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Original research article

When renewable energy, empowerment, and entrepreneurship connect: Measuring energy policy effectiveness in 230 countries☆

Andrea Gatto[a,b,c,*], Carlo Drago[d,e]

[a] Wenzhou-Kean University, Wenzhou, Zhejiang Province, 325060, China
[b] Natural Resources Institute, Greenwich University, Central Avenue, Chatham Maritime, ME4 4TB, UK
[c] Centre for Studies on Europe, Azerbaijan State University of Economics (UNEC), Azerbaijan
[d] University of Rome N. Cusano, Via Don Carlo Gnocchi 3, 00166 Rome, Italy
[e] NCI University in London, Northern & Shell Tower, 4 Selsdon Way, Isle of Dogs, London E14 9GL, United Kingdom

A R T I C L E I N F O

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A B S T R A C T

Renewable energy is fundamental for sustainable development challenges and social sciences advances. The development agenda prescribes to pursue renewable energy policies as a pillar of energy security and sustainable development in both developed and developing countries. A major policy implication for renewable energy derives from entrepreneurship boosting, targeting women, rural, youth, and vulnerable categories, where microfinance and resilience policies have found a wide consensus. The present work exploits a statistical approach to measure energy policy effectiveness, making use of the brand-new IBRD-World Bank release *SDG7 Tracking: The Energy Progress Report*. A composite indicator of renewable energy policy is built, exploring different perspectives. The determinants of energy policy effectiveness are analyzed. A statistical comparison of the different results is relevant to ensure robustness implications. We discover that countries endowed with natural resources, such as Brazil, perform better in renewable energy consumption. We confirm that green countries, e.g. the Nordic region, maintain a high renewable energy consumption attitude. We also validate that oil exporters – and notably most of the Arab countries –, are usually less prone to use renewable energy. These implications are foremost for the vulnerable empowerment and societal challenges required to foster the energy transition.

1. Introduction: Renewable energy in Agenda 2030 and social sciences scholarship

The United Nations' Sustainable Development Goal (SDG) 7 is dedicated to reaching energy security, primarily affordable and clean energy parameters, by 2030 [1,2]. SDG7 aims to "*endure access to affordable, reliable, sustainable and modern energy for all*". It stresses universal access to electricity (7.1.1), and clean fuels and technologies for cooking (7.1.2). Target 7.2 focuses on Renewable Energy, with the scope to "*increase substantially the share of renewable energy in the global energy mix*". Moreover, target 7.3 is based on Energy Efficiency, with the target to "*double the global rate of improvement in energy efficiency*". Target 7.A has the goal to foster international cooperation for access to clean energy research and technology. At the same time, 7.B is devoted to building infrastructure and technology for modern and sustainable energy services for all by 2030.

Amongst the energy policy goals, one turns pivotal in facilitating entrepreneurship and sustainable development, fostering business implementation and the vulnerable empowerment: *renewable energy*. It must be considered that the use of renewable energy worldwide has

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* Corresponding author at: Wenzhou-Kean University, Wenzhou, Zhejiang Province, 325060, China.
E-mail addresses: a.gatto@greenwich.ac.uk (A. Gatto), carlo.drago@unicusano.it (C. Drago).

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been increasing dramatically in the consumption tendency: its consumption arrived at 17.5% in 2015 when in fact it consisted of some 16.7% in 2010. The 17.5% share was made up of 9.6% of modern renewable energy – including solar and wind –, and only 7.9% of traditional biomass [2].

Another stylized fact to be pointed out comes from international policy trends: world growth has led many countries to change their consumption attitude, hence their energy consumption and energy mixes. Nevertheless, developing countries did not always manage to couple high growth rates with consistent renewable energy rates [2]. However, many of these countries converted their industrial models towards more sustainable, ecological models – the case of the circular economy in China is instructive in this outlook [3].

Following these indications, a need for composite indicators arises with the scope to describe, define, and gauge energy facts. The World Bank's Energy Sector Management Assistance Program (ESMAP) [4] considers composite indicators to be a valid methodology to assess the national policy, where the regulatory framework turns foremost [5,6]. The final goal is to strive to meet sustainable energy targets. Energy security and renewable energy are multidimensional concepts worthy of being analyzed and shaped by composite indicators.

About our study, the novelty lies not only in the application results but also in the methodology used. Choosing between the assumption of equal weightings on the composite indicator could be a reductive choice. In fact, in most of the cases, it is necessary to include a sensitivity analysis to validate the composite indicator [7,8]. In this regard, our outlook diverges and allows constructing a composite indicator in which it is possible to simulate different assumptions.

Then, in order to facilitate the scenario analysis and policy consideration, we are able to measure a variety of values for the indicator (upper bound, lower bound, some relevant percentiles that may be useful in interpreting the results). In particular, in these types of indicators, the interesting outcome is a single value (which is the expected value of the final interval-based composite indicator) and values as the lower and the upper bound. These values allow for scenario analyses [9,10,11,12].

To improve the robustness of the chosen analysis and the perspective, we have built an interval-based composite indicator and simulated different scenarios for the indicators we have computed.

At this point, we calculate the different ranks as an efficient way to obtain robust policy assessments. Simultaneously, the different upper and lower bounds as ranks allow for an adequate scenario and counterfactuals analysis [13]. For these reasons, we might assert that this work attempts to improve past indicators on the field. The approach allows us to examine the trend and evaluate simple, informal predictions about the capacity to attract initiatives related to renewable energies.

This work can be connected to the existing literature on energy and social sciences. The existing scholarship [14,15,16] stresses the integration of the social sciences within energy studies and its importance. In this respect, the authors propose a discussion on both the relevance of renewable energy technology solutions and the social dynamics of their acceptance [17]. This process can fully determine the technology diffusion (see also [16]). For instance, Noblet et al. [18] investigated the citizens' choices on an energy policy proposal. The analysis shows that citizen's support can be detected by the type of technology encompassed (i.e., renewable energies). However, this support does not necessarily lead to renewable energy investments and energy efficiency. Social and personal characteristics have a relevant impact on the support of energy technologies, including investment choices (see [19]).

In this section, we have dealt with the problem of renewable energy policy and energy security, framing the issue within sustainable development, the Agenda 2030 and social sciences research; Section 2 presents a critical review on these topics, motivating the adoption of composite indicators. In Section 3, the paper illustrates the utilization of the data employed and the variables rationale – 3.a. Hence, the methodology used to build the renewable energy indicator is illustrated – 3.b. Afterwards, Section 4 presents and comments on the outputs acquired through the chosen methodology and shows global rankings. Thus, in Section 5, we draw some decisive policy implications on renewable energy for entrepreneurship boosting; this strategy results in being valuable for women, rural people, youth, and the vulnerable categories. We finally wrap-up the work with conclusions in Section 6. The work is completed by annexes tables and figures sketching the global results achieved and additional analyses in the appendixes.

2. A critical review of renewable energy and sustainability composite indicators

Renewable energy is a hot research topic. The scientific interest of renewable energy is associated with sustainability and the environment in Romo-Fernández et al. [20], attributing relevance to the interdependent dimensions examined. Manzano-Agugliaro et al. [21] scrutinize global progress in renewable energy scientific production. Rizzi et al. [22] reviewed renewable energy within the scientific debate, examined primary trends and perspectives, and discussed newsworthy resulting management implications. Lund [23] emphasized the nexus amongst renewable energy and sustainable development. The research detects a lead role of renewables in shaping strategies for sustainable development, and more specifically, energy savings, energy efficiency and energy transition [24]. Policy recommendations often foresee the adoption of renewables, coupled with energy efficiency grafting, to reach economic, social and environmental goals [25].

In some countries, a sustainable and renewable energy mandate has been designed as an essential momentum to yield the optimization of energy mixes aiming at reducing carbon emissions [26]. In this respect, Sadik-Zada and Loewenstein [27] explore the relationship between income and the atmosphere in oil-producing countries and examine the air pollution drivers in these environments (see also Sadik - Zada [117]).

Policy design is focal for fostering renewable energy adoption. The use of renewable energy improves an economy's technical efficiency [28]. Kilinc-Ata [29] finds that the renewable energy policies are effective tools to enhance the renewable source capacity; this way, renewables can facilitate meeting energy, environmental and economic policy objectives, challenging policy priorities like fossil fuels depletion and the intensification of greenhouse gases [30].

Green policies are tight with renewables promotion. Regulatory policies, fiscal incentives and public investments are often referred to in order to promote investments in renewable sources; notwithstanding, the validity of this statement is not guaranteed, as the effectiveness of such policies depends on one nation's development phase [31]. This evidence suggests prominent implications for upcoming research on the environmental Kuznets curve hypothesis and the economic-ecological decoupling [32]. On the other hand, green policies demonstrate their efficiency in enhancing renewable source use [33].

Renewable energy utilization is a measure to tackle the challenges of climate change and promote environmental pollution mitigation; these have become critical concerns, particularly in large countries displaying high growth and demographic increase rates [34]. Nowadays, the situation is a conundrum in China, where the deployment of renewable energy has become an urgent quest [35]. Effective law and regulation are shown to be impactful in implementing renewable power schemes [36], as well as balancing renewable energy policies with renewable energy industrial policies [37]. Renewable energy must also be evaluated with regard to its environmental benefits compared to detrimental alternative sources [38].

Several valuable indexes on renewable and sustainable energy have been built formerly and revealed themselves focal in inspiring our rationale. Liu [39] drafts the framework for a comprehensive sustainability indicator in renewable energy, considered the best option for measuring the complexity of energy systems.

The renewable energy-sustainability nexus is further exploited using a grey regression [40]. This feature is confirmed by the fact that energy systems are likely to be subject to crises and shocks [41,42], displaying their vulnerability and needs for shaping resilience policies [43]. A further contribution is provided by García-Álvarez et al. [44]; hereby, a composite index is furnished – i.e. the Synthetic Index of Energy Sustainable Development for EU-15 recalling the economic, societal and environmental spheres. Tsai [45] reputes energy as a major driver of one country's sustainable development; therefore, in his index, energy supply, energy consumption, carbon dioxide emissions and renewable energy production are contemplated as variables.

The capacity of composite indicators to capture multidimensional concepts and yield decisionmaking solutions is stressed by La Rovere et al. [46], where sustainability is valued in the electricity sector. The Sustainable Energy Development Index proposes to catch both intra- and inter-generational necessities, following sustainability requirements; the index attributes a central role to the single dimensions of energy sustainability, pursuing the scope of emphasizing each variable [47].

Renewable energy systems are also reputed to promote economic growth and benefit the whole economic system; in order to examine these dynamics, Dalton & Lewis [48] launched an index to calculate the job creation created by renewable energy technologies. The social dimension has important attributes relative to energy sector assessment; to this end, Carrera & Mack [49] build a social indicator providing a measure of energy technology, based on energy security, political stability, social risks and quality of life. The environmental efficiency of renewable energy is caught by Woo et al. [50], who compute a Malmquist index analysis for OECD countries.

Revisiting the Renewable Energy Country Attractiveness Index, Bhattacharya et al. [51] estimate the national renewable energy consumption trends around the world. The international development advances in energy metrics are outlined by Vera & Langlois [52], where a set of indicators is examined. Arvidsson et al. [53] apply energy use measures to biofuels life cycle assessment; the quantification of these phenomena produces indicators on fossil fuels, secondary energy, cumulative energy demand, net energy balance and total extracted energy. Onat & Bayar [54] construct an index to gauge the response of electric systems in terms of accountability and continuity of energy transmission. Santoyo-Castelazo & Azapagic [55] provide a decision-support framework to embed the social, environmental and economic factors, making use of a number of techniques based on life cycle assessment.

Besides the indexes reviewed, other metrics investigated diverse phenomena, attempting to calculate different renewable and sustainable energy dynamics. Despite this fact, this work's authors are not aware of further indexes on renewable energy based on the interval-data criterion. Our conclusion on the past literature is that these publications tend to use classical methods to construct composite indicators, which are typically based on linear/non-robust choices. These approaches can be subjective or based on the necessity to validate the assumptions employed. However, even in this case, all procedures need using sensitivity analyses to corroborate their methodological decisions – especially when these are fragile [7]. An approach based on interval data can improve the measurement of the phenomenon per se, endogenizing the sensitivity analysis. This fact is allowed by the implementation of an array of different choices on the construction of the indicator.

Furthermore, none of the examined works was directly addressed to explore such social and energy dynamics using these types of approach and methodology – referring to the analysis of entrepreneurship boosting or the contemplation of the vulnerable empowerment. These topics are crucial, yielding significant research and policymaking advances for the social sciences. Yet different works which analyze these relationships through a different lens exist [56,57].

3. Research methods

3.a. Data

Composite indicators are increasingly determinant instruments for policy analysis purposes. However, they need attention to their application: albeit being highly influential on the message they convey, synthetic indicators raise potential critiques due to some choices' inherent subjectivity. Composite indicators can be usefully considered to aggregate different single indicators and obtain a unique measure; this measure can be usefully compared between several statistical units. In the recent past, many composite indicators have been developed with the purpose of solving pressing issues facing social phenomena [7,58,8]. A significant strength of composite indicators is the possibility of aggregating and summarizing complex measures and providing the general picture about a specific phenomenon [59]. In this framework, the facility to communicate synthetic indicators' outputs and a specific ranking to the public opinion is intuitively a lead asset.

The paper at hand constructs a composite indicator of renewable energy. In this respect, the indicators considered are four (Table 1):

1. Renewable Energy (renen 2015);
2. Liquid Biofuels (liquid 2015);
3. Wind (wind 2015);
4. Solar (solar 2015).

The four variables were considered as the share in total final energy consumption, computed in percentage. These variables were chosen for different reasons. The indicators are presented in Table 2. Above all, those selected are the only ones that are consistent within the dataset in terms of completeness; besides this, all of them covered the most recent issue – i.e. 2015. In this work, we use the brand-new IBRD-WB release SDG7 Tracking: The Energy Progress Report [2].

There is specified: "Equally important is to strengthen statistical capacity to produce accurate energy balances, particularly in the developing countries, where many challenges remain in capturing, for instance, the traditional uses of biomass. Furthermore, there is still relatively little information on the energy efficiency of major consuming sectors outside of the major economies that is critical to inform policy interventions." (Page 10). Considering the dataset characteristics, we have opted to use the available data of 2015 to construct the best composite indicator possible.

Given the completeness, affordability, and quality of the data, the dataset for 2015 is the most reasonable option. This choice also makes it possible to examine important economic trends for a longer period of time, resulting in more accurate speculation.

The classification criterion adopted was the following: we kept three of the major renewable energy sources present in the scrutinized dataset – liquid biofuels, wind energy and solar energy. Considering the multitude of renewable energies in the resource spectrum, we decided to embed the relevance of further renewables sources. These were, however, per se included in the dataset but could not meet our requirements.

Therefore, we chose as the fourth pillar of our index "renewable energy", which includes all the other energy sources. This data choice

Table 1
Renewable Energy Index variables.

Renewable Energy Index	A – Renewable – renen B – Liquid biofuels – liq C – Wind – win D – Solar – sol

Table 2
Indicator used on the composite indicator construction (Source: WB [6]).

Indicator	Year	Description
Renewable Energy	2015	Renewable energy: share in total final energy consumption (%)
Liquid Biofuels	2015	Liquid biofuels: share in total final energy consumption (%)
Wind	2015	Wind: share in total final energy consumption (%)
Solar	2015	Solar: Share in total final energy consumption (%)

allowed us to evaluate a much wider spectrum.

Renen is an indicator which is expressed as "share in total final energy consumption (%)" (see WB's RISE definition). The indicator is important by itself, and it is accounted as a single indicator, which shows a modest correlation with the other components of the composite indicator. It is relevant to note that our indicator is related to measuring the attitude to use renewable energy. The indicator "renen" is comprehensive of all the different renewable energy types (including geothermal and solid biofuels). For this reason, all the different types of renewable energy are calculated in our composite indicator. However, we focus our attention on some important components (liquid biofuels, wind, and solar as share in total final energy consumption) that we assess more suitable for the indicator (e.g. data quality). We select these indicators to emphasize their capacity to be used in combination with diverse renewable energy sources (see [60]).

Another point that led us to this rationale was the need to corroborate the three variables: considering the breadth of the renewables universe, adding an all-encompassing variable should provide our index with increased robustness, both in statistics, economics and energy policy terms [61]. A further motivation for contemplating the overall renewable energy variable lies in the fact that it is a way to preserve much information, considering all the renewables. The correlation analysis run displays scarce correlation values, confirming the goodness-of-fit of choice. This allows to proceed, indicating a considerable weight of the other renewable energy sources.

In terms of data, three data sources were explored:

1. Energy Balances from UN Statistics Division [62];
2. World Energy Balances from IEA [63];
3. World Bank Analysis, based on the World Energy Statistics and Balances, from the IEA [63]; Energy Balances, UN Statistics Division [62].

The data units analyzed consist of 237 countries, territories and regions worldwide, including OECD and non-OECD countries. The rationale of working on such a large dataset is to give a whole picture of the different attitudes on renewable energy consumptions.

The variables are chosen to obtain a composite indicator of renewable energy. Data consist of a cross-section dataset of 2015. For this scope, the designed composite indicator measures renewable energy and interprets each of the selected variables as the chosen composite indicator's components.

This way, it is possible to evaluate each indicator as a consistent part of the final composite indicator constructed.

3.b. Methodology

This work proposes a new statistical approach to the measurement of renewable energy. We build a cross-section dataset for 2015. We compute a global composite indicator on renewable energy – i.e. the Renewable Energy Index –, regarding renewable energy, solar energy, wind energy, and liquid biofuels. The phases of standardization, linear weighting, and aggregation are examined. We eventually analyze the outputs through a robustness check and expose the rankings and results. For these reasons, the work contemplates an interval-data analysis.

From the simulation, we take the min–max interval, instead of mean or median values. As a result, all the potential combinations of weights are simulated through a random number generator. Subsequently, an algorithm generating weights assortments is developed, allowing for a re-calculation of the composite indicator. The mean of the obtained values is computed, and the sorting ranking is compared to a sensitivity analysis. Some differences result, some regarding gaps between indicators. We also observe a low correlation between the variables: the choices on the variables' construction and sub-pillars combination influence the outputs more than the aggregation method itself.

The new index is of considerable use for practical policy implications, mostly in innovative business stimulation and job opportunities targeted at women, rural people, youth, and vulnerable categories. The methodology reveals an exploratory aim as it provides higher robustness concerning linear methods. The measures can be used for resilience intervention – take as a notable example microcredit and microfinance policies to fuel women entrepreneurship in developing countries, especially rural areas, and in geographical zones affected by high unemployment and poverty.

The proposed approach improves past techniques because it enables a robust assessment of the set of outputs sorting from the composite indicators computed, taking into account the quantiles. The use of the quantiles allows to better identifying extreme results and scenarios. The transformation and comparison using the different ranks of the composite indicator simulated allow robust analysis of the results.

Some methodological remarks arise from the outputs: the interpretation of the variables in terms of polarity toward renewable energy was considered an important explanatory step; it was attributed a positive sign for greener countries, whilst countries whose consumption was less prone to renewables were given a negative sign. Another important step is the examination of missing values: we treated missing data through case deletion. Hence, we only dropped 7 over 237 countries, which was an excellent fit for parsimony.

As for the normalization technique, we opted for standardization of the four variables. Therefore, we obtained four pillars and one index. To this end, we attributed an equal weighting and a linear aggregation. By doing this, we obtained the Renewable Energy Index and its international ranking.

When it comes to data standardization, we have been following Joint Research Centre-European Commission's recommendations [7]. Thus, we have got:

$$I^t_{qc} = \frac{x^t_{qc} - x^t_{qc=\bar{c}}}{\sigma^t_{qc=\bar{c}}}$$

where x^t_{qc} is the single indicator for the variable q at time t, $x^t_{qc=\bar{c}}$ is the average between the different indicators for each variable considered and finally $\sigma^t_{qc=\bar{c}}$ is the standard deviation for the single indicator.

The criterion we used was that no variable leads – hence no variable should get a greater weight. A further remark to be made concerns the variables: the correlation matrix shows low correlation and no multicollinearity among "Renen" and the other variables (Table 3). This result displays our choice's goodness, which is eventually confirmed by the sensitivity analysis we ran.

It must, however, be said that diverse variables correlations reveal diverse national policies and attitudes.

We perform a complete statistical analysis, assessing both univariate and multivariate analyses. The reason for this step is to explore the indicators as single components of the composite indicator [13,14]. More specifically, we examine eventual problems lying in data quality, which may potentially affect the construction of the composite indicator. At the same time, the multivariate analysis is conducted on the different indicators in order to evaluate the existence of different correlations between the different indicators. This step can help in identifying some overlapping contributions to single dimensions on the final definition of the composite indicator. We observe that the different single indicators do not show any strong correlation. Thus, we can consider the different single indicators as a part of the entire composite indicator (see [64]).

The performed multivariate analysis, also based on other statistical visual methods, shows no relevant associations between the different components of the composite indicator. The composite indicator is measured, taking into account all the different indicators in a single

Table 3
Correlation matrix between the variables.

	Renen	Liq	Win	Sol
Renen	1.00	0.26	−0.09	−0.05
Liq	0.26	1.00	−0.02	0.09
Win	−0.09	−0.02	1.00	0.02
Sol	−0.05	0.09	0.02	1.00

composite index.

The different indicators are standardized for obtaining the same scale for different indicators. The final components are aggregated on the final composite indicator.

Two reasons drove our methodological decision regarding the use of the equal-weight composite indicator:

1) The choice to opt for an equal-weight composite indicator lies in the fact that the pillars were conceived as sharing the same economic relevance.
2) An indicator based on four equal components is simpler to be communicated and explained, especially when it concerns policymaking.

Our choice is corroborated by two facts:

1) An approach that randomizes the different weights is exploited to validate the latter; the two techniques do not lead to substantially different outputs.
2) The sensitivity analysis shows that the results are robust and do not change when considering different specifications.

One relevant problem in the construction of the composite indicators is the weights to be applied to every component of the different indicators – each of them will contribute to the final composite index. A traditional way is to use an equal-weight approach. The weights' choice can also be subjective, so the results need to be analyzed on their robustness using sensitivity analyses. We fill this gap by proposing, together with this indicator, a further synthetic index based on interval data. A table comparing the different approaches is proposed in Appendix V (Table 11).

The equal-weights approach is assessed by considering various weightings; by doing this, different results are obtained. The weighting is a prior problem, to be handled carefully in the construction of composite indicators (see [65,66]). A different rationale is followed by Drago [9,67] and Gatto & Drago [10]. This perspective exploits interval data to face the uncertainty of the composite indicators (see [68]). We have considered as the general framework and statistical approach, those related to intervals as statistical data described in [69,70]. The intervals contain and represent all the different composite indicators acquired by randomizing the various weights aggregated on one unique data. Hence, we obtain the composite indicator and the rank considering the different equally-weighted indicators, to get a baseline rank for the composite indicator.

Finally, we calculate the sensitivity analysis in which we compute 10,000 different random weights of the composite indicator. The purpose of the sensitivity analysis is to provide a measure of any changes due to methodological assumptions and choices (see [59]). In the sensitivity analysis, we explicitly assess different weightings on the construction of the composite indicator. The procedure to simulate the candidates proceeds as follows (see also Table 12 and Fig. 4 in Appendix VI):

1) We simulate for each component a different "candidate" weight from 0 to 1. The single weights are generated by a uniform distribution with minimum 0 and maximum 1.
2) The different candidate weights are all summed.
3) Thus, the final weight for the component is obtained by dividing the single simulated weight for the total.
4) By considering the procedure, we obtain a different weight related to the different components for each simulation.

For each weighting obtained on the 10,000 different simulations, we are able to calculate the various composite indicators. Simultaneously, the final rank in each simulation is computed.

The different ranks are collected and finally averaged in order to obtain a final score for each country examined. More specifically, the 10,000 simulations are useful to analyze the sensitivity of the variety of outputs of the composite indicator by selecting different weightings. The exercise is eventually used to assess and compare the outputs sorting from the two different techniques.

Diverse ratios confirm our choice to adopt the equal-weights scenario. Our interpretation is that none of the variables leads or lags; this figure is eventually confirmed by the sorting correlations. The results can be corroborated by randomizing the weights: we can contemplate equal weights first, therefore considering different composite indicator specifications. The validation performed is based on various statistical analyses that confirm each other.

For instance, the correlation analysis and the scatter-plots diagram do not show the necessity to weigh differently the components of the composite indicator. This is why we have analyzed the correlation matrix to evaluate the correlations between the indicators, and no specific evidence of strong correlation was found (the maxima correlation was 0.25).

We have assessed the interval composite indicators based on the ranks and the composite indicators computed as in [9,10,67]. The sketched uncertainty analysis confirms that it is worth proceeding with the equal-weights hypothesis since the index is statistically robust. The sensitivity analysis is useful to validate the robustness of the findings obtained using the composite indicator based on all equal weights. When the different ranks on the sensitivity analysis tend to diverge from the ranking obtained with the equal-weights scenario, the meaning is that there is a specific good score for some indicators. In contrast, for other indicators, there is no similar good performance.

4. Results and ranking

The findings obtained from the equal-weights-based composite indicator show interesting outcomes. The country ranking first is Liechtenstein. The Nordic countries generally perform well: Norway is third on the ranking on equal weights, and Denmark ranks fourth, whereas Iceland is placed fifth at the final ranking out of 230 countries (somewhat similar to the analysis based on 10,000 simulations and different weights).

Eventually, we show Liechtenstein and Niue's interesting performances, which register outstanding results internationally in terms of the unique interval-based composite indicator. These countries perform particularly well for the solar energy indicator. In this specific regard, the key to Liechtenstein's final outcome is to be greatly efficient in terms of renewable and solar energy. These results are shown in Fig. 1, which shows the exceptional solar energy performance of these two countries.

Liechtenstein and Niue's cases are fairly interesting and allow to make full use of the proposed perspective. Niue performs truly well with equal weighting having obtained second place in the ranking, considering that the range indicator reaches eighth place. The point is that, commonly, equal-weight composite indicators can hide certain components in which the statistical unit performs badly (in the case of Niue, renewable energy). In this respect, the use of interval-based composite indicators seems to affirm conscious attention towards the different performances that can be achieved by examining the underlying indicators. Therefore, these indicators improve the performance of the equal weight related to the composite indicators.

The outcomes also show useful policy implications: when the difference between the result of the equally weighted composite indicator and the interval-based composite indicator is higher. It is possible to improve the country's global result by studying its weakness. Those will appear analyzing the lower bound of the interval-based indicator scenarios and results. Exploring the results, we are able to identify the single component determining poor results. Therefore, poor performance can eventually be changed in real economic terms by the policymaker (see [67]).

Another possible way is to identify weaknesses when considering and comparing the actual situation with the best international practices (this is the case for Liechtenstein). There is, indeed, a relevant space for economic intervention where the difference is higher. In this sense, the analysis of interval data is also peculiar for determining scenarios in economic policy.

Uruguay and Costa Rica exhibit significant results. Uruguay ranks fifth, with Costa Rica reaching the 10th place. Uruguay also has a higher possibility of improving its position – the lower bound reaches the third place. Brazil shows a very good performance on the final composite indicator ranking, indicating a striking outcome that allows to use it as a benchmark for this research. The economic and environmental intuition suggests motivating the score in light of the broad and rich natural resource embedment of Brazil and the good position obtained for every single indicator. The result seems to be interesting and widespread in other Latin and Central American countries (Paraguay and Panama, for example). As a consequence, those countries have the potential to adopt relevant strategies to boost entrepreneurship on the basis of the good results achieved in the indicator.

Remarkable is the position obtained by Portugal, coming in eighth on the final calculation (equal-weights-based) and ninth when considering the average rank between the different simulations. This shows that Portugal performs worse on a single different indicator rather than on the equal-weights-based scoring. Spain obtains good results where its position on the equal weights scenario is the eleventh, and the score on the average rank is the fourteenth. In this respect, the case of Portugal is instructive. Following UNDP [71] the 18 march 2019 we can see that Portugal on a UNDP project on Renewable Energies was chosen as the host of the initiative. UNDP [71] says that "Portugal was chosen as host for the kick-off event due to the country's international reputation as a renewable energy leader" (see also [72]). Similarly, Tajikistan (such as Croatia, Georgia and Somalia) is part of the group of the countries of the project ("Solar Mayors Platform"). So the results of our indicator adequately show the trend. Spain obtains good results where its position on the equal weights scenario is the eleventh, and the score on the average rank is the fourteenth.

Austria displays a good performance: it results in seventeenth out of 230 in the equal-weights scenario and reaches the twelfth position on the sensitivity analysis average rank. The dispersion scatterplot matrix below confirms that countries performing in one indicator do not necessarily exhibit good scores in another indicator. Zambia performs particularly well and is followed by other countries/territories: Mozambique, Saint Helena and French Guiana. The outputs show that these countries can envisage embarking renewable energies transition pathways to foster entrepreneurship and sustained economic growth.

We can also analyze the fragility of the various energy systems. In particular, we are concerned with the concept of vulnerability and resilience: countries with lower maxima in their ranks are naturally more stable than other countries. We are therefore considering some unexpected cases, such as Portugal, Tajikistan and Zambia. There are two lower fragility patterns in Portugal and Zambia (the upper bound of the ranks), where Tajikistan has significant potential to improve (the lower bound of the ranks). Our outlook makes it possible to detect these patterns (see [73]).

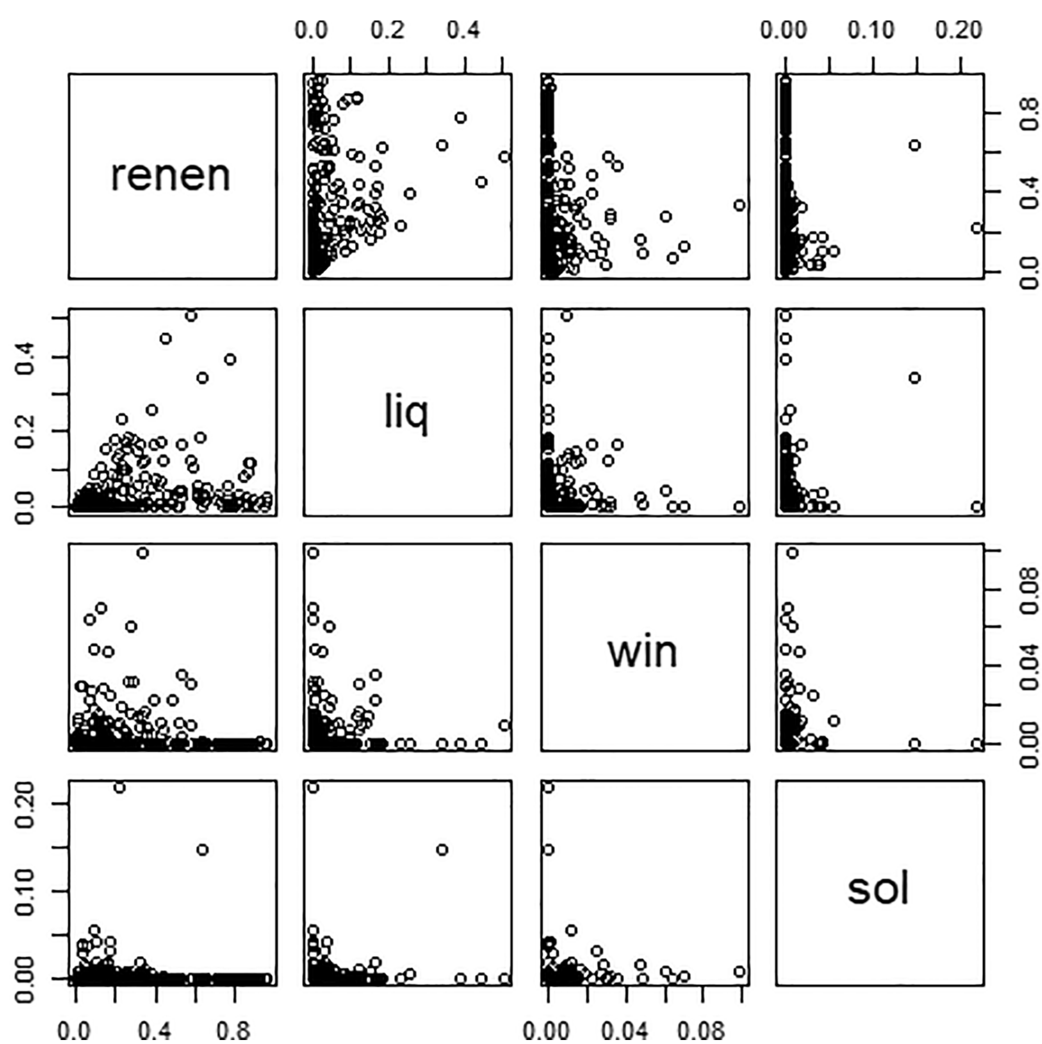

Fig. 1. Scatterplot matrix of the indicators.

The following tables sketch the top and bottom 10 countries for both the methodologies run (equal weights and interval-data estimation). Analyzing the results, one can observe that some countries perform similarly, while others rank dramatically differently (see Tables 4–7). The appendixes I and II present the complete ranks emerging from the two different techniques (Table 8, 9 and Fig. 5).

Table 4
Top 10, Equal weights ranking.

Country	comp_ind	Rank
Liechtenstein	3.17	1
Niue	2.56	2
Norway	1.91	3
Denmark	1.84	4
Iceland	1.50	5
Tajikistan	1.41	6
Sweden	1.22	7
Portugal	1.18	8
Uruguay	1.04	9
Saint Helena	1.03	10

Table 5
Bottom 10, Equal weights ranking.

Country	comp_ind	Rank
Antigua and Barbuda	−0.55	212
Bahrain	−0.55	212
Brunei Darussalam	−0.55	212
Cook Islands	−0.55	212
Gibraltar	−0.55	212
Guam	−0.55	212
Kuwait	−0.55	212
Montserrat	−0.55	212
Northern Mariana Islands	−0.55	212
Oman	−0.55	212
Palau	−0.55	212
Qatar	−0.55	212
Saudi Arabia	−0.55	212
Saint Barthelemy	−0.55	212
St. Martin (French part)	−0.55	212
Turkmenistan	−0.55	212
Tuvalu	−0.55	212
Wallis and Futuna Islands	−0.55	212
Western Sahara	−0.55	212

Table 6
Top 10, interval-data ranking.

Country	Mi	q25	Me	q75	ma
Liechtenstein	1	1	2.37	2	65
Norway	1	2	6.49	6	91
Sweden	2	6	8.95	9	60
Iceland	1	4	9.77	11	109
Uruguay	3	9	11.92	13	57
Denmark	1	2	12.59	8	138
Niue	1	2	14.57	8	171
Tajikistan	2	4	15.89	15	139
Portugal	2	5	16.05	17	94
Costa Rica	8	12	18.54	18	101

Where *ma* is maximum, *mi* is the minimum, *q25* the 25th percentile, *me* the median, and *q75* the 75th percentile.

Table 7
Bottom 10, interval-data ranking.

Country	Mi	q25	Me	q75	ma
Antigua and Barbuda	212	212	212	212	212
Bahrain	212	212	212	212	212
Brunei Darussalam	212	212	212	212	212
Cook Islands	212	212	212	212	212
Gibraltar	212	212	212	212	212
Guam	212	212	212	212	212
Kuwait	212	212	212	212	212
Montserrat	212	212	212	212	212
Northern Mariana Islands	212	212	212	212	212
Oman	212	212	212	212	212
Palau	212	212	212	212	212
Qatar	212	212	212	212	212
Saudi Arabia	212	212	212	212	212
Saint Barthelemy	212	212	212	212	212
St. Martin (French part)	212	212	212	212	212
Turkmenistan	212	212	212	212	212
Tuvalu	212	212	212	212	212
Wallis and Futuna Islands	212	212	212	212	212
Western Sahara	212	212	212	212	212

5. Policy implications: Renewable energy for entrepreneurship boosting and vulnerable empowerment

Entrepreneurship, renewable energy, sustainability, and development are strictly intertwined and relate to the vulnerable empowerment. Production and consumption relate to entrepreneurship and sustainable development, constituting determining factors [74,119,120]. In this regard, sustainable energy and renewable sources are detected as main drivers to lead the business towards sustainable habits [75]. Renewable energy is a leading industry when it comes to creating sustainable technology and competitive innovation models [76]. To fulfill the sustainability mandate, nowadays, firms are called upon to couple with cleaner technologies incentives with ecological job formation, primarily when applied to energy and resources [77].

Renewable energy consumption has a prime impact on economic growth [78]. Increasing renewable energy in the national energy mix can spread industrial expansion and opportunities, even in developing countries [79], leading to the energy transition and contributing to solving the environment-economy trade-off [80]. Regarding this, it has been shown that synergies amongst the public and private sectors and the civil society go hand-in-hand for increasing the investments in both industrialized and developing countries [51].

Public-private synergies in the field of renewables can promote empowerment amongst the poor and the vulnerable, above all in developing countries, fostering energy access and social sustainability [81,82]; being renewable energy capital intensive, the industry can significantly ease the energy access plague, spreading its enlargement amongst the poor. Public-private partnerships are exponentially growing strategies for fostering renewables use, above all for infrastructure sectors [83]. On the other hand, it has been demonstrated that effective policy can stimulate investments in clean energy [84]: institutions can be prominent actors in yielding policy instruments like economic and fiscal incentives such as feed-in tariffs, to be complemented with GHG emission trading and effective regulation – i.e. standards, labeling, and acts.

Another principal endowment coming from the private sector is attributed to cooperatives, which are today decisive for taking off a cleaner energy transition, being at the core of the energy policy agenda [85]. The ongoing energy transitions are strongly dependent on various social structural factors related to the implementation of the technologies (for instance urban size) and, more importantly, household income [86]. These factors affect or hinder the energy transition, along with domestic and regional policies, as well as international agreements [87].

In this context, environmental factors are paramount. Rusciano et al. [87] argue that in order to determine the true effect on the ecosystem, the environmental factor needs to be discussed in detail – differently, any social change might lead to additional deterioration that would be difficult to achieve. In particular, social and environmental dimensions are related to the urban gardens, and patterns are established between community gardens and social-ecological innovation. In their work, two attributes of community gardens, i.e., urbanization and health and community impact, have been granted as having the potential to affect other community garden attributes – hence, local sustainable development. Thus, their paper proposes using these highly influential variables to describe a social and ecological innovation strategy based on a community gardening system (see also [88,122]).

Besides governmental institutions, the society and technology can be decisive in the transition process [89–92]. Nonetheless, the results of an energy transition pathway are difficult to be forecasted [93].

Cooperatives can foster renewables' adoption, contributing to barrier removal [94]. Renewable energy cooperatives propose novel schemes, characterized by citizens' participation [95]; these decentralized energy systems are configuring as an evolution from the traditional energy infrastructures and are conceived as commons, where a significant contribution is provided by the strategic resolution of coordination and governance. Nowadays, renewable energy cooperatives are determining entrepreneurial facets, but they call for new business models and impulses to tackle market risks, also due to the new feed-in tariff systems [96]. Exploring and potentially stimulating the diverse local investors' motivations and involvements is a principal way to fuel communities' initiatives, where renewables investments are usually defined by the interplay between social norms and economic incentives [97].

Provisions like distributed generation – namely, solar photovoltaic installations –, can constitute top-tier entrepreneurial outlets, helping to face some of the premier issues in decarbonization and environmental accounting, local development, energy security, climate change mitigation and unemployment [98]; however, these instruments must be primarily addressed to the vulnerable, considering the former are major problems that inhibit the latter from enjoying self-generated power without tailored policies may be incurred [99].

While green consumption has a strong implication for environmental, societal and institutional reasons, the economic policy dimension remains less evident and explored. New generation energy is reputed to be an asset for worldwide sustainable growth and job creation: considering its socio-economic impact, renewable energy enhancement presents significant consequences for regional development [100]. New renewable energy jobs can also be conceived as a powerful measure to tackle brain drain in depressed areas, facing economic stagnations. New energy strategies and technologies can also be examined as a way to solve job loss due to long-term economic crises, not solely in the least developed regions, but even in industrialized countries [101–105,121,123].

If it is true that green jobs can represent a plea for employment in industrialized countries, especially in rural areas [106], their success is associated with sectoral financial incentives [107]. The effects of the renewable energy industry on employment has large potentials and can be measured by direct and indirect job generation [48]. Nevertheless, estimating the exact impact on the job market is not an easy exercise and relies on sound measures. The employment opportunities generated paramount results above all in the service sectors [108].

An outstanding policy fact must be underlined: in many regions of developing countries, renewable energy programs that implied employment benefits, energy-saving schemes and increased power access were launched. These strategies were often boosted by microfinance programs and gender equality and women's empowerment policies. A common strategy to achieve sustainable development via renewable energy is the adoption of microfinance programs. Women empowerment in the context of energy policy effectiveness is notably relevant, especially when applied to microfinance tools [101,102,103,110,111]. This figure paves the way for easing the vulnerable condition, challenging their *status quo*[109]. It has been shown that *ad hoc* microfinance policies foster women and rural people entrepreneurship and resilience in the least developed countries and depressed areas [3,102,103]. As a consequence of these policies for empowering the vulnerable is possible to presume that they will increase the social acceptance and support for the resulting change and transition [104,105,106].

Renewable energy configures fresh challenges for the penetration of new market segments. A typical example comes from nano, micro and mini-grid implementation, that became a trendy market in sub-Saharan Africa and several developing regions [2,101–103,118]. In this regard, renewable energy consumption strategies outline themselves as a set of powerful policy tools for innovative business stimulus, to be considered as a sustainable development priority.

It has been found that users became central in new smart grid projects [107] including nano, micro and mini-grids, where trust and confidence assumed a key role for engagement [108]. Against this background, electricity is interpreted as a common pool resource [116,125]: when it comes to its governance, energy communities can be decisive in providing the technology needed to satisfy the energy requirements designated from the development agenda [1]. Albeit these bright prospects, it has become urgent to draft novel models that will ensure the sustainable management of rural grids, entitling universal energy access to create green jobs, primarily targeting the vulnerable.

Finally, it is important to note that the finding that oil-abundant nations are less used to embracing renewable energy may seem an intuitive result, but it is also an interesting implication since empirical evidence of exceptions exists (see [117]).

6. Conclusions

The use of composite indicators can be a significant solution in social science research and energy studies. The outputs stemming from these indicators are typically based on alternative assumptions adopted throughout their constructions. However, these measures often lack robustness and do not manage to disentangle the depicted policy issues. The proposed outlook encompasses the existing approaches allowing analyses related to a central result, which can be directly used in normative economics policy analysis; this perspective also allows explorations based on the varying hypotheses on which the composite indicator is based.

The Development Agenda turns out to be crucial in shaping sound renewable energy policies. Clean energy adoption is necessary to reach sustainability in the economic, social, institutional and environmental spheres. Renewable energy is fundamental in the drafting of resilience policies to tackle energy vulnerability. The most affected categories are those social groups who are the most exposed to energy vulnerability and are the most likely to fall into energy insecurity traps. Some of the energy vulnerable categories include inhabitants of developing countries/regions/areas, the poor, rural people, women, elderly, people with disabilities, political, ethnic, religious, sexual orientations and further minorities or fragile groups. Ensuring energy security to all throughout resilience action has become a primary long-lasting social and sustainability mandate for each country and the international community, as well as a topical energy research topic.

New green energy jobs are of great worth for the empowerment of the vulnerable, by means of job creation in developing countries, and to curb brain drain and unemployment in industrialized regions – principally those undergoing (socio-)economic crises. Renewable energy policies constitute resilience strategies of central importance for development challenges. Sound policies deriving from sustainable development agendas and social sciences research and practice will be decisive for the upcoming energy transition. They will be markedly determinant in contributing fostering renewables consumption and production, enhancing technological innovation and boosting entrepreneurship. On the same wavelength, this process will facilitate changes towards resilient governance, tailored towards the vulnerable empowerment, striving for the ultimate mandate of shaping sustainable energy transition and clean resource governance futures [112,113,114,115,116,124].

This study built the Renewable Energy Index and ranked worldwide performances. For this scope, this work explored a large number of countries and territories (n = 230), representative of the entire planet. The work also proposes a revisitation of the WB's RISE database analyses, launching an adjusted version of the WB index in terms of methodology, data treatment and analysis.

The research at hand reached some important conclusion and delivered new pieces of information in the field of energy policy. In terms of renewable energy use, green countries perform better, oil producers are less prone to the use of renewable sources, whilst countries endowed with rich/wide resources perform better in this regard (e.g. Brazil). Exceptions result on the way. We have also been able to identify some "rising stars" in the field of renewable energies – such as Portugal – which are now relevant players. At the same time, the fragility analysis carried out shows some instructive case – for instance, Portugal is more resilient than other countries in the field of renewable energy.

Another potentially striking result sorting from this study is that the GDP is not necessarily a core driver of renewable energy, whilst Human Development Index and sustainable development measures generally are. However, remarkable exceptions exist. This is the case of Tajikistan, reaching good renewable energy performance despite displaying modest human development and sustainable development achievements. An equal-weights-based method may seem a less attractive technique, but is preferred for this exercise's scopes – i.e. research, outreach, communication and policymaking. Methodologically, our index's robustness is tested through an interval-data analysis and is validated from the low correlation existing amongst the variables.

With the purpose to take into account the barriers to the diffusion of new approaches, the composite indicator examination might want to assess the range between the measures computed. Higher ranges denote higher uncertainty on the parameters used. This implies various barriers to the transitions due to the gauging difficulties on the actual state and policy goals. The quantification of the barriers to energy transition is a pulsing topic for future energy research agenda within the social sciences framework.

The limitation of this work is the use of one single set of data. However, due to the theoretical framework and methodological outlook that has been adopted, the indicator's robustness is guaranteed. Upcoming research may want to stress additional observations regarding a larger set of years, with the scope to indicate further dynamics. Despite the methodological novelty, the work can potentially be further improved by exploiting the quantiles and the rank and other possible representations of the initial data – for instance, selected outliers may be removed from the interval.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix I. Final ranking equal weights

Table 8
Whole ranking, composite indicator 1: equal weights.

Country	comp_ind	rank
Liechtenstein	3.17	1
Niue	2.56	2
Norway	1.91	3
Denmark	1.84	4
Iceland	1.50	5
Tajikistan	1.41	6
Sweden	1.22	7
Portugal	1.18	8
Uruguay	1.04	9
Saint Helena	1.03	10
Spain	0.87	11
Costa Rica	0.82	12
Aruba	0.80	13
Albania	0.78	14
Greece	0.66	15
Paraguay	0.65	16
Austria	0.65	17
Zambia	0.65	18
Bhutan	0.64	19
French Guiana	0.57	20
Mozambique	0.56	21
Ireland	0.56	22
New Zealand	0.54	23
Cyprus	0.52	24
Malawi	0.49	25
Croatia	0.47	26
Kyrgyzstan	0.47	27
Brazil	0.45	28
Lithuania	0.45	29
Montenegro	0.44	30
Congo, Dem. Rep.	0.41	31
Germany	0.39	32
Cape Verde	0.38	33
Canada	0.36	34
Burundi	0.36	35
Lao People's Democratic Republic	0.36	36
Nicaragua	0.36	37
Namibia	0.35	38
Ethiopia	0.35	39
Georgia	0.34	40
Switzerland	0.33	41
Reunion	0.33	42
Cameroon	0.33	43
Nepal	0.32	44
Uganda	0.31	45
Somalia	0.30	46
Zimbabwe	0.30	47
Finland	0.29	48
Panama	0.27	49
Romania	0.27	50
Suriname	0.27	51
Honduras	0.26	52
Rwanda	0.26	53
Andorra	0.26	54
Central African Republic	0.25	55
Chad	0.25	56
Tanzania	0.24	57
Gabon	0.24	58
Nigeria	0.24	59
Italy	0.23	60
Guinea-Bissau	0.23	61
Swaziland	0.22	62
Togo	0.21	63
Guinea	0.20	64
Liberia	0.20	65
Sudan	0.20	66
Macedonia, FYR	0.18	67
Eritrea	0.17	68
Kenya	0.16	69
Sierra Leone	0.16	70
Niger	0.16	71
United Kingdom	0.16	72
Guatemala	0.15	73
Cambodia	0.15	74

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Table 8 (*continued*)

Country	comp_ind	rank
Faroe Islands	0.15	75
Sri Lanka	0.15	76
Madagascar	0.14	77
Myanmar	0.14	78
Haiti	0.14	79
Greenland	0.13	80
Burkina Faso	0.13	81
Peru	0.12	82
Chile	0.12	83
Palestine (State of)	0.11	84
Mali	0.10	85
Falkland Islands (Malvinas)	0.09	86
Bosnia and Herzegovina	0.08	87
Turkey	0.08	88
Lesotho	0.08	89
Congo, Rep.	0.07	90
China	0.07	91
Côte d'Ivoire	0.07	92
BES Islands	0.06	93
Colombia	0.06	94
Vietnam	0.05	95
Latvia	0.05	96
Belize	0.04	97
Solomon Islands	0.03	98
Papua New Guinea	0.02	99
Ghana	0.02	100
Belgium	0.01	101
Angola	0.01	102
Bulgaria	0.01	103
Malta	0.01	104
United States Virgin Islands	0.01	105
Estonia	0.00	106
Democratic People's Republic of Korea	0.00	107
Pakistan	0.00	108
Vanuatu	−0.01	109
Luxembourg	−0.03	110
Israel	−0.03	111
India	−0.04	112
Slovenia	−0.05	113
Fiji	−0.06	114
Venezuela	−0.06	115
Australia	−0.06	116
Mauritania	−0.07	117
Dominican Republic	−0.08	118
Afghanistan	−0.08	119
Samoa	−0.08	120
French Polynesia	−0.08	121
France	−0.08	122
Serbia	−0.08	123
Guadeloupe	−0.08	124
Gambia	−0.09	125
Benin	−0.09	126
Jordan	−0.09	127
Morocco	−0.11	128
Ecuador	−0.11	129
Senegal	−0.13	130
Comoros	−0.14	131
São Tomé and Principe	−0.14	132
United States	−0.17	133
New Caledonia	−0.17	134
El Salvador	−0.17	135
Netherlands	−0.17	136
Poland	−0.18	137
Armenia	−0.18	138
Japan	−0.18	139
Philippines	−0.18	140
Indonesia	−0.19	141
South Sudan	−0.20	142
Mayotte	−0.22	143
St. Kitts and Nevis	−0.22	144
Bangladesh	−0.23	145
Slovak Republic	−0.24	146
Puerto Rico	−0.25	147
Tunisia	−0.26	148
Argentina	−0.26	149
Mexico	−0.27	150
Thailand	−0.28	151
Botswana	−0.29	152
Bolivia	−0.29	153
South Africa	−0.30	154
Czech Republic	−0.30	155
Jamaica	−0.30	156
Hungary	−0.31	157
Guyana	−0.32	158
Kosovo	−0.34	159
Dominica	−0.35	160
Mauritius	−0.36	161
Cuba	−0.37	162
St. Vincent and the Grenadines	−0.37	163
Timor-Leste	−0.38	164
Egypt	−0.39	165
Moldova	−0.39	166
Chinese Taipei	−0.39	167
Equatorial Guinea	−0.40	168
Kiribati	−0.40	169
Djibouti	−0.41	170
Uzbekistan	−0.42	171
Mongolia	−0.42	172
American Samoa	−0.42	173
Lebanon	−0.42	174
Seychelles	−0.42	175
Malaysia	−0.42	176
Tonga	−0.42	177
Russian Federation	−0.43	178
Martinique	−0.43	179
Marshall Islands	−0.45	180
Grenada	−0.45	181
Ukraine	−0.45	182
Saint Pierre and Miquelon	−0.46	183
Republic of Korea	−0.46	184
Azerbaijan	−0.48	185
British Virgin Islands	−0.48	186
Belarus	−0.48	187
Curaçao	−0.48	188
Macao (SAR, China)	−0.48	189
Kazakhstan	−0.48	190
Isle of Man	−0.49	191
Micronesia (Federated States of)	−0.51	192
Iraq	−0.52	193
Iran (Islamic Republic of)	−0.52	194
Barbados	−0.52	195
Maldives	−0.52	196
Bermuda	−0.53	197
Yemen	−0.53	198
St. Lucia	−0.53	199
Syrian Arab Republic	−0.53	200
Libya	−0.53	201
Nauru	−0.53	202
Bahamas	−0.54	203
Hong Kong (SAR, China)	−0.54	204
Singapore	−0.54	205
Turks and Caicos Islands	−0.54	206
Trinidad and Tobago	−0.54	207
Algeria	−0.55	208
Anguilla	−0.55	209
Sint Maarten (Dutch part)	−0.55	210
United Arab Emirates	−0.55	211
Antigua and Barbuda	−0.55	212
Bahrain	−0.55	213
Brunei Darussalam	−0.55	214
Cook Islands	−0.55	215
Gibraltar	−0.55	216
Guam	−0.55	217
Kuwait	−0.55	218
Montserrat	−0.55	219
Northern Mariana Islands	−0.55	220
Oman	−0.55	221
Palau	−0.55	222
Qatar	−0.55	223
Saudi Arabia	−0.55	224
Saint Barthelemy	−0.55	225
St. Martin (French part)	−0.55	226

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Table 8 (*continued*)

Country	comp_ind	rank
Turkmenistan	−0.55	227
Tuvalu	−0.55	228
Wallis and Futuna Islands	−0.55	229
Western Sahara	−0.55	230

Appendix II. Sensitivity analysis on 10,000 simulations based on different weights

Table 9
Whole ranking, composite indicator 2: ranks obtained by the randomized weights.

Country	Mi	q25	Me	q75	ma
Liechtenstein	1	1	2.37	2	65
Norway	1	2	6.49	6	91
Sweden	2	6	8.95	9	60
Iceland	1	4	9.77	11	109
Uruguay	3	9	11.92	13	57
Denmark	1	2	12.59	8	138
Niue	1	2	14.57	8	171
Tajikistan	2	4	15.89	15	139
Portugal	2	5	16.05	17	94
Costa Rica	8	12	18.54	18	101
Zambia	4	11	23.54	31	117
Austria	13	17	23.83	24	73
Bhutan	5	13	24.41	31	116
Spain	5	9	24.87	31	120
Albania	5	9	25.20	33	123
Paraguay	6	13	26.45	35	128
Greece	5	13	28.43	36	114
Mozambique	7	16	29.07	38	121
Saint Helena	2	5	29.29	36	165
French Guiana	7	17	31.36	41	121
New Zealand	13	21	32.67	40	106
Malawi	9	19	33.54	43	123
Croatia	18	26	36.03	43	85
Brazil	22	28	36.78	44	71
Aruba	3	9	40.35	60	187
Congo, Dem. Rep.	1	18	41.01	57	141
Montenegro	9	23	43.04	60	148
Cyprus	3	14	43.36	68	161
Lithuania	8	19	44.52	67	122
Lao People's Democratic Republic	17	34	47.01	57	135
Kyrgyzstan	6	17	47.11	71	165
Ethiopia	4	23	47.25	65	148
Burundi	2	21	47.91	66	158
Ireland	5	13	47.92	77	170
Cameroon	19	33	47.92	59	130
Germany	11	21	48.68	72	134
Canada	18	30	49.05	68	134
Nicaragua	11	29	49.25	65	149
Nepal	13	30	50.62	66	143
Cape Verde	9	22	52.29	78	158
Finland	28	44	52.54	60	117
Uganda	6	27	52.86	72	154
Zimbabwe	18	34	53.34	68	139
Switzerland	11	31	53.44	73	142
Namibia	7	26	54.02	78	153
Reunion	4	24	54.44	82	142
Georgia	10	29	55.06	77	147
Honduras	21	47	55.51	63	108
Romania	18	38	57.34	78	109
Somalia	3	26	58.75	82	182
Panama	20	37	58.92	78	147
Central African Republic	23	41	59.50	74	138
Italy	11	38	60.13	82	117
Rwanda	10	33	60.90	82	163
Swaziland	32	49	62.89	72	133
Suriname	13	36	64.49	88	162
Gabon	17	40	64.90	84	159

Table 9 (*continued*)

Country	Mi	q25	Me	q75	ma
Chad	5	32	65.04	91	183
Tanzania	13	37	65.39	88	167
Sudan	36	54	66.52	75	137
Andorra	9	34	67.12	96	170
Togo	30	50	67.27	82	140
Nigeria	11	36	67.36	92	175
Macedonia, FYR	30	49	69.16	87	131
Guinea	25	47	69.44	88	152
Guinea-Bissau	9	38	69.93	95	184
Sri Lanka	46	68	73.42	79	124
Liberia	15	43	74.46	100	185
Chile	37	57	75.34	91	104
United Kingdom	14	40	75.42	111	164
Faroe Islands	17	43	75.52	105	170
Guatemala	35	63	75.65	88	119
Peru	31	58	77.30	97	124
Cambodia	33	62	77.32	92	143
Kenya	29	55	77.60	98	157
Myanmar	40	65	78.27	91	145
Eritrea	19	49	80.09	107	186
Sierra Leone	21	52	80.27	105	173
Turkey	24	54	80.47	101	128
Palestine (State of)	5	39	81.13	122	182
China	17	56	81.19	104	133
Madagascar	31	60	81.28	101	155
Greenland	17	47	82.12	114	176
Niger	20	51	82.38	109	187
Bosnia and Herzegovina	37	71	83.75	94	152
Haiti	26	56	86.27	112	178
Falkland Islands (Malvinas)	11	43	86.89	127	193
Lesotho	48	76	87.55	98	151
Mali	41	71	87.61	104	152
Latvia	54	82	87.65	94	137
Burkina Faso	27	59	87.69	113	176
Vietnam	35	74	88.44	102	156
Colombia	27	63	88.67	114	165
Bulgaria	24	71	90.91	109	122
Belgium	21	61	91.23	120	162
BES Islands	12	48	91.23	131	195
Belize	37	78	91.73	105	157
Congo, Rep.	37	73	93.26	113	158
Côte d'Ivoire	34	71	94.41	118	164
Malta	7	53	94.64	134	187
Estonia	22	74	94.67	117	181
United States Virgin Islands	6	51	95.00	136	189
Luxembourg	19	70	96.38	121	151
Ghana	47	86	96.41	106	156
Democratic People's Republic of Korea	33	77	97.91	121	167
Vanuatu	37	88	98.49	110	143
Papua New Guinea	47	83	99.22	115	160
Angola	52	86	99.94	114	159
Pakistan	54	90	100.71	112	145
Solomon Islands	36	76	101.33	126	182
Israel	8	60.75	101.63	141	191
India	54	97	103.20	111	127
Australia	26	81	103.42	127	148
Slovenia	31	91	104.41	121	149
Dominican Republic	38	93	106.14	124	134
Guadeloupe	16	80	106.21	134	170
France	39	92	107.10	125	141
Venezuela	29	81	107.30	135	180
Fiji	50	98	107.98	119	154
Jordan	10	74	108.28	143	182
Mauritania	43	97	108.67	122	171
French Polynesia	34	85	109.08	134	170
Samoa	35	102	110.15	121	149
Afghanistan	35	92	110.50	132.25	172
Morocco	25	91	112.09	137	170
Serbia	40	96	112.14	131	169
Ecuador	37	97	116.21	138	173
Gambia	50	97	118.46	138	188
Benin	51	98	118.91	138	185
United States	40	110	121.80	140	158
New Caledonia	42	110	122.18	140	167
Japan	18	111	123.30	143	164
Netherlands	27	105	123.34	148	180

(*continued on next page*)

Table 9 (*continued*)

Country	Mi	q25	Me	q75	ma
Senegal	60	110	124.66	140	174
Poland	32	114	125.67	145	175
São Tomé and Principe	62	113	126.86	142	173
Comoros	55	109	127.64	145	189
El Salvador	61	119	127.99	138	171
Armenia	44	116	128.88	145	177
Philippines	77	124	129.79	137	161
Mayotte	15	115	129.87	153	184
St. Kitts and Nevis	28	115	131.08	156	194
Indonesia	70	122	134.90	148	177
Slovak Republic	44	130	135.98	147	167
Puerto Rico	36	124	136.05	159	186
South Sudan	65	121	136.78	151	190
Tunisia	33	134	137.31	148	168
Argentina	55	131	140.27	156	177
Mexico	55	138	140.52	152	164
Bangladesh	76	128	141.56	154	184
South Africa	54	143	146.31	153	171
Thailand	59	140	146.34	154	173
Czech Republic	38	142	146.37	155	166
Bolivia	83	140	146.86	156	177
Jamaica	62	143	148.14	155	180
Hungary	63	145	149.64	157	177
Botswana	85	138	150.34	162	191
Dominica	68	148	155.16	166	184
Guyana	94	145	155.98	167	192
Kosovo	109	151	157.86	166	182
Mauritius	60	157	158.77	163	175
St. Vincent and the Grenadines	72	153	160.04	171	188
Chinese Taipei	55	158	160.91	172	183
Egypt	80	159	162.08	169	182
Kiribati	29	159	163.75	176	191
Cuba	112	157	164.40	174	190
Moldova	124	162	166.43	172	184
Equatorial Guinea	93	163	166.58	173	185
American Samoa	27	160	167.50	183	202
Timor-Leste	116	160	167.51	176	193
Mongolia	58	162	167.64	180	195
Seychelles	57	162	168.02	181	197
Lebanon	45	167	168.54	176	186
Uzbekistan	81	162	168.73	180	192
Tonga	30	164	169.08	182	198
Malaysia	90	167	170.80	178	189
Martinique	35	167	171.64	183	193
Russian Federation	89	167	172.02	182	191
Djibouti	126	164	172.08	180	194
Ukraine	94	176	176.66	180	184
Saint Pierre and Miquelon	65	172	177.12	187	202
Republic of Korea	63	177	178.00	184	189
Marshall Islands	143	172	178.17	185	195
Grenada	144	173	179.54	186	196
British Virgin Islands	79	182	183.49	190	198
Azerbaijan	112	181	183.50	189	195
Curaçao	71	179	184.02	192	206
Kazakhstan	110	181	184.47	191	199
Belarus	161	182	185.71	189	196
Macao (SAR, China)	159	182	186.28	191	197
Isle of Man	146	185	187.11	190	194
Micronesia (Federated States of)	88	188	190.29	194	200
Iraq	137	190	192.42	196	203
Iran (Islamic Republic of)	142	192	193.73	198	201
Barbados	181	192	194.35	197	198
Maldives	101	193	195.63	200	202
Bermuda	186	194	196.02	198	199
Yemen	187	196	197.20	199	200
Syrian Arab Republic	151	195	198.13	202	206
St. Lucia	188	197	198.53	201	201
Nauru	102	197	199.57	204	207
Libya	190	198	199.71	202	202
Bahamas	196	202	202.12	203	203
Hong Kong (SAR, China)	200	203	203.54	204	204
Singapore	202	204	204.71	205	205
Turks and Caicos Islands	203	206	205.78	206	206
Trinidad and Tobago	206	207	206.94	207	207
Algeria	208	208	208.00	208	208
Anguilla	208	208	208.00	208	208
Sint Maarten (Dutch part)	208	208	208.00	208	208
United Arab Emirates	208	208	208.00	208	208
Antigua and Barbuda	212	212	212.00	212	212
Bahrain	212	212	212.00	212	212
Brunei Darussalam	212	212	212.00	212	212
Cook Islands	212	212	212.00	212	212
Gibraltar	212	212	212.00	212	212
Guam	212	212	212.00	212	212
Kuwait	212	212	212.00	212	212
Montserrat	212	212	212.00	212	212
Northern Mariana Islands	212	212	212.00	212	212
Oman	212	212	212.00	212	212
Palau	212	212	212.00	212	212
Qatar	212	212	212.00	212	212
Saudi Arabia	212	212	212.00	212	212
Saint Barthelemy	212	212	212.00	212	212
St. Martin (French part)	212	212	212.00	212	212
Turkmenistan	212	212	212.00	212	212
Tuvalu	212	212	212.00	212	212
Wallis and Futuna Islands	212	212	212.00	212	212
Western Sahara	212	212	212.00	212	212

Where ma is maximum, the mi is the minimum, q25 the 25th percentile, me is the median and q75 is the 75th percentile.

Appendix III. Descriptive statistics for the variables

Descriptive statistics (Table 10) show that the variable renewable energy (renen) has a more asymmetric distribution than the other variables (namely: liquid biofuels/liq, wind/win, and solar energy/sol). Thus, some nations got some high values in these regards. This output might translate into the risk of being of influence for the indicator, but we notice that also liq is high, hence the risk results in being reduced.

Table 10
Descriptive statistics: Renewable energy, liquid biofuels, wind, solar energy.

Renen	Liq	win	Sol
Min.:0.0000	Min.:0.00	Min.:0.00	Min.:0.00
1st Qu.:0.04	1st Qu.:0.00	1st Qu.:0.00	1st Qu.:0.00
Median:0.17	Median:0.01	Median:0.00	Median:0.00
Mean:0.27	Mean:0.04	Mean:0.01	Mean:0.01
3rd Qu.:0.43	3rd Qu.:0.05	3rd Qu.:0.00	3rd Qu.:0.00
Max.:0.96	Max.:0.51	Max.:0.10	Max.:0.22

Appendix IV. Kernel density estimations

We run Kernel density estimations to make an ex-post analysis (Fig. 2). It consvists of an explorative-graphical method to analyze the distribution of data. As a result, we get a smoothed curve. Here we have on the y axis the estimated probability density function, whilst we have on the x axis the range of the scores value, that is skewed-right on the high values. We analyze the bumps on the right, representing the best performing states – in our exercise, only a few states. Then we analyze the Kernel density estimation of the average ranking of each country observations/simulations (Fig. 3). Intuitively, we can assert that a bimodal distribution is observable. Bimodality is due to small nations ranking first.

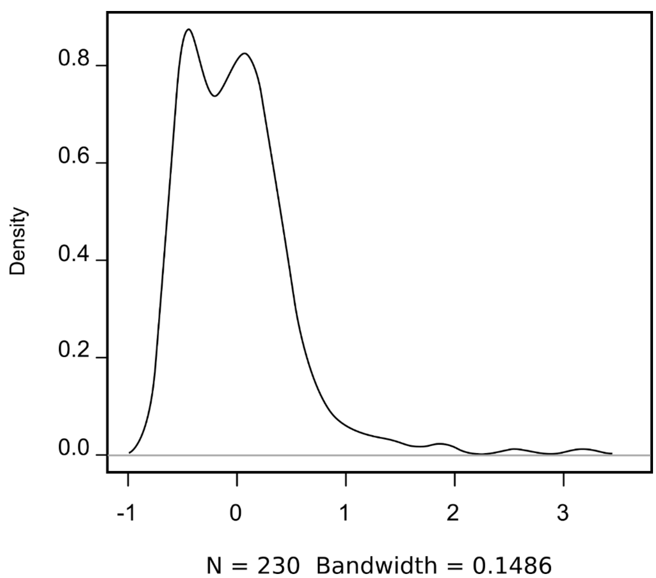

Fig. 2. Kernel density estimation: equal-weights composite indicator.

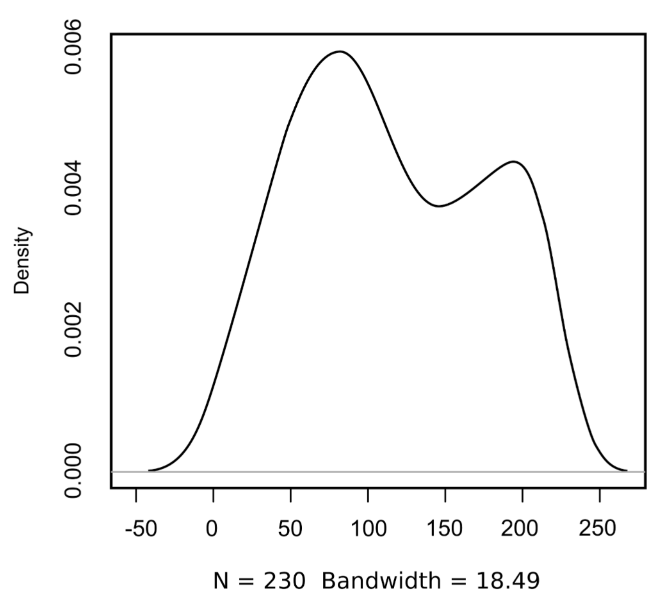

Fig. 3. Kernel density estimation: final average median rank.

Appendix V. Weighting and interval-based composite indicators

Table 11
Weighting in composite indicators and interval-based composite indicators.

Reference	Approach	Sensitivity Analysis	Review
Joint Research Centre – European Commission [13]	Weighting(allowed equal weighting)	Can be considered to assess the robustness of the results	Yes
Becker et al. [63]	Weighting(allowed equal weighting)	Can be considered to evaluate the contribution of the different variables (inputs) to the composite indicator	No
Drago [15]	Randomization of the weights. Construction of the interval based on all possible assumptions on the inputs and outcomes	Endogenized on the concept of interval	No
Drago & Gatto [59]	Randomization of the weights and construction of the interval based on all possible outcomes	Endogenized on the concept of interval	No
Greco et al. [64]	Weighting(allowed equal weighting)	Can be considered to assess the robustness of the results	Yes
Gatto & Drago – this work	Randomization of the weights and construction of the interval based on all possible ranks	Endogenized on the concept of interval	No

Appendix VI. Construction and phases of the interval-based composite indicator

Table 12
Construction of the Interval-Based Composite indicator.

The construction of the interval-based composite indicator
1) We simulate different weights for each factor from 0 to 1. The uniform distribution produces single weights, taking into account a minimum of 0 and a maximum of 1
2) All the different weights are summed up
3) The final weight is obtained by dividing the sum of the single simulated weight
4) We obtain a different weight for each simulation of the components
5) We quantify the various composite indicators for each weighting obtained on the 10,000 different simulations. The final rank in each simulation is determined
6) To achieve a final score for each country studied, the different ranks are compiled and eventually averaged
7) The 10,000 simulations are useful for assessing the sensitivity of the composite indicator outputs
8) The exercise manages to test and compare the results of the different assumptions. The final interval is obtained by identifying the upper and lower bound; the mean and the quantiles are computed

Appendix VII. Comparison using a ranking plot of the results (composite indicator with equal weights and the center of the interval-based composite indicator)

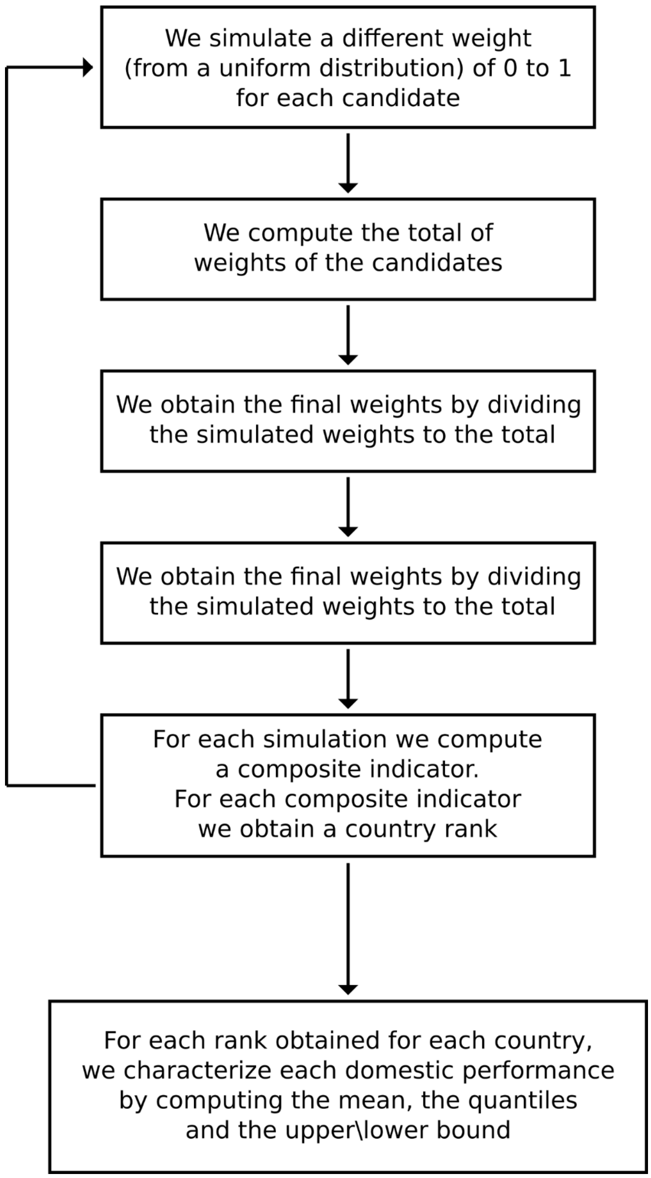

Fig. 4. Visualization of the phases of construction of the interval-based composite indicator.

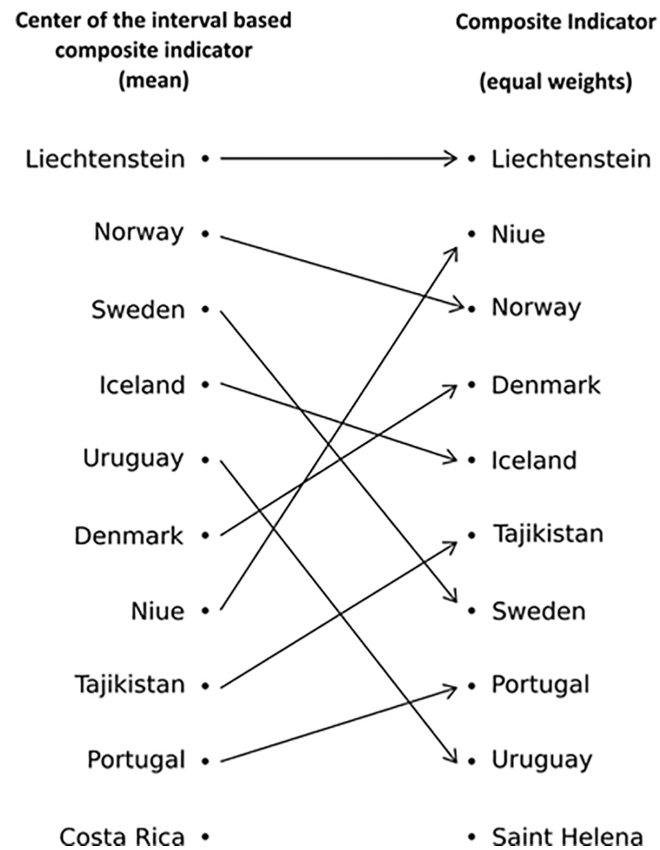

Fig. 5. Comparison using a ranking plot of the results (composite indicator with equal weights and the center of the interval-based composite indicator).

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