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Article

Measuring corporate sustainability in a synthetic way. Is it possible?

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Abstract: This study develops a synthetic sustainability indicator (SSI) to assess corporate sustainability performance using data from Spanish IBEX 35 companies. Utilizing sparse principal components analysis (sPCA), the study condenses 65 Environmental, Social, and Governance (ESG) variables into a single indicator, addressing the lack of standardization in CSR evaluations and enabling comparisons across companies and sectors. The results show that environmental practices are the most significant factor (37.30%), followed by labor practices (19.23%) and corporate governance (18.52%). The study's key contribution lies in offering a quantifiable, transparent method for evaluating corporate sustainability. The SSI provides valuable insights for investors and analysts, promoting data-driven decision-making and encouraging corporate improvements in sustainability performance.

Keywords: corporate sustainability; synthetic indicator; sparse principal components analysis; environmental, social and governance (ESG); IBEX 35

1. Introduction

Corporate Social Responsibility (CSR) is a multifaceted concept that integrates social, environmental, and economic concerns into business operations [1,2]. It goes beyond legal compliance, emphasizing voluntary actions to address societal needs and stakeholder interests [3]. CSR is seen as a management approach that balances profit optimization with accountability to various stakeholders, including employees, consumers, and communities [4,5]. It is closely linked to sustainable development, with companies recognizing the interconnectedness of business success and ecosystem health [6]. CSR practices can enhance corporate reputation, employee motivation, and customer satisfaction [7]. While definitions vary, CSR generally involves transparent and accountable decision-making that creates wealth and improves society [1]. As globalization increases, CSR has gained prominence as a response to the expanding role of companies in society [8]. Implementing CSR requires strategic integration into core business operations and constant evaluation [9,10].

Corporate Social Responsibility (CSR) has emerged in response to the growing demand for more ethical business practices [11,12]. The integration of ethical principles into business behavior is facilitated through CSR, promoting business continuity via long-term objectives and planning [13–20], and fostering the development of intangible assets, such as corporate reputation [21,22]. However, many companies and business leaders lack a robust set of ethical business values, which in turn results in reputational damage. Additionally, many business leaders are tempted by the immediate benefits, both economic and non-economic, derived from a

short-term focus [23,24]. Emphasizing business ethics and CSR-focused strategies enables companies to improve their reputation, ensure long-term success, and strengthen their competitive differentiation. Ultimately, business ethics and CSR have become crucial for building sustained competitive advantage [25–27] and improving financial performance [28,29].

The traditional corporate objective has been framed as maximizing the combined wealth of all stakeholders with claims on the company's assets and cash flows [30,31]. Nevertheless, a new corporate paradigm is taking root, driven by societal expectations for companies to broaden their scope of social responsibility towards the environment in which they operate. This paradigm shift aligns with the stakeholder approach [32], holding companies accountable for the consequences of their social, economic, and environmental actions [33]. These shifts have led to substantial changes in business behavior [34], though certain challenges, such as evaluating socially responsible performance, remain unresolved [35,36]. One such challenge involves the assessment of corporate sustainability [37].

Considering these developments, an examination of the evolution of CSR from the perspective of stakeholder theory [38] has been conducted [32,39–44]. A comprehensive review of the methodologies employed by ethical stock indices, such as the Dow Jones Sustainability Index (DJSI) and FTSE4Good, for assessing sustainability has also been undertaken [45,46]. Additionally, the CSR conceptual guidelines outlined by ISO 26000 have been studied. The findings from this review have revealed patterns consistent with those identified in similar studies, which have been used as the foundation for creating a synthetic corporate sustainability indicator (SSI). Using a limited set of environmental, social, and corporate governance (ESG) factors and public data from Spanish IBEX 35 companies, gathered from the ASSET4 database, a statistical analysis was performed using sparse principal components analysis (sPCA) to formulate a synthetic sustainability index (SSI).

It is feasible to develop a transparent, uniform, and comprehensive conceptual framework to evaluate, rate, and compare corporate sustainability performance [47]. The increasing acceptance of synthetic indicators provides a valuable tool for analyzing business policies and behaviors while facilitating the dissemination of complex information in a more understandable format [48].

The integration of environmental, social, and governance (ESG) factors into corporate decision-making has gained increasing importance. Investors, regulators, and consumers are increasingly demanding transparent and objective information on corporate sustainability [49]. However, the evaluation of sustainability still faces significant methodological challenges due to the heterogeneity of corporate reporting and the lack of standardized metrics that allow for effective comparisons across companies and sectors [50].

This study addresses this gap in the literature by proposing the synthetic sustainability indicator (SSI), a composite index that integrates multiple dimensions of sustainability using sparse principal component analysis (sPCA). Unlike traditional approaches that rely on individual reports or specific indices such as the Dow Jones Sustainability Index (DJSI) or FTSE4Good, the SSI provides a quantitative and objective assessment of corporate sustainability, allowing for more robust comparisons across firms. Moreover, the SSI not only facilitates longitudinal analysis

of corporate sustainability but also contributes to greater transparency and data-d riven decision-making within the context of responsible investment.

Given the growing emphasis on sustainable finance and the importance of ESG metrics in global financial markets, the SSI represents an innovative tool for assessing corporate sustainability performance. It offers a methodological framework adaptable to different sectors and regions. This approach may be of particular interest to institutional investors, regulators, and corporate managers who seek more precise and comparable metrics to evaluate the sustainability of companies within their portfolios.

2. Theoretical framework

2.1. CSR as a triple bottom line

The development of CSR as a three-dimensional concept began to take place at the end of the twentieth century. It was during this time that the relationship between corporate sustainability and the "triple bottom line" (TBL) started to formalize [51–53]. According to the TBL school of thought, a company is sustainable when it combines its quest for economic prosperity with respect for the environment and concern for social justice [54,55]. These three dimensions of the TBL framework are interrelated but are often in conflict with one another. Hence, this approach creates a new business paradigm that requires thought and action that involves seven elements: market, values, transparency, technology and product lifecycle, agreements, temporal perspective, and corporate governance [52,56].

The concept of the TBL has acquired increasing popularity within the last few years, not only among large corporates but also among assessors and social rating agencies [57,58]. The integration of the three dimensions of CSR has practical consequences in the so-called sustainability reporting, given that interest groups put pressure on organizations with the intention of determining the degree to which these three dimensions have been adopted by companies [59–62]. There is certainly a growing demand for transparency, which would enable agencies to make comparisons and measure a company's performance, not only from an economic perspective but also based on the triple bottom line [63]. In fact, in the last few years, a new tendency in accountability has emerged in which interest groups demand transparency in reporting profits and economic performance as well as in how economic results are obtained and the impact that such results have on the companies' reputation [64] and on the legitimacy of their actions [65]. In conclusion, the disclosure of information considering the triple bottom line framework permits stakeholders to reevaluate their assessment of a company [66]. And consequently, pressure the company into modifying its strategy and behavior or assume the negative consequences of maintaining its unsustainable practices [67,68].

2.2. Synthetic sustainability indicator (SSI)

The design of the synthetic sustainability indicator (SSI) is based on stakeholder theory, which argues that the analysis of corporate sustainability is incomplete and cannot be assessed solely from a financial perspective. Instead, it must incorporate the expectations and needs of all stakeholder groups to whom the company should be

accountable and ideally provide value [40,69]. Stakeholder theory maintains that companies have responsibilities beyond maximizing shareholder value, as they interact with a variety of groups (stakeholders) to whom they must provide meaningful and sustainable value over time: employees, customers, communities, regulators, and investors [70]. In this context, the construction of the SSI aligns with this approach by integrating in its design the economic, social, and environmental (ESG) dimensions that reflect the interests of these stakeholder groups.

2.3. Non-financial reporting

CSR is based on the idea that corporate management is more effective and can improve company performance when decisions consider social and economic consequences [32,39,71–74]. According to this point of view, the best way to guarantee sustainability, in the long term, consists in balancing the demands of stakeholders with the financial and economic needs of the company to ensure its viability [75,76]. The company's published annual reports are therefore crucial to providing shareholders and other stakeholders with a vested interest in the company as well as management staff with a written account of the impact that a company's activities have on society. Consequently, this added transparency could force a company to be more socially responsible and consider the needs of its principal stakeholders [77]. Aside from publishing financial statements, companies have begun to divulge other types of information on corporate activities, particularly regarding sustainable practices. Such disclosure is known as non-financial information and is normally summarized in sustainability reports [78].

In the 1970s, some theories, such as accounting and social balance, started to develop, even though they were rarely applied to practice. They were the prelude to current sustainability reports [79]. Companies took little interest in accounting and social balance, largely due to a lack of governmental and civil support (little public awareness of the impacts companies have on society) and for economic reasons such as the belief that a company's ability to compete was limited [61]. In the 1990s, because of the 1992 Rio Earth Summit, legislation to control the environmental impact of business activity was driven forward. As a result, environmental management systems such as the ISO standard 14000 and the EMAS, among others, as well as environmental impact reports, were developed [80].

Subsequently, these reports included social and economic aspects related to CSR [81]. A company issues a sustainability report to inform its stakeholders of its strategy, commitments, actions, and results regarding CSR [82]. By publishing such information, a company can be held accountable for its actions. Accountability refers to "a mechanism of corporate control meant to establish corrective actions and penalties for infractions committed" [83].

Due to the growing belief in recent years that business and society have an interdependent relationship [84,85], it is no longer sufficient for a company to reveal information regarding its economic activity; social and environmental activity should also be included [86]. It is becoming more common for companies who are interested in sharing their self-regulatory strategies to report on their performance, goals, and actions taken regarding corporate social responsibility. A sustainability report

therefore aims to inform of the significant positive and negative impacts a company's activity has on its stakeholders and its sustainability. Ultimately, such a statement attempts to improve transparency, integrate the stakeholder interests, priorities, and concerns in the business planning, and assess a company's commitment to social responsibility [68].

2.4. Standardization of sustainability reports

Standardization and escalation in corporate reporting of sustainability cannot be decoupled from the Global Reporting Initiative (GRI) [61,87]. Enterprise Information Systems were developed in the 1930s for a different world and for an industrial economy. These types of reports place emphasis on the historical perspective (what has happened) and, in general, provide scarce information of relevance in the current economic-business environment and existing decision-making processes [88,89]. Therefore, sustainability reports, which gather all this information, don't interlink ESG information with financial performance [90].

Recently, a groundswell has developed that tries to agglutinate both financial and non-financial reporting into a single document [91]. This integrated report (IR) is a document containing a combination of the most relevant elements of corporate reporting, which are normally published under separate documents (financial report, management report, corporate governance statement, sustainability report...). The approach taken by integrated reporting is to show the interdependence among the different data and reports explaining how they are part of the decision-making process [92]. The IR reflects the "Integrated Thinking" philosophy, a concept that expects to link how different resources (i.e., capital) of a company interact with each other; proactive, human, intellectual, natural, and social capital [93]. IR is therefore a commitment to stakeholders to provide them with a holistic view of their interests as well as to explain how financial and non-financial information interact with each other and the impacts and consequences they have [94]. Even though the IR initiative is still in an early stage, there are several positive consequences that its implementation is expected to provide [95,96], not only within the company inner sphere but also placing the companies in a predominant situation to manage potential regulatory risks derived from new requirements, allowing them to take an active part in a new environment that claims different business information [97].

The means in which companies report their results have both internal and external consequences [98]. Companies that rely on integrated reporting models provide disaggregated results by country in comparison to companies that publish traditional sustainability reports [96,99]. An increasing number of companies are advancing towards the incorporation of non-financial information together with financial information in their annual reports. In line with this tendency, it was reported that in 2013 [100], 51% of the first 100 companies, ranked by income level, within the 41 countries that comprise the study, included non-financial information in their annual financial reports.

2.5. Financial markets and CSR

Socially Responsible Investment (SRI), according to the Global Sustainable

Investment Alliance, is "that which takes into account the environmental, social, and corporate governance criteria" (henceforth ESG) in the selection and management of their investments" [101,102]. The relationship between CSR and SRI is undeniable [103], as they would represent both sides of the coin [104]. SRI contributes to the analysis of company involvement levels in CSR and acts as an incentive for commitment to sustainability through participation in SRI indices [105].

In recent years, several instruments and agencies have been developed with the purpose of providing information to the financial community on how intense support is for sustainability of listed and unlisted companies [106]. Some of the main manifestations of the impacts that CSR [107] is having in the financial sector are ethical or sustainable stock market indices, specific financial products linked to the ethical or social corporate dimension [108], ethical banking [109,110], social rating agencies or ESG agencies, the growing push of the stakeholder activism and other initiatives such as the publication of the Principles for Responsible Investment (PRI) by the United Nations [111,112]. The growing importance that CSR is starting to have within large multinational corporations comes along with the growing volume of funds managed under SRI criteria [37,113] and the Socially Responsible Investment Indices [114] as well as with the active interest shown by institutional investors supporting the incorporation of ethics and sustainability into their investment criteria [115–118].

However, the correspondence between social and financial performance is not clearly verifiable [119–121] even though some researchers defend the existence of this correspondence [35,122–125]. That is why social actions performed by companies are associated with endogenous aspects, non-dependent on the economic results, such as culture, values, quality of management, managing styles, and decision-making processes [126]. According to several authors, commitment to the SRI implies obtaining reduced profitability as companies' social concern might weaken financially, given the multiple interests they must attend to [127–129]. This would imply that a company might lose its way as it is prepared to sacrifice profits in pursuit of other interests [130,131]. There are even some who claim that the competitive environment can force companies to behave against the CSR premises to maintain their position in the market [132,133]. Other authors believe that there is no difference, in terms of profitability, between investing in SRI products and investing in standard products [134]. On the other hand, some affirm that commitment to the SRI implies obtaining higher returns compared to investment in standard products, as companies that are not committed to the CSR will be less attractive to investors, leading to higher financing costs (cost of capital) and a reduction of the profits from companies that are not committed to the CSR [135,136] and therefore, shares of companies that are socially irresponsible will be less attractive to potential investors [137,138]. On the other hand, socially committed companies provide higher long-term value for stockholders, minimize the existence of conflicts, and lessen future costs [139–141]. A strong commitment of companies towards CSR, should it extend and generalize, will necessarily imply advances towards the development of measuring instruments for these "new" business goals and will require new instruments for reporting and broadcasting of the achievements made. This challenge has already found an early way towards its future framing with the gradual implementation of stakeholder reporting: broadcast and generalization of information related to value creation for all interest

groups involved in the activity of the company under review.

2.6. Ethical stock market indices

Measures of social performance in the sense of measuring CSR lack consensus, and therefore evaluation is difficult [21,142]. It is hard to transfer to an empirical or practical approach a proposal that would enable monitoring, quantifying, and contrasting business social performance. Ethical or socially responsible indices combine information on the progress of a specific financial market about the market capitalization—prices of the titles that are part of the index, which could be called economic success—with the commitment of those companies to sustainable development [143,144]. They have been acting, for over a decade, as a tool that allows analysts, fund managers, and investors to embed in their analysis, suggestions, and investment criteria of the so-called extra-financial analysis, apart from offering a quick overview of the average profitability achieved [142]. There is no unanimity regarding the relationship between the presence of a company in a sustainable index and its financial behavior [145]. In general, it has been found that the companies that take part in these indices are as profitable as the rest [146]. This behavior should encourage the development of the CSR and the SRI [147,148]. Institutional participation of these companies in socially responsible activities works as a "life insurance" in case a negative event would happen and would affect them negatively [149]. Nonetheless, other studies state the growing challenge for investors to discern between companies that truly commit to CSR and those who do not, due to the excessive and heterogeneous information that comes from companies themselves. In this regard, they advocate for higher standardization in the shape and method of reports [150]. Additionally, it has been shown that companies focus on publishing and manifesting their virtues related to CSR policies, regardless of whether they have been included or excluded from the indices. Very few companies acknowledge their problems related to sustainability and CSR [151,152].

3. Methodology and discussion

There are currently a profusion of actions, tools, and proposals in the market to measure business sustainability; in fact, "there are, on a global level, over one hundred entities that request data regarding social responsibility" [153]. All of them share the same objective (evaluation of social business performance) but depart from different perspectives, methodologies, points of view, and budgets. Given the large number of initiatives, rankings, and monitors, it is necessary to provide a certain level of normalization and standardization when it comes to evaluating business sustainability. In fact, we believe that, even though there are hundreds of potential indicators and multiple combinations, it is enough to analyze only a few indicators to assess business sustainability [154]. It is not the subject of our analysis to deepen into the tendencies and ESG criteria that analysts and financial professionals make use of, but we consider that it is possible to analyze and evaluate CSR or business sustainability by paying attention to a small group of indicators, and the investment community requires simple, clear, and transparent tools in order to incorporate ESG aspects and criteria into their analysis procedure [155].

Given the greater prominence that ethical stock indices have been acquiring over the last years, it is especially important to understand which criteria are defined by some, the most relevant, and how the analysis process is used so that a company can or cannot be part of these indices. As the conceptualization of these indices may act as a lighthouse for listed companies (and a guide for other companies as well) to adapt their CSR strategy to what is stated in those indices. We assume that companies, managers, and investors will tend to adapt, in a certain way, their strategies, suggestions, or commitments to the criteria to be included or not in those indices. Both sustainable indices and social rating agencies apply different criteria to evaluate social performance and to select those companies that are the object of their analysis [156].

We reckon that what we measure affects what we do, and therefore it is extremely important to have thoroughly clear what we measure, how we do it, and with what purpose [157]. We additionally confirm that there is a growing demand, from a client perspective, for more transparency and more coherence in corporate information. We can also identify a growing interest, from an investor's point of view, towards the incorporation—along with the financial-economic variable—of other information related to social and environmental business behavior. We also noticed that scarce progress has been made in order to evaluate as a whole (social, environmental, and corporate governance dimension) social responsibility and its relationship with financial results [158,159]. On the other hand, it is very well known the progress that, in the economic and financial information field, has been developed, providing comparable, homogeneous, and liable data. We notice that there is a growing tendency, both in international and national environments, towards the standardization of certain data and indicators (non-financial) whose main purpose is to state comparisons and valuations on the social responsibility of companies and countries [160–162]. The initiative developed by the United Nations Conference on Trade and Development (UNCTAD) whose "purpose is to help those who have to prepare company reports in order for them to include in their annual financial reports, concise and comparable indicators of the regarding company responsibilities" [77]. Work developed by the Spanish Accounting and Business Administration Association, which intends to provide a standardized process of information related to social corporate responsibility, concludes with the presentation of a series of CSR indicators [83].

Finally, we confirm that synthetic indicators are instruments highly accepted as they enable the analysis of corporate policies and/or behaviors, in addition to transforming complex issues into simple information. These are useful tools in those subjects in which, due to their breadth and complexity, it is difficult to analyze tendencies if the consulted information sources include partial indicators regarding the subject in question [48]. Both from the corporate perspective and from the analyst and investor perspective, there is a need to rely on criteria, methodologies, and processing procedures of information published by the main ESG agencies that allow them to visualize commitment to sustainability and CSR corporate strategies in a synthetic way. The final purpose is to transmit in a single snapshot (with a single datum or score) the aggregated corporate performance in terms of sustainability. The before mentioned information must enable comparisons and relationships with other companies of the same industry and size (competitors) or with other companies from the same geographical area or before a specific investor collective.

From a conceptual point of view, the analysis here displayed is meant due to the following challenges:

- There is a lack of, as mentioned before, general agreement on the measurement of the sustainability. This lack of agreement is due to three circumstances: lack of standardization—analysts may interpret (measure) sustainability in different ways—the necessary interaction between dimensions purpose of analysis—good results in a dimension that should not hide deficient behavior in others—and the fact that different actors may grant different relevance to the categories, which compound the whole analysis [163].
- It is a complex matter, both for its multi-dimensional nature (three dimensions in play: economic, social, and environmental dimensions) and for the lack of standardization when it comes down to analyzing and evaluating corporate sustainability; this is CSR. In this regard, we state that a system is complex when the different edges of the problem cannot be analyzed from a single perspective [164] and when in the analysis comes into play the intention and purpose of those who formulate the study [165].
- We intend to create a procedure that allows us to state comparisons of the sustainability-related results (CSR) regardless of the sector of industrial activity in which the company develops its activity. With this vision in our minds, we want to point out that the result of our proposal intends to contribute, through a proprietary creation, with arguments and streamlined information, transparency so that those who have to make decisions regarding the sustainability of a company can modify their decision-making processes and/or argue the pros and cons and/or change their decision-making process, and, in the end, are able to decide accordingly to their interests, taking into account the information displayed [166]. We believe that the emphasis at the process here described (as well as for the outcome) must be put on whether the final proposal adds relevant information that improves the evaluation and comparison process of corporate sustainability.
- Ultimately, it implies a certain level of decision-making about how companies generate value independently of the fact that different stakeholders may have (and actually have) different motivations and conceptualizations of what the word "value" means for them [167].
- Complex systems have the characteristic of allowing different possible descriptions over the same matter, all of them generally correct. Therefore, the characteristic of the complexity is more present in the evaluation processes than in the problem itself [165].

If we attend to the methodological aspects, we believe it is relevant to consider the following issues:

- An indicator is a quantitative or qualitative measure, based on data sets, whose purpose is to reflect a certain position on a certain aspect. They are useful tools to identify tendencies, to provide a snapshot about the subject analyzed in a certain moment in time, to generate comparisons with a certain benchmark, and/or to review multidimensional concepts [48]
- In the methodological conception of an indicator, decisions must be taken or

proposals made on the following matters:

- Which is the conceptual framework object of the analysis (in our case, corporate sustainability).
- Which are the data that will lead to the build-up of the indicator, and how representative is it. It implies making decisions regarding data selection, its treatment, and standardization.
- Which will be the statistical technique used to process data, and which will be the suggested process to ponder and add the different dimensions that build the indicator up.
- How the results will be presented.

- A high degree of transparency and participation is key to generating identification and reliance in the indicator suggested [165].

The empirical analysis procedure followed has been developed according to the following stages:

- STAGE 1: Comparative analysis of the scrutiny criteria used in stock indices (DJSIndex y FTS4Good) in relation to the CSR view stated in ISO 26000.

We carried out a comparative analysis, trying to set up relationships between the main actions and expectations of the fundamental subjects listed by the ISO 26000 guide with the main concepts of eligibility stated by the two ethical indices already mentioned. From that comparative analysis, we can identify matching aspects (3 or 2 matches) for each fundamental subject stated by ISO 26000 to define the scope of corporate social responsibility and the eligibility matters of both indices. As a result, we may produce a detailed conceptual suggestion of the possible aspects of analysis with the description of the indicators and their equivalence with those analysis indicators referred to by GRI. The table highlights as "VR—Very relevant" those aspects that appear described both in the ISO26000 and in the two ethical indices analyzed, and as "R—Relevant" those aspects that are described in the ISO26000 and in one out of the two indices. Aspects highlighted as "VR—Very relevant" should obtain, according to this comparative analysis, a significantly higher weighting when it comes down to composing the global synthetic indicator of CSR—sustainability (SSI).

- STAGE 2: Identification of the fields and data that will build up the sample on which we will form out our synthetic indicator (SSI).

The sample of companies and data used to elaborate the current study corresponds to Spanish companies, belonging to several industrial sectors and which are part of, or were part of, the stock market index IBEX35 in at least some of the analyzed periods. The temporary period analyzed has been 5 years (data from the financial years 2009 to 2013). To obtain the sample, we have selected a public database provided by Thomson Reuters called Asset4. Such a database is characterized by the transparency of the sources of information provided and for being accessible and flexible regarding the processing of the provided data. Therefore, we count in our study with data (variables) previously incorporated into the database throughout the analysis of the sources of information used by analysts who build up such information (annual reports, web pages of the companies that are incorporated).

- STAGE 3: Validation of the model through the main components analysis

technique.

The two statistical techniques that we are going to use to obtain the CSR indicator are the missing values processing and the principal component analysis. Hereafter, we briefly describe the two methodologies, without turning to detailed statistical and mathematical developments that are out of our scope and interest as users of such techniques.

The missing values methodology serves towards replacing missing data with estimated ones according to the information contained in the data sample [168]. The presence of missing values carries the difficulty that, naturally, most statistical methods cannot be applied directly to that gathering of incomplete data [169]. Moreover, for instance, the simple calculation of the arithmetic mean turns out statistically incomplete. To solve that situation, one of the most popular approaches consists of using the so-called Single Allocation Assignment methods. These methods fill out missing values with statistical samples, generally the average. This methodology preserves the average of the sample but reduces the variance and distorts the correlation between the variables. Given that our study is based on the study of variance and correlation between variables, and that the method of Single Allocation Assignment would therefore completely distort our results we believe that for our analysis to be more efficient, we should use other methodological proposals. The solution comes up with two families of methods: the Multiple Allocation Assignment and the Maximum Likelihood Estimation [170–173]. The previous methodological proposals were completed afterwards by an iteration of multivariable techniques (multiple correspondence analysis), which allows a much stronger punctual estimation of the missing values [174]. Therefore, the method allows for the calculation, by the interactions, of the optimal estimation that will not distort the variance of the variables or the interrelationship with other variables.

The Principal Component Analysis is a technique of data processing and dimensional reduction with multiple uses in the fields of economics, finance and social sciences. The Principal Component Analysis (henceforth PCA) was first formulated in the early 20th century [175] and complemented and developed in the 1930s [176]. Afterwards we can find a detailed description of such methodology in the work "Principal Component Analysis" [177]. The PCA technique consists of searching for the linear combination of the original variables in a way that the new variables capture the maximum variance. Henceforth, it is a technique used to reduce the multidimensionality of a data set into a reduced dimension for its analysis [178]. This downsizing is obtained by transforming data into a new set of variables (the principal components), which are uncorrelated and ordered in a way in which the first set incorporates most of the information of the data set. PCA can be calculated by singular value decomposition (henceforth SVD) of the data matrix. Shall X be a matrix of size $n \times p$ (data matrix), where n is the number of observations and p is the number of variables. Without prejudice to the generality, we consider that the average of the matrix columns is all 0. Then, the SVD of X is [177].

$$X = UDV^t,$$

where $Z = UD$ the principal components, and the V columns are corresponding factors or the weight of those principal components. The variance of the sample of each

principal component it is D^2ii / n. Usually the first q principal components ($q \ll min(n, p)$) are selected to show the data, in such way that way a great reduction of the dimensionality is obtained. In our case, we will select one principal component.

The success of the PCA is achieved by accomplishing two optimal properties:

- The principal components sequentially capture the maximum variability between the columns of X, guaranteeing the minimum information loss.
- The principal components are uncorrelated, so one principal component may be analyzed without referring to the others.

Nevertheless, it is necessary to point out that this PCA technique has several inconveniences. Given that the principal components are a linear combination of all the variables, factors, and weight, they are usually different from zero [179]. As a result, the interpretation of the components is further complicated, and it highly generates difficulties in the use of this methodology in situations where it would be more convenient that the components would have very little factors or weightings different from 0, as is the case. As a solution to this problem, the Sparse Principal Component Analysis (henceforth sPCA) has been developed during the last few years [180,181]. With the sPCA technique, a reduction of the dimensionality is achieved, but also the number of variables used in each component is cut down. The technique used to obtain the sPCA is based on solving a problem of optimization of the type of regression with a mean square penalty—lasso penalty [182], which allows modifying the principal components for them to have scarce weight [183].

- STAGE 4: Creating a CSR or sustainability indicator (SSI) for a set of companies listed in the Spanish market (IBEX35)

The use of sPCA methodology to create a synthetic indicator aims to reduce the 65 variables that try to explain the behavior of companies that implement CSR to a single variable.

The idea consists of accepting the existence of an unobservable indicator which explains the company behavior in relation with the CSR strategy and that we would be able to estimate it starting from a big set of observable variables (65) which have been selected as representative of the different aspects/areas that explain the performance of sustainability. A priori, these variables, from a theoretical point of view, have a causal relationship with the sustainability indicator, whether direct (positive) or indirect (negative). If the indicator were observable (and not made up of variables) the analysis would involve estimating a regression model that would determine the variables and sign (positive or negative) that best explain the indicator.

But this scenario was not possible in our study. We had to create an empirical indicator (estimator of the unobservable) by studying the correlation that exists between the 65 variables. For this purpose, we used the sPCA technique, which allowed us to select and reduce the number of variables that are used to explain the higher variability ratio and correlation between the set of data. Therefore, the first step was to select the variable, and the second, to establish how we sum the variables (percentage of each variable in the indicator) to delimit a single indicator.

Even though there are many ways to obtain the indicator from the selected variables [184], using sPCA allows us to carry out the two stages at the same time, and to select weighting coefficients (positive) which correspond with the information

obtained by the total variance given, and helps define each selected variable. The bigger the contribution of one variable to the variability of the results, the greater its weight on influencing the indicator. However, with the data we have, it is impossible to determine (except when seen in previously proposed hypotheses by the researcher), whether there is a positive or negative, correlation. As a result, this methodology does not indicate whether a variable is positively or negatively related to the indicator since the indicator is unknown. Therefore, the results are always positive when representing a percentage of the total variance that explains each variable. In summary, this methodology demonstrates how important a variable is when explaining the aspect/area that we are analyzing, regardless of the sign.

Moreover, the indicator tries to minimize the scope of the data by selecting a variable that would explain the greatest possible correlation with the initial variables. It is important to select variables that have greater correlation between each other and to be able to synthesize the information they yield without losing the conceptual element necessary to understand, from a synthetic point of view, the behavior of the company and its commitment to CSR.

We have analyzed data from 65 variables (data that refers to different areas and to different aspects of sustainability) and 153 reports (from 31 companies listed in the IBEX35 from fiscal years 2009 to 2013). As a result, we have a data matrix size of 153×65.

This study uses ASSET4 data from 2009–2013, as this period represents a critical phase in the evolution of corporate social responsibility (CSR) and corporate sustainability in Spain, marked by the implementation of new regulations and increasing stakeholder pressure [50].

In this data matrix there are numerous missing values (NA) that were not included in the database (ASSET4) due to the lack of information given by companies. The first challenge we had to overcome was to solve the problem of the missing values, and that is why we resorted to the technique, the multiple correspondence analysis [174]. Without this initial stage, it was impossible to do a proper analysis.

An exploratory analysis was conducted to assess patterns of missing data, confirming that data absence was not correlated with factors that could bias the results. This supports the validity of the imputation approach used. To evaluate the impact of imputation on the robustness of the model, we conducted sensitivity tests comparing results obtained with complete versus imputed data, finding minimal differences in the classification of companies within the SSI.

The analysis of financial and sustainability data in corporate environments often faces the problem of missing data, especially in ESG metrics, where disclosure varies across companies and time periods [49]. In this study, we applied the multiple imputation method to mitigate bias in the estimation of sustainability indicators, ensuring that missing information does not distort the results. The percentage of missing values in the model variables was 4.61% of the total. The statistical analysis was based on 135 × 65 data points (with missing data representing, as noted, 4.61% of the total).

The practical application of correcting missing information was developed using the statistical software *R*, specifically the "missMDA" package, and implemented using Josse-Husson's technique.

Once the estimation of the missing values was obtained, the goal was to estimate indicators for each area (fundamental sustainability issues according to the ISO 26000), and therefore to reduce the number of variables in our analysis.

We began to determine the indicators in each area by creating a centered data matrix based on the average of each variable scaled to the standard deviation (in reality, the data has been categorized). This stage is necessary when relating continuous variables to discrete variables and, additionally, to variables with different units of measurement (variables zero or 1, to variables in euros, for instance). By classifying variables, we have eliminated the units of measurement.

The following variables were transformed and included in the study according to the 5 different areas of analysis:

1) Corporate governance = A_1
2) Human rights = A_2
3) Labor practices = A_3
4) Environment = A_4
5) Others: Fair operating practices, customer affairs, and active involvement in community development = A_5

In summary, each area of analysis included the following number of variables (see **Table 1**):

Table 1. Allocation of areas of analysis used to create the sustainability synthetic indicator (SSI) by the number of variables used initially.

	Areas of sustainability analysis				
	A_1	A_2	A_3	A_4	A_5
# Variables	19	4	18	17	8

Source: Data presented by authors.

Our intention was to select the variables that best characterize each area of analysis and obtain a weighting coefficient, which combines the variables to produce an indicator for each area of analysis. We have applied Sparse Principal Component Analysis (sPCA) to each area of analysis [181].

The practical aspects of the analysis were carried out using *R* software, specifically the "nsprcomp" package.

As we have mentioned above, by using sPCA, we were able to select the variables that comprise the indicator from a set of proposed variables, particularly those that show the greatest variance in the area we are analyzing. By using this method, we were able to reduce the number of variables used. We began with many original variables and by the end of our analysis, had narrowed them down to only a few that explain a large amount of information on each area of our sustainability analysis. Using sPCA enables us to reduce the number of components that constitute the indicator to a single variable made up of a linear combination of selected variables. Therefore, it is an estimation of a single principal component that determines the indicator for each area of analysis.

However, sPCA is not only an important method for selecting variables but also enables us to determine a weighting coefficient (by weights or values) for each variable used to comprise the indicator (the key component of analysis). The sum of

these weighting coefficients is 1, and as a result, we can determine which variable is most important in each area of study.

In the next section, we present a detailed analysis of each indicator in their respective areas with their corresponding weighing coefficients. **Table 2** below is a summary that serves to clarify the number of variables that constitute each of the indicators.

Table 2. Classification of areas of analysis used to create the synthetic sustainability indicator (SSI) and the number of variables selected by sPCA.

	Areas of sustainability analysis					
	A_1	A_2	A_3	A_4	A_5	Total
# Variables	19	4	18	17	8	67
Selected by sPCA	9	2	9	8	4	32

Source: Data presented by authors.

The variance (the variable used to determine the behavior of the indicator) of each partial indicator reflects its relative importance in influencing the SSI; the greater the variance, the greater the variability between the initial variables (see **Table 3**).

Table 3. Summary of variance of the five partial indicators that constitute the synthetic sustainability indicator (SSI).

	Partial indicators **Areas of sustainability analysis**				
	IA_1	IA_2	IA_3	IA_4	IA_5
Variance	1.739967	1.189482	1.772954	2.471760	1.626851

Source: Data presented by authors.

The most important feature of the synthetic sustainability indicator, applied to the various areas of analysis, is that it can have a positive or negative value, and it allows us to compare the performance of different companies in different years of study.

The higher the value of the indicator, the better the company's performance for that year in the corresponding area of analysis (or partial sustainability indicator). Therefore, a negative value indicates a bad performance in a particular area of analysis (or partial sustainability indicator) compared to the rest of the companies analyzed. It is important to note that the results depend on the sample analyzed and the variables selected. Additionally, the indicator reflects the results of a particular study in a specific year, and therefore such results are relative and dependent on the rest of the data used in our analysis.

Finally, a value close to zero should be interpreted as an improvement in the average of the sample studied.

The principal index's measure of position and central tendency used to evaluate partial sustainability indicators (areas of analysis) is shown in **Table 4**. The figures indicate that the average is zero and the distribution of values is not symmetric.

Table 4. Measures of position and central tendency used to evaluate the synthetic sustainability indicator (SSI) in a 5-year study.

Area of Analysis	Minimum	Quartile 1	Median	Mean	Quartile 3	Maximum
1	−4.2530	−1.1002	0.2278	0	1.2347	3.5632
2	−4.7041	0.4052	0.5660	0	0.5660	0.5660
3	−4.5086	−0.9221	0.3648	0	0.9735	5.7672
4	−1.1203	−1.0727	−0.9621	0	−0.3575	12.4176
5	−1.8125	−0.9548	−0.3683	0	0.5001	5.3522

Source: Data presented by authors.

Once we created 5 indicators in each area of analysis, we proceeded to calculate the CSR indicator as a combination of the 5 indicators by dividing the weighting coefficient of the variance of each indicator by the total variance of all the indicators, as indicated in the methodology for creating a synthetic indicator proposed by the [48] and the European Commission.

The synthetic sustainability indicator (SSI) is detailed in the following **Table 5**:

Table 5. The synthetic sustainability indicator (SSI) and descriptive statistics.

	Minimum	Quartile 1	Median	Mean	Quartile 3	Maximum
SIS	−2.1999	−0.7766	−0.2252	0	0.2656	4.5689

Source: Data presented by authors.

$$\text{SSI} = 0.1852 \times IA_1 + 0.0865 \times IA_2 + 0.1923 \times IA_3 + 0.3738 \times IA_4 + 0.1619 \times IA_5.$$

Once the SSI is calculated, we can evaluate all the observations that we have made according to the company and year and determine their importance. In the same way, we can calculate synthetic sustainability indicators for specific areas of analysis (partial sustainability indicators). The variables that compose each indicator have been centered and scaled and can be positive or negative. The positive or negative nature of the variables demonstrates how strongly the variables affect the area of analysis.

The partial indicators are the following:

IA_1, a partial synthetic indicator of corporate governance.

IA_1 = CGBSO17V × 0.0294 + CGBSO07V × 0.1328 + CGBFO01V × 0.1757 + CGBFDP019 × 0.0397 + CGBFO06V × 0.1589 + CGCPO03V × 0.0677 + CGCPO05V × 0.0781 + CGBFO04V × 0.1591 + CGBFDP021 × 0.1586

IA_2, a partial synthetic indicator of human rights.

IA_2 = SOHRD01V × 0.5 + SOHRDP026 × 0.5

IA_3, a partial synthetic indicator of labor practices.

IA_3 = SODODP020 × 0.1773 + SOEQDP034 × 0.1534 + SOEQDP033 × 0.1318 + SOEQD01V × 0.0881 + SOHSDP024 × 0.0740 + SOHSDP036 × 0.0553 + SOTDDP024 × 0.1220 + ECPEDP039 × 0.1038 + SODODP026 × 0.0942

IA_4, a partial synthetic indicator of the environment.

IA_4 = ENERDP091 × 0.1161 + ENRRDP054 × 0.0833 + ENRRDP056 × 0.1564 + ENERDP023 × 0.1564 + ENERDP024 × 0.1538 + ENERDP025 × 0.0812 + ENERDP034 × 0.1221 + ENERDP035 × 0.1309

IA_5, a partial synthetic indicator of fair operating practices, customer affairs, and

community development.

IA_5 = SOPRDP025 × 0.2081 + SOCODP027 × 0.3010 + SOCODP028 × 0.2987 + SOCODP029 × 0.1922

- STAGE 5: Analysis of results obtained.

From a PCA perspective, the areas in which sustainability is most commonly evaluated are environmental impact (37.30%), labor practices (19.23%), and corporate governance (18.52%). Our model indicates that environmental impact is the most significant to determine a company's commitment to sustainability. Recent studies suggest that there is a positive correlation between a company's commitment to sound environmental policy and improved performance in terms of sustainability [185]. As a result, we have verified that the companies that obtain better results with respect to synthetic sustainability indicators (SSI) are companies that stand out and have achieved good results regarding the three dimensions that carry the most weight in the quantitative model (environment, labor practices, and corporate governance). Energy companies—companies with a high environmental risk level and therefore high negative potential—are especially well-qualified if they successfully manage the environmental risk due to the relative weight that the environmental impact has on the construction of the indicator (37.30%). Our explanation is the following: the indicator takes into consideration such potential risk (placing a high weight on the area), which could then lead to good ratings if the company's activities reflect a strong commitment, such as ethical practices and achievements, to adhering to the variables that make the area.

The synthetic sustainability indicator (SSI) is persistent according to the results obtained by the companies that are studied. For instance, if we review the companies that receive the five best marks regarding SSI, we see that a high level of consistency is maintained (being understood here as the stability or solidity of their results when the company undergoes sustainability evaluation). Indeed, if we analyze the data, we see a pattern of the same four companies out of five that have satisfactory marks (all of them are always placed in the quartile 4) during the evaluation period. Finally, it is worth noting that the indicator is asymmetrical. The number of companies that receive a rating that is higher than the average is always less than the number of companies that are placed below the average.

4. Conclusion

We believe that, although different aspects have been identified, such as CSR partial indicators and combinations of various indicators, it is sufficient to analyze a small amount of data to draw reasoned conclusions in relation to a company's corporate sustainability. From the results obtained in our analysis, we can conclude that according to the proposed model and with the data that was available for the analysis, a reasoned assessment can be made regarding global CSR performance by analyzing a total of 32 variables of different areas related to the business sustainability strategy.

The composition of the global synthetic sustainability indicator (created according to the results obtained), by the principal components technique (sPCA), gives special relevance to the corporate performance in the environmental areas

(37.3%), followed by labor practices areas (19.2%) and corporate governance areas (18.5%). According to our model, the results obtained in these three areas explain 75% of the global synthetic sustainability indicator. As a result, we have verified that the companies that obtain better results in the global sustainability indicators (SSI) are companies that stand out for receiving good results in the three dimensions that have a higher weight in the quantitative model (environment, labor practices, and corporate governance). Energy companies—companies with a high environmental risk level and therefore high negative potential—are especially well-qualified if they successfully manage the environmental risk, due to the relative weight that the environmental impact has on the construction of the indicator (37.30%). Our explanation is the following: the indicator takes into consideration such potential risk (placing a high weight on the area), which could then lead to good ratings if the company's activities reflect a strong commitment, such as ethical practices and achievements, to adhering to the variables that make the area.

The suggested global sustainability indicator (SIS) is characterized by being persistent and asymmetric. This means that the results possess a high level of consistency that is maintained when a company undergoes sustainability evaluation. Therefore, as we have already mentioned above, the indicator is asymmetric due to the large number of companies that obtain scores that are higher than average, which is always lower than the number of companies that score under the average.

The social reputation, understood as the growth in confidence from the stakeholders involved in the company, is one of the most difficult competitive advantages for competitors to sustain in the long run. This reality causes managerial staff to focus on communicating the definition and performance of the company's actions in the economic, social, and environmental areas. There is a lot of work to be done to standardize the information systems, the measurements—evaluations, and the responsibilities that the companies assume regarding their participants, analysts, and investors.

The synthetic sustainability indicator (SSI) developed in this study serves as a practical tool for evaluating and comparing corporate sustainability performance. Its quantitative approach provides investors, financial analysts, and corporate executives with an objective metric to integrate ESG factors into strategic decision-making [186]. By offering a standardized assessment of corporate sustainability, the SSI responds to the growing demand from institutional investors for consistent sustainability metrics to improve portfolio management and mitigate risks associated with poor ESG practices. Implementing the SSI in financial analysis would enable more effective comparisons across companies and sectors, thereby supporting sustainability-driven investment decisions.

5. Limitations and future research

This study has some limitations that must be mentioned because they could affect the interpretation of the results shown here, as well as the generalized manner of the application of the conclusions described above.

The main limitation is related to the data used for the quantitative analysis. We possess data that was obtained by public non-standardized sources; therefore, the

consistency cannot be guaranteed. However, the variables finally selected through the principal components technique (PCA) may have given different results had the information source provided information on other ESG variants.

The second limitation is related to the level of development of the sustainability reporting culture. It is relevant that publicly listed companies and other big enterprises dedicate resources to implement policies and strategies related to sustainability (among them are resources related to extra financial reporting). However, these practices are still anecdotal when referring to smaller companies. Therefore, the effectiveness of this type of synthetic evaluation analysis of sustainability is greatly reduced when expected to be applied to small companies.

Concerning future perspectives, we believe that this study will allow for the development of future work in the following ways:

- Standardize analytical criteria standardization found in CSR to create global and partial synthetic corporate sustainability indicators.
- Establish and develop specific patterns to gather and/or find the corporate sustainability data needed to create global and partial synthetic corporate sustainability indicators.
- Develop initiatives that reduce the impact that the size of the company has when performing an analysis of its CSR performance.
- Study and propose versions of synthetic sustainability indicators created for the industrial sectors or specific areas of activity.
- To enhance the external validity of the proposed model, future research could expand the sample by including smaller firms or by comparing the SSI with similar indicators in non-listed markets. Additionally, it would be relevant to explore how sustainability frameworks such as the Global Reporting Initiative (GRI) standards and the Sustainability Accounting Standards Board (SASB) guidelines relate to the model. These extensions would provide a deeper understanding of the model's applicability to diverse business realities and improve the usefulness of the SSI as a comparative sustainability tool across different sectors and company sizes.
- This study relies on quantitative metrics derived from ASSET4 data to assess corporate sustainability, enabling objective and reproducible comparisons. However, sustainability cannot be reduced solely to financial or environmental indicators; it also involves the perceptions and expectations of stakeholders such as employees, customers, local communities, and regulators [40]. Integrating qualitative perspectives in future research could provide a more holistic view of ESG performance. For instance, surveys or interviews with key stakeholders could complement the quantitative results of the synthetic sustainability indicator (SSI), allowing for an assessment of how corporate sustainability strategies are perceived and valued in practice.

In any case, as we have seen throughout this study, we have carried out an analysis on corporate sustainability, and we have proposed a methodology to elaborate a synthetic sustainability indicator.

Author contributions: Conceptualization, LDM, RQS, OAT and MGBS;

methodology, LDM, RQS, OAT and MGBS; software, LDM, RQS, OAT and MGBS; validation, LDM, RQS, OAT and MGBS; formal analysis, LDM; investigation, LDM, RQS, OAT and MGBS; resources, LDM, RQS, OAT and MGBS; data curation, LDM, RQS, OAT and MGBS; writing—original draft preparation, LDM, RQS, OAT and MGBS; writing—review and editing, LDM, RQS, OAT and MGBS; visualization, LDM, RQS, OAT and MGBS; supervision, LDM, RQS, OAT and MGBS; project administration, LDM, RQS, OAT and MGBS. All authors have read and agreed to the published version of the manuscript.

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