bonferroni mean (GBM) operator [84]. Thus, the potential interrelationships between the criteria are considered. And finally, as Alias et al. [3], a method based on the fusion between the GBM and CFPRs methods is proposed to analyse the mandatory information of FAPs in the EU. The method extends Alias et al. [3] because we also apply GBM to the weights obtained for each of the DMs in a way in which we can now denominate our model as CFPR-GGBM method –the first G for Grand.

Table 3
The importance of the mandatory information for FAPs in the EU.

C1. The name of the product and the species	1	2	3	4
C2. Whether it is a wild or farmed product	1	2	3	4
C3. The area of catch or production	1	2	3	4
C4. The fishing gear (e.g., longlines, trawls) used to catch the product	1	2	3	4
C5. Whether the product was previously frozen	1	2	3	4
C6. The "use by" or "best before" date	1	2	3	4

Source: Own elaboration
Very important (4); Fairly important (3); Not very important (2) and Not at all important (1)

4.1. The model

Orlovsky [57] defines that R is an FPR on a set of criteria $A=\{a_1, a_2, \ldots, a_n\}$ if and only if $R=(r_{ij})$ is a matrix of dimension n that,

$$r_{ij} \geq 0, r_{ij} + r_{ji} = 1,\ r_{ii} = 0.5 \text{for all} i, j = 1, 2, \ldots, n \quad (1)$$

Where r_{ij} represents the preference degree of the criteria a_i over the criteria a_j. The values of the matrix R have the following meaning over the preferences: if r_{ij} is equal to 0.5, then DM shows indifference between both criteria; if r_{ij} is greater than 0.5, then criteria i is preferred over criteria j; similarly, if r_{ij} is lower than 0.5, then criteria j is preferred over criteria i; if r_{ij} is equal to 1, then criteria i is preferred to criteria j; and finally, if r_{ij} is equal to 0, then criteria j is preferred to criteria i.

In MCDM problems, the information matrix over the criteria is usually based on answers given by a sample of DMs who express their preferences regarding the criteria. The preferences of the importance of each of the criteria are usually given by answers in a certain n-point Likert scale (not important at all - very important) or in the Saaty [67] format of pairwise comparisons such as equally important (1), moderately more important (3), strongly more important (5), very strongly more important (7), extremely more important (9). In the Saaty format, the intermediate values 2, 4, 6 and 8 for intermediate judgments are also permitted.

The problem with the Saaty format is that consistency of the preferences, especially regarding the transitivity property, is not guaranteed. Herrera-Viedma et al. [35] resolve the inconsistency problems with a method that constructs a CFPR using the following two propositions:

Proposition 1. For a reciprocal multiplicative preference relation $S=(s_{ij})$ with $s_{ij} \in [1/9, 9]$, it is possible to build a corresponding reciprocal FPR $R=(r_{ij})$ with $r_{ij} \in [0,1]$ as follows:

$$r_{ij} = g(s_{ij}) = \frac{1}{2}(1 + log_9 s_{ij}) \quad (2)$$

In general, if $s_{ij} \in [1/n, n]$, then $log_n s_{ij}$ is used in Eq. (2).

Proposition 2. If R is a reciprocal FPR, the following expressions are equivalent:

$$r_{ij} + r_{jk} + r_{ki} = \frac{3}{2},\ \forall i, j, k \quad (3)$$

$$r_{ij} + r_{jk} + r_{ki} = \frac{3}{2},\ \forall i < j < k \quad (4)$$

$$r_{i(i+1)} + r_{(i+1)(i+2)} + \cdots r_{(i+k-1)(i+k)} + r_{(i+k)i} = \frac{k+1}{2},\ \forall i, k \quad (5)$$

The conversion of a decision matrix that is not normalized in the interval [0,1] can be obtained through the transformation function assuming that the decision matrix values belong to some interval [-c, 1+c] without loss of generality. The transformation function is defined as follows to create an FPR R:

$$r_{ij} = f(s_{ij}) = \frac{s_{ij} + c}{1 + 2c} \quad (6)$$

Once the FPR is obtained, it is possible to evaluate the aggregation score u_i for each criterion as follows:

$$u_i = \frac{1}{n_c}\left(\sum_{j=1}^{n_c} r_{ij}\right) \tag{7}$$

Where n_c is the number of criteria. Finally, the weight of each criterion can be calculated as:

$$w_i = \frac{u_i}{\sum_{j=1}^{n_c} u_j} \tag{8}$$

Once the weights have been obtained for each criterion, it is now possible to prioritize each of them according to the weight ranking. Alias et al. [3] contend that CFPRs are simple and efficient tools to achieve the prioritization of the criteria, meanwhile, the preservation of consistency is guaranteed.

4.2. The GBM operator

Xia et al. [84] define the *GBM(p,q,a_1,a_2,…,a_n)* for *p, q> 0* and $a_i \geq 0$ as follows:

$$GBM(p,q,a_1,a_2,\ldots,a_n) = \frac{1}{p+q}\prod_{\substack{i,j=1\\ i\neq j}}^{n}\left(pa_i + qa_j\right)^{\frac{1}{n(n-1)}} \tag{9}$$

If q is equal to 0, the GBM is equivalent to the geometric mean. The implementation of the GBM operator as an aggregation method performs much better than other methods as it considers the potential interrelationships between the different criteria in the decision problems.

Based on the definitions and concepts and similarly to Alias et al. [3], we are going to use the CFPR-GGBM method as a way to: (1) provide a decision matrix after any survey administration regarding a criteria importance analysis; (2) analyse two alternative scenarios which are built using the reduction number of criteria comparisons proposed by Herrera-Viedma et al. [35] in the first case, and the maximum matrix explosion using all the pairwise comparisons as the second scenario; and (3) to rank the mandatory information criteria for FAPs established by the EU regulation using all the respondents to Eurobarometer 475 as DMs.

4.3. Steps to apply the CFPR-GGBM in the analysis of the mandatory scale proposed by the EU 1379/2013

In this subsection, we discuss the five steps needed to apply the CFPR-GGBM in the context of the analysis of the mandatory scale proposed by the EU 1379/2013.

4.3.1. Step 1

In the first step, the information matrix obtained in the survey is transformed into linguistic evaluations that researchers had obtained surveying a la Saaty. In our case, the information matrix is based on answers given in a 4-point Likert scale, so when we make pairwise comparisons between criteria *j* and *k* subtracting the values, we can obtain for each respondent the following preference relation (PR) matrix $S = s_{jk} = imp_j - imp_k$. The matrix can have the following values: − 3,− 2,− 1,0,1,2 and 3. When the value is equal to 0, it means that criteria *j* and *k* are equally important. When the value is 1, it means that the criterion *j* is moderately more important than *k*. When the value is 2, it means that the criterion *j* is strongly more important than *k*. And finally, when the value is 3, it means that the criterion *j* is very strongly more important than *k*. For the negative values, the corresponding meaning is straightforward. The transformation function that converts the above preference relation matrix in one Preference Relation (PR) a la Saaty matrix can be defined as follows: $g(-3,-2,-1,0,1,2,3) = (\frac{1}{7},\frac{1}{5},\frac{1}{3},1,3,5,7)$. A neater mathematical expression can be given according to:

$$S' = s'_{ij} = (1+2|s_{ij}|)^{sign(s_{ij})},\ \text{where} sign x = 1\ if x \geq 0,\ 0\ \text{otherwise} \tag{10}$$

4.3.2. Step 2

In this step, we obtain the decision matrices. For the first scenario, CFPR propositions are used to complete the matrix, meanwhile, the second decision matrix is obtained considering all the criteria comparisons as a way to analyse the robustness of the results. To construct the CFPR *R* using propositions 1 and 2, we calculate the initial fuzzy preference ratios using Eq. (2) using 7 as the base for the logarithm function. Thus, the r_{ij}'s are obtained for the upper principal diagonal of the CFPR matrix, i.e., for the elements $\{r_{12}, r_{23}, \ldots, r_{(n-1)n}\}$. Then, we construct the complete decision matrix R with the equations of Proposition 2. The second scenario is based on the CFPR R^* matrix in which all the elements are calculated with Eq. (2). The first matrix R is normalized whenever the values are out of the range [0,1] with the transformation function shown in Eq. (6) if needed.

4.3.3. Step 3

Step 3 is characterized by the application of the GBM operator to deal with the potential interrelationships among the criteria. In the real world, it is possible that whether the product was previously frozen is related to whether the product is wild or farmed. Then, in step 3, the GBM operator as shown in Eq. (9) is applied to both matrices considering the two scenarios. Thus, the aggregated values consider the potential interrelationships between all the criteria.

4.3.4. Step 4

In step 4, the priority weights of each criterion are obtained to see the most influential criterion. The priority weights for each criterion is computed using Eq. (8) for each DM, and as previously explained, the most influential criterion for each DM is that of the maximum value.

4.3.5. Step 5

Finally, in Step 5 the rankings of the weights will be analysed for both scenarios as well as for some segmentation based on the country and the age. In this step, we obtain again using the GBM (GGBM –Grand Geometric Bonferroni Mean) the aggregate values of the weights for each criterion of the sample and segments of interest. Thus, it is possible to analyse whether the mandatory information is perceived more or less homogeneously by different population segments.

5. Results

The proposed method is applied to the module of the mandatory information for FAPs in the Eurobarometer 475 survey. As explained, there are six criteria for the analysis and 27,734 respondents that are going to be used as the DMs. In order to explain in a clearer way how we applied the CFPR-GGBM, we will initially use as an example, the responses of the first respondent in the sample, who has answered question 13 with the following values (4,3,2,2,4,4).

The linguistic evaluation of the first step is clear. Thus, the matrix of the differences is converted to one PR matrix a la Saaty [1/7,7]. Then, we can calculate the PR matrix S and convert it to S' (Table 4).

In the second step, we use Eq. (2) to derive the elements $\{r_{12}, r_{23}, r_{34}, r_{45}, r_{56}\}$. In the case of the elements of the upper diagonal matrix of *S'*, it can be easily seen that r_{12} is equal to $0.782 = \frac{1}{2}(1+log_7 3)$. Similarly, it can be obtained that $\{r_{12}, r_{23}, r_{34}, r_{45}, r_{56}\}$ is equal to $\{0.782, 0.782, 0.5, 0.086, 0.5\}$. Analysing now, for example, the values of r_{34} and r_{45}, it can be concluded that criteria 3 and 4 are equally important, meanwhile, criterion 5 is strongly more important than criterion 4. Then, we calculate the complete matrix *R* using the equations of Proposition 2. For example, from Eq. (4) it is possible to obtain r_{24} as $\frac{3}{2} - r_{12} - r_{45} = \frac{3}{2} - 0.782 - 0.086 = 0.632$.

Table 4
First step PR matrices.

Matrix S						
	c1	c2	c3	c4	c5	c6
c1	0	1	2	2	0	0
c2	-1	0	1	1	-1	-1
c3	-2	-1	0	0	-2	-2
c4	-2	-1	0	0	-2	-2
c5	0	1	2	2	0	0
c6	0	1	2	2	0	0
Matrix S'						
	c1	c2	c3	c4	c5	c6
c1	1.00	3.00	5.00	5.00	1.00	1.00
c2	0.33	1.00	3.00	3.00	0.33	0.33
c3	0.20	0.33	1.00	1.00	0.20	0.20
c4	0.20	0.20	1.00	1.00	0.20	0.20
c5	1.00	3.00	5.00	5.00	1.00	1.00
c6	1.00	3.00	5.00	5.00	1.00	1.00

Source: Own elaboration. The matrices are calculated with the assumption that the respondent has answered (4,3,2,2,4,4)

Similarly, the rest of the values of R can be calculated according to the expansion method that uses the eqs. of Proposition 2. Thus, the matrix R is constructed (Table 5). In this case, it can be seen that we need to normalize the matrix as some of the values are out of the range [0,1]. Using Eq.(6) with a c value equal to 0.064, the normalized matrix is obtained (Table 5) according to the following normalized function:

$$f{:}[-0.063, 1.0063] \rightarrow [0,1],\ f(r_{ij}) = \frac{r_{ij} + 0.063}{1 + 2(0.063)}$$

Table 5 also shows the decision matrix R^* that uses all the pairwise comparisons to directly obtain the complete matrix without the need of Proposition 2. It can be seen that the relative preference for each of the attributes is equivalent but some of the values are different, so the robustness of the results of the expansion method can be analysed.

Step 3 aggregates the preference relation values of the decision matrices for both scenarios by using the GBM operator (Eq. (9)). The GBM operator is applied with $p = q = 5$ –the standard values of this operator. The aggregate values for the first and second scenarios and the criterion c_1 are obtained as:

Table 5
Second step CFPR matrices.

Matrix R						
	c1	c2	c3	c4	c5	c6
c1	0.5	0.782	1.064	0.914	0.5	0.5
c2	0.218	0.5	0.782	0.632	0.218	0.218
c3	-0.064	0.218	0.5	0.5	0.218	0.218
c4	0.086	0.368	0.5	0.5	0.086	0.086
c5	0.5	0.782	0.782	0.914	0.5	0.5
c6	0.5	0.782	0.782	0.914	0.5	0.5
Matrix R normalized						
	c1	c2	c3	c4	c5	c6
c1	0.500	0.750	1.000	0.867	0.500	0.500
c2	0.250	0.500	0.750	0.617	0.250	0.250
c3	0	0.250	0.500	0.500	0.250	0.250
c4	0.133	0.383	0.500	0.500	0.133	0.133
c5	0.500	0.750	0.750	0.867	0.500	0.500
c6	0.500	0.750	0.750	0.867	0.500	0.500
Matrix R*						
	c1	c2	c3	c4	c5	c6
c1	0.500	0.782	0.914	0.914	0.500	0.500
c2	0.218	0.500	0.782	0.782	0.218	0.218
c3	0.086	0.218	0.500	0.500	0.086	0.086
c4	0.086	0.086	0.500	0.500	0.086	0.086
c5	0.500	0.782	0.914	0.914	0.500	0.500
c6	0.500	0.782	0.914	0.914	0.500	0.500

Source: Own elaboration based on the S and S' Matrices shown in Table 4.

$$u_1 = GBM(p, q, c_1, c_2, \ldots, c_6) = \frac{1}{10} \prod_{\substack{i,j=1 \\ i \neq j}}^{6} \left(5c_i + 5c_j\right)^{\frac{1}{30}} = 0.674$$

$$u_1^* = GBM(p, q, c_1, c_2, \ldots, c_6) = \frac{1}{10} \prod_{\substack{i,j=1 \\ i \neq j}}^{6} \left(5c_i + 5c_j\right)^{\frac{1}{30}} = 0.674$$

Surprisingly, both values are equal. The GBM operator aggregates the preference values for each criterion considering all the potential interrelationships of all the criteria. Following a similar procedure for the rest of the criteria, the aggregated preference values are obtained (Table 6). Also, following step 4 and 5, the priority weights and ranking of each criterion are obtained.

Table 6 shows that the two scenarios are different. The first scenario which is less demanding regarding the information asked to the DMs presents the first criterion as the most priority, following by the fifth and the sixth criteria. In the second scenario, these three criteria have the same priority. The fourth and the third criteria are those which exhibit the least priority for both scenarios. Nevertheless, the rankings of these two criteria are inversely related in both scenarios. The third criterion shows the minimum priority in the first scenario, meanwhile, it is the fourth criterion for the second scenario.

Similarly, as above, the aggregate values are now obtained for each criterion and each scenario applying the GBM operator to the vector of aggregate values for each criterion at the individual level. Thus, we can calculate *gu1* and *gu1** as follows:

$$gu_1 = GBM\left(p, q, u_1^1, u_1^2, \ldots, u_1^n\right) = \frac{1}{10} \prod_{\substack{i,j=1 \\ i \neq j}}^{n} \left(5u_1^i + u_1^j\right)^{\frac{1}{n(n-1)}} = 0.537$$

$$gu_1^* = GBM\left(p, q, u_1^{*1}, u_1^{*2}, \ldots, u_1^{*n}\right) = \frac{1}{10} \prod_{\substack{i,j=1 \\ i \neq j}}^{n} \left(5u_1^{*i} + u_1^{*j}\right)^{\frac{1}{n(n-1)}} = 0.556$$

The extended method permits not only to calculate the aggregate values but also the weights as an average using the GBM operator, highlighting that in this case, the interrelationships that are considered are those of the DMs. Thus, the method can also be applied to any population segment that can be of interest to researchers or practitioners according to:

$$g_s u_1 = GBM\left(p, q, u_1^{1s}, u_1^{2s}, \ldots, u_1^{ns}\right) = \frac{1}{10} \prod_{\substack{is,js=1 \\ is \neq js}}^{ns} \left(5u_1^{is} + u_1^{js}\right)^{\frac{1}{ns(ns-1)}} \quad (11)$$

$$g_s^* u_1 = GBM\left(p, q, u_1^{*1s}, u_1^{*2s}, \ldots, u_1^{*ns}\right) = \frac{1}{10} \prod_{\substack{is,js=1 \\ is \neq js}}^{ns} \left(5u_1^{*is} + u_1^{*js}\right)^{\frac{1}{ns(ns-1)}} \quad (12)$$

Table 6
Aggregated and priority weights of criteria for the CFPR matrices.

Notation	First scenario		Second scenario	
	Aggregated score	Priority weight (Rank)	Aggregated score	Priority weight (Rank)
c1	0.674	0.232 (1)	0.674	0.237 (1)
c2	0.417	0.143 (4)	0.422	0.148 (4)
c3	0.268	0.092 (6)	0.214	0.075 (5)
c4	0.275	0.095 (5)	0.186	0.065 (6)
c5	0.637	0.219 (2)	0.674	0.237 (1)
c6	0.637	0.219 (2)	0.674	0.237 (1)

Source: Own elaboration using GBM for the matrices R and R^* shown in Table 5

The super indices in Eqs. (11) and (12) mean that the GBM operator is only applied to a segment subsample *s*. In the study, the following segments are analysed: countries and age group. The idea behind this approach is that it is likely that the responses by some specific group can also have somehow more interrelationship.

Finally, Table 7 shows the aggregate values and the weights of the criteria for the total respondents to the survey. It can be seen that both scenarios are different, as scenario one shows the following ranking for the criteria $c1 > c6 > c3 > c5 > c2 > c4$. Meanwhile, the ranking for the criteria under the second scenario is $c6 > c1 > c5 > c2 > c3 > c4$. It can be seen that there is only one basic agreement between both scenarios regarding the least priority criterion is observed in the information regarding "the fishing gear (e.g. longlines, trawls) used to catch the product", which is also in accordance with the study of Pieniak et al. [60], that found that there is no interest on comprehensive information about fishing methods for Spanish and Belgian consumers. The rest of the criteria shows a very different priority. For example, the less demanding information method –first scenario- concludes that "the name of the product and the species" is the most priority criterion, meanwhile, for the second scenario, it changes to "the "use by" or "best before date" criterion, however, is interesting to note that in both scenarios, c1 and c6 are the top two ranked criteria.

5.1. Segmentation and results robustness

This section analyses the ranking results obtained by the CFPR-GGBM for two segmentation variables: country of residence and age. This section provides two interesting insights: regulation adequacy and robustness of the results obtained by the less demanding information method. First, we can compare for each of the scenarios whether the EU28 represents adequately the preference relations on the mandatory information for FAPs or, contrarily, some segment is not well represented. For this first analysis, the Spearman correlation coefficients between the rankings for EU28 and each of the segments − 29 countries and 7 age groups- will be calculated. And second, the Spearman correlation coefficients between the rankings for each of the segments for both scenarios will be obtained.

Spearman's rank correlation coefficient (ρ) measures the nature (positive and negative) and strength (very strong to non-existent) of association between two variables [13]. It is simply calculated as the Pearson correlation coefficient of the ranks of the values of the two variables. A rule of thumb to interpret the coefficient in absolute value is: very strong association for values higher than 0.8; strong association for values between 0.5 and 0.8; moderate association for values between 0.3 and 0.5; weak association for values between 0.1 and 0.3; and very weak or non-existent association for values lower than 0.1.

Tables 8 and 9 show the Spearman correlation coefficients, the statistical coefficient and the p-value of the analysis of the positive association that exists between the preference relations for the mandatory information for FAPs in EU28 and each of the segments under analysis for both scenarios. It can be seen that for the first scenario (Table 8), there are 9 countries for which the preferences are different: France, the Netherlands, Italy, Luxembourg, Ireland, Greece, Portugal, Cyprus and Malta. Noticeably, there are not any differences observed when the age of segmentation is used. It is also remarkable that for 18 segments (14 country segments and 4 age segments), the respective preference rankings coincide exactly with the ranking of the EU28. Thus, it can be concluded that European preferences are representative of the analysed segments.

Table 9 can be analysed similarly to Table 8. In this case, it can be seen that the differences are almost negligible as only two countries present a significantly different pattern than the EU (France and Italy). Interestingly now, there are only 13 segments (9 countries and 4 age segments) with the same ranking preference order as the EU28. The results show that for the second scenario the representativeness of the ranking preferences of the EU28 is much more consistent. Nevertheless, the authors do not find any possible explanation for these facts.

Finally, the results' robustness for the method of Herrera-Viedma et al. [35] is going to be checked. Table 10 shows the Spearman correlation coefficients, the statistical coefficient and the p-value of the analysis of the positive association that exists between the preference relations obtained for each segment under the two different methods. The results show that only for 16 segments (the EU28, 13 countries and 2 age segments), the preference ranking positive association is not statistically significant. The extreme cases are observed in Croatia and Sweden. A group of ten segments formed by EU28, West Germany, Denmark, United Kingdom, Spain, Latvia, Slovenia, Romania, age (15–24 years) and age (35–44 years), shows more moderate differences. The case of the EU28 was already analysed and discussed. Similar patterns are observed for the rest of the segments, as in all the cases the criterion on the information of "the fishing gear (e.g., longlines, trawls)

Table 7
Aggregated and priority weights of criteria for all respondents.

Notation	First scenario		Second scenario	
	Aggregated score	Priority weight (Rank)	Aggregated score	Priority weight (Rank)
c1	0.537	0.188 (1)	0.528	0.188 (2)
c2	0.474	0.166 (5)	0.459	0.164 (4)
c3	0.499	0.175 (3)	0.459	0.164 (5)
c4	0.315	0.110 (6)	0.285	0.102 (6)
c5	0.496	0.174 (4)	0.515	0.184 (3)
c6	0.534	0.187 (2)	0.556	0.198 (1)

Source: Own elaboration using GGBM for the matrices formed with the aggregated preference scores of all the respondents

Table 8
Comparison of EU 28 with segments based on countries and age (First Scenario).

Segment	Spearman Correlation	S.coef	p-value
Countries			
FR - France	0.714	10	0.136
BE - Belgium	0.943	2	0.017
NL - The Netherlands	0.829	6	0.058
DE-W - Germany - West	0.886	4	0.033
IT - Italy	0.486	18	0.356
LU – Luxembourg	0.829	6	0.058
DK – Denmark	0.943	2	0.017
IE – Ireland	0.829	6	0.058
GB-UKM - Great Britain	1.000	0	0.003
GR – Greece	0.829	6	0.058
ES -Spain	0.943	2	0.017
PT - Portugal	0.714	10	0.136
DE-E Germany East	1.000	0	0.003
FI - Finland	1.000	0	0.003
SE - Sweden	1.000	0	0.003
AT - Austria	1.000	0	0.003
CY - Cyprus (Republic)	0.771	8	0.103
CZ - Czech Republic	1.000	0	0.003
EE - Estonia	1.000	0	0.003
HU - Hungary	1.000	0	0.003
LV - Latvia	1.000	0	0.003
LT - Lithuania	1.000	0	0.003
MT - Malta	0.829	6	0.058
PL - Poland	0.943	2	0.017
SK - Slovakia	1.000	0	0.003
SI - Slovenia	0.943	2	0.017
BG - Bulgaria	1.000	0	0.003
RO - Romania	1.000	0	0.003
HR - Croatia	1.000	0	0.003
Age			
15–24 years	1.000	0	0.003
25–34 years	1.000	0	0.003
35–44 years	1.000	0	0.003
45–54 years	0.943	2	0.017
55–64 years	0.943	2	0.017
65–74 years	0.943	2	0.017
75 years and older	1.000	0	0.003

Table 9
Comparison of EU 28 with segments based on countries and age (Second Scenario).

Segment	Spearman Correlation	S.coef	p-value
Countries			
FR - France	0.829	6	0.058
BE - Belgium	1.000	0	0.003
NL - The Netherlands	1.000	0	0.003
DE-W - Germany - West	1.000	0	0.003
IT - Italy	0.771	8	0.103
LU – Luxembourg	0.943	2	0.017
DK – Denmark	0.943	2	0.017
IE – Ireland	1.000	0	0.003
GB-UKM - Great Britain	1.000	0	0.003
GR – Greece	0.943	2	0.017
ES -Spain	0.943	2	0.017
PT - Portugal	0.943	2	0.017
DE-E Germany East	0.943	2	0.017
FI - Finland	0.943	2	0.017
SE - Sweden	0.886	4	0.033
AT - Austria	0.943	2	0.017
CY - Cyprus (Republic)	0.943	2	0.017
CZ - Czech Republic	0.943	2	0.017
EE - Estonia	0.943	2	0.017
HU - Hungary	0.943	2	0.017
LV - Latvia	1.000	0	0.003
LT - Lithuania	0.943	2	0.017
MT - Malta	1.000	0	0.003
PL - Poland	1.000	0	0.003
SK - Slovakia	0.943	2	0.017
SI - Slovenia	0.943	2	0.017
BG - Bulgaria	0.943	2	0.017
RO - Romania	1.000	0	0.003
HR - Croatia	0.886	4	0.033
Age			
15–24 years	1.000	0	0.003
25–34 years	0.943	2	0.017
35–44 years	1.000	0	0.003
45–54 years	0.943	2	0.017
55–64 years	1.000	0	0.003
65–74 years	1.000	0	0.003
75 years and older	0.943	2	0.017

Table 10
Comparison of the First and Second Scenarios.

Segment	Spearman Correlation	S.coef	p-value
Countries			
EU28	0.771	8	0.103
FR - France	0.829	6	0.058
BE - Belgium	0.886	4	0.033
NL - The Netherlands	0.943	2	0.017
DE-W - Germany - West	0.771	8	0.103
IT - Italy	0.943	2	0.017
LU – Luxembourg	0.829	6	0.058
DK – Denmark	0.771	8	0.103
IE – Ireland	0.943	2	0.017
GB-UKM - Great Britain	0.771	8	0.103
GR – Greece	0.829	6	0.058
ES -Spain	0.771	8	0.103
PT - Portugal	0.829	6	0.058
DE-E Germany East	0.886	4	0.033
FI - Finland	0.886	4	0.033
SE - Sweden	0.714	10	0.136
AT - Austria	0.886	4	0.033
CY - Cyprus (Republic)	0.943	2	0.017
CZ - Czech Republic	0.886	4	0.033
EE - Estonia	0.886	4	0.033
HU - Hungary	0.886	4	0.033
LV - Latvia	0.771	8	0.103
LT - Lithuania	0.886	4	0.033
MT - Malta	0.943	2	0.017
PL - Poland	0.886	4	0.033
SK - Slovakia	0.886	4	0.033
SI - Slovenia	0.771	8	0.103
BG - Bulgaria	0.886	4	0.033
RO - Romania	0.771	8	0.103
HR - Croatia	0.714	10	0.136
Age			
15–24 years	0.771	8	0.103
25–34 years	0.886	4	0.033
35–44 years	0.771	8	0.103
45–54 years	0.943	2	0.017
55–64 years	0.886	4	0.033
65–74 years	0.886	4	0.033
75 years and older	0.886	4	0.033

used to catch the product" has the least priority. Outstandingly, the results that minimize the number of pairwise comparisons in surveys that assure the consistency property are robust as Table 10 shows that for the rest of the 21 segments the positive association between both methods is statistically significant. The result is not a surprise as CFPR is a method that is well known in the strand of the literature on MCDM analysis. In our case, CFPR requires only 5 adjacent pairwise comparisons –a figure which is lower than the total 15 pairwise comparisons which are needed on a scale of six criteria.

6. Policy implications

The results indicate that for European residents the most important criteria are "the name of the product and the species" and "the "use by" or "best before" date", which means that this information should be highlighted among the rest of the criteria in the packages of the products or the information accompanying these products. Also, the fact that the "name of the product and the species" is highlighted as one of the most important criteria evidences the importance of strengthening the policies against fraud and particularly mislabelling, which has also been identified as a problem in Europe [52].

On the other hand, it was found that the least priority criterion was "the fishing gear (e.g., longlines, trawls) used to catch the product". This might be caused by the lack of knowledge that consumers have about the environmental impact of the fishing gear. Therefore, more information should be given to consumers about the different fishing gears and their impacts on the environment through labels added to the products or marketing campaigns. Investigations such as the one of Løkkeborg [46] analysed mitigation measures for seabirds' mortality in longline, trawl and gillnet fisheries. Further research and knowledge transfer to society might be important to grow consumers' awareness of the environmental impacts that might be caused by the fishing gears.

Moreover, regarding the association that exists between the preference relations for the mandatory information for FAPs in EU28 and the different countries, the intersection of the two scenarios identified that in Italy and France the preferences are different from the rest of the EU. In particular, Italy can be considered the most extreme case regarding the differences observed in the first scenario. For Italian residents, the preferences over criteria can be ordered as $c5 > c6 > c1 > c2 > c3 > c4$. So, for Italian residents, the most important criterion is to have information about whether the product was previously frozen –the fourth criterion at the European level. Italy is among the group of European countries which consumes more fish per-capita, and Italian residents are also characterized by eating out regularly [68], so the differences might be explained by the fact that Italian residents prefer to clearly know whether the fish they are eating is fresh or refrigerated. On the other hand, the second scenario does not show so extremely different results for Italy, so it might not be necessary to apply the principle of subsidiarity of the EU.

Still, the main outcome that we can extract from the previous results is that it might be necessary to evaluate ex-ante the future mandatory information scale to find out whether some countries show several differences so the regulation can be adapted specifically for these cases throughout the application of the principle of subsidiarity. It seems evident that if the future scale contains more attributes, the differences at the country level can be greater than those observed here in the

current analysis with only six attributes.

Furthermore, the preference relations for the mandatory information for FAPs in EU28 according to the age group seem to be statistically the same. These results are similar to those obtained by Pieniak et al. [60] who found that the preferences for label information do not differ between young and old Spanish and Belgian consumers. Nevertheless, future modifications of the regulation that assesses the mandatory information for FAPs (EU 1379/2013) should also contemplate that this issue might change if another type of mandatory information more associated with the environment and climate change is finally included.

Finally, we recommend applying the model CFPR-GGBM to evaluate the degree of importance scales, as this model considers the interrelationship between both the criteria and respondents, which is an important feature that provides more consistent and accurate results than other multi-criteria methods.

7. Conclusions

Normally, the majority of MCDM methods consider that the criteria and the respondents are independent, i.e., they do not exhibit any type of interrelationship. However, in the real world, this is a very strong assumption difficult to assume. In most of the preferences' studies, criteria and respondents exhibit some sort of dependency. For this reason, our proposal is based on a CFPR-GGBM method that properly handles both of the commented issues.

In DM problems, researchers are usually interested in obtaining the best alternative or the most priority criterion, and sometimes, we tend to minimize the role of the rest of the criteria. Nevertheless, this can be problematic in some cases when the analysis has to be done in the set of all the criteria as the scale has already been decided by some process that has involved multiple and different stakeholders such as regulators, policy makers, politicians, fishermen associations, aquaculture farms, retailers, intermediaries, consumers, researchers and other interested parties in the food logistic chain.

We firmly believe that interrelationship is an important feature that needs to be considered to provide more consistent and accurate results [3]. For that reason, we extend the model CFPR-GBM proposed by Alias et al. [3], considering also the possible relationship between the respondents with the model CFPR-GGBM. Thus, the GBM operator handles not only the dependency aspect between the criteria but also the respondents in the aggregation step.

Our results are more conclusive in the least priority criterion "the fishing gear (e.g., longlines, trawls) used to catch the product". The results are less conclusive in the upper part of the priority criteria, but it can be concluded that two of the most important criteria for European citizens are "the name of the product and the species" and "the "use by" or "best before" date".

The analysis of the segments shows that Italian residents exhibit for the first scenario a very different pattern regarding the preferences for the mandatory information. As for the second scenario, the results are not so extreme then the principle of subsidiarity of the EU might not be necessary. Nevertheless, our main conclusion in this respect is to analyse the future scale ex-ante to see if some Member State shows many differences so the regulation can be specifically adapted in some cases.

Our study is not exempt from some limitations. First, we do not intervene in the questionnaire, so a real survey based on CFPR was not administered. It would be an interesting issue for future research to compare the results obtained from this CFPR survey with traditional surveys like the one used in the study. Nevertheless, the database is very rich and contains all the countries of the EU28, and for the first time, the scale of the mandatory information for FAPs in the EU28 has been analysed.

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