

Evaluating sustainability in organisations with a fuzzy logic approach*

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EVALUATING SUSTAINABILITY IN ORGANISATIONS WITH A FUZZY LOGIC APPROACH

Abstract

Purpose - To determine whether the organisations more strategically committed to its stakeholders present better social and financial performance and, based on this relationship, know the state of the art of the Spanish sectors' approach to the sustainable development.

Design/methodology/approach - This paper analyses the sustainability approach of a sample of 52 Spanish listed firms. This process is based on the study of different indexes generated in order to evaluate the company's commitment through its stakeholders, the social and financial performance of these organisations, and the relationship between them. Previous results showed a positive and not significant relationship between these variables and a positive financial performance. This paper replicates a former research by introducing a fuzzy-logic-based methodology in order to generate the aforementioned indexes.

Findings -The current results support the conclusions formerly obtained and simultaneously demonstrate that the big Spanish companies are at an incipient stage of development of a clearly sustainability-oriented management.

Research limitations/implications - The unavailability of a long series of organisations sustainability information is an obstacle for a broader analysis. This research could motivate the usefulness of the fuzzy logic methodology for analysing the business sustainability approach and to develop studies on the corporate social performance.

Originality/value - The use of fuzzy logic methodology for the generation of indexes related to the organisations social responsibility and sustainability results.

Keywords Stakeholder approach, Social performance, Financial performance, Fuzzy logic, Spain

Paper type Research paper

Introduction

Since the work of Bowen (1953), who is considered to be the precursor of the modern Corporate Social Responsibility era (Carroll, 1979), the body of the so - called Corporate Social Responsibility (CSR) related literature has incremented at an exponential rate. Moreover, issues related to modern enterprise strategic management theories and tools (Chakraborty and Sharma, 2007; Agle et al., 2008 or Smith, 2008, among others) as well as to the performance measurement topic (for example, Hyland et al., 2007 or Phusavat et al., 2007) are targeted both by the academia and the business world.

Notwithstanding, the study of the CSR concept and its strategic integration is still at its embryonic stage and, as McWilliams et al. (2006) underscore, important issues such as the concept measurement and the elaboration of a widely accepted theoretical framework, are yet to be resolved. On the other hand, due to the complexity associated to the definition and measurement of the sustainability concept, it is currently still not possible to differentiate a generally accepted evaluation methodology for projects or policies (Lee, 2006).

In this context, a previous research developed by Moneva et al. (2007), used a sample of 52 Spanish listed firms in order to determine whether the strategic commitment of the organisation to its stakeholders leads to better social and financial results. Although some of the differences in terms of returns have limited significance, the main conclusion drawn from the analysis showed that the financial performance of the sectors or organisations with a greater stakeholder strategic commitment was not inferior to that of the sectors or organisations with a shareholder approach, thus rejecting the hypotheses supported by those theories that establish a negative relationship between social and financial performance.

Building on the premise of this work, the objective of the present study focuses on the thorough examination of the abovementioned relationship by introducing, as a main contribution, the application of a fuzzy-logic - based methodology (Zadeh, 1965). Thus not only will the robustness of the results be checked,

but also the suitability of the methodology application to the study of CSR - related issues measurement will be assessed, along the lines of other studies which have used fuzzy logic in the sustainability quantification (Ducey and Larson, 1999; Phillis and Andriantiatsaholiniaina, 2001; Andriantiatsaholiniaina et al., 2004; Chiou et al., 2005).

The article is structured in five parts: this brief introduction is followed by the literature review. Then, the research design and the obtained results have been defined. Finally, the main conclusions of the study are presented.

Literature review and conceptual framework

Evaluation of Corporate Social Responsibility of Organisations

Academic literature has proposed a great number of definitions for the term Corporate Social Responsibility in the course of the last decades. In general terms, these are not contradictory in nature but evolutionary, as the definition of the concept is taking shape with the contribution of different authors (Carroll, 1999). As a result, nowadays CSR comprises various theories, approximations and terminology (Garriga and Melé, 2004).

Notwithstanding, as the quoted authors claim, we would not face a strict defining among the different theories but witness the existence of interrelations among them. In fact, as Wheeler et al. (2003) state, CSR, sustainable development and strategic stakeholder management are concepts intertwined in a context of corporate value generation. Having in mind that the long - term corporate value generation does not refer solely to economic issues but it also incorporates social and environmental aspects (Graafland et al., 2004), these authors maintain that a model that has the corporate value generation at its core will permit the concepts of CSR, sustainability and the stakeholder approach to find their natural place be it on strategic or

management level. Thus they distinguish among three styles of corporate culture in terms of the company's attitude towards their stakeholders and the corporate value generation. The first one receives the name of "*compliance culture*" and is characteristic of those companies that respect basic social norms but do not show any particular commitment to their stakeholders. The second level comprises "*relationship management culture*", inherent to companies that recognize the instrumental value of relying on good stakeholder relationships but within certain limits and after having satisfied their investors' demands. Finally, the third level would refer to the "*sustainable organisation culture*", where the organisation recognises the interdependence of company, stakeholders and society in general and seeks out the maximising of corporate value generation in economic, environmental and social terms.

Along this line of thought, "corporate sustainability" is one of the terms that have recently been incorporated in the CSR sphere (Garriga and Melé, 2004) and it refers to "*the company's voluntary actions that demonstrate the inclusion of social and environmental concerns in its operations and stakeholder interactions*" (van Marrewijk and Werre, 2003). The so - called corporate sustainability encompasses the adaptation of corporate processes and strategies to the so - called sustainable development and would be, according to Wempe and Captein (2002), the ultimate CSR objective.

As Whitehouse (2006) points out, even though it has not been possible yet to coin a universally accepted definition of the CSR concept, a great number of companies, especially big ones, seem to have found a common ground for the generation and application of CSR - related policies and practices. This fact provides the academic community with corporate information linked to economic, environmental and social issues, which can serve as empiric data in the elaboration of numerous research papers.

One aspect of these works relates to the study of the existence of a possible relation between the corporate financial performance (CFP) and the company's social performance (CSP). Although results obtained are not conclusive yet, the latest research seems to be in favour of the existence of a positive

interrelation between social and financial performance. Thus there are works which underscore the fact that a better CSP is linked to a better CFP but the organisation needs to have a strategic CSR approach (Husted and de Jesus Salazar, 2006), a view that coincides with the previously commented proposition of Wheeler et al. (2003).

Nevertheless, the debate on the relation between the corporate economic-financial performance and the company's social performance is still open (Kolstad, 2007; Van der Laan et al., 2007). The difficulties to estimate the corporate performance in CSR terms (Graafland et al., 2004), particularly when no consensus has been reached yet on the evaluation methodology, (McWilliams et al., 2006) and this, added to the different quality levels of available information, give rise to an intricate process of comparison between the results obtained from different research lines.

In this context, fuzzy logic could be of use to the CSR study and would imply the application of methodologies that different authors employ for the measurement and quantification of sustainable development - related issues (Ducey and Larson, 1999; Phillis and Andriantiatsaholiniaina, 2001; Andriantiatsaholiniaina et al., 2004; Chiou et al., 2005), to the concrete sphere of corporate sustainability integration (Bansal, 2005).

Fuzzy logic for CSR

The fuzzy inference system (FIS), known also as a “fuzzy-rule-based system”, a “fuzzy expert system” or a “fuzzy model” (Jang and Sun, 1995), is a popular methodology for implementing fuzzy logic (Shapiro, 2004). Jang (1993) describes the five functional blocks that constitute the FIS: i) database, which defines the membership functions of the fuzzy sets; ii) rule base, containing fuzzy if - then rules; iii) decision-making unit or inference engine (Shapiro, 2004); iv) fuzzification interface and v) defuzzification interface. Through these, initial quantified values are introduced in the system after having generally passed through a

normalization process and are transformed into linguistic values associated to the so called membership functions, where expert knowledge has been of use. There are different types of membership functions such as triangular, trapezoidal or Gaussian (Jang and Sun, 1995), but the triangular membership function is commonly used (Wu and Lee, 2007) because it is intuitively easy for the decision makers to use and calculate it (Lin et al., 2007). The resulting linguistic variables become fuzzy inputs of the decision - making unit. Then, via the application of the if - then rules, a fuzzy output is obtained, similarly expressed in linguistic terms. The if - then rules represent the knowledge and describe the logical evolution of the system according to the linguistic values (Phillis and Andriantiatsaholiniaina, 2001).

It is possible to distinguish between different types of FIS (Jang and Sun, 1995), but the Mamdani fuzzy model has been commonly mentioned in the fuzzy theory application to sustainability (Phillis and Andriantiatsaholiniaina, 2001) because it is widely accepted, intuitive and well-suited to human input. Mamdani-type inference expects the output membership functions to be fuzzy sets. With the defuzzification process, the fuzzy output is changed into numerical values. There are several defuzzification methods in the literature (Lee, 1990), but the centroid is the most frequently employed (Wu and Lee, 2007).

Besides its use as a measurement tool for sustainability, fuzzy logic (Zadeh, 1965) is extensively applied as an analysis methodology in such areas as company organisation and financial economics (Shapiro, 2004; Cassia et al., 2005; Sheen, 2005; Tiryaki and Ahlatcioglu, 2005; Bottani and Rizzi, 2006; Gunasekaran et al., 2006; Cheng et al., 2007; Lin et al., 2007; Perez Gladish et al., 2007; Wu and Lee, 2007; Wu et al., 2007), a fact that emphasizes the relevance of mathematics of uncertainty in environments submitted to profound business changes (Gil-Aluja 1996).

Research Design

In the Spanish context, a previous work of investigation undertaken by Moneva et al. (2007) held as an objective to determine whether the corporate strategic stakeholder commitment was associated to better financial and social performance. In addition, it was analysed whether those companies that demonstrate a higher level of strategic consistency, in social responsibility terms, would equally generate a better economic-financial performance.

As long as the stakeholder concept encompasses groups with different interests and needs beyond the strictly economic-financial ones, when the abovementioned strategic consistency was evaluated, what was taken into account was not only the integration of those interests into the company mission and corporate values but also the level of communication transparency as exposed in the triple bottom line reporting, i.e. its performance in terms of sustainability. Even though, as Reynolds and Yuthas (2007) note, public reporting cannot guarantee that all corporate interests are exposed, at least it provides the mechanism for making transparent some corporate actions. Thus it is assumed that stakeholder commitment and consequently, the socially responsible performance is not limited to isolated actions but they are integrated into a strategic process that implies the whole organisation.

The evaluation process of corporate sustainability reporting has been carried out according to a number of parameters. In the first place, once determined if the organisation has sustainability information at public disposal, it is assessed whether the latter can be qualified as a report. Then its level of compatibility to generally accepted guidelines is studied. Even though at present no consensus exists regarding this issue, the Global Reporting Initiative Guide 2002 (GRI, 2002) -currently, the G3 Guide (GRI, 2006) are applied-, due to its wide acceptance (KPMG and University of Amsterdam, 2005), has been chosen as the standard of reference. As far as the quality of the provided information is concerned, the GRI qualification “in

accordance”[1] and the validation and verification or certification reports have served as guidelines in developing the analysis as regards the transparency of the corporate information disclosed.

Once the evaluation process has been concluded, a Sustainability Reporting Index (SRI) is proposed. The latter, alongside the stakeholder strategic approach declared in the company’s principles and corporate values (the corporate mission), makes it possible to classify the different organisations, object of the study, according to their degree of strategic consistency, i.e. in the so called Strategic Consistency Index (SCI).

Despite the scarce significance obtained in some cases, the major conclusion pertains to the fact that the financial performance of those sectors or organisations with higher stakeholder commitment is not inferior to the one displayed by those sectors or organisations that are mainly shareholder-oriented.

Table I. Sample Sector Composition

<u>Sector</u>	<u>Market Capitalisation</u>	
	<u>(%)</u>	<u>Num. of Companies</u>
1. PETROL AND POWER	13.55	8
2. BASIC MAT./INDUSTRY/CONSTR.	7.42	10
3. CONSUMER GOODS	4.07	4
4. CONSUMER SERVICES	5.60	11
5. FINANCIAL SERV. & REAL ESTATE	22.49	16
6. TECHNOLOGY & TELECOMM.	16.89	3
Total	70.02	52

Source: Moneva *et al.* (2007)

Building on the premise of this research, the objective of the present study focuses on the thorough examination of the abovementioned relationship by introducing, as a main contribution, the application of a fuzzy-logic based methodology (Zadeh, 1965).

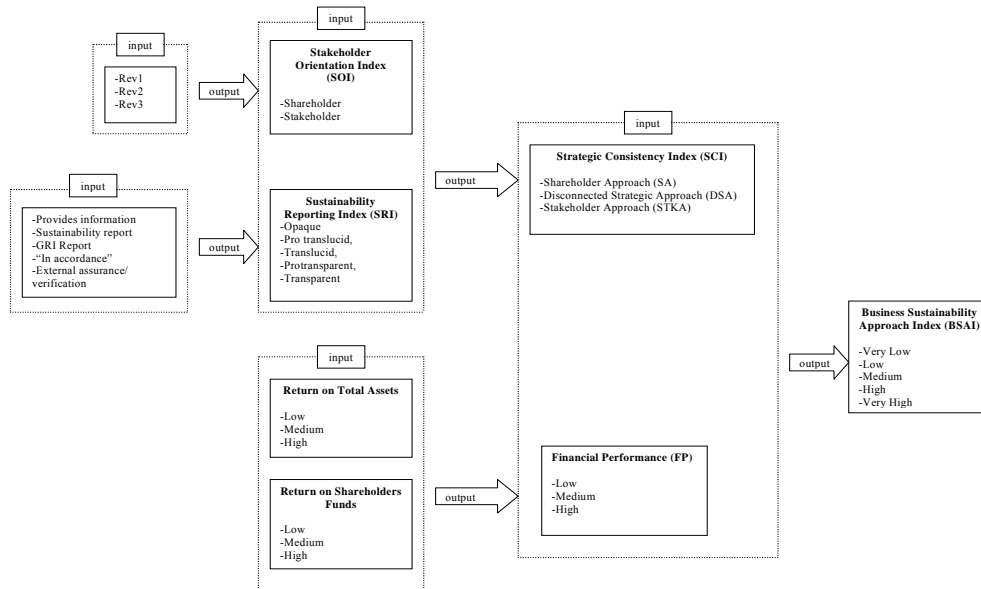
In order to generate the relevant corporate responsibility and sustainability indexes, to the previously defined, a new Business Sustainability Approach Index is added, which will sum up both the corporate

strategic consistency in terms of commitment and social performance and the results obtained of the company's economic-financial performance (figure 1). The computations have been executed by means of MATLAB's Fuzzy Logic Toolbox [2], where the sample of analysis is the one displayed in table I.

The inputs that result in the corporate Stakeholder Orientation Index (SOI), were generated according to the authors' opinion on the basis of the analysis of the corporate mission and values, in compliance with the methodology proposed by Roman et al. (1999). The results from the analysis of the sustainability reporting, gathered as of 31/12/2003, serve as inputs in the elaboration of the level of corporate actions transparency in sustainability terms (SRI). As figure 1 shows, the proposed Sustainability Reporting Index, classifies the organisations as "opaque", "pro-translucid", "translucid", "pro-transparent" or "transparent", according to their accomplishment of the aforementioned parameters. In this sense, an "opaque" organisation does not provide sustainability information; on the contrary, the "transparent" organisation publishes a sustainability report, produced in accordance to the GRI guidelines and with an external verification.

Both indexes (SOI and SRI) comprise the inputs for the fuzzy inference system created for the generation of the Strategic Consistency Index (SCI) of the organisation as an answer to the expectations and needs of a number of stakeholders, i.e. it discloses the company's approximation to CSR and sustainability values. In terms of this index, the organisation can be considered as "shareholder approach" (SA) or "stakeholder approach" (STKA), depending on its management orientation and commitment towards the shareholders or the stakeholders respectively. The "disconnected stakeholder approach" (DSA) organisations are not strategically consistent in their stakeholder management.

Figure 1. Business Sustainability Approach Index Generation. An Outline.



Source: Moneva et al. (2007) and own work.

On the other hand, the financial and economic return ratios of the different companies calculated as of 31/12/2003 and obtained from the SABI and BANKSCOPE databases resulted in the Financial Performance index (FP), after having been submitted to a normalization process (Krajnc y Glavič , 2005) as a preliminary step to their introduction in the system.

$$I_{N,ij}^+ = \frac{I_{A,ij}^+ - I_{\min,j}^+}{I_{\max,j}^+ - I_{\min,j}^+}$$

Where, $I_{N,ij}^+$ is the normalized ratio i for a group of ratios j
 $I_{A,ij}^+$ is the ratio i for a group of ratios j
 $I_{\min,j}^+$ is the minimum value for a group of ratios j
 $I_{\max,j}^+$ is the maximum value for a group of ratios j

Finally, SCI and FP make up the inputs for the last fuzzy inference system whose ultimate outcome is the so-called Business Sustainability Approach Index (BSAI).

The defined membership functions for all cases are triangular membership functions, not only due to their simplicity (Lin et al., 2007) but also because they can approximate most non - triangular ones (Pedrycz, 1994).

Expert knowledge formed the basis for the definition of the different systems' rules of fuzzy inference. The sum total of the generated rules comes up to 10 for the SOI, 8 for the SRI, 15 for the SCI, 9 for the FP and 11 in the case of BSAI. Table II displays an extract from the rule formulation succinctly presented here for reasons of brevity [3].

Table II. Formulated Rules. An Extract.

<u>Rules for the Strategic Consistency Index (SCI)</u> <u>definition</u>	<u>Rules for the Business Sustainability Approach</u> <u>Index (BSAI) definition</u>
1. If (input1 is mf2) and (input2 is mf1) then (output1 is mf1) (1) 2. If (input1 is mf2) and (input2 is mf2) then (output1 is mf1) (0.5) 3. If (input1 is mf2) and (input2 is mf3) then (output1 is mf2) (1) 4. If (input1 is mf2) and (input2 is mf4) then (output1 is mf2) (1) 5. If (input1 is mf2) and (input2 is mf5) then (output1 is mf2) (1) 6. If (input1 is mf3) and (input2 is mf1) then (output1 is mf2) (1) 7. If (input1 is mf3) and (input2 is mf2) then (output1 is mf2) (1) 8. If (input1 is mf3) and (input2 is mf3) then (output1 is mf3) (0.25) 9. If (input1 is mf3) and (input2 is mf4) then (output1 is mf3) (0.5) 10. If (input1 is mf3) and (input2 is mf5) then (output1 is mf3) (1) 11. If (input1 is mf2) and (input2 is mf3) then (output1 is not mf3) (1) 12. If (input1 is mf2) and (input2 is mf4) then (output1 is not mf3) (0.5) 13. If (input1 is mf2) and (input2 is mf5) then (output1 is not mf3) (0.25) 14. If (input1 is mf3) and (input2 is mf1) then (output1 is not mf3) (1) 15. If (input1 is mf3) and (input2 is mf2) then (output1 is not mf3) (0.5)	1. If (input1 is mf1) and (input2 is mf1) then (output1 is mf1) (1) 2. If (input1 is mf1) and (input2 is mf2) then (output1 is mf2) (0.5) 3. If (input1 is mf1) and (input2 is mf3) then (output1 is mf3) (0.5) 4. If (input1 is mf2) and (input2 is mf1) then (output1 is mf1) (0.5) 5. If (input1 is mf2) and (input2 is mf2) then (output1 is mf2) (1) 6. If (input1 is mf2) and (input2 is mf3) then (output1 is mf3) (1) 7. If (input1 is mf3) and (input2 is mf1) then (output1 is mf3) (1) 8. If (input1 is mf3) and (input2 is mf2) then (output1 is mf4) (1) 9. If (input1 is mf3) and (input2 is mf3) then (output1 is mf5) (1) 10. If (input1 is mf3) then (output1 is mf5) (0.25) 11. If (input1 is mf1) then (output1 is mf1) (0.25)

NOTE:

Input 1:

mf2=SH, mf3=STK

Input 2:

mf1=Opaque, mf2= Pro-translucid, mf3=Translucid,
mf4=Pro-transparent, mf5=Transparent

Output 1:

mf1=SA, mf2=DSA, mf3=STKA

Input 1:

mf1=SA, mf2=DSA, mf3=STKA

Input 2:

mf1=Low, mf2=Medium, mf3=High

Output 1:

mf1=Very Low, mf2=Low, mf3=Medium

mf4=High, mf5=Very High

Source: Own work

As far as SCI rules generation in sustainability terms is concerned, more importance has been given to rule 1 than to rule 2, since the former discloses no information on the companies' sustainable development actions. On the other hand, new rules have been added for the differentiation of those cases where the SCI is classified as disconnected. These emphasize the fact that the companies are not strategically consistent from sustainability perspective and the importance given to each rule varies according to sustainable quality and stakeholder commitment of the enterprises.

In the BSAI related rule generation, those cases that have shown low SCI, despite their not low financial performance, have been penalized. Conversely, in the sustainability context, a high SCI has been rewarded and a low one has been penalized.

The FIS employed has been the Mamdani fuzzy inference system type, using the min-operator for the logical AND, the max-operator as an aggregation method, and the centroid as a defuzzification method. As Mendoza and Prabhu (2003) point out the minimum operator represents a conservative attitude towards sustainability.

Following this methodology, table III highlights the hypothesis tested in this research work.

Table III. Research hypothesis

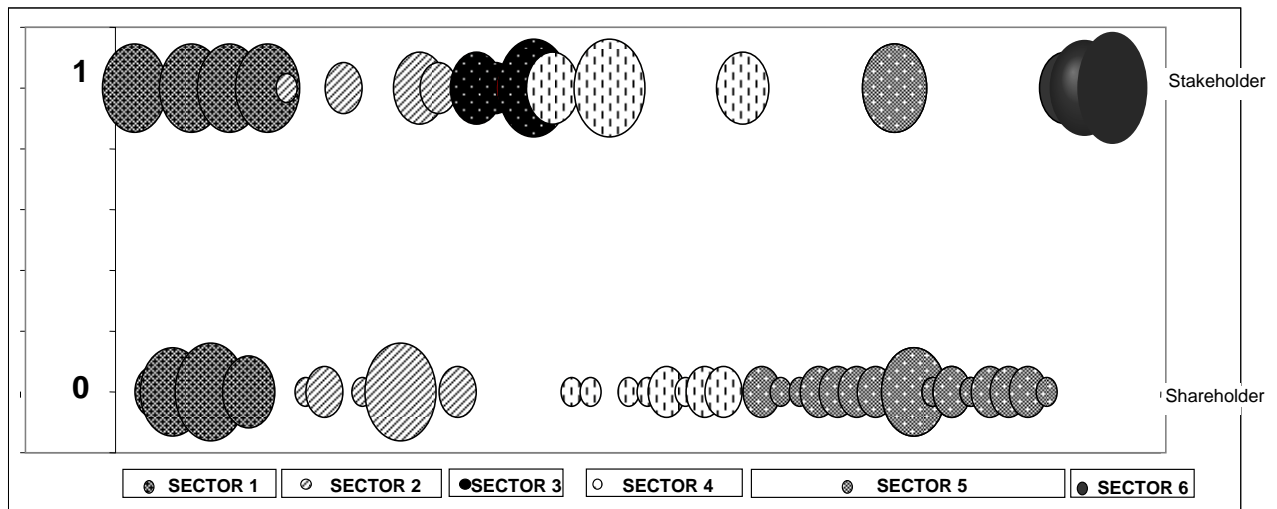
H1	<p><i>Stakeholder oriented companies present better social performance than Shareholder orientated companies.</i></p> <p>Firms with a stakeholder mission and vision present better Sustainability Reporting Index than firms with a shareholder mission and vision.</p>
H2	<p><i>Stakeholder Approach companies (STKA) present better financial performance than Shareholder Approach (SA) and Disconnected Strategic Approach (DSA) companies.</i></p> <p>Firms with a stakeholder mission and vision, which also have GRI sustainability reports, present better economic-financial indicators than firms with shareholder mission and vision without GRI sustainability reports, and than firms without strategic consistency –</p>

firms with a stakeholder orientation without GRI sustainability reporting or vice versa-

Analysis of Results

The final results of the analysis are disparate for each sample organisation. The so - called Sustainability Reporting Index, used as a proxy variable in the social performance, serves as the first approximation to the sustainability disclosure study.

Figure 2. Sustainability Reporting Index and Stakeholder Orientation Index



Note: The size of the circle area is proportional to the SRI value

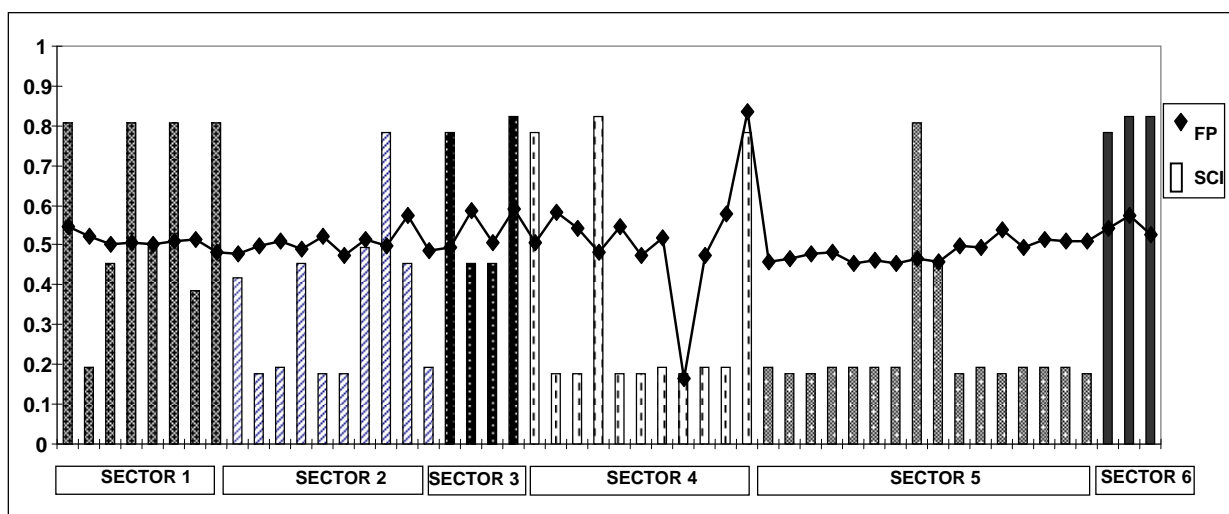
Source: Own work.

The first hypothesis to be contrasted (table III) dealt with the relationship between the stakeholder commitment of a company and its level of sustainability information disclosure. Like Gelb and Strawser (2001), we have also detected some positive relationship between disclosure level and advanced social goals.

The results of figure 2 display the existence of some clearly stakeholder - oriented sectors (technology and telecommunications and consumer goods), which additionally demonstrate a high quality of information disclosure. In the other extreme the “financial services and real estate” sector is mainly shareholder-oriented. As far as the “petrol and power” sector is concerned, the high level of information disclosure alternates with the miscellaneous strategic orientation of its components. This could indicate that due to the level of sustainability-related risks of the sector, the companies employ a *pferding* conduct and “copy” the information systems without having always a true strategic commitment.

The second hypothesis to be contrasted (table III) refers to the existence of significant differences of economic-financial performance among the sectors or organisations that display a higher sustainability - oriented Strategic Consistency Index (sectors 1, 3 and 6, i.e., petrol and power, consumer goods and technology and communication) as compared to the other sectors. Figure 3 exposes the lack of significant differences between both groups of companies, thus confirming the conclusions of the aforementioned work of Moneva et al. (2007), that is, the financial performance of sectors or organisations with a greater stakeholder strategic commitment, is not inferior to that of sectors or organisations with a clear shareholder approach.

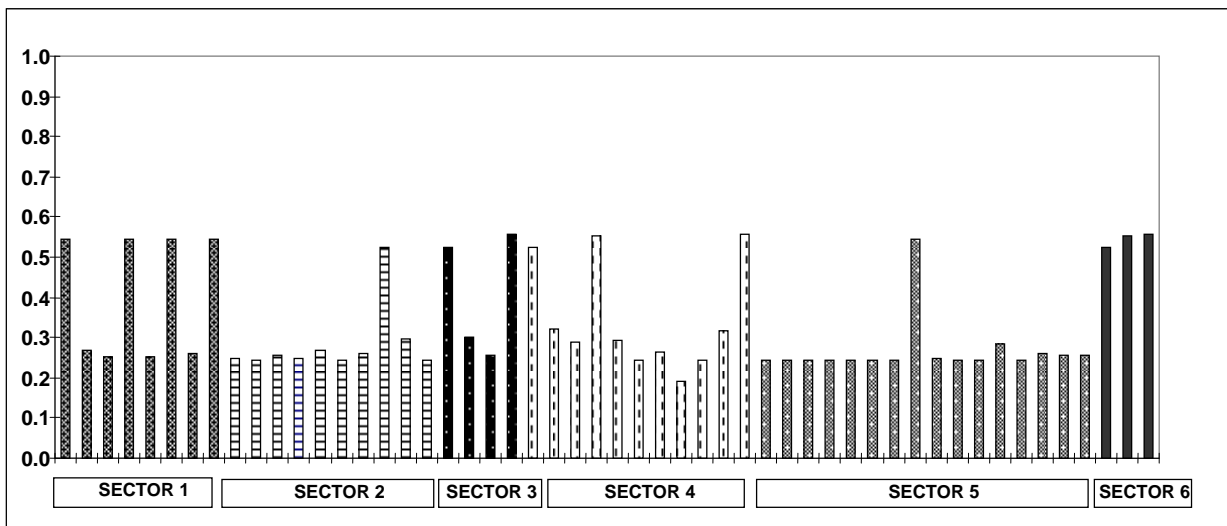
Figure 3. Strategic Consistency Index vs. Financial Performance



Source: Own work

Finally, figure 4 presents the results for the Business Sustainability Approach Index (BSAI) that has been proposed following the triple bottom line concept (economic, social and environmental) through the integration of the stakeholder business orientation, the disclosure level of sustainability and its economic results. Among all the economic sectors, Technology and Communication manifests the leading values, shared by some companies from the other sectors. Notwithstanding, it should be underscored that the sustainability orientation of the sample listed Spanish companies is never higher than 0.6 out of 1. Rules design has rewarded high strategic consistency more than high financial performance; this is the main reason to justify the small differences between companies with the same SCI, and different financial performance (FP). These results underlie the incipient stage of development of a clearly sustainability - oriented business management.

Figure 4. Business Sustainability Approach Index



Source: Own work.

Conclusions

Based upon the argument of a previous work on the listed Spanish companies (Moneva et al, 2007), this study has proposed different indexes in order to measure their strategic commitment with several stakeholders and its relationship with the financial and social performance. Moreover, integrating these three aspects related to the corporate social responsibility into a sole index, it is possible to analyze the organization approach towards sustainability. To this end, a fuzzy - logic - based methodology has been conservatively used in the course of the whole process of evaluation and weighting. The degree of uncertainty that is associated to both the sustainability concept itself and the methodology that evaluates and guarantees a good quality of the information disclosure as an indicator of the companies' real contribution to achieve sustainability (available information, management commitment to the public, report validation, etc.) has called for caution when generating the rules which determine the companies' position in the elaboration of the various indices.

The current results support the conclusions formerly obtained and simultaneously demonstrate that the big Spanish companies are at an incipient stage of development of a clearly sustainability - oriented management.

More specifically, the "technology and telecommunication" sector stands out due to both its stakeholder orientation and its sustainability and TBL strategic consistency. In the other sectors we could talk about companies "leaders" in strategic consistency and financial -economic performance, which show positive results in the Business Sustainability Approach Index.

The results obtained in this paper have several implications. First, in methodological terms, fuzzy logic can be seen as a useful methodology for the study of sustainability issues, not only in macroeconomic terms as aforementioned works show, but also in relation to the organisations' approach to the sustainable

development, that is, in relation to the corporate social responsibility. Moreover, considering the existence of investors who may be interested in invest in firms that engage in socially responsible activities (Mackey et al., 2007), the proposed indexes give them information about the consistency of this engagement. Finally, the study goes on with the emphasis on the relevance of the current stakeholders' theoretical and empirical approaches as a reference in the corporate social responsibility research.

In order to deep in the strategic behaviour of companies related to sustainability, a further research is required, not only to know the time evolution of companies, but also to improve the significance of variables to be considered in the analysis; this will be possible insofar as companies develop their CSR policies and strategies.

Notes

[1] The present G3 Guidelines has established a different framework to recognise the application levels of the organisation. This is based on three levels (A higher, B, C lower) and a qualification (+) for the externally assured reports.

[2] The MATLAB's Fuzzy Logic Toolbox (The MathWorks) lets us model complex system behaviours using simple logic rules and then implement these rules in a fuzzy inference system.

[3] A full report is available upon request to the authors.

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