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JRC Statistical Audit of the 2020 Environmental Performance Index

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Abstract

The 2020 Environmental Performance Index (EPI) ranks 180 countries on 32 performance indicators across 11 issue categories covering environmental health and ecosystem vitality. These metrics provide a gauge at national scale of how close countries are to established environmental policy goals. Since 2006 that the EPI is released biannually by the Yale Center for Environmental Law & Policy (YCELP) and the Center for International Earth Science Information Network (CIESIN) at Columbia University. The European Commission's Competence Centre on Composite Indicators and Scoreboards (COIN) at the Joint Research Centre (JRC) was invited by the Yale Center for Environmental Law & Policy to audit the 2020 edition of the EPI. The statistical audit presented herein aims to contribute to ensuring the transparency of the EPI methodology and the reliability of the results. The report touches upon data quality issues, the conceptual and statistical coherence of the framework and the impact of modelling assumptions on the results. The analysis suggests that meaningful inferences can be drawn from the EPI. It confirms that the 2020 EPI meets the quality standards for statistical soundness and acknowledges the EPI as a reliable composite indicator to measure environmental performance worldwide.

1 Introduction

About 20 years ago, the dissatisfaction with the results of environmental policy efforts and the need to make the environmental arena more data-driven and fact-based led to the creation of the Environmental Performance Index (EPI). The EPI was a pioneer in composite indicators of sustainable development.

Since 2006 that the EPI is released biannually by the Yale Center for Environmental Law & Policy (YCELP) and the Center for International Earth Science Information Network (CIESIN) at Columbia University.

The index measures environmental performance of countries, focusing on outcomes of environmental policy rather than drivers or policy inputs. In this way, the EPI helps policy discussions to focus on the effectiveness of policies as well as to ensure better environmental investments. The 2020 EPI ranks 180 countries on 32 performance indicators across 11 issue categories covering environmental health and ecosystem vitality. These metrics provide a gauge at national scale of how close countries are to established environmental policy goals. Along the years, the index has been able to engage policymakers with the data on environmental performance and even prompted some countries to prioritise the environmental policy agenda (Wendling et al., 2018).

The European Commission's Competence Centre on Composite Indicators and Scoreboards (COIN) at the Joint Research Centre (JRC) was invited by the Yale Center for Environmental Law & Policy to audit the 2020 edition of the EPI (Wendling et al., 2020). The JRC has previously audited five consecutive editions of the EPI from 2006 to 2014 (Esty et al., 2006) (Michaela Saisana & Saltelli, 2008) (Michaela Saisana & Saltelli, 2010) (Emerson et al., 2012) (Athanasoglou et al., 2014).

The JRC statistical audit is based on the recommendations of the Handbook on Composite Indicators (OECD & JRC, 2008) as well as on more recent research from the JRC. The Handbook offers a 10-step guidance on the process of building composite indicators. The assessment of the relevance of the EPI conceptual framework as well as the verification of indicator selection, construction and data collection are not within the scope of this audit.

The audit of the EPI focuses on two main issues: the statistical coherence of the structure of indicators (Section 3) and the impact of key modelling assumptions on the EPI ranking (Section 4). The audit follows three main steps: the first focuses on the main descriptive statistics and on the detection of missing values and potential outliers; the second on the analysis of the statistical coherence through a multilevel analysis of the correlations of the indicator, issue categories and policy objectives; and the third, on the robustness analysis of the index and the testing of the impact of key modelling assumptions. The results are supported by a spreadsheet in Excel format shared with the EPI team.

The JRC analysis also complements the reported country rankings for the EPI with confidence intervals in order to better appreciate the robustness of these ranks to the computation methodology, in particular the exclusion of potentially problematic indicators, weights and aggregation formula at policy objective level.

The results of the audit presented herein aim at shedding light on the transparency and reliability of the EPI. It expects to contribute to enable policymakers and advocates to derive more accurate and meaningful conclusions as well as to guide choices on priority setting and policy formulation.

2 Conceptual framework

The EPI is based on two main policy objectives: Environmental Health, which measures threats to human health, and Ecosystem Vitality, which measures natural resources and ecosystems services. The EPI includes 32 indicators grouped within 11 issue categories (Table 1). The EPI is aggregated at each level using a simple weighted arithmetic average.

Table 1. Conceptual framework of the 2020 Environmental Performance Index. Source: (Wendling et al., 2020)

| Policy objective | Issue category | Indicator | Code |
|----------------------|-----------------------------|---|------|
| Environmental Health | Air Quality | Ambient particulate matter pollution | PMD |
| | | Household air pollution from solid fuels | HAD |
| | | Ozone | OZD |
| | Sanitation & Drinking Water | Unsafe drinking water | UWD |
| | | Unsafe sanitation | USD |
| | Heavy Metals | Lead Exposure | PBD |
| | Waste Management | Solid Waste | MSW |
| Ecosystem Vitality | Biodiversity & Habitat | Terrestrial Biome Protection - National weights | TBN |
| | | Terrestrial Biome Protection - Global weights | TBG |
| | | Marine protection | MPA |
| | | Protected Areas Representativeness Index | PAR |
| | | Species Habitat Index | SHI |
| | | Species Protection Index | SPI |
| | | Biodiversity Habitat Index – Vascular Plants | BHV |
| | Ecosystem Services | Tree cover loss, % | TCL |
| | | Grassland Loss | GRL |
| | | Wetland Loss | WTL |
| | Fisheries | Fish Stock Status | FSS |
| | | Regional Marine Trophic Index | RMS |
| | | Fish caught by Trawling | FGT |
| | Climate Change | CO ₂ intensity trend | CDA |
| | | Methane intensity trend | CHA |
| | | F-gases intensity trend | FGA |
| | | N ₂ O intensity trend | NDA |
| | | Black Carbon intensity trend | BCA |
| | | GHG emission intensity growth rate | GIB |
| | | GHG emissions per capita | GHP |
| | | CO ₂ from Land Cover, trend | LCB |
| | Pollution Emissions | SO ₂ intensity trend | SDA |
| | | NO _x intensity trend | NXA |
| | Agriculture | Sustainable Nitrogen Management Index | SNM |
| | Water Resources | Wastewater treatment level | WWT |

The policy objectives were found by the EPI team to mirror the most relevant policy domains within which policymakers generally deal with environmental problems. The EPI hierarchical framework is conceptually well justified and its structure into two policy objectives allows a direct link between measuring environmental performance and government portfolios of public health and natural resources. In addition, the 11 issue categories cover the most relevant issues on environmental policy.

The indicators were selected based on six criteria (Wendling et al., 2020): relevance; performance orientation; established methodology to ensure comparability; verification of data by a third party; spatial completeness in terms of country coverage; temporal completeness in terms of measurement across time; recency of datasets; and open source data. Ideally, each indicator should satisfy all the selection criteria, though occasionally this was not always possible and was justified in the EPI documentation.

3 Statistical coherence

The statistical coherence in the EPI framework was analysed as follows:

- » Assessment of missing data and outliers (section 3.1);
- » Identification of indicators with strong collinearity, “silent” indicators and indicators that point to the opposite direction (section 3.2);
- » Assessment of the statistical dimensionality and reliability of the components (section 3.3).

3.1 Data quality and availability

The data analysis presented herein uses the normalised dataset (0-100 scale) for 180 countries provided by the EPI team. The dataset already included some imputations for missing data (except for non-applicable cases such as landlocked countries) and treated data using logarithmic transformations. The distance-to-target technique was applied by the EPI team for the normalisation using the whole set of time series and countries (220) for which data was available. The reason for using the whole set of countries was to identify the best and worst performances worldwide and regardless of whether countries are included in the final list of 180 countries.

The data sources included in the EPI vary widely, ranging from international organisations, government agencies to research institutions and academia. These sources also used a variety of techniques, such as remote sensing data; observations from monitoring stations; surveys; academic research; estimates from both on-the-ground measurements and statistical methods; industry reports; and government statistics. The data sources are a very important element when building composite indicators, since the quality and adequacy of the index lies not only on its development, but also on obtaining reliable data.

Table 2 offers summary statistics for the 32 indicators included in the EPI using the normalised data and highlights the cases in which specific issues were found in terms of data coverage and presence of outliers. Moreover, it shows the specific targets set for best and worst performance for each indicator, based on international agreements targets, expert judgment or on the 5% - 95% or 1% - 99% percentile.

Overall, the normalised indicators are not affected by outliers or skewed distributions, except for the Species Habitat Index (SHI) and the Regional Marine Trophic Index (RMS). Potentially problematic indicators that could bias the overall index results are identified on the basis of two measures related to the shape of the distributions: the skewness and kurtosis. A practical rule is that an indicator should be considered for treatment if it has an absolute skewness greater than 2.0 and kurtosis greater than 3.5 (OECD & JRC, 2008) (Groeneveld & Meeden, 1984).

In such cases, we would suggest data winsorisation¹ to be applied, if in accordance with the conceptual framework. After discussion with the EPI team, it was concluded that transformation for the Regional Marine Trophic Index (RMS) would over-reward very poor performance in the issue category and for this reason it was decided not to treat. With respect to the Species Habitat Index (SHI), six countries (Guatemala, Madagascar, Malaysia, Nicaragua, Paraguay and Laos) have outlying performances (with the first five having a value of zero and Laos a value of 6.4). This can be clearly seen in Figure 1.

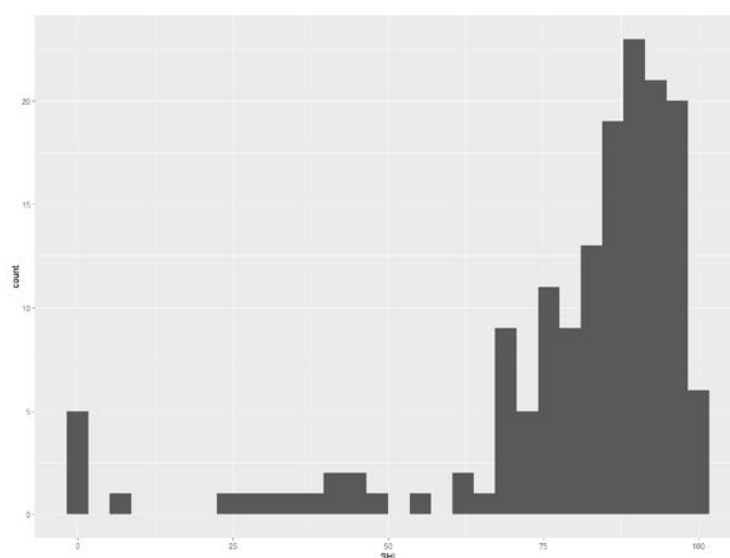


Figure 1. Species Habitat Index (SHI) histogram.

Source: European Commission's Joint Research Centre, 2020.

The data coverage by indicator or by country is also very good. The cases highlighted in red in Table 2 (missing data column) are associated to indicators that depend on a country's natural resource endowments, such as access to oceans and seas and forest cover.

¹ By winsorisation, one converts the value(s) of data points that are considered to be too high (low) to a value of the highest (lowest) data point not considered to be an outlier. It is not suggested to use this technique for more than five data points.

Table 2. Summary statistics of the indicators (normalised data) included in the 2020 EPI.

| Code | Countries | % Missing data | Skewness | Kurtosis | Mean | Min. value | Max. value | Target Good | Target Bad | Direction |
|------------------|-----------|----------------|----------|----------|-------|------------|------------|-------------|------------|-----------|
| PMD | 180 | 0.0 | 0.74 | 0.25 | 42.68 | 0.00 | 100.00 | 1% | 99% | negative |
| HAD | 180 | 0.0 | 0.41 | -1.26 | 46.10 | 0.00 | 100.00 | 5% | 99% | negative |
| OZD | 180 | 0.0 | 0.80 | 0.68 | 46.19 | 0.00 | 100.00 | 5% | 99% | negative |
| UWD | 180 | 0.0 | 0.48 | -0.58 | 45.06 | 0.00 | 100.00 | 5% | 95% | negative |
| USD | 180 | 0.0 | 0.13 | -1.14 | 50.74 | 0.00 | 100.00 | 5% | 95% | negative |
| PBD | 180 | 0.0 | 0.39 | -0.50 | 53.00 | 0.00 | 100.00 | 1% | 99% | negative |
| MSW | 180 | 0.0 | 0.40 | -1.41 | 37.10 | 0.00 | 100.00 | 1 | 0 | positive |
| TBN | 180 | 0.0 | -0.58 | -1.11 | 66.84 | 0.00 | 100.00 | 17 | 0 | positive |
| TBG | 180 | 0.0 | -0.62 | -1.02 | 67.63 | 0.00 | 100.00 | 17 | 0 | positive |
| MPA ¹ | 136 | 24.4 | 0.95 | -0.88 | 30.60 | 0.00 | 100.00 | 10 | 0 | positive |
| PAR | 180 | 0.0 | 0.72 | 0.18 | 31.35 | 0.00 | 98.60 | 0.31 | 5% | positive |
| SHI | 156 | 13.3 | -2.20 | 4.76 | 79.56 | 0.00 | 100.00 | 100 | 1% | positive |
| SPI | 156 | 13.3 | -1.14 | 0.50 | 73.31 | 0.00 | 100.00 | 100 | 0 | positive |
| BHV | 180 | 0.0 | 0.27 | -0.59 | 54.84 | 23.60 | 82.40 | 1 | 0 | positive |
| TCL ¹ | 168 | 6.7 | 1.31 | 0.90 | 38.40 | 0.00 | 100.00 | 1.67E-05 | 99% | negative |
| GRL ² | 166 | 7.8 | 0.46 | 0.00 | 59.73 | 9.40 | 100.00 | 2.14E-05 | 99% | negative |
| WTL ³ | 157 | 12.8 | 0.38 | -0.79 | 59.54 | 0.00 | 100.00 | 2.14E-05 | 99% | negative |
| FSS ¹ | 111 | 30.3 | 1.00 | 0.57 | 11.58 | 0.00 | 36.20 | 0 | 99% | negative |
| RMS ¹ | 124 | 31.1 | 3.03 | 10.70 | 19.65 | 0.00 | 100.00 | 0 | 99% | negative |
| FGT ¹ | 77 | 57.2 | 2.00 | 2.65 | 17.33 | 0.00 | 100.00 | 0 | 99% | negative |
| CDA | 180 | 0.0 | 0.02 | -0.50 | 40.58 | 0.00 | 100.00 | -0.0759 | 95% | negative |
| CHA | 180 | 0.0 | -0.36 | -0.71 | 64.92 | 0.00 | 100.00 | -0.0107 | 95% | negative |
| FGA | 116 | 35.6 | -1.08 | 3.56 | 90.59 | 67.40 | 100.00 | -0.0394 | 95% | negative |
| NDA | 180 | 0.0 | -0.22 | -0.43 | 56.40 | 0.00 | 100.00 | -0.0195 | 95% | negative |
| BCA | 180 | 0.0 | -0.08 | -0.98 | 55.03 | 0.00 | 100.00 | -0.0187 | 95% | negative |
| GIB | 180 | 0.0 | 0.13 | -0.05 | 48.82 | 0.00 | 100.00 | 5% | 95% | negative |
| GHP | 180 | 0.0 | -0.08 | -1.05 | 50.77 | 0.00 | 100.00 | 5% | 95% | negative |
| LCB | 167 | 7.2 | -0.03 | -0.52 | 51.04 | 0.00 | 100.00 | 5% | 95% | negative |
| SDA | 180 | 0.0 | -0.42 | -0.86 | 66.34 | 0.00 | 100.00 | -0.0394 | 95% | negative |
| NXA | 180 | 0.0 | -0.01 | -1.10 | 56.04 | 0.00 | 100.00 | -0.0394 | 95% | negative |
| SNM | 180 | 0.0 | 0.11 | -0.61 | 39.33 | 0.00 | 79.50 | 0 | 99% | negative |
| WWT | 180 | 0.0 | 1.30 | 0.18 | 21.82 | 0.00 | 100.00 | 1 | 0 | positive |

Note: Indicators highlighted in red have absolute skewness greater than 2.0 and kurtosis greater than 3.5 and/or data coverage below 65%.

¹ MPA, FSS, RMS, FGT: due to SEA materiality filter (landlocked), total number of remaining countries is 136.

² TCL: due to TCF materiality filter (tree cover), total number of countries is 168.

³ GRL: due to GRF materiality filter (grasslands), total number of countries is 166.

⁴ WTL: due to WLF materiality filter (wetlands), total number of countries is 157.

Source: European Commission's Joint Research Centre, 2020.

3.2 Cross-correlation analysis

The statistical coherence of an index should be considered a necessary but not a sufficient condition for a sound index. Given that the statistical analysis is mostly based on correlations, the correspondence of the EPI to a real world phenomenon needs to be critically addressed because “correlations do not necessarily represent the real influence of the individual indicators on the phenomenon being measured” (OECD & JRC, 2008). This relies on the interplay between both conceptual and statistical soundness. The degree of coherence between the conceptual framework – 32 indicators grouped within 11 issue categories grouped into two policy objectives and finally into an index – and the statistical structure of the data is an important factor for the reliability of an index, among other things.

The cross-correlation analysis is used to address to what extent the data support the conceptual framework. The 1% significance level is used to determine whether the correlation between two variables is statistically significant.

In the ideal case, there should be positive significant correlations within every level of the index, i.e. each indicator positively correlated with its issue category, each issue category with its policy objective and each policy objective with the index. This effectively ensures that the overall index scores adequately reflect the underlying indicator values.

Redundancy should be avoided in the framework because if two indicators are collinear, this may amount to double counting (and therefore over-weighting) the same phenomenon. It also increases the complexity, which is contrary to good practices of data modelling, in which the simplest model that explains the data (or phenomenon) is preferable (Occam's Razor).

Table 3 shows the correlation coefficients between issue categories, policy objectives and the index. Overall, correlations are significant and positive, namely between the two policy objectives ($r=0.69$) and between a policy objective and the index ($r=0.94$ for Environmental Health and $r=0.90$ for Ecosystem Vitality). Since the correlation of the Environmental Health policy objective is very high (>0.93), and thus flagging for potential collinearity, we would suggest monitoring this issue in coming releases and, if necessary, reduce slightly the weight.

Correlations between each issue category and the respective policy objective are mostly significant and positive. However, there are two issue categories, which show no significant correlation with the Ecosystem Vitality policy objective – Ecosystem Services ($r=0.03$) and Fisheries ($r=-0.12$). To note that both categories have materiality filters (i.e. for landlocked countries or countries with no tree cover, grasslands or wetlands) applied to all its indicators. This means that there is a number of countries left out of these two categories, which may be a reason for the very weak correlations. We would recommend refining these two categories by exploring additional indicators that reflect the consumption of countries in terms of fish and forestry products (in case consumption or trade (as proxy) data is available).

A very strong correlation ($r=0.96$) between air quality and water quality and the policy objective Environmental Health suggests that these two issue categories are dominating the policy objective in relation to the other two categories. Given that air quality accounts for 50% of the weight and water quality for 40% in the Environmental Health policy objective, we would suggest exploring the possibility of lowering slightly both weights.

Table 3. Pearson correlation coefficients between issue categories, policy objectives and the index.

| | EPI | Environmental Health | Air Quality | Water Quality | Heavy Metals | Waste Management | Ecosystem Vitality | Biodiversity | Ecosystem services | Fisheries | Climate Change | Air Pollution | Agriculture | Water Resources |
|----------------------|--------------|----------------------|-------------|---------------|--------------|------------------|--------------------|--------------|--------------------|--------------|----------------|---------------|-------------|-----------------|
| Environmental Health | 0.94 | 1.00 | | | | | | | | | | | | |
| Air Quality | 0.89 | 0.96 | 1.00 | | | | | | | | | | | |
| Water Quality | 0.92 | 0.96 | 0.86 | 1.00 | | | | | | | | | | |
| Heavy Metals | 0.79 | 0.83 | 0.81 | 0.77 | 1.00 | | | | | | | | | |
| Waste Management | 0.79 | 0.81 | 0.73 | 0.77 | 0.66 | 1.00 | | | | | | | | |
| Ecosystem Vitality | 0.90 | 0.69 | 0.63 | 0.68 | 0.59 | 0.62 | 1.00 | | | | | | | |
| Biodiversity | 0.49 | 0.29 | 0.32 | 0.24 | 0.28 | 0.23 | 0.66 | 1.00 | | | | | | |
| Ecosystem Services | -0.06 | -0.11 | -0.17 | -0.02 | -0.20 | -0.18 | 0.03 | -0.23 | 1.00 | | | | | |
| Fisheries | -0.06 | -0.02 | -0.03 | 0.00 | 0.04 | 0.00 | -0.12 | -0.22 | 0.02 | 1.00 | | | | |
| Climate Change | 0.82 | 0.70 | 0.63 | 0.70 | 0.59 | 0.68 | 0.83 | 0.26 | -0.08 | -0.18 | 1.00 | | | |
| Air Pollution | 0.72 | 0.63 | 0.57 | 0.63 | 0.55 | 0.53 | 0.72 | 0.29 | -0.14 | -0.04 | 0.71 | 1.00 | | |
| Agriculture | 0.35 | 0.26 | 0.22 | 0.28 | 0.22 | 0.29 | 0.40 | 0.26 | -0.19 | -0.23 | 0.29 | 0.29 | 1.00 | |
| Water Resources | 0.82 | 0.80 | 0.78 | 0.76 | 0.72 | 0.70 | 0.69 | 0.35 | -0.14 | -0.03 | 0.59 | 0.61 | 0.34 | 1.00 |

Note: Correlations that are not significant at the significance level of $\alpha=0.01$ are in grey (critical value of 0.19). Very high correlations (Pearson correlation coefficients greater than 0.92) are in purple and negative ones in red.

Source: European Commission's Joint Research Centre, 2020.

The cross-correlation analysis confirms that most of the indicators are more correlated with their own issue category than with any other issue category. The same is valid between issue categories and policy objectives. Only Water Resources/Wastewater treatment level correlates more with Environmental Health ($r=0.80$) than with Ecosystem Vitality ($r=0.69$). Conceptually, this indicator contributes to measure the state of natural resources, but at the same time can also contribute to measure human health due to the use of water resources for drinking water, agriculture irrigation and bathing.

As shown in Table 4, overall, there are strong correlations between indicators and their corresponding issue category, policy objective and the index, thus suggesting that the indicators provide meaningful information on the variation of the category scores. Nevertheless, a few indicators were found to be highly collinear (i.e. Pearson correlation coefficients greater than 0.92) with their corresponding issue category, while one indicator was found to be strong negatively correlated. This suggests a few challenging areas requiring refinement:

- **Water Quality:** Two very strong correlated indicators – Unsafe drinking water (UWD) and Unsafe sanitation (USD) – with the issue category ($r=0.99$ in both) and the policy objective ($r=0.96$ and $r=0.94$, respectively). In order to avoid redundancy, we would recommend keeping only one of them or assigning half weights to both of them. Sanitation and drinking water networks are usually developed side by side, so by including only one indicator it could still be possible to capture both aspects. Note that

in case a third indicator would be introduced in this category in the future, these two indicators should account for one (be averaged together) to avoid double counting within the issue category.

- ▶▶ Ecosystem Services: Tree cover loss (TCL) indicator has a correlation of 100% with the issue category, meaning that the other two indicators within the category do not have any explanatory power, which is actually lost at the next two levels of aggregation. We would suggest attributing higher weight to these two indicators in order to justify their presence in the framework. Currently, Tree cover loss has a weight of 90%, while the other two indicators have 5% each.
- ▶▶ Climate Change: CO₂ intensity trend (CDA) indicator is strongly correlated with the issue category ($r=0.94$), leading to a greater explanatory power of this indicator in relation to the others within the issue category. This could be improved by slightly decreasing the weight of the CO₂ intensity trend indicator (currently 55%). The Greenhouse gas emissions per capita (GHP) indicator is negatively correlated with the issue category ($r=-0.51$), the policy objective ($r=-0.55$) and the index ($r=-0.69$). In fact, this indicator is not correlated with any other indicator in the framework. Although Greenhouse gas emissions per capita is a very relevant indicator for climate change, the correlation analysis shows that it does not fit in the framework. This may be explained by the nature of the other indicators within the same issue category, which are mostly measuring emission trends instead of current emissions. An alternative option could be replacing by Greenhouse gas emissions per capita trend indicator.
- ▶▶ Biodiversity & Habitat: Two very strong correlated indicators – Terrestrial Biome Protection _ National weights (TBN) and Terrestrial Biome Protection _ Global weights (TBG) and ($r=0.95$), though not so much dominating at issue category level. Nevertheless, as both indicators appear to be measuring the same phenomenon we would recommend keeping only one indicator or adjust the weights so that they account as one indicator in order to avoid double counting within the issue category.
- ▶▶ Fisheries: Fish Stock Status (FSS) and Fish caught by Trawling (FGT) are negatively correlated with the policy objective ($r=-0.22$ and $r=-0.38$, respectively) and the index ($r=-0.26$ and $r=-0.32$, respectively), though they are positively correlated with their issue category.

Furthermore, some indicators are “silent” in the framework, i.e. they have non-statistically significant correlations with their respective issue category. This implies that they have no explanatory power within the category. These indicators are as follows:

- ▶▶ Biodiversity & Habitat: The Biodiversity Habitat Index (BHV) and the Species Habitat Index (SHI) have no significant correlation with the respective issue category ($r=-0.01$ and $r=0.07$, respectively) neither with the EPI. It could be considered to drop these two indicators or use specific components of the indexes instead of the overall indexes scores.
- ▶▶ Climate Change: GHG emission intensity growth rate (GIB), F-gases intensity trend (FGA) and CO₂ from Land Cover trend (LCB) have no significant correlation with most of the other indicators within the category. However, these indicators show very low correlation with the Climate Change issue category ($r=0.25$, $r=0.19$, $r=0.30$, respectively). This might be taken into consideration in the weighting scheme within the issue category.

Table 4. Pearson correlation coefficients between indicators and their corresponding issue category, policy objective and the index.

| Issue category | Indicator code | Corresponding issue category | Corresponding policy objective | EPI |
|------------------------|----------------|------------------------------|--------------------------------|-------|
| Air Quality | PMD | 0.84 | 0.72 | 0.66 |
| | HAD | 0.86 | 0.91 | 0.85 |
| | OZD | 0.39 | 0.35 | 0.27 |
| Water Quality | UWD | 0.99 | 0.96 | 0.92 |
| | USD | 0.99 | 0.94 | 0.89 |
| Heavy Metals | PBD | 1.00 | 0.83 | 0.79 |
| Waste Management | MSW | 1.00 | 0.81 | 0.79 |
| Biodiversity & Habitat | TBN | 0.89 | 0.49 | 0.39 |
| | TBG | 0.89 | 0.48 | 0.36 |
| | MPA | 0.71 | 0.75 | 0.62 |
| | PAR | 0.53 | 0.31 | 0.26 |
| | SHI | 0.07 | 0.20 | 0.11 |
| | SPI | 0.81 | 0.57 | 0.44 |
| | BHV | -0.01 | -0.11 | -0.13 |
| Ecosystem Services | TCL | 1.00 | 0.01 | -0.09 |
| | GRL | 0.21 | 0.16 | 0.16 |
| | WTL | 0.44 | -0.09 | -0.12 |
| Fisheries | FSS | 0.26 | -0.22 | -0.26 |
| | RMS | 0.79 | 0.21 | 0.26 |
| | FGT | 0.83 | -0.38 | -0.32 |
| Climate Change | CDA | 0.94 | 0.78 | 0.79 |
| | CHA | 0.64 | 0.53 | 0.52 |
| | FGA | 0.19 | 0.17 | 0.14 |
| | NDA | 0.49 | 0.41 | 0.38 |
| | BCA | 0.62 | 0.57 | 0.56 |
| | GIB | 0.25 | 0.34 | 0.14 |
| | GHP | -0.51 | -0.55 | -0.69 |
| | LCB | 0.30 | 0.34 | 0.28 |
| Air Pollution | SDA | 0.89 | 0.55 | 0.57 |
| | NXA | 0.90 | 0.73 | 0.72 |
| Agriculture | SNM | 1.00 | 0.40 | 0.35 |
| Water Resources | WWT | 1.00 | 0.69 | 0.82 |

Note: Numbers represent the Pearson correlation coefficients between each indicator and the corresponding issue category, between each indicator and the corresponding policy objective and between each indicator and the index. Correlations that are not significant at the significance level of $\alpha = 0.01$ are in grey (critical value of 0.19). Very high correlations (i.e. Pearson correlation coefficients greater than 0.92) are in purple and negative correlations in red.

Source: European Commission's Joint Research Centre, 2020.

3.3 Principal components analysis

Principal components analysis (PCA) (Bryant & Yarnold, 1995) (Johnson & Wichern, 1992) explores the correlation of all the indicators simultaneously, highlighting, if present, some common trends that describe a common concept among the indicators. PCA aims at assessing to what extent the conceptual framework of the EPI can be confirmed by statistical approaches.

The results of the PCA performed to the total group of 32 indicators show that there are 11 principal components with eigenvalues greater than, or almost, 1 that explain 75% of the total variance (Table 5).

Table 5. Results of the Principal Component Analysis on the 32 indicators of the EPI.

| | Eigenvalue | Percentage of variance | Cumulative percentage of variance |
|-------------|-------------|------------------------|-----------------------------------|
| PC1 | 9.12 | 28.50 | 28.50 |
| PC2 | 3.03 | 9.46 | 37.97 |
| PC3 | 2.03 | 6.33 | 44.30 |
| PC4 | 1.69 | 5.28 | 49.58 |
| PC5 | 1.50 | 4.68 | 54.26 |
| PC6 | 1.38 | 4.32 | 58.59 |
| PC7 | 1.24 | 3.86 | 62.45 |
| PC8 | 1.17 | 3.67 | 66.12 |
| PC9 | 1.08 | 3.37 | 69.48 |
| PC10 | 0.98 | 3.08 | 72.56 |
| PC11 | 0.93 | 2.89 | 75.45 |
| PC12 | 0.83 | 2.58 | 78.03 |
| PC13 | 0.77 | 2.41 | 80.45 |
| PC14 | 0.70 | 2.19 | 82.64 |
| PC15 | 0.67 | 2.09 | 84.73 |
| PC16 | 0.63 | 1.98 | 86.71 |
| PC17 | 0.61 | 1.90 | 88.61 |
| PC18 | 0.50 | 1.55 | 90.16 |
| PC19 | 0.46 | 1.44 | 91.60 |
| PC20 | 0.39 | 1.22 | 92.81 |

Note: Results shown for the first 20 out of 32 principal components.

Source: European Commission's Joint Research Centre, 2020.

At a second step, PCA is performed to the issue categories within each of the two policy objectives. Ideally, it is expected to have one principal component (PC) in each policy objective explaining at least 70%-80% of the total variance in order to claim that there is a single latent phenomenon behind the data.

The results show that the Environmental Health policy objective can be considered as uni-dimensional with one latent variable explaining 82.53% of variance in the four underlying issue areas (Air Quality, Water Quality, Heavy Metals and Waste Management) (see Table 6).

Table 6. Results of the Principal Component Analysis on the four issue categories of the Environmental Health policy objective.

| | Eigenvalue | Percentage of variance | Cumulative percentage of variance |
|---------------|-------------|------------------------|-----------------------------------|
| comp 1 | 3.30 | 82.53 | 82.53 |
| comp 2 | 0.35 | 8.86 | 91.39 |
| comp 3 | 0.21 | 5.29 | 96.68 |
| comp 4 | 0.13 | 3.32 | 100.00 |

Source: European Commission's Joint Research Centre, 2020.

Though, this is not the case for the Ecosystem Vitality policy objective, as the results show that there are three principal components explaining around 70% of the variance. Table 7 shows that the first principal component explains close to 40% of the variance, although there are two other components that are explaining a considerable amount (eigenvalues ≥ 1).

Table 7. Results of the Principal Component Analysis on the seven issue categories of the Ecosystem Vitality policy objective.

| | Eigenvalue | Percentage of variance | Cumulative percentage of variance |
|---------------|-------------|------------------------|-----------------------------------|
| comp 1 | 2.75 | 39.28 | 39.28 |
| comp 2 | 1.15 | 16.44 | 55.72 |
| comp 3 | 0.99 | 14.19 | 69.91 |
| comp 4 | 0.74 | 10.56 | 80.48 |
| comp 5 | 0.68 | 9.78 | 90.25 |
| comp 6 | 0.40 | 5.75 | 96.01 |
| comp 7 | 0.28 | 3.99 | 100.00 |

Source: European Commission's Joint Research Centre, 2020.

Figure 2 shows in more detail the three main principal components in the seven issue areas of the Ecosystem Vitality policy objective. The first one captures 39.28% of the variance and it is described by Water Resources (WRS), Climate Change (CCH) and Pollution Emissions (APE). Then, it is possible to observe that Ecosystems Services (ECS) and Fisheries (FSH) form a second group on the upper left quadrant that captures 16.44% of the variance. Note that these two issue categories are the ones that show no significant correlation with the respective policy objective (see section 3.2). In addition, a third group emerges in the bottom right quadrant comprising of two issue categories – Biodiversity & Habitat (BDH) and Agriculture (AGR). From the above, it is evident that there is a notable amount of information lost when aggregating directly the seven issues areas into the policy objective.

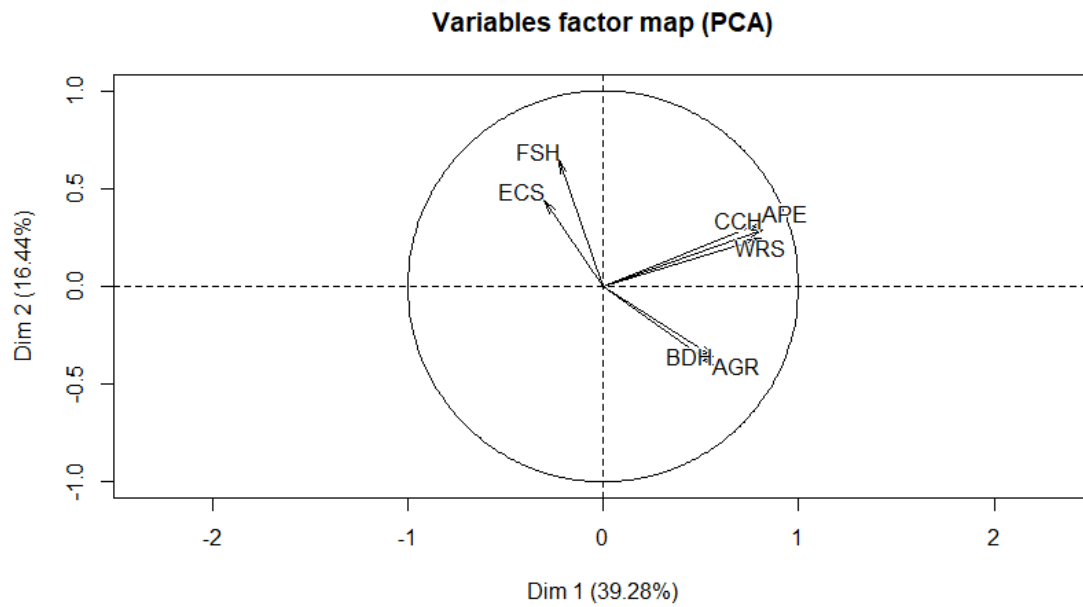


Figure 2. Factor map of the seven issue categories of the Ecosystem Vitality policy objective.

Source: European Commission's Joint Research Centre, 2020.

The PCA analysis concludes that a revision of some of the indicators in the Ecosystem Vitality policy objective should be considered in future editions of the EPI. This could target first the Ecosystems Services (ECS) and Fisheries (FSH) categories that, as shown in other parts of the analysis, could be more problematic.

4 Impact of modelling assumptions on the EPI results

A fundamental step of the statistical analysis of a composite indicator is to assess the effect of different modelling assumptions among reasonable alternatives. The development of a composite indicator, like any model, involves assumptions and subjective decisions. The Environmental Performance Index is the outcome of a number of choices concerning, among other things, the theoretical framework, the indicators selected, the normalisation method, the weights assigned and the aggregation method. Some of these choices may be based on expert opinion or environment considerations, driven by statistical analysis or by the need for ease of communication or draw attention to specific issues

This section aims to test the impact of varying some of these assumptions within a range of plausible alternatives in an uncertainty analysis. The objective is therefore to try to quantify the uncertainty in the ranks of the EPI, which can demonstrate the extent to which countries can be differentiated by their scores.

The uncertainty analysis herein focuses on examining two assumptions, namely the aggregation formula and the weights at policy objective level as outlined in Table 7. These were chosen as plausible alternative pathways in the construction of the index, which can be relatively easily investigated.

Table 8. Sources of uncertainty examined in the uncertainty analysis.

| Assumption | Reference | Alternative |
|--|--|------------------------------|
| I. Uncertainty in the aggregation method at policy objective level | Arithmetic mean | Geometric mean |
| II. Uncertainty intervals for the policy objectives weights | Environmental Health: 0.4 Ecosystem Vitality: 0.6 | U[0.30;0.50] U[0.45;0.75] |

In the EPI, the two policy objectives are aggregated into a single score using a weighted arithmetic mean. While arithmetic averages are easy to interpret, they also allow perfect compensability between the policy objectives, whereby a high score on one objective can fully offset low scores in other objective. An alternative approach would be to use the geometric mean, which is non-compensatory, and fits with the view that high scores in one objective should not compensate low scores in the other. The comparison of the two aggregation approaches should be able to highlight the countries with unbalanced profiles because the geometric mean tends to penalize the existence of a low value, even when the other values are not so low.

As suggested in the literature (Michaela Saisana et al., 2011)(M. Saisana et al., 2005), the robustness assessment is based on Monte Carlo simulation and multi-modelling approach, assuming 'error free' data because eventual errors have been corrected in the preliminary stage of the construction. A Monte Carlo simulation comprised 1,000 runs of different sets of weights for the Environmental Health and Ecosystem Vitality policy objectives. The weights are the result of a random extraction based on uniform continuous distributions centred in the reference values (0.40 – 0.60) plus or minus 25% of this value. Two models were tested comparing the different aggregation formulas obtaining a total of 2,000 runs of simulation for the EPI. The main results are shown in Figure 3.

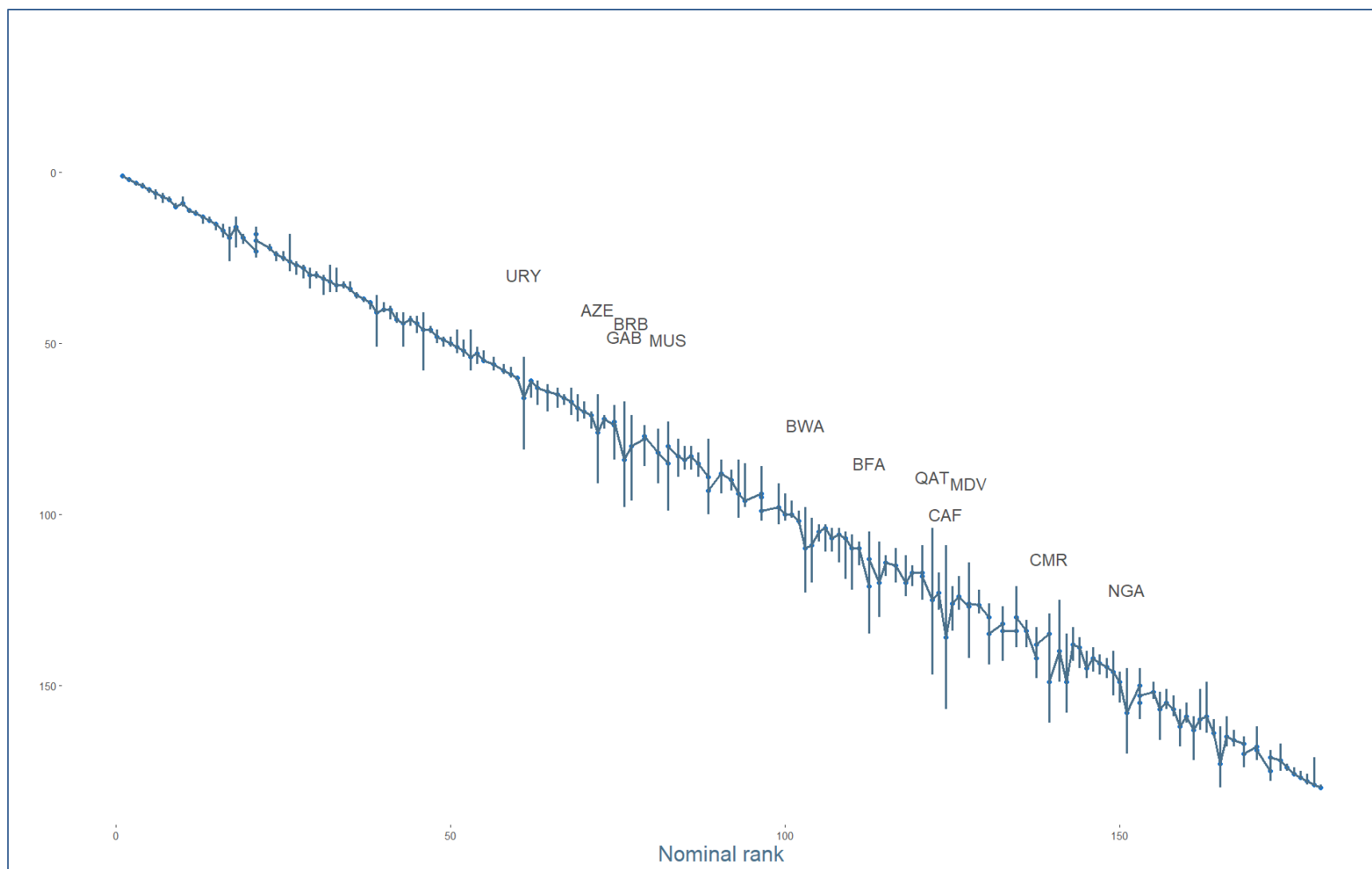


Figure 3. Robustness analysis (90% confidence intervals of ranks in descending order of nominal rank).

Note: Labelled countries have confidence intervals larger than 25 positions. Assumptions for the full framework.

Source: European Commission's Joint Research Centre, 2020.

The country ranks in the EPI are very close to the median rank. The simulated median in all countries shift less than ± 10 positions with respect to the nominal rank, with the exception of Central African Republic that shows a difference of 12 positions. In 95% of the countries, the shift is less than ± 5 positions. The uncertainty in the rankings, given the assumptions tested, is mostly modest, but there are some countries, which show particular sensitivity to changes.

There are 72% of countries that have 90% confidence intervals² of 10 places or less, out of which 40% have confidence intervals of five places or fewer. The average confidence interval size is about nine rank places, which, in the context of 180 countries, represents a rather small uncertainty.

A small number of countries have wider confidence intervals (9% of them have intervals wider than 20 places), with Central African Republic and Qatar in particular having an interval of 48 and 43 places respectively. The ranking of Cameroon and Gabon is also rather uncertain, with a confidence interval of more than 30 places. These stand-out cases are likely due to the fact that their scores in the two policy objectives are very different: Central African Republic, Cameroon and Gabon perform much better in Environmental Health than Ecosystem Vitality (36.9 vs 12.2, 33.6 vs 13.6 and 45.8 vs 27.9 respectively) while Qatar scores better in Ecosystem Vitality (56.9) and worse in Environmental Health (37.1). This means that for these countries any changes in the weighting and aggregation scheme have a great impact.

Overall, country ranks in EPI are fairly robust to changes in the policy objective weights and the aggregation formula for the majority of the countries considered. Special attention should be given to countries with very wide confidence intervals as they are less robust and they are especially sensitive to the assumptions made. One can also observe from Figure 1 that the confidence intervals are generally wider for mid-ranking countries, and narrower for top and bottom-ranking countries.

For full transparency and information, Annex I reports the EPI country ranks together with the simulated median ranks and 90% confidence intervals in order to better understand the robustness of these ranks to the computation methodology (choice of weights and aggregation formula) and analyse the behaviour of specific countries with respect to the perturbations.

The Monte Carlo results can also give an idea of sensitivity to the various assumptions. Figure 4 shows the median ranks of the EPI for simulations with arithmetic against geometric mean. This shows the sensitivity of the rankings only due to the change in the aggregation method. The plot shows an evident but fairly limited scatter, which implies that the alternative geometric mean assumption causes some noticeable rank shifts in a limited number of countries that prove to be less robust in this change. Furthermore, as can be seen in Figure 2, the countries with the bigger shifts (Central African Republic, Cameroon, Gabon, Botswana, Lesotho, Nigeria) lie above the line, which suggests that their ranks are penalized from a less compensatory approach such as the geometric mean.

² A 90% confidence interval means that, given the uncertainties tested, the rank falls within this interval with 90% probability.

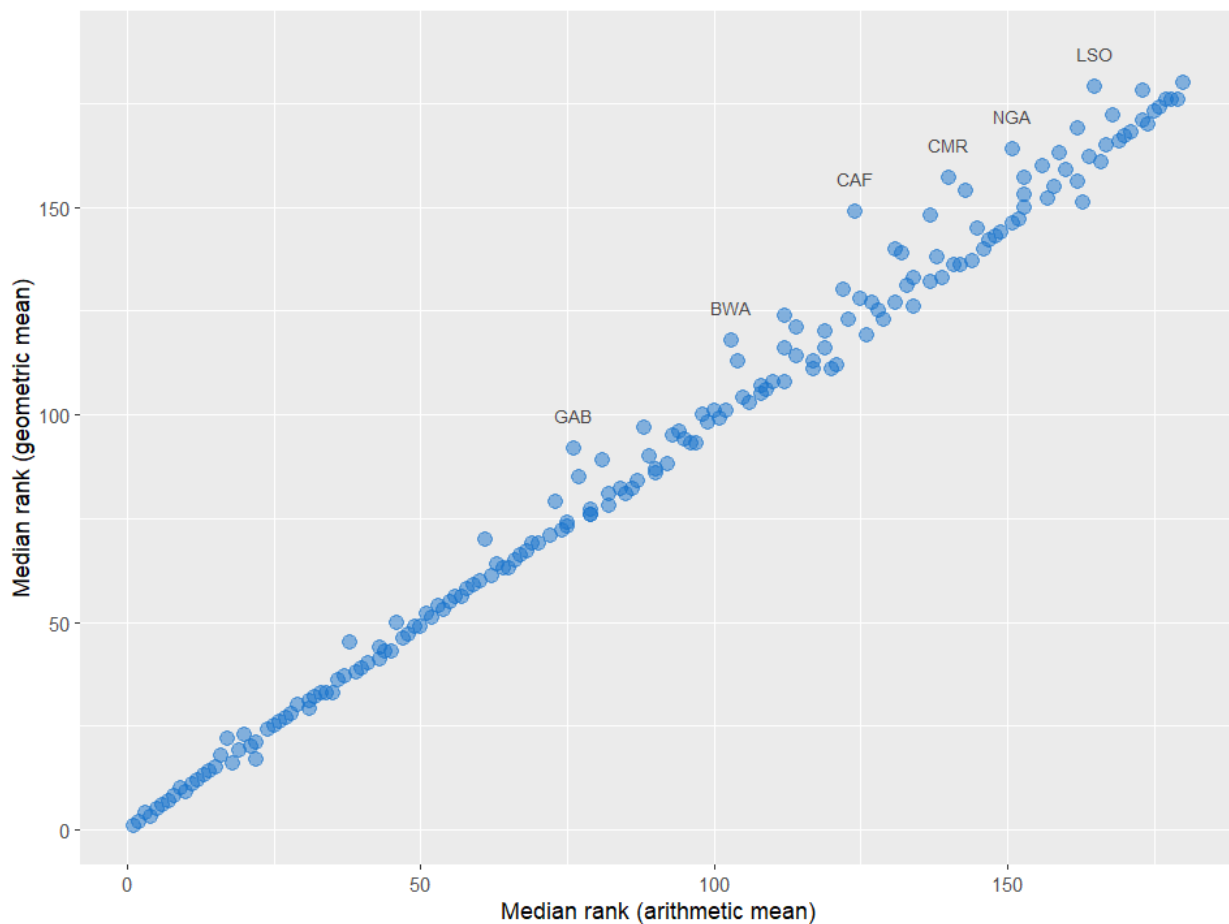


Figure 4. Median ranks of the EPI with arithmetic mean against geometric mean.

Source: European Commission's Joint Research Centre, 2020.

The uncertainty analysis is also complemented by a sensitivity exercise, in which the EPI ranking is compared with the rankings resulting from specific changes in the modelling assumptions, without the Monte Carlo stimulations.

Figure 5 shows the impact of excluding two issue categories – Ecosystem Services and Fisheries, that were found problematic due to missing data and absence of significant correlations (see sections 3.1 and 3.2). The main reason is to try to understand how this affects countries with materiality filters. The analysis shows that there are some considerable rank changes for some countries, as discussed below.

There are 37 countries (20%) with rank changes of more than 10 positions, out of which 21 are countries where materiality filters apply. The nine biggest rank change shifts (more than 22 positions) also occur to countries with materiality filters. This type of countries (highlighted in red in Figure 5) would decrease in rank positions in the reduced set in relation to the full set, while the rank position of countries without materiality filters (dark labels) would improve. This shows that some countries without materiality filters might be being penalized in their scores in the EPI. However, as discussed, in section 3.2, the problem with these two issue categories could only be addressed by conducting more research into consumption-based metrics, which the EPI team is currently doing so. Only in this way, the impact of each country in these two categories could be assessed, both from the consumption and production perspectives.

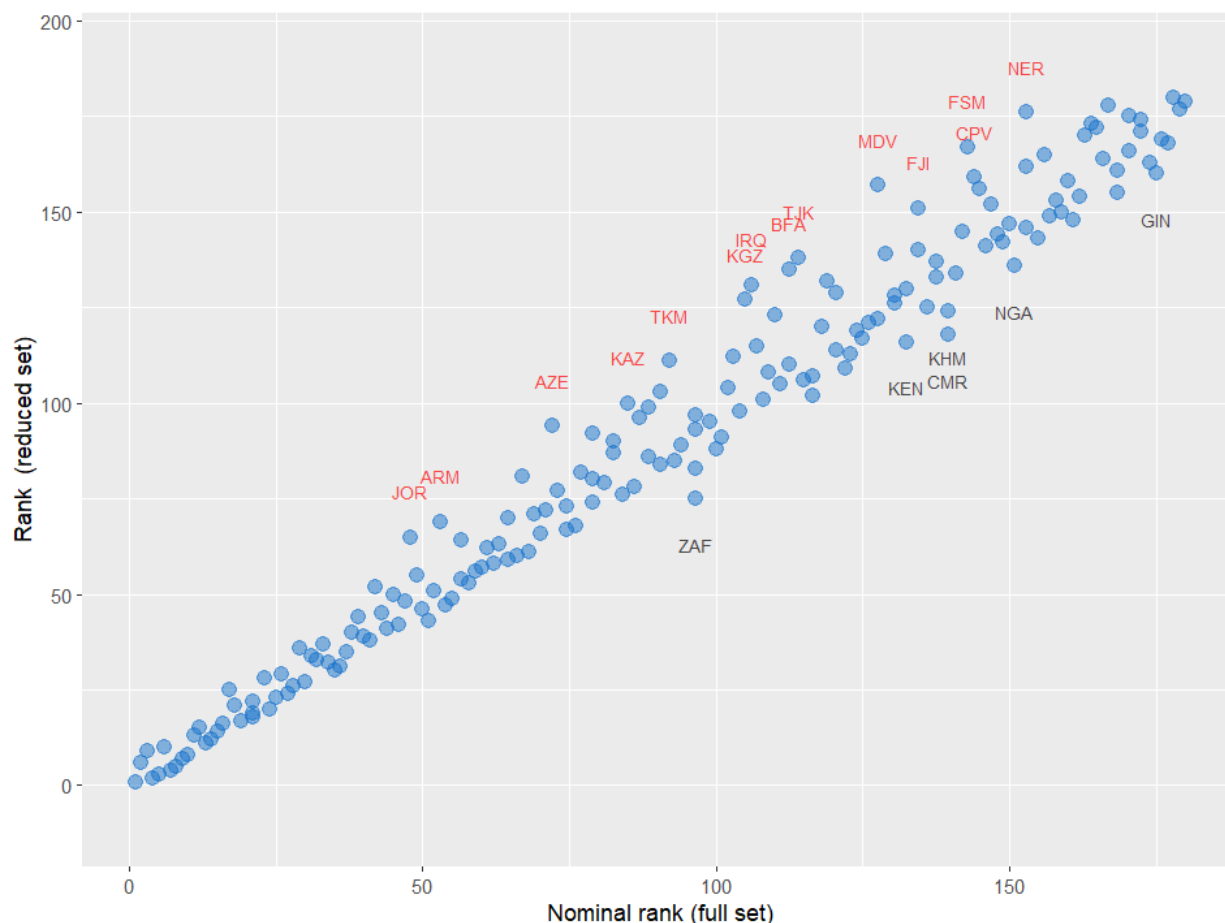


Figure 5. Ranks of the EPI with full set of issue categories against a reduced set (without Ecosystems Services and Fisheries).

Note: Labelled countries have a rank change greater than 15 positions. Countries with materiality filters and rank change greater than 15 are labelled in red.

Source: European Commission's Joint Research Centre, 2020.

In Figure 6, the index is computed with the geometric average of the policy objectives instead of the arithmetic one, with the same set of weights as the developers propose. The results are very similar to the ones shown in Figure 4 (using 1,000 stimulated weights). There are 10 countries with shifts by more than 10 positions and the largest shifts correspond to Central African Republic (25 positions) and Cameroon (16.5 positions).

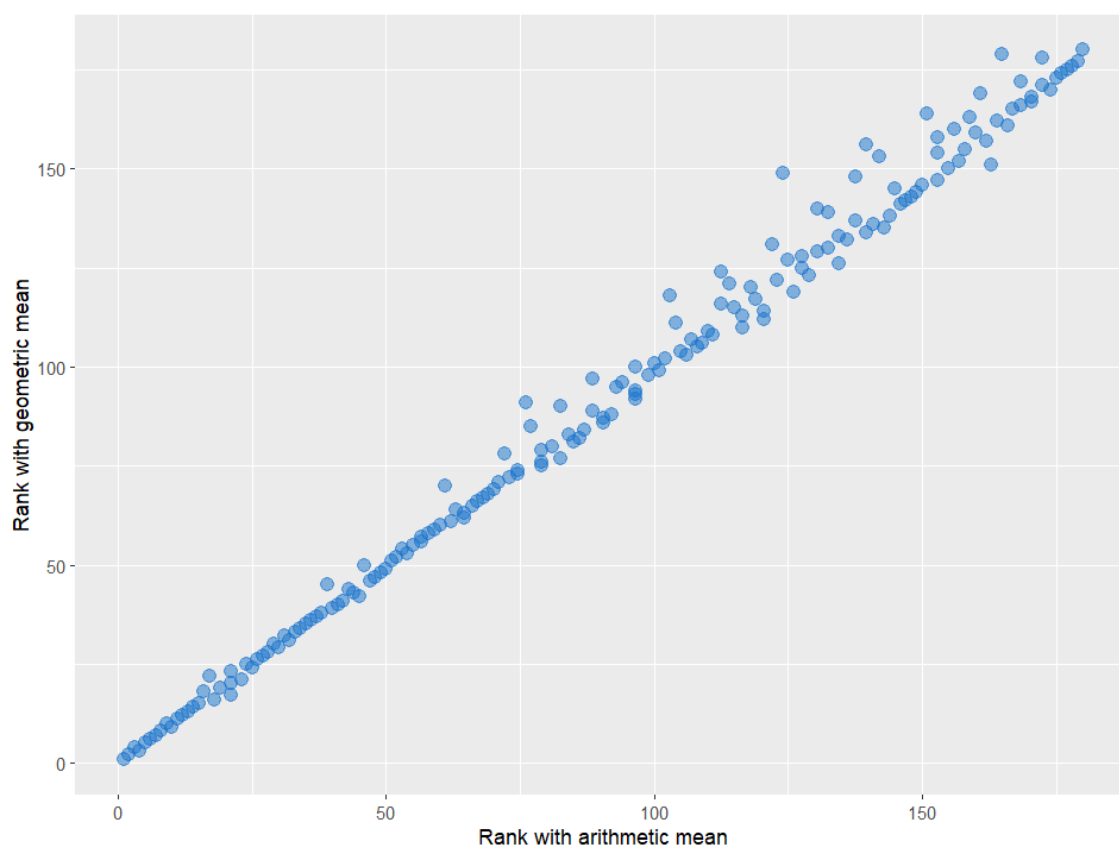


Figure 6. Ranks of the EPI with full set of indicators with arithmetic mean against geometric mean.

Source: European Commission's Joint Research Centre, 2020.

5 Conclusions

The JRC statistical audit delves into the extensive work carried out by the developers of the EPI with the aim of suggesting improvements in terms of data characteristics, structure and methods used. The analysis aims to ensure the transparency of the EPI methodology and the reliability of the results.

This report focuses on the assessment of the statistical coherence of the EPI by carrying out a multilevel analysis of the correlations within and across the indicators, issue categories and policy objectives as well as by an assessment of the impact of key modelling assumptions on the EPI ranking.

The analysis suggests that the EPI is statistically well balanced with respect to the two policy objectives. Correlations between each issue category and the respective policy objective are mostly significant and positive. All the indicators are more correlated with their own issue category than with any other issue category. The same is valid between issue categories and policy objectives. Overall, there are strong correlations between indicators and their corresponding issue category, policy objective and the index, thus suggesting that most of the indicators provide meaningful information on the variation of the category scores.

However, there are two issue categories, which show no significant correlation with the Ecosystem Vitality policy objective – Ecosystem Services and Fisheries, and thus do not contribute to the variation in the policy objective scores or in the EPI scores. We recommend revising the indicators in these two categories, possibly by including consumption-based indicators as more data in the future might become available. In this way, the performance of all countries, independently of their natural resource endowments, could be accounted.

The results of the uncertainty analysis reveal that for most countries, the confidence intervals are narrow enough for meaningful inferences to be drawn from the index: there is a shift of fewer than 10 positions for 50 of the 180 countries included in the EPI. Nevertheless, there are 16 countries³ with 90% confidence interval widths of more than 20 positions, and thus their ranks vary significantly with changes in weights and aggregation formula. Consequently, their ranks should be interpreted cautiously.

In general, the present audit confirms that the 2020 EPI meets the quality standards for statistical soundness and acknowledges the EPI as a reliable composite indicator to measure environmental performance worldwide. By looking beyond the overall index scores, the EPI allows to provide insights on its underlying categories where the real essence of a composite indicator lies.

The EPI has been the result of 20 years of research and constant refinements, bringing a first-of-its-kind composite measure to the global environmental policy arena.

³ Central African Republic, Qatar, Cameroon, Gabon, Burkina Faso, Maldives, Uruguay, Azerbaijan, Mauritius, Botswana, Nigeria, Barbados, Vietnam, Pakistan, Tajikistan and Uzbekistan.

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Annex I. Median ranks of countries with 90% confidence intervals

Countries ordered by nominal rank.

| Country | Median rank | Country | Median rank |
|-----------------------------|--------------|-------------------------------------|----------------|
| 1 Denmark | 1 [1, 1] | 46 Brunei Darussalam | 46 [41, 58] |
| 2 Luxembourg | 2 [2, 2] | 47 Kuwait | 46 [45, 47] |
| 3 Switzerland | 3 [3, 4] | 48 Jordan | 48 [46, 50] |
| 4 United Kingdom | 4 [3, 4] | 49 Belarus | 49 [48, 51] |
| 5 France | 5 [5, 6] | 50 Colombia | 50 [48, 51] |
| 6 Austria | 6 [5, 8] | 51 Mexico | 51 [46, 53] |
| 7 Finland | 7 [6, 9] | 52 Costa Rica | 52 [49, 54] |
| 8 Sweden | 8 [7, 8] | 53 Armenia | 54 [46, 58] |
| 9 Norway | 10 [9, 10] | 54 Argentina | 53 [51, 56] |
| 10 Germany | 9 [7, 10] | 55 Brazil | 55 [52, 55] |
| 11 Netherlands | 11 [11, 12] | 57 Bahrain | 56 [54, 58] |
| 12 Japan | 12 [11, 12] | 57 Ecuador | 56 [55, 57] |
| 13 Australia | 13 [13, 15] | 58 Russia | 58 [56, 59] |
| 14 Spain | 14 [13, 14] | 59 Venezuela | 59 [57, 60] |
| 15 Belgium | 15 [15, 17] | 60 Ukraine | 60 [60, 61] |
| 16 Ireland | 17 [15, 19] | 61 Uruguay | 66 [54, 81] |
| 17 Iceland | 19 [16, 26] | 62 Albania | 61 [61, 66] |
| 18 Slovenia | 16 [13, 22] | 63 Antigua and Barbuda | 63 [61, 68] |
| 19 New Zealand | 19 [18, 21] | 65 Cuba | 64 [62, 65] |
| 21 Canada | 23 [18, 25] | 65 Saint Vincent and the Grenadines | 64 [62, 70] |
| 21 Czech Republic | 18 [16, 24] | 66 Jamaica | 65 [63, 69] |
| 21 Italy | 20 [19, 21] | 67 Iran | 66 [65, 68] |
| 23 Malta | 22 [21, 23] | 68 Malaysia | 67 [63, 71] |
| 24 United States of America | 24 [23, 26] | 69 Trinidad and Tobago | 69 [65, 73] |
| 25 Greece | 25 [23, 26] | 70 Panama | 70 [67, 72] |
| 26 Slovakia | 26 [18, 29] | 71 Tunisia | 71 [70, 75] |
| 27 Portugal | 27 [26, 30] | 72 Azerbaijan | 76 [65, 91] |
| 28 South Korea | 28 [27, 31] | 73 Paraguay | 72 [71, 75] |
| 29 Israel | 30 [28, 34] | 75 Dominican Republic | 74 [68, 84] |
| 30 Estonia | 30 [29, 31] | 75 Montenegro | 73 [72, 76] |
| 31 Cyprus | 31 [30, 36] | 76 Gabon | 84 [67, 98] |
| 32 Romania | 32 [27, 35] | 77 Barbados | 80 [71, 96] |
| 33 Hungary | 33 [28, 35] | 79 Bosnia and Herzegovina | 78 [75, 80] |
| 34 Croatia | 33 [32, 34] | 79 Lebanon | 78 [74, 86] |
| 35 Lithuania | 34 [32, 35] | 79 Thailand | 77 [74, 83] |
| 36 Latvia | 36 [35, 37] | 81 Suriname | 82 [75, 91] |
| 37 Poland | 37 [37, 38] | 83 Mauritius | 85 [73, 99] |
| 38 Seychelles | 38 [38, 40] | 83 Tonga | 80 [78, 83] |
| 39 Singapore | 41 [36, 51] | 84 Algeria | 83 [78, 89] |
| 40 Taiwan | 40 [38, 41] | 85 Kazakhstan | 84 [80, 87] |
| 41 Bulgaria | 40 [39, 43] | 86 Dominica | 83 [80, 87] |
| 42 United Arab Emirates | 43 [41, 44] | 87 Moldova | 85 [82, 89] |
| 43 North Macedonia | 44 [41, 51] | 89 Bolivia | 89 [80, 95] |
| 44 Chile | 43 [42, 45] | 89 Uzbekistan | 93 [78, 100] |
| 45 Serbia | 44 [42, 47] | 91 Peru | 88 [85, 91] |
| 91 Saudi Arabia | 88 [84, 94] | 136 Mozambique | 134 [131, 139] |
| 92 Turkmenistan | 90 [87, 93] | 138 Rwanda | 138 [134, 140] |
| 93 Bahamas | 94 [84, 101] | 138 Eswatini | 142 [133, 148] |
| 94 Egypt | 96 [85, 98] | 140 Cameroon | 149 [130, 161] |

| Country | Median rank | Country | Median rank |
|------------------------------|------------------|-----------------------|------------------|
| 97 Grenada | 95 [92, 98] | 140 Cambodia | 135 [129, 141] |
| 97 Saint Lucia | 94 [90, 99] | 141 Viet Nam | 140 [125, 149] |
| 97 El Salvador | 94 [91, 97] | 142 Pakistan | 149 [135, 158] |
| 97 South Africa | 99 [86, 102] | 143 Micronesia | 138 [133, 143] |
| 99 Turkey | 98 [91, 103] | 144 Cabo Verde | 139 [136, 145] |
| 100 Morocco | 100 [94, 102] | 145 Nepal | 145 [140, 148] |
| 101 Belize | 100 [96, 101] | 146 Papua New Guinea | 142 [139, 146] |
| 102 Georgia | 102 [99, 103] | 147 Mongolia | 143.5 [141, 147] |
| 103 Botswana | 110 [98, 123] | 148 Comoros | 144.5 [142, 148] |
| 104 Namibia | 109 [101, 120] | 149 Guatemala | 146 [140, 153] |
| 105 Kyrgyzstan | 105 [103, 108] | 150 Tanzania | 149 [146, 155] |
| 106 Iraq | 104 [103, 111] | 151 Nigeria | 158 [145, 170] |
| 107 Bhutan | 107 [104, 111] | 153 Republic of Congo | 153 [151, 155] |
| 108 Nicaragua | 106 [104, 114] | 153 Marshall Islands | 150 [145, 160] |
| 109 Sri Lanka | 107 [105, 119] | 153 Niger | 155 [150, 158] |
| 110 Oman | 110 [106, 122] | 155 Senegal | 152 [149, 154] |
| 111 Philippines | 110 [108, 115] | 156 Eritrea | 157 [152, 166] |
| 113 Burkina Faso | 121 [105, 135] | 157 Benin | 155 [151, 157] |
| 113 Malawi | 113 [110, 119] | 158 Angola | 157 [153, 159] |
| 114 Tajikistan | 120 [108, 130] | 159 Togo | 162 [157, 168] |
| 115 Equatorial Guinea | 114 [112, 118] | 160 Mali | 159 [155, 161] |
| 117 Honduras | 115 [110, 120] | 161 Guinea-Bissau | 163 [159, 172] |
| 117 Indonesia | 115 [113, 119] | 162 Bangladesh | 160 [151, 163] |
| 118 Kiribati | 120 [112, 124] | 163 Vanuatu | 159 [149, 164] |
| 119 São Tomé and Príncipe | 117 [115, 121] | 164 Djibouti | 164 [160, 165] |
| 121 China | 117 [109, 123] | 165 Lesotho | 173 [162, 180] |
| 121 Samoa | 118 [109, 125] | 166 Gambia | 165 [159, 168] |
| 122 Qatar | 125 [104, 147] | 167 Mauritania | 166 [163, 168] |
| 123 Zimbabwe | 123 [117, 128] | 169 Ghana | 167 [165, 169] |
| 124 Central African Republic | 136 [109, 157] | 169 India | 170 [166, 174] |
| 125 Dem. Rep. Congo | 126 [121, 134] | 171 Burundi | 168 [162, 171] |
| 126 Guyana | 124 [118, 128] | 171 Haiti | 169 [163, 172] |
| 128 Maldives | 127 [114, 142] | 173 Solomon Islands | 171 [169, 173] |
| 128 Uganda | 126 [124, 128] | 173 Chad | 175 [170, 178] |
| 129 Timor-Leste | 126.5 [122, 129] | 174 Madagascar | 172 [167, 175] |
| 131 Laos | 130 [127, 132] | 175 Guinea | 174 [173, 175] |
| 131 Sudan | 135 [126, 144] | 176 Côte d'Ivoire | 176 [174, 176] |
| 133 Kenya | 132 [128, 133] | 177 Sierra Leone | 177 [175, 177] |
| 133 Zambia | 134 [127, 143] | 178 Afghanistan | 178 [176, 179] |
| 135 Ethiopia | 134 [129, 136] | 179 Myanmar | 179 [171, 179] |
| 135 Fiji | 130 [121, 139] | 180 Liberia | 180 [179, 180] |

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