CUADERNOS ECONÓMICOS
ICE
INFORMACIÓN COMERCIAL ESPAÑOLA

The Sustainable Society Index: Analysis of the Recent Situation of the Sustainability Worldwide*

El Índice de Sociedad Sostenible: análisis de la situación reciente de la sostenibilidad en el mundo

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Abstract

This paper aims to investigate the current prospects of sustainability worldwide using the Sustainable Society Index. To do so, we use the Partial Triadic Analysis multivariate strategy, a generalization of the Principal Component Analysis for three-dimensional data, studying the relations among countries and indicators along the period 2006-2016. The analysis shows that social and economic indicators are higher in high-income countries while countries with lower incomes are more connected with environmental issues. In addition, the analysis allows observing the evolution of countries and indicators during the period regarding sustainability.

Keywords: *sustainability, Sustainable Society Index, partial triadic analysis, income levels, countries worldwide.*

JEL Classification: *C38, F63, F64, I31, O15.*

Resumen

Este artículo tiene como objetivo investigar la situación reciente sobre sostenibilidad en países de todo el mundo según el Sustainable Society Index. Para ello, se usa la estrategia multivariante del análisis parcial triádico, que es una generalización del análisis de componentes principales para datos tridimensionales, estudiando las relaciones entre los países e indicadores a lo largo del periodo 2006-2016. El análisis realizado muestra que los indicadores sociales y económicos son más elevados en aquellos países de renta más alta, mientras que los países con renta más baja están más conectados con temas medioambientales. Además, este procedimiento permite observar la evolución en términos de sostenibilidad de cada país a lo largo del tiempo.

Palabras clave: *sostenibilidad, Sustainable Society Index, análisis parcial triádico, niveles de ingresos, países de todo el mundo.*

* The authors wish to acknowledge the financial support provided to the Research Unit of Excellence "Economic Management for Sustainability" (GECOS) by the Junta de Castilla y León and the European Regional Development Fund (Grant CLU-2019-03).

DOI: https://doi.org/10.32796/cice.2021.101.7197
Recibido: Marzo 2021 · Aceptado: Abril 2021

1. Introduction

During the last years, a great interest for issues like sustainable development or sustainability has arisen, at both a microeconomic and a macroeconomic level. By a microeconomic level we mean sustainability in the business arena. This kind of sustainability is becoming more widespread, as shown by the sustainability reports that many companies now produce. By a macroeconomic level we mean sustainability at the country level, a topic which may be less developed than at the microeconomic level but which is definitely very important.

This paper focuses on sustainability at the macroeconomic level, which has become increasingly relevant since the United Nations Conference on Environment and Development held in Rio de Janeiro in 1992. The Conference, also known as the Earth Summit, incorporated the topic of sustainable development into the international political agenda as defined in the Brundtland Report of 1987. In that report we find the first record in an official document of the concept of sustainable development, which is defined as the growth that satisfies present needs without endangering the capacity of future generations to satisfy their own needs (Brundtland et al., 1987). In this way, the general principle that must guide international relations regarding the relationship between the economy and the environment is defined, where the need of looking for strategies that allow to make compatible the processes of growth with sustainability are highlighted (Erias Rey, 2003).

The attainment of sustainable development implies making progress in three fundamental dimensions: social sustainability, economic sustainability and environmental sustainability. Each dimension is defined as follows:

- Social sustainability. It implies the need of guaranteeing both the intra-generational equity (satisfying the actual basic needs of the people), and the intergenerational equity (guaranteeing at the same time that next generations will be able to satisfy as well all their basic needs in the future).
- Environmental (ecological) sustainability. It is defined as the need of keeping the stock of environmental resources along the time. It can be attained through the limitation in the consumption of resources and products easily exhaustible, the reduction of waste and pollution in all sorts, the conservation of the energy and recycling.
- Economic sustainability. It implies the search of the economic equilibrium through an optimal combination between economic development and the conservation of natural resources.

To be able to attain sustainability the first step is to define its components in measurable terms (Hales & Prescott-Allen, 2002). However, the notion of what sustainability means considerably varies and the way of measure it is still ambiguous (Mori & Christodoulou, 2012). Needless to say, the literature on sustainability is huge (Hák et al., 2007; Arezki & Van der Ploeg, 2007; Bell & Morse, 2008; Betsill & Rabe, 2009; Guy & Kibert, 1998; Meadows, 1998).

The new definition of sustainability incorporated by Van de Kerk and Manuel (2008) is useful in the sense they treat the three main dimensions, namely, social, environmental and economic sustainability. According to them, a sustainable society is a society where each human being is able to: develop by themselves in a healthy way and obtain an adequate education, live in a clean environment, live in a safe and well balanced society, use non-renewable resources in a responsible way so that future generations will not be empty-handed, and to contribute to a sustainable world. Other different definitions of sustainability can be found in Moore et al. (2017).

Sustainability has received great attention and big advances have been made in this topic. For instance, the term sustainability has been used by politicians and economists, in order to declare that a society is economically achievable, rationally environmental and socially responsible, although the big changes that social and economic topics have suffered make a measure for the sustainability (Saisana & Philippas, 2012). Speaking about environmental sustainability, Valizadeh and Hayati (2021) regard the challenges faced by researchers, decision-makers and policymakers in improving and attaining agricultural sustainability, so they developed an agricultural sustainability measurement index that might be used for the comparison of different countries.

The new indices that have increasingly appeared try to measure the three aspects of sustainability, but only one at a time. Some of them have been established by the OECD or the UN by means of the Sustainable Society Index (SSI). The SSI is elaborated since 2006 and that can be considered one of the newest indices (Van de Kerk & Manuel, 2012). The new index treat the three aspects in a more complex way (in the sense that it measures the three aspects of the sustainability at the same time) but still in an accurate fashion. The Sustainable Society Index has recently been audited by the Joint Research Center of the European Commission that considers it an integral and quantitative method for internationally measuring and guarding the health of the human and environmental systems. Moreover, it considers the index a conceptual and statistically solid tool that is widely applicable for the continuous evaluation of the human and environmental systems and a key point of reference with which comparing the future progress and reporting about the actual society (Saisana & Philippas, 2012). As it can be seen in the following section, the Sustainable Society Index is built from 21 different indicators, which can be individually separated in order to see how each one of the countries does regarding a specific sustainability aspect, a feature that provides very valuable additional information.

The goal of this paper is to review the evolution of the concept of sustainability, and the discussion about measuring it. This paper also aims to analyze the current situation of sustainability in the world by means of these sustainability indicators mentioned above. It will be analyzed by means of the use of a statistical tool called Partial Triadic Analysis, which is very useful when the data is available as a three-dimensional matrix, in our case, countries in rows, indicators in columns and the different years of study in layers. The structure of this paper is as follows: section 2 shows how sustainability can be measured and discuss the chosen set of sustainability indicators, the Sustainable Society Index, section 3 explains the methodology of the chosen statistical technique, in section 4 we present the results and section 5 includes the conclusions.

2. Measuring sustainability

2.1. Available sustainability indices

Generally speaking, indices have three main functions. Firstly, they reduce the number of measurement instruments needed to give a description of a situation (Organization of Economic Co-operation and Development, 2003). Secondly, it is imperative that they measure the progress to the politic objectives and for evaluating the effectivity of politics (Dalal-Clayton & Krikhaar, 2007). And thirdly, the development of indices at national, regional or local level has to be an approximation commonly used for knowing the crucial need for evaluation tools. Such tools are a pre-requirement for the implementation of the concept of sustainability (Hansen, 1998; Jasch, 2000; Perotto et al., 2008).

Recently (Karavanas et al., 2009), several indices have been used for topics like quality of life and environment, mainly in order to sort the level of performance of a country. Moreover, these indices provide information about the status of the environment and they evaluate the economic, social and environmental impact in the development.

With the purpose of studying the sustainability at international level, Bell and Morse (2008), Meadows (1998), Guy and Kibert (1998) and Van de Kerk and Manuel (2008) reviewed a lot of actual indices and indicators related to sustainability (where the difference between index and indicator is that an index is a single number that summarizes the information of all the indicators that comprise the index, that is, an index can be seen as a set of indicators). They did that in order to find a good set of indicators, that is, those that give a complete view of all relevant aspects of sustainability in a transparent and easily understandable way. The criteria that each of the indicators of the chosen set must meet are the following:

- They must be relevant for some of the aspects related to the previous sustainability definition.
- All of them must cover the whole field of sustainability, in line with the definition.
- All of them have to be independent so they do not mutually overlap.
- The aspect of sustainability that they capture must be measurable.
- They must be easily accessible, also for the general public. This implies that the number of indicators must be limited.
- The data for building the indicators must be publicly available.

– The data must be available for all countries, at least for all of them except for the smallest ones.
– The data must be reliable.
– The data must be recent and regularly updated.
– All of them must give an accurate picture of the current prospects of sustainability and indicate the gap between the current prospects and a complete sustainable situation.
– They must allow the comparison between countries.

Next, some of the more relevant indices on sustainability that were selected by Van de Kerk and Manuel (2012) and Saisana and Philippas (2012) are presented:

– Human Development Index (HDI) (UNDP, 2005). It is published every year.
– Environmental Sustainability Index (ESI-2005) (Esty, 2005).
– Environmental Performance Index (EPI-2006) (Esty, 2006).
– Commitment to Development Index (CDI-2006) (Center for Global Development, 2007). It is published every year.
– Index for Sustainability Economic Welfare (Daly & Cobb, 1989).
– Ecological Footprint (Wackernagel & Rees, 1998). It is published every two years.
– Well-being of Nations (Prescott-Allen, 2001): published only once.
– Millennium Development Indicators (United Nations, 2005).
– Indicators for the EU Sustainable Development Strategy (UNECE, 2007).
– CSD Indicators (United Nations, 2007). It is published every year.

The general conclusion is that none of the mentioned indices seems to completely adjust to the criteria mentioned above, due to some of the following shortcomings: they only partially cover sustainability in a wider way, they do not include some of its aspects, they have redundant indicators, they only offer information for a limited number of countries, the sets comprise a lot of indicators, they offer too much information, so they are not very transparent, they are not uploaded, they do not give a clear point of view of the level of sustainability, their calculation methods are questioned and they only were published once.

2.2. The Sustainable Society Index (SSI)

Taking into account the limitations found in most indices, especially when it comes to making international comparisons, we have chosen the Sustainable Society Index (SSI), established by Van de Kerk and Manuel (2012), to carry our analysis. The SSI comprises 21 indicators grouped in three categories, human, environmental and economic well-being and its being detailed next (Van de Kerk & Manuel, 2012).

- Social well-being
  - Sufficient Food (SF): Prevalence of undernourishment (expressed in percentage terms).
  - Sufficient to Drink (SD): Percentage of population using at least basic drinking water services (expressed in percentage terms).
  - Safe Sanitation (SS): Percentage of population using at least basic sanitation services.
  - Education (ED): Number of students enrolled in primary, secondary and tertiary levels of education, as a percentage of the population of official school age for the three levels.
  - Healthy Life (HL): Life expectancy at birth in number of healthy life years.
  - Gender Equality (GE): Gender Gap Index: a comprehensive index yearly published by World Economic Forum.
  - Income Distribution (ID): Ratio of income share held by lowest 10 % to income share held by highest 10 %.
  - Population Growth (PG): Average yearly 5-years change in population, total.
  - Good Governance (GGO): Sum of the values of the six Worldwide Governance Indicators, yearly published by the World Bank.
- Environmental well-being
  - Biodiversity (B): 10-years change in a) Forest area (expressed in percentage terms of land area) and b) Terrestrial protected areas (expressed in percentage terms of total land area).
  - Renewable Water Resources (RWR): Water consumption per year as a percentage of total available renewable water resources.
  - Consumption (C): Ecological Footprint (global hectares per person).
  - Energy Use (EU): Total Primary Energy Supply as production plus imports minus exports ± stock changes.
  - Energy Savings (ES): Change in primary energy usage expressed in percentage terms.
  - Greenhouse Gases (GGA): Total CO_2 emissions minus Fuel Combustion (metric tons of CO_2).
  - Renewable Energy (RE): renewable energy consumption (expressed in percentage terms of the total final energy consumption).
  - Economic well-being
  - Organic Farming (OF): Organic area share of total farming (expressed in percentage terms).
  - Genuine Savings (GS): True rate of savings in an economy after taking into account investments in human capital, depletion of natural resources and damage caused by pollution, including particulate emission damage (expressed in percentage terms of Gross National Income).
  - Gross Domestic Product (GDP): GDP per capita in Purchasing Power Parity (current international dollars).

– Employment (EM): Unemployment, total (percentage of total labor force). This is an International Labour Organization estimate.
– Public Debt (PD): General Government liabilities or debt plus loans or net lending.

3. Data and analysis techniques

3.1. Data

The indicators data were available for 154 out of the 195 existing countries for the last available biennia –2006, 2008, 2010, 2012, 2014 and 2016 (they can be found on the Sustainable Society Index website[1]). Thus, Van de Kerk and Manuel (2008) calculated the SSI for most of the medium or large sized countries (Appendix A). Exceptions for larger sized countries are Afghanistan, Somalia and Suriname. Apart from that, most of the insular states have been excluded due to a lack of data. Therefore, the SSI has been obtained for every possible major country. This allows comparing among countries from several points of view: bordering countries, countries from the same region, countries with similar characteristics, compare among rich countries, like the members of the Organization for Economic Co-operation and Development (OECD), compare among north and south hemispheres, etc.

With the objectives of this research in mind, the available data is useful for the interest of extending and generalizing the obtained results in previous studies, and overcoming two limitations: the studied countries and the data analysis techniques used there. The previous studies usually focused on contexts about specific geographical areas, such as industrialized occidental countries (Scruggs, 2003; Jahn, 1998; Crepaz, 1995), 14 OECD countries and five well-being measures (Giles & Feng, 2005), and 131 countries (Hosseini & Kaneko, 2011).

In this research, 154 countries from all over the world are considered (they are listed in Appendix A) grouped in 4 income classes (low, lower-middle, upper-middle and high incomes, Appendix A); the 21 numerical variables are the values obtained for the chosen countries related to the constituent indicators of the SSI mentioned in the previous section for the last available biennia (2006, 2008, 2010, 2012, 2014 and 2016).

So, in this research, the data consist of the SSI values for every country in every period, that is, a three-dimensional matrix 154 rows × 21 columns × 6 repetitions.

3.2. Analysis techniques

The analysis of all the elements included in the set of sustainability indicators at once requires a large volume of data. In order to explore the data to get a better understanding of them, it is important to identify the principal underlying structure.

[1] https://ssi.wi.th-koeln.de/index.html

The methods for reducing the dimensionality of the data help us to summarize the information from a large number of variables with a smaller number of latent variables. Graphics that simultaneously show both the rows and the columns of the data set can be very useful in this regard. These kind of graphics are used in this article.

The methods for reducing the dimensionality of the data will allow to check if the proposed indicators included in the SSI are similar along the different countries (for instance, if social, environmental or economic topics are similar in different countries from the same income class) or along the different years, to find geographical areas with similar sustainability profiles and to identify the most differentiated countries and sort them according to a sustainability gradient. In addition, the most important components of the sustainability for each income class for each year can be identified.

The Partial Triadic Analysis is one of the Structuration des Tableaux À Trois Indices de la Statistique (STATIS) methods for three-dimensional data analysis (L'Hermier des Plantes, 1976). A STATIS method can be thought as a generalization of the Principal Component Analysis not for a bi-dimensional matrix, but for a set of three-dimensional data. The Partial Triadic Analysis is the simplest of these methods, but also the most restrictive one. Its objective is to analyze a sequence of k matrices (the layers of the three-dimensional data) with the same number of rows and columns, what means that the same variables have to be measured for the same individuals, several times (every layer represents a repetition). The Partial Triadic Analysis, as every STATIS method, comprises three steps: interstructure, compromise and intrastructure, also known as 'trajectories' (Thiolouse 2011).

The interstructure step provides the coefficients of a special linear combination of the data matrices from the sequence, which leads to an optimum representation called 'compromise'. The second step computes the Principal Component Analysis of this linear combination, this 'compromise'. The intrastructure step is a projection of the rows and columns from every repetition in the compromise analysis.

The interstructure is based on a matrix of inner products among repetitions (the vector covariance matrix), built as $Covv(X_{k1}, X_{k2}) = Tr(X^t_{k1} D_I X_{K2} D_J)$, where X_{k1} and X_{k2} are the k1-th and the k2-th matrices in the sequence, D_I is the diagonal matrix with the weights for the rows and D_J is a metric in the space of the columns (the latter ones are usually the euclidean metrics). The eigendecomposition of this vector covariance matrix results in a first eigenvector, and the coordinates, α_k, of this first eigenvector are used as the weights for computing the compromise.

Moreover, this interstructure can be plotted with vectors from the origin to the points given by the rows of $V_2\Lambda_2$ where V_2 are the first two eigenvectors of the vector covariance matrix and Λ_2 is the diagonal matrix with the two associated eigenvalues, so the different repetitions can be graphically represented.

The compromise X_c is a linear combination of the initial layers (the repetitions), weighted by the coordinates of the first eigenvector of the interstructure: $X_c = \Sigma_k \alpha_k X_k$. The principal property of this compromise is that it maximizes the similarity with all the layers.

The weight of each layer is proportional to its similarity, so matrices different from the others will be poorly weighted. This property ensures that the compromise will be similar to all the repetitions. The compromise analysis, for example, by means of a Principal Component Analysis, results in bi-dimensional representations (principal axes plots) that can be used for interpreting the structure.

The intrastructure is obtained by projecting the rows and the columns of each repetition onto the compromise analysis. Let V_r be the matrix with the first r eigenvectors of the compromise analysis, that is, of $X^t_c D_I X_c D_J$. The coordinates for the rows of the matrix X_k are $X_k D_J V_r$ and for the columns are $X^t_k D_I U_r$, where U_r are the first r eigenvectors of $X_c D_J X^t_c D_I$.

The advantage of the Partial Triadic Analysis and what makes it different from other methods for reducing the dimensionality of three-dimensional data, is that it highlights the 'stable structure' of a matrix sequence. The compromise step plots this stable structure (whenever exists), and the intrastructure step shows how each matrix moves away from it (Thiolouse, 2011).

The Sustainable Society Index has been analyzed in other studies, using different approximations. Gallego-Álvarez et al. (2015a) studied the relations among countries and indicators only for the year 2012 with the Biplot technique. Gallego-Álvarez et al. (2015b) studied the 2006-2012 period data with the STATICO technique, so that means the relations between the indicators two at a time (social/environmental, social/economic and environmental/economic) and without the income levels for the countries, unlike we did in this paper, where the three dimensions were studied at the same time and the countries were grouped in income classes. Rodríguez-Rosa et al. (2017) studied the 2006-2012 period data with the Partial Triadic Analysis and the COSTATIS techniques, where they paid more attention to the economic indicators, that is why we build this paper, in order to study the most recent situation with the 2006-2016 period, and paying the same attention to the three dimensions of the sustainability and Rodríguez-Rosa et al. (2019) studied the 2006-2012 period data with the Co-Tucker3 technique, so, again, the relations between the indicators are studied two at the time, not the three dimensions at the same time, moreover, Co-Tucker3 technique is useful for highlighting the non-stable structure of the data, unlike the Partial Triadic Analysis here, which serves to study the stable part of the data.

The software used for implementing the methods for reducing the dimensionality is an R package called 'KTensorGraphs' developed by Rodríguez-Rosa (2019).

4. Results

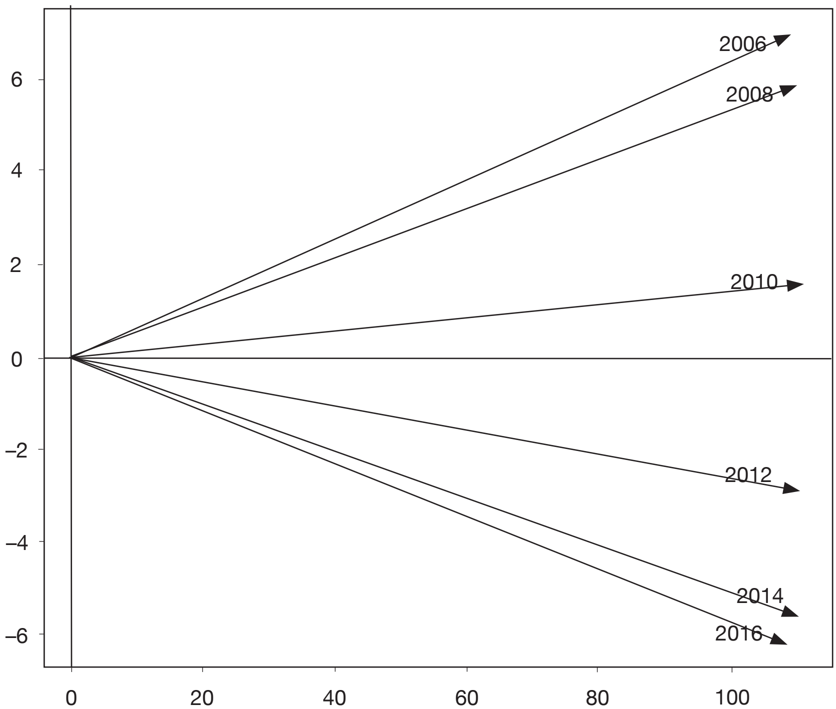
Our data are sorted in a three-dimensional array (cube) with 154 rows, the countries, 21 columns, the indicators from the Sustainable Society Index, for six repetitions, the six years of study (2006, 2008, 2010, 2012, 2014 and 2016).

The objective of the Partial Triadic Analysis (PTA) is to highlight the stable structure along the six years of the countries and the indicators, that is, to find an 'average year', to graphic the countries and indicators from this stable structure, and to show how each one of the former separates from the latter.

For all the graphics in this section, the axes do not have units, the numbers on them only serve to find out the scale, that is, the variability that the elements (countries, indicators, or years) present along the horizontal and vertical axes. In some of them even a percentage indicating this variability can be found.

The first resulting graphic obtained after the PTA analysis is the Figure 1, called interstructure. It is a graphic representation that helps to interpret the similarities and differences among the repetitions that have been studied, in our case, the different years, as well as to make evident which of those repetitions are more relevant by the time of building the so called compromise matrix, that is, those years that are more similar to an 'average year' that will highlight the stable part of the evolution of the data along time.

FIGURE 1
INTERSTRUCTURE FROM THE PARTIAL TRIADIC ANALYSIS



SOURCE: Own elaboration.

In this kind of plot, the horizontal axis, represents the average repetition, the most stable configuration, so it can be seen that the most similar year to, on average, all of the rest of the years is 2010, which is the one that is placed nearer to the horizontal axis, that is, the one that has the smallest, most horizontal slope. Moreover, with this kind of plot it can also be seen how the years are different or similar among them: on the one hand, 2006 and 2008, in quadrant I, are placed very near to each other and far from the rest of the years; on the other hand, 2014 and 2016, in quadrant IV, are also placed very near to each other and far from the others; while 2010 and 2012 are placed in between far from each other and from the others. Generally speaking, the vectors placed on the quadrant I are different from the ones placed in the quadrant IV. Therefore, significant evidences have been found to show that the countries took different values on the indicators of the SSI (generally speaking) between 2008 and 2010, between 2010 and 2012, and between 2012 and 2014, that is, the difference among the repetitions in this kind of plot implies a difference among the rows and/or the columns of the corresponding repetitions.

In a second step, once the similarities and differences between the repetitions and the 'average year' are known, the latter can be explicitly obtained as a combination of all the repetitions. Therefore, the so called compromise matrix has been calculated, which includes the countries and the most stable values that they take into the indicators. This matrix can be analyzed by means of the Principal Component Analysis (PCA) according to which the graphic in Figure 2 has been obtained.

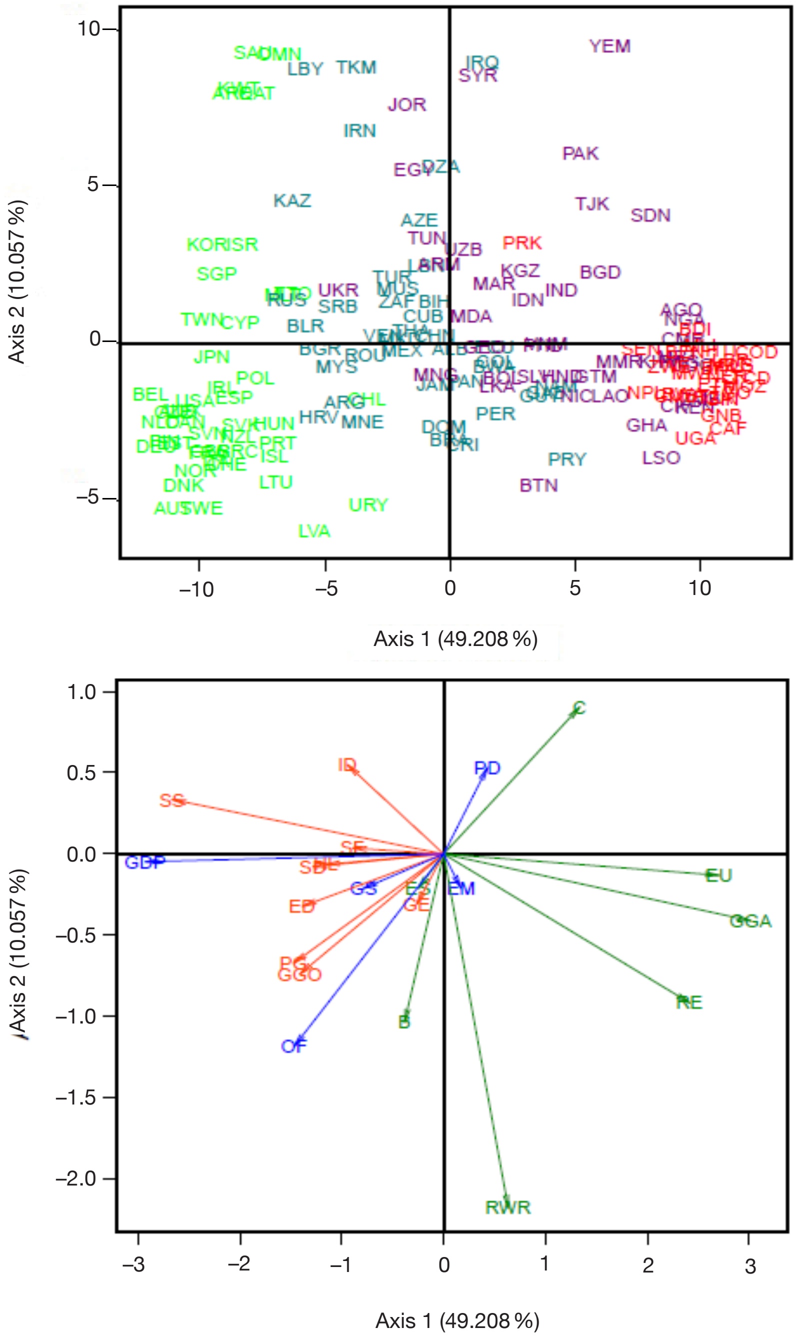
This graphic includes the countries (see Appendix A) and the indicators from the SSI, listed in a previous section. All the countries are represented with different colors according to their income classes: the countries from the low income class in red, the ones from the lower-middle income class in purple, the ones from the upper-middle income class in light blue and the ones from the high income class in light green. The indicators are represented with vectors with colors according to which one of the three different dimensions from the SSI they belong to: the social indicators in orange, the environmental ones in dark green and the economic ones in dark blue.

Figure 2 is interpreted like a PCA: on the left part, interpretations about the relations among the countries can be done. It can be observed that the countries from the same income class are near each other, those groupings show that the countries from the same income class have similar profiles. Moreover, the income classes groups are placed in the graphic forming a gradient from left to right: high incomes, upper-middle incomes, lower-middle incomes and low incomes. That means that the main reason for the separation of the countries is the income level, because that is the feature represented on the horizontal axis, that is, the first axis from the eigendecomposition of the compromise matrix, which is the axis that holds the highest variation, because it is related to the highest eigenvalue.

On the right part of the same figure, the relations among the SSI indicators can be interpreted. On the one hand, social and economic indicators are placed forming small angles among them (except for Employment (EM) and Public Debt (PD))

FIGURE 2

COUNTRIES AND INDICATORS ACCORDING TO THE COMPROMISE FROM THE PARTIAL TRIADIC ANALYSIS



SOURCE: Own elaboration.

and, on the other hand, on the opposite side, the environmental indicators are placed (except for Biodiversity (B) and Energy Savings (ES)); that means that the social and economic indicators are positively correlated among them, and in a negative way with the environmental ones, which, at the same time, are also positively correlated among them. That implies that when a country takes high values on the social indicators, it also takes high values on the economic indicators (and vice versa) but low values on the environmental indicators, and the other way round, if a country takes high values on the environmental indicators, it takes low values on the social and economic indicators (both conclusions generally speaking).

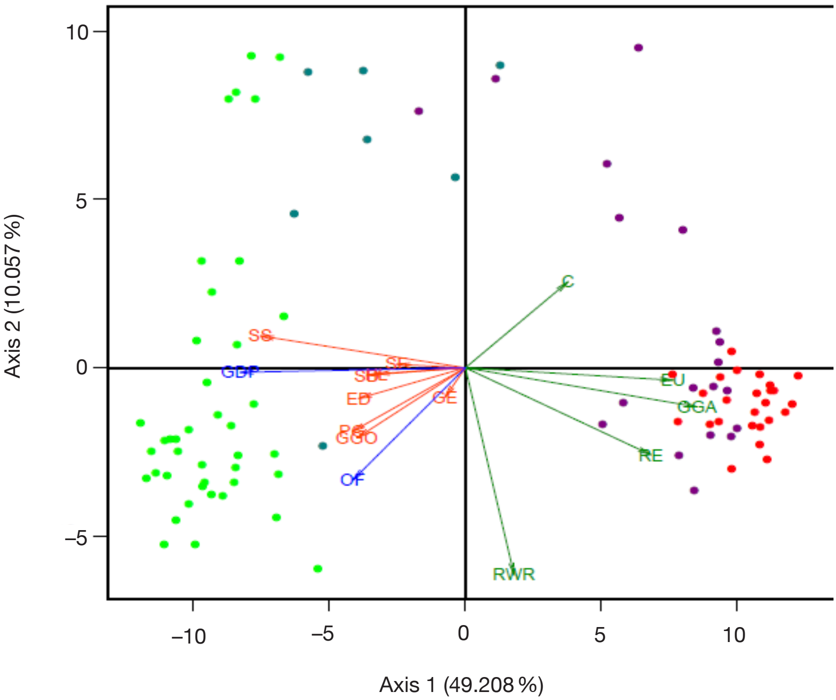
The lengths of the vectors that represent the indicators can also be interpreted, so vectors with longer lengths mean columns that present a higher variability in the values, while vectors with shorter lengths represent columns with a high similarity in their values. In our case, the countries present a higher variability in the values that they take in the environmental indicators, while they present a higher similarity in the values that they take in the social and economic indicators, because the former ones are represented by longer vectors, while the latter ones are represented by shorter vectors.

Finally, the similarities between the countries and the indicators can be interpreted by means of both sides of Figure 2 but, in order to better clarify these similarities, a joint plot was created, with the countries and the indicators on the same graphic (see Figure 3). On this Figure 3, all the indicators were multiplied by a constant so that they could be represented with the same coordinates system, but the conclusions are independent of this fact. Moreover, the labels for the countries were removed, so that the plot was not too much overfilled, so just the points with their corresponding color were plotted. Also, not all the countries and the indicators were plotted, just the ones with a higher quality of representation on the first-second axes factorial plane, that is, just the ones that are more related to the first two axes. With elements (countries or indicators) with higher quality of representation we mean the following: first, we calculate a value of how near each element is to each factorial axis (in a 0-1000 scale), then, we calculate the sum of the values for the corresponding factorial plane (the first-second axes factorial plane in our case), and finally, only the elements with a value higher than 500, that is, the ones with a higher quality of representation in that factorial plane, are represented.

The interpretation is as follows, according to which quadrants or half-planes belong the countries and the indicators. Therefore, countries with high and upper-middle incomes pay more attention to social and economic issues because those countries and those indicators are placed on the left half-plane, in quadrants II and III. And on an opposite way, the countries with low and lower-middle incomes are more related to the environmental indicators, because they are placed on the right half-plane, that is, in quadrants I and IV.

At last, the countries and indicators from all of the years are projected onto the same subspace as the compromise matrix (Figure 4), the so called intrastructure representation or trajectories. The evolution along time of the countries and the SSI

FIGURE 3
JOINT PLOT FOR THE COMPROMISE FROM THE PARTIAL TRIADIC ANALYSIS



SOURCE: Own elaboration.

indicators can be interpreted in a more detailed way with that graphic. For example, the indicators that have the longest trajectories, those that have presented a higher evolution along time, are the economic indicators. In particular, Public Debt (PD) stands out.

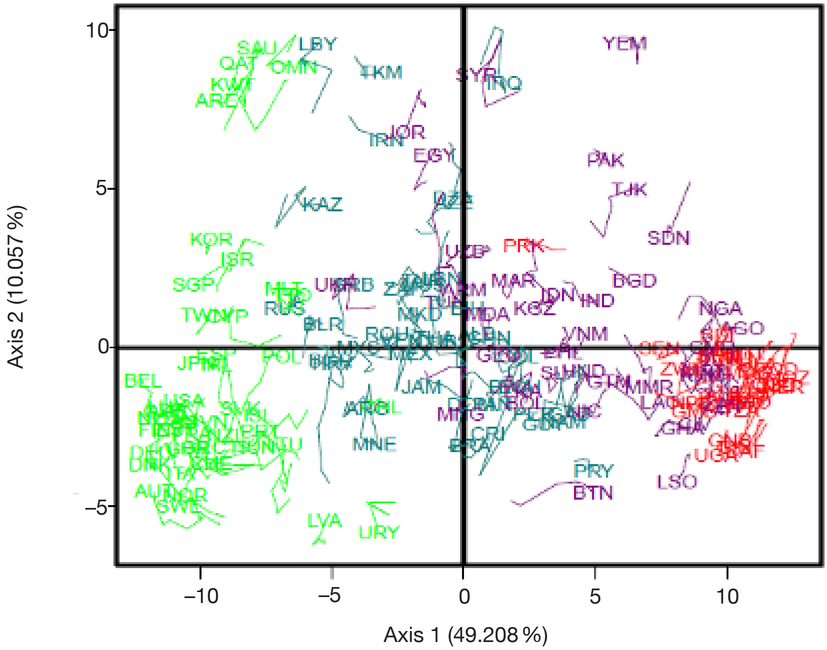
The thing is that the Public Debt indicator vector does not have a good quality of representation on the 1-2 factorial plane, although it is the indicator that has presented the highest evolution, so we chose to represent the 1-3 factorial plane too (see Figure 5). That means that not only the first and second eigenvectors for the intrastructure eigendecomposition have been calculated, but the third one too, the axis that retains more variability from the data after the first two axes.

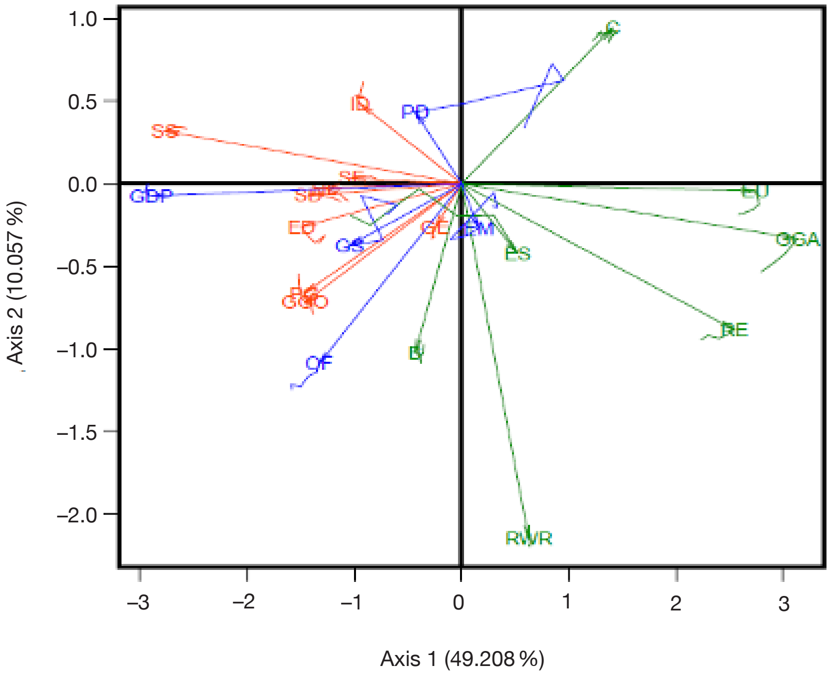
In a similar way as for the Figure 3, we only plotted the joint representation for the countries and the SSI indicators on the 1-3 factorial plane for the intrastructure. Moreover, only the elements (countries or indicators) with higher quality of representation on that plane are represented.

As it can be seen in that graphic (Figure 5) the longest vector and the one that is placed the nearest to the third axis (the vertical axis) is the one that represents the

FIGURE 4

COUNTRIES AND INDICATORS ACCORDING TO THE 1-3 FACTORIAL PLANE FOR THE INTRASTRUCTURE FROM THE PARTIAL TRIADIC ANALYSIS

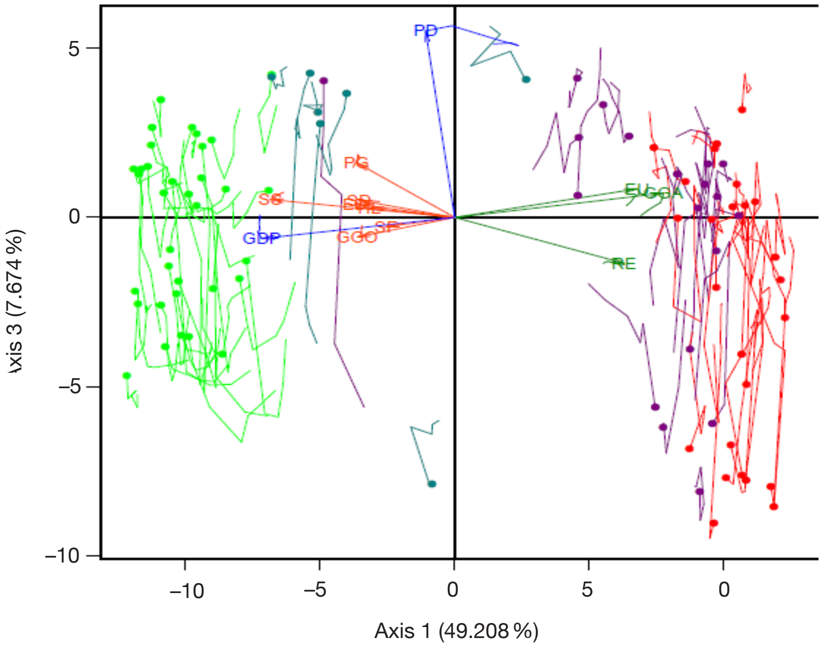




SOURCE: Own elaboration.

FIGURE 5

JOINT PLOT OF THE 1-3 FACTORIAL PLANE FOR THE INTRASTRUCTURE FROM THE PARTIAL TRIADIC ANALYSIS



SOURCE: Own elaboration.

PD indicator. Again, that means that this indicator presents a higher variability in the values that the countries take in it. Also, the most interesting result is that all the countries evolve along the time according to a vertical trajectory, that is, the main reason to the countries evolving this way is because of the Public Debt, in other words, after the main separation due to the income classes, the changes in the Public Debt are the reason that explains how the countries, according to their sustainability level, evolve along the studied period of time. So the final conclusion for the trajectories (evolution) of the countries along the time is that: those ones that have a descending trajectory, that is, one that goes from the quadrants I or II (where the vector that represents Public Debt is placed) to the quadrants III or IV, behave worse on sustainability; while countries with an ascending trajectory (from the quadrants III or IV to the quadrants I or II) improve their behavior about sustainability. In both cases, the countries with low or lower-middle incomes behave worse or better about the environmental sustainability (because those countries and those indicators are placed on the same I-IV quadrant semi plane), while the countries with high or upper-middle incomes get better or worse in the social and economic sustainability (countries and indicators are placed on the II-III quadrant semi plane).

5. Conclusions

The objective of this exploratory research was to dissect the appraisal of sustainability indicators all through the period 2006–2016 trying to build up whether they experienced any diversity. Simultaneously, we needed to decide how these indicators had advanced in countries belonging to various income classes. That is why we chose to use the Partial Triadic Analysis, because it is the statistical tool for analyzing not a single data matrix, like the Principal Component Analysis does, but a sequence of matrices where each one of them can represent a year of study. Partial Triadic Analysis can be then thought as a generalization of the PCA for three-dimensional data.

None of the current indices appears to satisfy our requirements totally, since no single one is altogether reasonable or able to accommodate our exploratory needs. Considering this, we display the constraints of the sustainability indices that have overwhelmingly been utilized with regards to sustainability. The SSI ended up being the one that best fits in our exploratory requirements as it conceals sustainability in its most extensive meaning encompassing social, environmental and economic viewpoints, while most of the different lists do so incompletely. Moreover, this SSI index was audited by the Joint Research Centre of the European Commission, which considers it a conceptual and statistically solid tool that is widely applicable to the continuous assessment of human and environmental systems (Saisana & Philippas, 2012).

The SSI is useful for these most relevant aspects: comparing the sustainability of each country with others from the same geographical area and identifying the most effective aspects; for the government, showing in a transparent and effective way to the general audience the situation of the sustainability in each country and making decisions about politics, projects and social, environmental or economic strategies to be adopted; at the educational level, being able to include sustainability subjects in secondary schools and universities so that the students can know the situation in the world around us; at the business level, knowing the sustainability indicators of the different countries where the companies perform their activities in order to observe if they can have some kind of competitive advantage in terms of business innovation.

Interpretations of the diagrams given by Partial Triadic Analysis allowed us to derive which of the years considered are equivalent from the viewpoint of every class of indicator studied together: social, environmental and economic.

Two principal results were obtained in this investigation, the first being, speaking about the evolution of sustainability, that Public Debt is the indicator that has evolved with the biggest contrasts along the 2006-2016 period, the countries with low and lower-middle incomes paid more attention to the environmental indicators, but some of them evolved by getting worse values in Public Debt, while others got better values in Public Debt. The same outcome happened for the countries with high or upper-middle incomes, but with social and economic indicators.

The second main result is that countries with high and upper-middle incomes got an improvement in the social and economic indicators while having poor values in the environmental ones, while the opposite can be said for the countries with low and lower-middle incomes.

The investigation portrayed here is an endeavour to propel our insight into the evaluation of sustainability indicators; nevertheless, the research does not lack of restrictions. For instance, it would likewise be prudent to study more factors that may impact in the sustainability indicators, for example, invention, innovation and diffusion of technology or processes, investigation and development, stock exchanges or production of human material provisions.

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APPENDIX

LIST OF COUNTRIES

Low incomes		Lower-middle incomes		Upper-middle incomes		High incomes	
≤ $ 1005		$ 1006 - $ 3955		$ 3956 - $ 12235		> $ 12235	
BDI	Burundi	AGO	Angola	ALB	Albania	ARE	United Arab Emirates
BEN	Benin	ARM	Armenia	ARG	Argentina	AUS	Australia
BFA	Burkina Faso	BGD	Bangladesh	AZE	Azerbaijan	AUT	Austria
CAF	Central African Republic	BOL	Bolivia	BGR	Bulgaria	BEL	Belgium
COD	Congo, Dem. Rep.	BTN	Bhutan	BIH	Bosnia and Herzegovina	CAN	Canada
ETH	Ethiopia	CIV	Côte d'Ivoire	BLR	Belarus	CHE	Switzerland
GIN	Guinea	CMR	Cameroon	BRA	Brazil	CHL	Chile
GMB	Gambia, The	COG	Congo, Rep.	BWA	Botswana	CYP	Cyprus
GNB	Guinea-Bissau	EGY	Egypt, Arab Rep.	CHN	China	CZE	Czech Republic
HTI	Haiti	GEO	Georgia	COL	Colombia	DEU	Germany
LBR	Liberia	GHA	Ghana	CRI	Costa Rica	DNK	Denmark
MDG	Madagascar	GTM	Guatemala	CUB	Cuba	ESP	Spain
MLI	Mali	HND	Honduras	DOM	Dominican Republic	EST	Estonia
MOZ	Mozambique	IDN	Indonesia	DZA	Algeria	FIN	Finland
MWI	Malawi	IND	India	ECU	Ecuador	FRA	France
NER	Niger	JOR	Jordan	GAB	Gabon	GBR	United Kingdom
NPL	Nepal	KEN	Kenya	GUY	Guyana	GRC	Greece
PRK	Korea, Dem. Rep.	KGZ	Kyrgyz Republic	HRV	Croatia	HUN	Hungary
RWA	Rwanda	KHM	Cambodia	IRN	Iran, Islamic Rep.	IRL	Ireland
SEN	Senegal	LAO	Lao PDR	IRQ	Iraq	ISL	Iceland
SLE	Sierra Leone	LKA	Sri Lanka	JAM	Jamaica	ISR	Israel
TCD	Chad	LSO	Lesotho	KAZ	Kazakhstan	ITA	Italy
TGO	Togo	MAR	Morocco	LBN	Lebanon	JPN	Japan
TZA	Tanzania	MDA	Moldova	LBY	Libya	KOR	Korea, Rep.

SOURCE: Own elaboration.

LIST OF COUNTRIES *(Cont.)*

Low incomes		Lower-middle incomes		Upper-middle incomes		High incomes	
≤ $ 1005		$ 1006 - $ 3955		$ 3956 - $ 12235		> $ 12235	
UGA	Uganda	MMR	Myanmar	MEX	Mexico	KWT	Kuwait
ZWE	Zimbabwe	MNG	Mongolia	MKD	North Macedonia	LTU	Lithuania
		MRT	Mauritania	MNE	Montenegro	LUX	Luxembourg
		NGA	Nigeria	MUS	Mauritius	LVA	Latvia
		NIC	Nicaragua	MYS	Malaysia	MLT	Malta
		PAK	Pakistan	NAM	Namibia	NLD	Netherlands
		PHL	Philippines	PAN	Panama	NOR	Norway
		PNG	Papua New Guinea	PER	Peru	NZL	New Zealand
		SDN	Sudan	PRY	Paraguay	OMN	Oman
		SLV	El Salvador	ROU	Romania	POL	Poland
		SYR	Syrian Arab Republic	RUS	Russian Federation	PRT	Portugal
		TJK	Tajikistan	SRB	Serbia	QAT	Qatar
		TUN	Tunisia	THA	Thailand	SAU	Saudi Arabia
		UKR	Ukraine	TKM	Turkmenistan	SGP	Singapore
		UZB	Uzbekistan	TUR	Turkey	SVK	Slovak Republic
		VNM	Vietnam	VEN	Venezuela, RB	SVN	Slovenia
		YEM	Yemen, Rep.	ZAF	South Africa	SWE	Sweden
		ZMB	Zambia			TTO	Trinidad and Tobago
						TWN	Taiwan, China
						URY	Uruguay
						USA	United States

SOURCE: Own elaboration.