Ecological Indicators 69 (2016) 400–406

Contents lists available at ScienceDirect

Ecological Indicators

journal homepage: www.elsevier.com/locate/ecolind

Improving the objectivity of sustainability indices by a novel approach for combining contrasting effects: Happy Planet Index revisited

Julia Bondarchik[a,*], Matylda Jabłońska-Sabuka[b], Lassi Linnanen[a], Tuomo Kauranne[b]

[a] Lappeenranta University of Technology, School of Energy Systems, Department of Sustainability Science, PO Box 20, 53851 Lappeenranta, Finland
[b] Lappeenranta University of Technology, School of Engineering Science, Department of Mathematics and Physics, PO Box 20, 53851 Lappeenranta, Finland

ARTICLE INFO

Article history:
Received 25 November 2015
Received in revised form 21 April 2016
Accepted 25 April 2016
Available online 21 May 2016

MSC:
15Axx
15A18
65Fxx
65F15

Keywords:
Sustainability indices
Composite indicator
Singular value decomposition
Happy Planet Index
Global Peace Index

ABSTRACT

Measuring complex and rather intuitive qualities such as sustainability requires combining many different measures together. These measures often quantify contrasting effects. The resulting composite index then also depends not only on the component indices but also on the way that these have been combined together. An example of such a measure is the Happy Planet Index (HPI) that aggregates information on positive qualities like life-expectancy and human well-being with negative ones like ecological footprint to rank countries according to their sustainability. However, since component indices are often mutually correlated and feature quite different distributions of entities ranked, elaborate rules are used in the process of combination. As a result, the resulting composite index may look somewhat contrived and its rankings may depend heavily on subjective parameters in the combination process. We propose a geometrically motivated parameter-free method for combining indices with contrasting effects together. The method is independent of the number of contrasting indices to be combined and eliminates mutual correlation between component indices by using Singular Value Decomposition (SVD) analysis. As an example of its use, we revisit the Happy Planet Index and demonstrate the impact of adding new component indices to HPI on ranking nations by their sustainability.

1. Introduction

The concept of sustainability has rapidly evolved during the past decades. The fact that we are facing such anthropogenic effects as climate change, resource depletion and land degradation cannot be ignored anymore. Environmental issues are becoming more and more visible in political decision-making. Many countries around the world have already adopted a climate change mitigation plan with the focus on greenhouse gas emissions reduction.

However, the concept of sustainability embraces a wider range of human activities. These are the environmental impact on the natural ecosystems, and those associated with economic stability and social integrity. The need to account for all three pillars of sustainability brings additional complexity to this issue in a sense of redefining as well as measuring sustainability. There is already an ongoing debate about the need for a new field of study called *sustainometrics* (Steward and Kuska, 2011; Todorov and Marinova, 2009), which would allow us to gain a stronger knowledge base for modeling and measuring sustainability.

Despite the growing awareness around sustainable development, sustainometrics, as a part of sustainability science, has not yet been well established, mainly due to the challenges of integrating the socio-economic aspects owing to their complexity. Thus, the main aim of this work is to apply a more formal, mathematically justified approach to identify sustainability-related progress in the presence of multiple contradictory goals. This would provide an opportunity to gain a deeper understanding of the process itself and to create a solid, scientifically affirmed base for political decision-makers.

Mathematical modeling can represent a useful tool for better understanding and tracking the sustainable development process. Currently, the mathematical modeling of sustainability concepts is such that the relationship between environmental and social dimensions is usually described in the form of differential equations. These relationships are usually based on the main balance laws in physical science such as, for example, mass, momentum, or energy (Singh, 2014). Nevertheless, there are other ways to design a model for identifying the state and progress of sustainability. For instance, in Krajnc and Glavic (2005) or Zhou et al. (2012)

* Corresponding author. Tel.: +358 504531253.
E-mail addresses: julia.bondarchik@lut.fi (J. Bondarchik), matylda.jablonska-sabuka@lut.fi (M. Jabłońska-Sabuka), lassi.linnanen@lut.fi (L. Linnanen), tuomo.kauranne@lut.fi (T. Kauranne).

http://dx.doi.org/10.1016/j.ecolind.2016.04.044

a model was considered to assess companies' sustainability performance based on their *composite sustainable development index*. The idea behind composite indicators is to aggregate multidimensional issues into a single index. However, there is a lot of criticism toward such an approach due to the subjective nature of composite indicators, since they are heavily dependent on normalization, weighting as well as aggregation methods.

This paper proposes a different way of building an aggregate indicator, which would be able to cover the complexity of the issues behind the sustainability concept without completely losing its objectivity. In Section 2 of the paper, a brief overview of the current position of the sustainability indicators will be given, with a deeper investigation of the *Happy Planet Index*. Section 3 is dedicated to explanation of the methodology proposed in this work, followed by Section 4 which collects our results. Section 5 concludes.

2. Indicators of sustainability

It has been acknowledged that focusing on the monetary value and using GDP as the one and only progress indicator is not appropriate anymore (Green, 2014; Bergheim, 2006). Therefore, there is a rising trend of shifting the focus of political decision-making toward various issues by developing sets of sustainability indicators and goals: the most known are Sustainable Development Goals and Millennium Development Goals (UNDP, 2015). In order to succeed on this path, it is crucial to understand the scientific underpinnings of such an approach as well as the meaning of this rather subjective matter.

Ever since the concept of sustainability started to emerge, several attempts have been made to quantify and measure sustainability, but the intention to fairly account for all the three dimensions of sustainable development (environmental, social, economic) still remains challenging. While indices related to the natural environment (such as CO_2 emissions, water quality and biodiversity) can be calculated and modeled (Rockström et al., 2009), the socio-economic factors represent the main obstacles for creating sustainability metrics due to their very subjective nature. In order to be able to cover all the three sustainability aspects, it is important to treat them all equally without highlighting, for instance, the economic performance. Moreover, the completely different natures of social and natural sciences adds complexity to the modeling task.

From a technical point of view, some of the major challenges for sustainability assessment methodologies include data gaps, inconsistencies in data sets across disciplines, and a need to analyze the data across scales. Ever since the sustainability challenges were acknowledged, multiple attempts were made to quantify and measure sustainability. At the moment the most successful assessment method is measuring sustainability via various indicators and indices (Singh et al., 2012).

In Kissinger and Rees (2010), Sustainable Development Indicators (SDI) are defined as an attempt to create a holistic approach to measure sustainability through assigning a value or a number to describe the relation between environmental, social and economic dimensions of sustainability. It can be represented in a form of a set of indicators or as one separate index.

Some of the most known SDI's are:

- Human Development Index
- Happy Planet Index
- Indicators of Sustainable Development (United Nations)
- Environmental Performance Index/Environmental Sustainability Index
- Genuine Progress Indicator
- Green GDP

Indicator schemes share a common goal of measuring the crucial sustainability dimensions, yet they differ in conceptual definitions, methodological approaches and modes of operation. Therefore, there is a need for knowledge systematization and a formalized framework.

According to the recently published World Happiness Report (Helliwell et al., 2015) there is an increasing number of local and national governments that use happiness and people's well-being as a guide in policy development. These subjective measures for planning have been used for years, because they aim at finding the most satisfying end results at a whole, rather than focusing on economical values alone.

2.1. Happy Planet Index

The Happy Planet Index (HPI) (Abdallah et al., 2012), is one of the most successful global measures to assess such a subjective matter as sustainable well-being. HPI uses global data on experienced well-being, life expectancy, and ecological footprint to generate an index revealing which countries are most efficient at producing long, happy lives for their inhabitants, whilst maintaining the conditions for future generations to do the same. This simple headline indicator gives a clear sense of whether a society is heading in the right direction. It provides a vital tool to ensure that fundamental issues are accounted for in crucial policy decisions.

Inherently, HPI is a measure of efficiency: it is defined as a product of national well-being and life-expectancy (which are represented by the number of *Happy Life Years*) achieved per unit of resource use (here ecological footprint). Most of the currently existing indicators of a similar nature are in fact composite indices: i.e. aggregate indices that comprise several sub-indices. Also, HPI has a common indicator's feature to divide its sub-indices as ones with a positive and with a negative effect. The product of the former ends up in the denominator and the product of the latter in the nominator, as presented in Eq. (1)

$$\mathrm{HPI} \approx \frac{\text{Well-being} \times \text{Life expectancy}}{\text{Ecological footprint}} \tag{1}$$

However, as can be seen from the methodology used to actually evaluate the final results, the data was modified and adjusted with four different constants (α, β, γ, δ). First of all, statistical adjustments were applied to balance the degree of variation in the components, whereas life expectancy was used as a reference. In the HPI methodology a term Happy Life Years (HLY) is introduced. HLY are calculated according to the equation below and adjusted to have a result between 0 and the average life expectancy of each country, as presented in Eq. (2).

$$\mathrm{HLY} = [(\text{Well-being} + \alpha) \times \text{Life expectancy}] / (10 + \alpha) \tag{2}$$

In turn, ecological footprint was adjusted as well in order to make the coefficient variance to be equal to that of the happy life years given by Eq. (3).

$$\mathrm{HPI} = \delta \times \frac{\mathrm{HLY} - \gamma}{\text{Ecological footprint} + \beta} \tag{3}$$

To calibrate the final HPI score to be between 0 and 100, the following two boundary conditions were used:

- if well-being is 0 or life expectancy is ≤ 25, then HPI is 0;
- if well-being is 10, life expectancy is 85 and footprint is 1.78 gha/capita, then HPI is 100.

The challenge with the composite indicators such as HPI is the way their sub-indices are aggregated. For instance, by tuning the free parameters α, β, γ and δ in HPI calculations and the cut-off age 25 for life expectancy, it is possible to obtain a different order for the countries assessed. The arbitrary nature of how the results can be manipulated gives cause for criticism and loss of credibility, even though the adjustments of the sub-indices are based on “educated guesses”.

In this work we are attempting to assess a vague measure of people’s well-being by the means of statistical analysis. The main goal is to find out sensitivity of the effect on the results depending on the chosen method; and, if possible, to devise a robust way to combine several sub-indices in a manner that is not subject to the adjustment of parameters according to the opinions of the decision-makers. It is possible to use the method we are developing on any kind of data, however we have chosen to use the data for Happy Planet Index for the experimentation.

Therefore, we have chosen to use the relevant indicators provided by Abdallah et al. (2012), as well as follow through with the proposed approach of recalculating the HPI with a different set of mathematical operations.

2.2. Global Peace Index

Global Peace Index (GPI), see IEP (1999), ranks the nations of the world according to their level of peacefulness. The index is composed of 23 qualitative and quantitative indicators from highly respected sources. Based on these, global peace is evaluated through three broad themes: the level of safety and security in society, the extent of domestic and international conflict and the degree of militarization (IEP, 2015).

Analogously to happiness or other rather subjective matters (which normally come along with social sustainability concept), peace is notoriously difficult to define. However, a rather quantitative attempt has been made by the Institute for Economics and Peace under the Vision of Humanity Initiative. They introduce the GPI in terms of the harmony achieved by the absence of violence or the fear of violence, which has been described as Negative Peace. Negative Peace is a compliment to Positive Peace which is defined as the attitudes, institutions and structures which create and sustain peaceful societies. The GPI measures a country’s level of Negative Peace using the following three domains of peacefulness:

- Ongoing domestic and international conflict: indicators of the number and intensity of ongoing civil and international wars.
- Societal safety and security: indicators of the levels of safety and security within a country, such as the perception of criminality in society, the level of political instability and the rate of homicides and violent crimes.
- Militarization: indicators of a nation’s military capacity, both in terms of the economic resources committed to the military and support for multilateral operations.

The GPI is also an example of a composite indicator, appropriateness of which can be questioned similarly to that of the HPI. However, since research boundaries have to be set somewhere, the GPI indicator is considered in this study as complete and accurate. It has been introduced into our work to bring the aspect of political stability to our calculations along with GDP in order to extend the original HPI.

3. Methodology

In this article we formulate a universal algorithm, dubbed a *Happier Index for the Planet*, or HIP, to build aggregate indices from sub-indices that can feature both positive- and negative-effect sub-indices. The algorithm takes the same starting points as HPI, i.e. the method takes the product of both positive and negative indices separately and uses their quotient as the final aggregate index. It differs from HPI and many other composite indices in the following essential ways:

1. There are no free parameters to adjust – and therefore no subjectivity whatsoever – in the way the sub-indices are combined. The only freedom a user of HIP has is the choice of sub-indices.
2. All sub-indices are treated in a totally uniform way, that is, any transformations are performed with exactly same steps for all the variables.
3. Any pre-existing correlations, positive or negative, between sub-indices are removed before aggregation.
4. The number of sub-indices has no impact on the aggregate index – only the variability in their information content does.

All this means that the method of calculating the Happier Index for the Planet is not dependent on “educated guesses” of tuning coefficients. Instead, it is based on a mathematically robust approach which does not need any “human” intervention in the model parameters. The details of the mathematical universalization are presented in the following subsections of this work.

3.1. Data normalization

In our work, first of all, it is necessary to choose the indicators for calculating the index. From the mathematical point of view, there can be two different types: the ones with a positive meaning (such as well-being and life expectancy) and the ones with a negative meaning (ecological footprint). Since we use the Happy Planet Index as a reference point for validation of our results, we try to limit the number of indicators to a minimum, and to mostly use the same ones used in the calculation of HPI. Also, countries’ GDP was used to include the economic aspect. Moreover, as further results will show, we found it necessary to add the Global Peace Indicator (GPI) in the analysis.

Many of the chosen indicators have very different statistical distributions (mean value and standard deviation, to start with). Therefore, the first significant difference between our study and the original calculation of the HPI is that we aim at working with normalized variables. That means, the values of the variables are rescaled to the same mean value and standard deviation. Normalization includes the following steps:

(a) Shift each value of a variable by one and calculate its logarithm as demonstrated in Eq. (4).

$$Y_i = \ln(X_i + 1), \quad i = 1, \ldots, 5 \tag{4}$$

We know that all of our original indicators are non-negative. However, the shift by one ensures that we avoid taking the logarithm of zero or any values very close to zero. On the other hand, the logarithm operation scales down any possible outliers (outperforming/underperforming countries) to make the values of all countries more comparable.

(b) Rescale all the variables to have mean value zero and standard deviation 1/3. This is done using a simple formula (5)

$$Z_i = \frac{Y_i - \bar{Y}_i}{\sigma_{Y_i}}, \quad i = 1, \ldots, 5 \tag{5}$$

where $\bar{Y}_i$ means the mean value and σ_{Y_i} – the standard deviation of variable Y_i.

(c) Shift all the variables by one. This is necessary due to the fact that the calculation of the Happier Planet Index will require division of some variables by other ones. Therefore, to ensure the feasibility of these simple mathematical operations, we need to have the variable values centered around one rather than zero.

3.2. Singular value decomposition

The next step is to apply singular value decomposition (SVD) in order to find the principal components for each of the distributions to avoid a high level of correlation between the indices. Those components will become the new variables in calculation of the Happier Index for the Planet.

According to the definition (Barnett, 1990), for any matrix $\mathbf{X}_{m\times n}$ with the rank r, there exist matrices $\mathbf{U}_{m\times m}$ and $\mathbf{V}_{n\times n}$, such that $\mathbf{X}=\mathbf{USV}$, where $\mathbf{S}$ is an $m \times n$ diagonal matrix with the singular values of $\mathbf{X}$ located on its diagonal (all the rest elements equal 0). At the same time, $\mathbf{U}$ is the matrix of singular vectors and $\mathbf{V}$ demonstrates the scores of how much each of the principal components represents (explains) the original variables.

After the principal components have been identified, their set is truncated by the corresponding singular values, possibly dropping the ones corresponding to very small singular values. The principal components retained are all re-normalized to have mean value 1 and standard deviation 1/3 to assure the values are not the exact original values, but rather the relative distribution shapes that carry out the key information for index calculation. The remaining principal components are assigned to positive and negative ones. Instead of the product, the geometric average of both sets is taken separately and the quotient of these two geometric averages defines the HIP value for each target country. Moreover, since SVD is applied to all variables, positive and negative simultaneously, it is ascertained that principal components in the denominator and nominator do not correlate.

The only two parameters in the process, namely the standard deviation 1/3 used in normalization, and the truncation level 1/100 applied to principal components, are set by statistical standards to these values so as to correspond to a sub-index cut-off at three-sigma and at a corresponding truncation level for the normalized normal distribution, so that both parameters de-noise the indices in the same level.

3.3. HIP – a Happier Index for the Planet?

As mentioned before, the calculation of the Happier Index for the Planet will use similar indicators as are used in HPI, since we acknowledge that the indicators (ecological footprint, well-being and life expectancy) well represent the state of sustainability in all three considered dimensions (NEF, 2016). However, they may need to be accompanied by one or two alternative variables, to complement the information. Thus, the set of indicators considered in this work are

- Well-being (WB)
- Life Expectancy (LE)
- Ecological Footpring (EF)
- Gross Domestic Product (GDP)
- Global Peace Indicator (GPI)

Fig. 1 presents histograms of the chosen indicators. The original histograms have been divided by the total number of countries in order to make them comparable with theoretical probability density functions (with area under each histogram being equal to 1).

In this approach, the singular value decomposition is performed on a matrix containing the normalized indicator column vectors. After the principal components are identified from our data set, HIP is calculated as presented in Eq. (6).

$$\mathrm{HIP} = \frac{\sqrt[k]{\prod_{i=1}^{k} P_i^{+}}}{\sqrt[l]{\prod_{j=1}^{l} P_j^{-}}} \tag{6}$$

where P_i^{+} are the principal components represent the indicators with positive effects and P_j^{-} are the principal components represent the indicators with negative effects. The choice of components of the P^{+} and P^{-} sets is based on the analysis of score matrix $\mathbf{V}$.

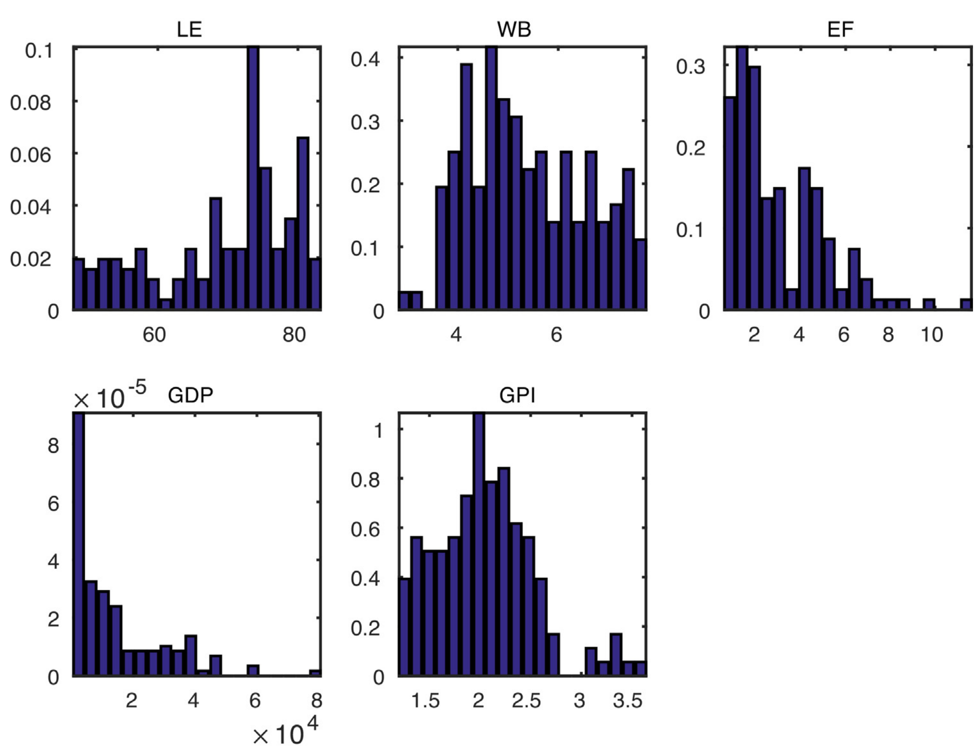

Fig. 1. Histograms of indicators used in calculation of Happier Index for the Planet, divided by the total of number of countries in order to represent probability density functions.

4. Results

In this section the results of data normalization, singular value decomposition and, finally, the calculation of the various combinations of the HIP are presented. The first step is data normalization for all the variables to be of the same scale and range of values. Fig. 2 shows the base indicators normalized with respect to the steps (a)–(c) given in Section 3.1. As can be seen from these histograms, the values of all the indicators now range between 0 and 2 with very similar spread. Moreover, even though the histograms remain quite different, they all could be interpolated by a Weibull distribution approximation, all with different parameters. In this case, the Weibull representation is more appropriate than normal distribution, for two reasons. Firstly, Weibull can fit a whole range of shapes from exponential-like to Gaussian bell-shaped histograms. Secondly, it has the non-negativity feature which cannot be guaranteed in data coming from a normal distribution.

Once the indicators have been normalized, they can now be subjected to SVD to reduce their mutual correlation and identify the real information each of them carries in the entire data set. Since the HIP will be studied in four different combinations, the SVD is performed four times on the following subsets of all the indicators:

For HIP_1: LE, WB, EF (using the same base indices as in the original HPI)
For HIP_2: LE, WB, EF, GDP
For HIP_3: LE, WB, EF, GPI
For HIP_4: LE, WB, EF, GDP, GPI

In this paper, the details of the results of the decomposition will be reported for only one, most interesting, combination of indices. However, for all the four possible combinations, a correlation of the obtained results with the original HPI is presented.

Let us consider the example matrix **V** for HIP combination using LE, WB, EF and GPI, that is V_{HIP_3}. The columns of the matrix determine the principal components, and the rows – the original variables in the stated order. To calculate HIP, in is necessary to know which variable represents the negative indicators and which the positive indicators.

$$V_{HIP_3} = \begin{bmatrix} -0.5096 & 0.3544 & -0.7244 & -0.2998 \\ -0.5081 & 0.4332 & 0.2847 & 0.6879 \\ -0.5235 & -0.0444 & 0.5973 & -0.6059 \\ 0.4561 & 0.8275 & 0.1933 & -0.2642 \end{bmatrix}$$

The values in matrix V_{HIP_3} are color-coded for easier interpretation, where green color indicates a positive effect and maroon color indicates a negative effect. In the first column, which represents the first principal component, the first two scores which represent LE and WB respectively, are negative. The components represent the negative effect of the originally positive indicator of that degree. At the same time, the score for the negative effect variable GPI has positive value, which emphasizes the negative effect of the first principal component. Analogously the third principal component can be seen to have a negative effect, and the fourth one is clearly positive. The second component provides the most challenging assessment. On the one hand, if we sum up the absolute values of the positive and the negative effects, we get a slight advantage on the negative side. However, since there are three out of four variables that have positive effect scores, we treat this component as a positive one.

Once the meaning of the components is identified, it is possible now to express the formula for HIP_3. If we denote all the principal components as P_i, $i = 1, \ldots, 4$, then $\{P_2, P_4\} \in P^+$ and $\{P_1, P_3\} \in P^-$, meaning also $P_1 = P_1^-$, $P_3 = P_2^-$, $P_2 = P_1^+$ and $P_4 = P_1^+$. Fig. 3 presents the original normalized indicators used in calculation of HIP_3 together with the normalized histograms of their respective

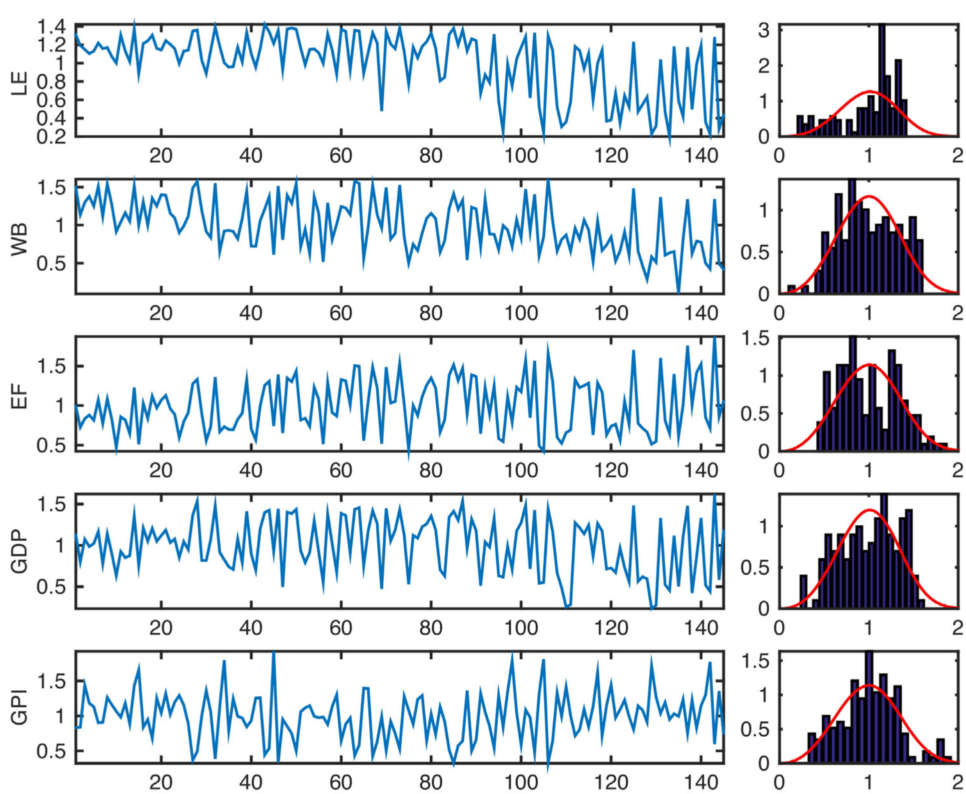

Fig. 2. Normalized indicators used in calculation of Happier Index for the Planet.

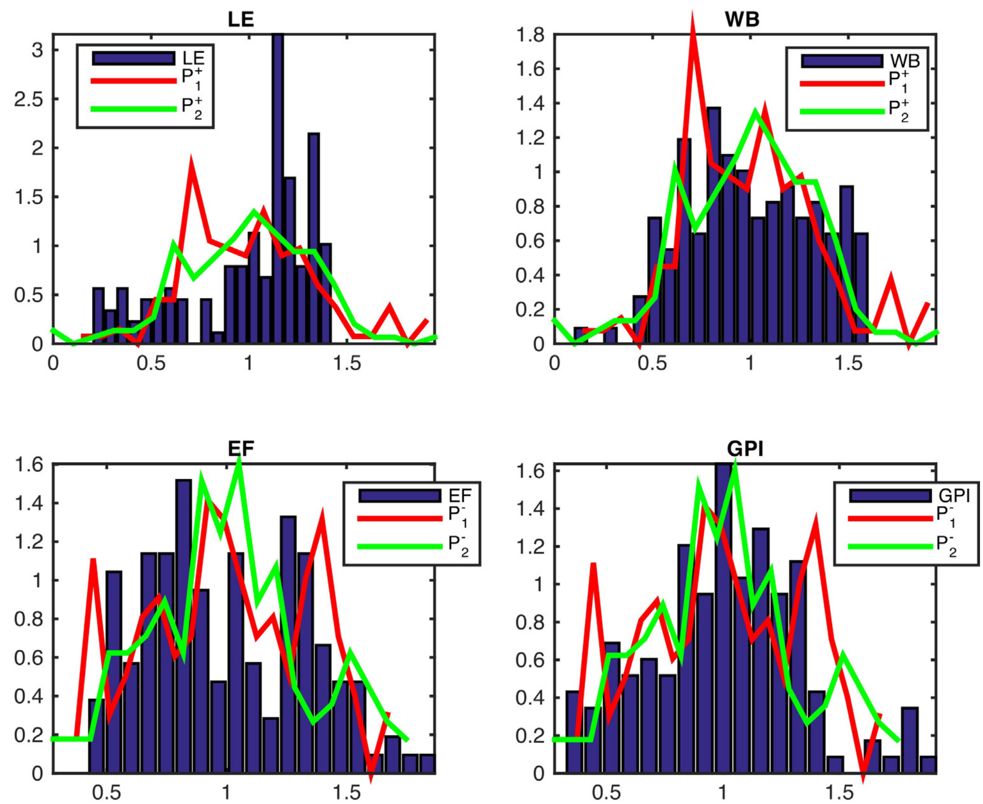

Fig. 3. Normalized indicators used in calculation of Happier Index for the Planet and the obtained positive (P^+) and negative (P^-) principal components.

positive and negative effect principal components. Finally, the Happier Index for the Planet is calculated for this case as presented in Eq. (7).

$$\mathrm{HIP}_3 = \frac{\sqrt{P_1^+ P_2^+}}{\sqrt{P_1^- P_2^-}} = \frac{\sqrt{P_2 P_4}}{\sqrt{P_1 P_3}} \tag{7}$$

Reciprocally to the case of HIP_3, we calculate HIP_1, HIP_2 and HIP_4 and compare the country rankings with the original Happy Planet Index. Since the scales of HPI and HIP are different, Spearman rank correlation (Spearman, 1904) should be used as the comparison tool. In the rank correlation test we verify $H_0: \rho = 0$ against $H_A: \rho \neq 0$, namely, we test that there is no significant correlation between the set of ranks against the alternative that the opinions are correlated to. The correlation coefficient ρ is given in Eq. (8).

$$\rho = 1 - \frac{6\sum_{i=1}^{n} d_i^2}{n(n^2-1)} \tag{8}$$

where d is the difference between the ranks of the respective sample observations and n is the sample size. The significance of the rest of the result is verified via a t-statistic as given in Eq. (9).

$$t = \rho\sqrt{\frac{n-2}{1-r^2}} \tag{9}$$

Table 1 presents the top-7 and bottom-3 ranked countries calculated using HIP_1 and HIP_2 when compared with the original Happy Planet Index. These two combinations do not account for the state of political stability (here a Global Peace Indicator). It can be seen that these versions of the Happier Index do not reproduce any of the top 25 countries ranked by the HPI, even though lower ranking classifications are fairly comparable. The overall rank correlation between HIP and HPI reaches 52% for the one without GDP included in the calculations, and just 40% for the one with GDP. Even though both these numbers indicate significant correlation between the ranks, we suspect that this set of indices is not yet fully representative, as it favors mainly rich, developed countries.

We argue that the political stability and militarization are very important in terms of overall sustainability. Thus HIP was extended by adding GPI and repeating the calculations both without and with GDP. The results are collected in Table 2. Now it can be seen that the rank correlation with the original HPI in both cases reaches about 90% with a slight favor toward excluding GDP. This is because GDP is initially highly correlated with Life Expectancy. It, therefore, repeats part of the information, and over-determines the model without adding any unique values to the result. Moreover, the degree of repetition of top- and bottom-ranked countries is a lot higher with respect to HPI, including the fact that the top country is the same in all of them.

Table 1
HIP results **without** Global Peace Indicator: HIP_1 and HIP_2 versus the original HPI ranking r.

r	**HPI**	r	**HIP_1/0.52**	r	**HIP_2/0.40**
1	Costa Rica	73	Australia	28	Norway
2	Vietnam	32	Switzerland	32	Switzerland
3	Colombia	43	Japan	63	Canada
4	El Salvador	85	Iceland	106	Denmark
5	Jamaica	63	Canada	64	Netherlands
6	Panama	50	Sweden	50	Sweden
7	Nicaragua	64	Netherlands	46	Austria
143	Qatar	145	Botswana	138	Niger
144	Chad	105	Afghanistan	145	Botswana
145	Botswana	96	Zambia	139	Mongolia

Table 2
HIP results **with** Global Peace Indicator: HIP_3 and HIP_4 versus the original HPI ranking *r*.

r	**HPI**	*r*	**HIP_3/0.91**	*r*	**HIP_4/0.89**
1	Costa Rica	1	Costa Rica	1	Costa Rica
2	Vietnam	2	Vietnam	28	Norway
3	Colombia	10	Bangladesh	3	Colombia
4	El Salvador	11	Cuba	5	Jamaica
5	Jamaica	28	Norway	31	Dominican Republic
6	Panama	32	Switzerland	15	Pakistan
7	Nicaragua	6	Panama	13	Indonesia
143	Qatar	145	Botswana	122	Angola
144	Chad	140	Bahrain	133	Sierra Leone
145	Botswana	134	Macedonia	145	Botswana

5. Conclusions

In this work we have considered an alternative approach to calculate the composite indices in which indicators with contrasting effects have been incorporated. As a case study, the Happy Planet Index was chosen, which represents a subjective measure of countries' sustainable well-being. In this work a similar data set of indices to those used for HPI calculations was used for HIP. Obtaining a new ranking system for countries' sustainability using a different mathematical approach has been the main outcome of this work. However, by including a Global Peace Index as a measure of the political stability to the data set, it was possible to achieve a strong correlation with the original HPI ranking. Whereas, adding GDP as a measure of the economical well-being does not contribute much to the final result, because of its high correlation with another indicator – life expectancy.

Based on the results, we argue that the proposed Happier Index for the Planet calculations are more robust than the ones for Happy Planet Index. First of all, it allows the freedom to include any set of explanatory indicators with respect to which aspects of sustainability are most relevant in a particular context. Moreover, the mathematical approach is universal for any set of variables. Therefore, there is no need to re-tune any constants through hand-picked educated guesses, no matter how many sub-indices are required to be considered.

It is important to emphasize that the new index combination methodology proposed here is not an absolute measure of sustainability. The rankings it produces still depend completely on the validity and relevance of the component indices chosen. But because the process of index combination is no longer subjective, we hope that the relative rankings calculated with this method are consistent over time, and a time series of such rankings can be used for establishing reliable trends in sustainability.

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