

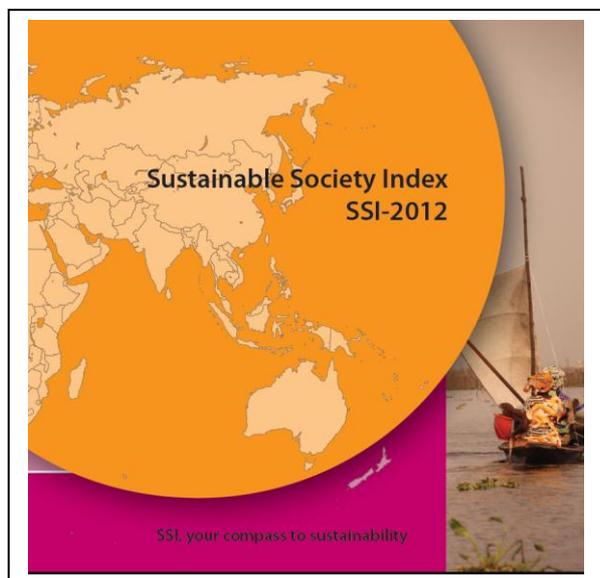


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Sustainable Society Index (SSI): Taking societies' pulse along social, environmental and economic issues

The Joint Research Centre
audit on the SSI



Michaela Saisana, Dionisis Philippas

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Contact information

Michaela Saisana, Dionisis Philippas

Address: Joint Research Centre, Via Enrico Fermi 2749, TP 361, 21027 Ispra (VA), Italy

E-mail: michaela.saisana@jrc.ec.europa.eu, dionysios.filippas@jrc.ec.europa.eu

Tel.: +39 0332 78 6572

Fax: +39 0332 78 5733

<http://composite-indicators.jrc.ec.europa.eu/>

<http://www.jrc.ec.europa.eu/>

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Executive Summary

A ‘sustainable society’ is considered to be a society that is economically viable, environmentally sound and socially responsible. Developing a gauge of economic, environmental and social progress has been on the international agenda for at least two decades. At the European level, it has received a boost from the publication of the 2009 Stiglitz-Sen-Fitoussi Report and from the political meta-framework of the Europe 2020 strategy.

In this context, the Sustainable Society Foundation in the Netherlands has been developing since 2006 the Sustainable Society Index (SSI) that aims to be a comprehensive and quantitative method to measure and monitor the health of coupled human-environmental systems at national level worldwide. The SSI framework departs from a purely protectionist approach that would aim to maintain natural systems with minimal human impact. It aims instead to describe societal progress along all three dimensions: human, environmental and economic. To this end, the SSI comprises eight policy categories and three Wellbeing dimensions (Human, Environmental, Economic) and is calculated for 151 countries accounting for 99% of the world population.

The Econometrics and Applied Statistics Unit at the European Commission Joint Research Centre (JRC) in Ispra-Italy was invited by the Sustainable Society Foundation to audit and refine the SSI. The JRC analysis was based on an in-house quality control process¹ that aims to ensure the transparency of the SSI methodology and the reliability of the results. The JRC recommendations on the revision of the framework together with fine-tuning suggestions related to indicator calculation formulas were taken into account in the final version of the SSI model. In this way, the development of the SSI-2012 moved from a one-way design process to an iterative process with the JRC with a view to arrive at a balanced index, where no indicator dominates the results and no indicator is only cosmetic to the framework.

This report touches upon the necessity for going beyond GDP in order to assess societal progress, presents the new SSI-2012 framework, the revisions made with respect to the previous framework and the rationale behind the selection of the indicators. A total of 21 indicators were selected from fifteen sources, such as the Food and Agriculture Organization, World Health

¹The JRC analysis was based on the recommendations of the OECD (2008) Handbook on Composite Indicators, and on more recent research from the JRC. The JRC conducts auditing studies of composite indicators upon request of the index developers. For more information visit: <http://composite-indicators.jrc.ec.europa.eu>

Organization, UNESCO, World Economic Forum, World Bank and International Monetary Fund.

The revised methodology used to calculate the SSI components includes data quality issues (missing data, possible outliers), choice of normalization, weighting and aggregation formula. Raw data are first checked for reporting errors and outliers that could strongly bias the results are treated. The indicators are normalized using the min-max method in 1-10 scale (10 = most sustainable score) and aggregated into eight SSI categories by simple geometric mean. Three SSI Wellbeing dimensions are calculated as the geometric mean of the underlying categories. In the SSI-2012, the aggregation formula was changed from an arithmetic to a geometric mean, because the latter formula: (a) implies only partial substitutability, i.e. poor performance in one indicator cannot be fully compensated by good performance in another, (b) rewards balance by penalizing uneven performance in the underlying indicators, (c) provides incentives for improvement in the weak dimensions: the geometric mean considers that the lower the performance in a particular indicator, the more urgent it becomes to improve achievements in that indicator.

The statistical coherence of the SSI framework is first assessed by analyzing the covariance structure within and across the categories and the dimensions. The analysis confirms that the SSI is well-structured, as the indicators are more correlated to their own category than to any other category and all correlations within a category are significant and positive. Same conclusion is drawn at the dimension level. Second, an assessment of the implicit weights via non-linear methods (kernel smoothing regression) reveals that in most SSI categories the underlying indicators have similar implicit weights in classifying countries within each category, though some indicators are slightly more important than others. A few imbalances were found within the Transition and the Economy category. Before deciding whether to adjust the nominal weights of the indicators whose implicit weight was much lower than what would have been expected given the equal nominal weights, the marginal weights (sensitivity of SSI categories to 10% change in the underlying indicators keeping all other indicators fixed) were analyzed. It was found that the marginal weights of the indicators on the SSI categories scores do not differ too much. All things considered, had the objective of the SSI components been to merely provide a ranking of countries, then the few imbalances in the implicit weights would have necessitated some methodological refinements (for example adjusting the nominal weights from equal to unequal). However, since the primary aim of the SSI components is to benchmark country performance with respect to a perfect 10 score, looking at the marginal weights, which convey exactly this piece of information is more relevant in this context. Upon all these considerations,

the SSI team, together with the JRC decided not to alter the nominal weights for the indicators but to keep them equal.

A robustness analysis of country ranks for each SSI Wellbeing dimension is conducted to assess to what extent the results depend on the selected set of indicators or on the methodological judgments (normalization and weighting) made during the development of the SSI. Overall, country ranks in any of the SSI Wellbeing dimensions are supported by the simulations, whereby 90% of the countries shift less than ± 1 position with respect to the simulated median. These results suggest that the SSI-2012 provides a reliable picture of the countries' performance, that is not driven by methodological assumptions. Some countries with wide intervals in the simulations are flagged in order to give more transparency in the entire process and to help appreciate the uncertainty in the SSI results for those countries.

Key results on the world landscape of societies' achievements confirm the inverted shaped relationship between economic and environmental wellbeing (known as Environmental Kuznets Curve). The Environmental Wellbeing has a strong and negative correlation to the Human Wellbeing and to the Economic Wellbeing. It appears, thereafter, that the Human and Economic Wellbeing go hand-in-hand in several countries, but often at the expense of the Environmental Wellbeing. Fortunately, this is not the case for all countries. Furthermore, while country scores on the SSI wellbeing dimensions provide a quantitative indication of societies' achievement, changes in the wellbeing variability convey information on the quality of the changes: an increase in a Wellbeing dimension may be achieved by improving performance in specific indicators, but also by reducing gaps in performance between indicators. Countries with higher levels of Wellbeing performance exhibit less variability since they tend to achieve high values in all the underlying indicators. The opposite holds generally true for countries with lower levels of achievement (scissors' pattern). This reflects the fact that countries with lower levels of achievement generally display larger discrepancies in performance between indicators, and that focusing only on particular indicators while allowing performance gaps between them yields only marginal results. Results also show that countries with similar scores on a Wellbeing dimension do not necessarily have the same performance on the underlying categories of sustainability. Hence, it is important to delve into the SSI components in order to identify where and why some sustainability policies work well and where they do not.

In a nutshell, all JRC's recommendations have been implemented in the new update of the SSI-2012, and the overall conclusions of this audit are:

1. *The revised SSI framework is conceptually coherent:*

- the indicators are more correlated to their own category than to any other category;
- all correlations within a category are significant and positive;
- the same conclusions are drawn at the dimension level.

2. *The revised SSI framework meets the statistical requirements set by JRC:*

- in most SSI categories the underlying indicators have similar implicit weights in classifying countries within each category;
- few imbalances were found within the Transition and the Economy category;
- the marginal weights of the indicators on the SSI categories scores do not differ too much;
- the robustness analysis of country ranks for each SSI Wellbeing dimension showed that the SSI provides a reliable picture of the countries' performance, that is not driven by methodological assumptions.

3. *The SSI is well suited to assess nations' development towards sustainability in its broad sense: Human, Environmental and Economic Wellbeing:*

- the SSI framework goes beyond a purely protectionist approach that would aim to maintain natural systems with minimal human impact;
- it describes societal progress along all three dimensions: human, environmental and economic, built on 21 indicators;
- it is a conceptually and statistically sound tool, that is widely applicable for on-going assessment of the human-environmental systems;
- it can be used to simulate the consequences of a range of potential actions, providing a powerful tool to inform decisions about how to achieve human and economic growth without compromising the environmental wellbeing.

1. Introduction

A ‘sustainable society’ is commonly used to declare a society that is economically viable, environmentally sound and socially responsible. Developing a gauge of economic, environmental and social progress has been on the international agenda for at least two decades (first publication of the Human Development Report in 1990). At the European level, it has received a boost from the publication of the Stiglitz-Sen-Fitoussi Report and from the political meta-framework of the Europe 2020 strategy. Additionally, the banking crisis of 2008, which led the world to the brink of financial disaster and shook the dominant economic model to its foundation, had a paradoxical effect on GDP: it increased its pertinence as a universal and easy mode of measurement of the progress and setbacks of states in preserving a level of economic activity but it has also stressed the need to revitalize another conception of growth, that goes beyond pure economic parameters. At the time of the writing of this report, a Google search on sustainability gave 124 million hits, whilst a search on gross domestic product resulted in merely 22 million hits. Certainly, this simple anecdote does not prove that sustainability is more important than GDP. Nevertheless, it may indicate that the concept of sustainability is already well rooted as a concern in people’s daily lives.

In a world with over seven billion people, there is urgent and constant need of new analytical approaches to guide how to balance multiple competing and potentially conflicting public goals and connect human development with the earth’s capacity to sustain progress. Without a framework to define and guide the measurement of sustainable societies, policy management will resort to assessments that are less transparent, more subjective and that lack standardisation across locations and through time.

In this context, the Sustainable Society Foundation in the Netherlands has been developing since 2006 the Sustainable Society Index (SSI) that aims to be a comprehensive and quantitative method to measure and monitor the health of coupled human-environmental systems. The SSI comprises eight policy categories and three Wellbeing dimensions (Human, Environmental, Economic) and is calculated for 151 countries around the world accounting for 99% of the world population. Globally, the 2012 index score for Human Wellbeing is 6.2 out of 10, for Environmental Wellbeing is 4.5, and for Economic Wellbeing is 3.8, with developed countries generally performing better than developing countries on Human and Economic Wellbeing, but worse on Environmental Wellbeing, yet with notable exceptions. On Human Wellbeing, only

42% of countries score higher than 7, whereas 23% score lower than 5. On Environmental Wellbeing, only 14% of the countries score higher than 7, whereas 61% score lower than 5. Finally, on Economic Wellbeing, only 7% of countries score higher than 7, whereas 78% score lower than 5.

Measuring and summarizing the complex concepts underlying a sustainable society, such as biodiversity, good governance, healthy life, employment and others, with single index numbers as attempted by the Sustainable Society Foundation in its fourth release of the SSI-2012, raises several practical challenges (Van de Kerk & Manuel, 2012). These challenges include the selection of indicators, the quality of data and the statistical combination of these into a model. Yet, if done properly, the exercise could yield a useful tool capable of assessing nations' development efforts following more or less sustainable paths. The tool could be used to raise public awareness, benchmark across space and time, monitor changes, identify problems, contribute to priority setting and policy formulation and prioritize scientific research.

The Econometrics and Applied Statistics Unit at the European Commission Joint Research Centre (JRC) in Ispra-Italy was invited by the Sustainable Society Foundation to audit the SSI along two main issues: the conceptual and statistical coherence of the structure, and the impact of key modeling assumptions on the SSI scores and ranks over 2006-2012. The JRC has researched extensively on the complexity of composite indicators and ranking systems that classify countries' performances along policy lines (Saisana *et al.*, 2005; 2011; Saltelli *et al.* 2008). The JRC recommendations for revising the structure of the index, together with fine-tuning suggestions, for example in some of the indicator calculation formulas, were taken into account in the final version of the SSI model. In this way, the development of the SSI-2012 moved from a one-way design process to an iterative process with the JRC with a view to set the foundation for a balanced index.

The report is structured as follows.

Section 2 touches upon the necessity to go beyond GDP in order to assess societal progress, presents the new SSI-2012 framework, the revisions made with respect to the previous framework and the rationale behind the selection of the indicators.

Section 3 discusses the methodological approach used to calculate the SSI components: data quality issues (missing data, possible outliers), choice of normalization, weighting and aggregation formula.

Section 4 analyzes the statistical coherence of the SSI framework based on an analysis of the covariance structure within and across the categories and the dimensions.

Section 5 discusses whether aggregating the SSI components into an overall index, a temptation particularly appealing for media communication, is methodologically sound.

Section 6 assesses the robustness of country ranks for each SSI Wellbeing dimension, with a view to examine to what extent the results depend on the selected set of indicators or on the methodological judgments made during the development of the SSI.

Section 7 offers key messages on the world landscape of societies' achievements, beyond those already presented in the SSI-2012 report.

Section 8 provides a summary of the conclusions.

2. Sustainable Society Index - Framework

Background

Sustainable societies are considered to be those societies with mutually reinforcing policies that protect the environment, create jobs and build scaled growth economies aiming altogether to achieve a high quality of life which has to be sustained and constantly improved. In other words, the notion of sustainability implies a mutual dynamic balance between social well-being, economic growth, and environmental quality. This balance is widely recognized by various international organizations such as the International Union for Conservation of Nature (IUCN), the United Nations Environment Programme (UNEP) and the World Wildlife Fund (WWF) in their definition of sustainable development as ‘Improving the quality of life of humans while living within the carrying capacity of supporting ecosystems’.

The term ‘sustainable society’ is also commonly used by politicians and economists to declare a society that is economically viable, environmentally sound and socially responsible. Yet, the complexity of interdependencies among emerging global environmental changes and the tremendous changes in social and economic issues make the measurement and attainment of sustainability very difficult.

Aiming for sustainability implies in the first hand defining its components in measurable terms and clearly fixing the responsibility to assess progress comprehensively (Hales and Prescott-Allen, 2002). Nevertheless, the notion of what is meant by sustainability varies considerably. No wonder that the relevant literature is abundant with studies on sustainability (Hák et al., 2007; Arezki and Van Der Ploeg, 2007; Bell and Morse, 2003; Betsill and Rabe, 2009; Guy and Kibert, 1998; Meadows, 1998). Table 1 lists over 30 aggregated measures that attempt to describe either sustainability or more generally societal progress in a quantitative way. It is evident that there is a wealth of indices that attempt to quantify sustainability in its broad sense or to emphasize particular issues, and these studies vary in the number of indicators and updating. Yet when it comes to measuring progress along human, environmental and economic issues, a tool that is sound and regularly updated would be needed.

Table 1. Overview of Indices of Sustainability or Societal Progress

Indices of Societal Progress	Developer(s)	Main Dimensions	Description	Number of indicators	Number of units assessed
Human Development Index (HDI, 2011)	United Nations Development Programme	1) Life expectancy index, 2) Education index, 3) Income index	The index introduces a measuring development by combining indicators of life expectancy, educational attainment and income	4	187 countries
Human Sustainable Development Index (HSDI, 2010)	Chuluun Togtokh & Owen Gaffney and; UNEP	Same as HDI but with GHG emissions per capita		5	163 countries
EU Regional Human Development Index (2010)	European Commission	1) Health, 2) Education, 3) Income	It includes healthy life expectancy, net adjusted household income ¹⁶ and low and high educational attainment for people aged 25–64	3	27 EU countries
Environmental Sustainability Index (ESI, 2005)	Yale University, Columbia University	1) Environmental Systems, 2) Reducing Stresses, 3) Reducing Human Vulnerability, 4) Social and Institutional Capacity and 5) Global Stewardship.	The ESI benchmarks the ability of nations to protect the environment over the next several decades	21	146 countries
Environmental Performance Index (EPI, 2012)	Yale University, Columbia University	1) Environmental burden of disease, 2) water (effects on human health), 3) air pollution (effects on human health), 4) air pollution (ecosystem effects), 5) water resources (ecosystem effects), 6) biodiversity and habitat, 7) forestry, 8) fisheries, 9) agriculture, 10) climate change.	EPI indicators focus on measurable outcomes such as emissions or deforestation rates rather than policy inputs	22	132 countries
Commitment to Development Index (CDI, 2002)	Center for Global Development	1) Quantity and quality of foreign aid, 2) Openness to exports, 3) Policies that encourage investment, 4) Migration policies, 5) Environmental policies, 6) Security policies, 7) Support for technology creation and dissemination	It contains 27 rich countries on their dedication to policies that benefit the 5.5 billion people living in poorer nations and gives the level of support given to poor countries to realize prosperity, good governance and security. It is composed of seven components: aid, trade, investment, migration, environment, security, and technology.	7	27 countries
Index for Sustainable Economic Welfare (ISEW) - Genuine Progress Indicator (GPI)	Philip A. Lawn (2003)	1) personal consumption, 2) public non-defensive expenditures, 3) private defensive expenditures, 4) capital formation, 5) services from domestic labour, 6) costs of environmental degradation, 7) depreciation of natural capital	Indicators from 12 countries	20-25	12

Indices of Societal Progress	Developer(s)	Main Dimensions	Description	Number of indicators	Number of units assessed
Ecological Footprint (2012)	National Footprint Accounts in WWF's <i>Living Planet Report</i> .	1) Carbon uptake land 2) Grazing land 3) Forest land 4) Fishing ground 5) Cropland 6) Built-up land.	A data set of individual consumption items, materials, required area on earth, the number of hectares per capita	6	232 countries
Human Wellbeing Index (HWI)	Robert Prescott-Allen (2001)	HWI: 1) Health and population, 2) Wealth, 3) Knowledge and culture, 4) Community, 5) Equity EWI: 1, Land, 2) water, 3) Air, 4) Species and genes, 5) Resource use	The HWI and EWI are comprehensive measures of the quality of life and the environment. The Wellbeing Index juxtaposes the HWI and EWI so they can be compared while the WSI shows how much human wellbeing each nation obtains for the amount of ecosystem stress it causes	36 (HWI) 51 (EWI)	180 countries
Ecosystem Wellbeing Index (EWI)					
Wellbeing Index (WI)					
Wellbeing Stress Index (WSI)					
Sustainability Rating (2011)	Credit Suisse	1) Social, 2) Environment 3) Economics	The index evaluates the sustainability, based on 100 largely quantitative, but in part also qualitative, environmental and social aspects	100	30 OECD countries
Australian SAM Sustainability Index (AuSSI, 2012)	SAM Group	1) Economic, 2) Environment, 3) Social	The AuSSI comprises the top sustainability-driven companies from each of 21 industry clusters covering the entire Australian economy	38	21 industry clusters (200 largest Australian companies in the Dow Jones Global Total Stock Market Index)
FEEM Sustainability Index (FEEM SI methodology report 2011)	Fondo Eni Enrico Mattei (2009)	1) Economic, 2) Environment, 3) Social	The index is built within a dynamic model for sustainability, which allows to project different scenarios in the future.	18	40 countries
Welfare Index (2010)	Charles I. Jones Stanford GSB and NBER Peter J. Klenow Stanford University and NBER	1)life expectancy, 2) Income and Consumption, 3)Leisure, 4) Inequality	The index aims to describe the level of welfare in 134 countries and the efficiency of these countries to create a high economic standard and welfare for their citizens	8	134 countries

Indices of Societal Progress	Developer(s)	Main Dimensions	Description	Number of indicators	Number of units assessed
American Human Development Index (2011)	American Human Development Project	1) Health, 2) Education, 3) Income	The American HDI measures the same three basic dimensions as the standard HDI, but it uses different indicators to better reflect the U.S. context and to maximize use of available data	4	50 US states
Environmental Vulnerability Index (EVI, 2005)	SOPAC	1) Climate Change, 2) Biodiversity, 3) Water, 4) Agriculture and fisheries, 5) Human health aspects, 6) Desertification, 7) Exposure to Natural disasters	The EVI is based on 50 indicators for estimating the vulnerability of the environment of a country to future shocks	50	235 countries
Environmental Degradation Index (EDI, 2006)	Raghbendra Jha, KV Bhanu Murthy & Australian National University and U of Delhi	1) Annual per capita fresh water withdrawals, 2) Printing and writing paper consumed per capita, 3) Per capita CO2 emission 4) Share of world total CO2	The data are observations among both the environmental and consumption related variables	4	174 countries
Canadian Index of Wellbeing (CIW, 2011)	Institute of Wellbeing	1) Culture and recreation, 2) community vitality, 3) democratic engagement, 4) education, 5) environment, 6) healthy populations, 7) living standards 8) time use	It measures the quality of life of Canadians that matter: standard of living, health, the quality of environment, education and skill levels, the way of using time, the vitality of communities, the participation in the democratic process, and the state of arts.	~80	1 country (Canada)
Best Performing Cities (2011)	Milken Institute	1) Job growth, 2) Wage and salary growth, 3) technology growth, 4) GDP growth, 5) population	The index measures growth in jobs, wages and salaries, and technology output over a five-year span (2004– 2009 for jobs and technology output and 2003-2008 for wages and salaries) to adjust for extreme variations in business cycles.	10	200 US Metropolitan areas
European Cities Monitor (2011)	CUSHMAN & WAKEFIELD	1) Easy access to markets, customers or clients 2) Availability of quality staff 3) Quality of telecommunications 4) Transport links with other cities and internationally. 5) Ease of travelling within the city 6) Languages spoken 7) Cost of staff 8) Value for money 9) Climate created by government for business through tax policies or financial incentives 10) Quality of life 11) Availability of office 12) Freedom from pollution	In total, 500 companies were surveyed from nine European countries. It is a representative sample, selected from “Europe’s largest companies”, of industrial, consumer, retail & distribution companies and professional services companies were included	12	36 European cities

Indices of Societal Progress	Developer(s)	Main Dimensions	Description	Number of indicators	Number of units assessed
European Smart Cities (2011)	Edinburgh Napier University	1) Economy 2) People 3) Governance 4) Mobility 5) Environment 6) Smart Living	It assesses medium-sized cities and their perspectives for development. For the ranking two criteria were selected: Cities should be of medium size and they should be covered by accessible and relevant databases. It covers almost cities 1,600 cities in the Espon space (EU27+NO+CH) with data on population and some functional data	75	70 European cities
European Green City Index (2010)	Siemens and Economist Intelligence Unit (EIU)	1) CO2 Emissions 2) Energy 3) Buildings 4) Transportation 5) Water 6) Air 7) Waste/Land Use 8) Environmental Governance	It compares the environmental performance of 30 major cities in 30 European countries	30	30 European cities
Happy Planet Index (2012)	Friends of the Earth - New Economics Foundation	1) Ecological footprint 2) life-satisfaction 3) life expectancy	It measures the extent to which countries deliver long, happy, sustainable lives for the people that live in them.	3	151 countries
Living Planet Index (2012)	WWF	1) Tropical index 2) Temperate index, 3) Biogeographic realms	In the latest LPI, data from nearly 8,000 populations of over 2,500 animal species were used	2500	200 countries
Most Livable Cities (2012)	Economics Intelligence Unit		The index contains 39 key quality-of-life factors, that include political stability, currency-exchange regulations, political and media censorship, school quality, housing, the environment and public safety	30	140 cities
European Economic Sustainability Index (EESI, 2010)	European Policy Centre	1) Deficits, 2) national debt, 3) growth, 4) competitiveness, 5) governance/ corruption 6) cost of ageing	The EESI enables a comparison of the long term economic sustainability of EU Member States	6	26 EU countries
Alternative Country Risk Rating (IRPA, 2008)	CLAES & D3E	1) Economic, 2) Social, 3) Environment, 4) Institutions, 5) Technology	12 indicators: 1. Primary exports 2. debt service as a % of total exports of goods and services 3. protected areas as a % of total country surface 4. carbon dioxide emissions in metric tons per capita 5. social expenditure as a % of GDP 6. literacy rate 7. household income distribution 8. Gross enrollment rate 9. internet users 10. political and civil liberties 11. support for democracy 12. % of undernourished	12	18 Latin America & Caribbean countries

Brundtland+ definition of sustainability

The SSI-2012 is based on a definition of sustainability that was provided by the Brundtland Commission (WCED, 1987). To make explicitly clear that sustainability includes Human Wellbeing as well as Environmental Wellbeing, the SSF has extended the definition of Brundtland with a third sentence, as follows:

“A sustainable society is a society that (a) meets the needs of the present generation; (b) does not compromise the ability of future generations to meet their own needs, and (c) in which each human being has the opportunity to develop itself in freedom within a well-balanced society and in harmony with its surroundings.”

This extended definition of sustainability will be referred hitherto as the “Brundtland+” definition. Existing indices of sustainability, some of which were briefly described in Table 1, do not fully comply to the “Brundtland+” definition. This is to be expected, as they were developed to serve different purposes, although under the auspices of a general sustainability framework.

Revised SSI framework

Along the lines of the Brundtland+ definition, a pilot SSI was created back in 2006. Since then, the SSI has been updated in order to account for improvements in the data, but also conceptually and methodologically refined in order to arrive at an index that is both conceptually and statistically sound. These refinements to the framework were made an iterative way between the SSI team and the JRC. The new framework for the SSI-2012 is shown in Figure 1. The framework (in its fourth edition²) builds on four levels of information: 21 indicators, eight categories, three dimensions, one index. The SSI framework departs from a purely protectionist approach that would aim to maintain natural systems with minimal human impact. It aims instead to describe societal progress along all three directions: human, environmental, and economic.

² Earlier editions of the SSI were produced in 2006, 2008 and 2010. The SSI-2012 report includes results for 2006-2012 (biannually), where past country scores were re-calculated by the Dutch Sustainable Society Foundation using the latest framework for 2012.

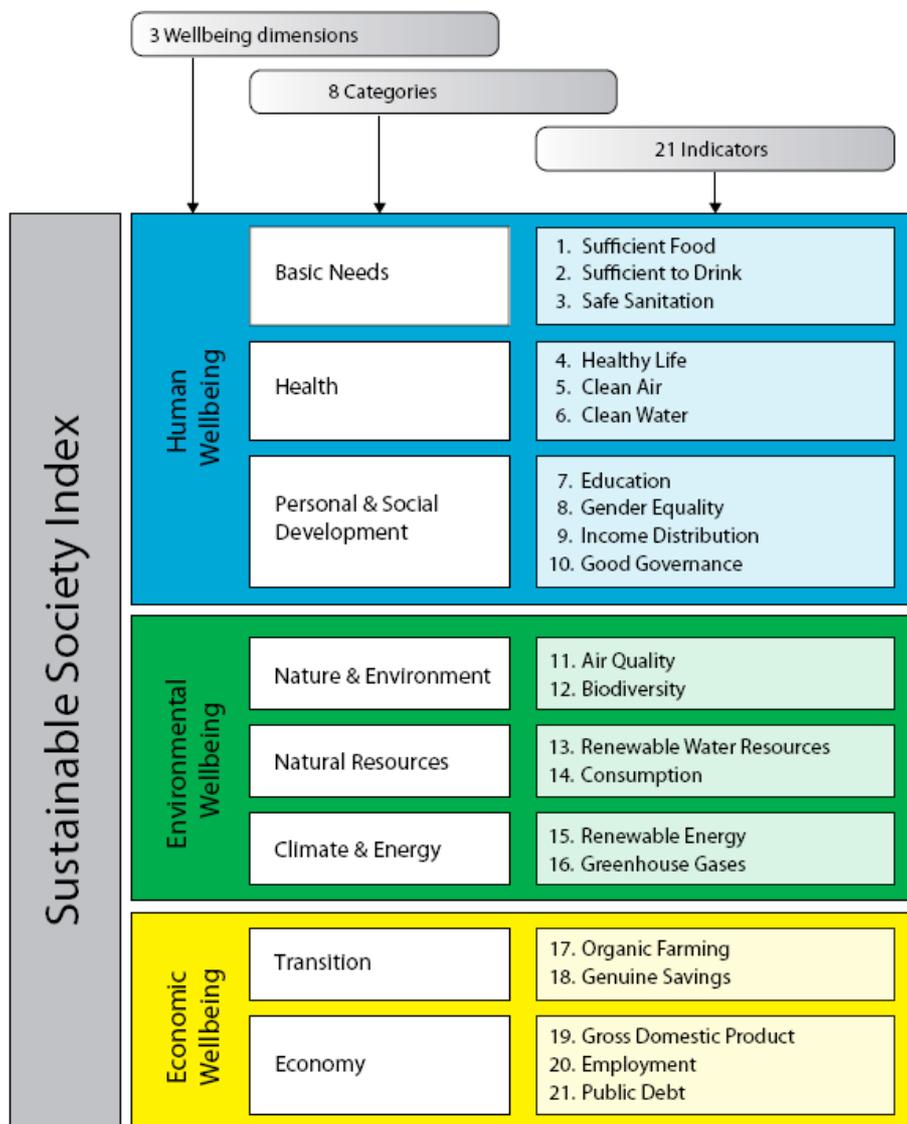
The Human Wellbeing dimension is populated with ten indicators that measure: the number of undernourished people and the number of people with sustainable access to an improved water source (both expressing conditions for the development of an individual), number of people with sustainable access to improved sanitation (a condition for the prevention and spreading of diseases that would severely hamper a person's development), life expectancy at birth in number of healthy life years (condition for development of each individual in a healthy way), air pollution in its effects on humans (PM_{2.5}) and surface water quality (both expressing conditions for human health), enrolment for primary, secondary and tertiary education (condition for a full and balanced development of children), gender gap index (condition for a full and balanced development of all individuals and societies at large), ratio of income of the richest 10% to the poorest 10% of the people (fair distribution of prosperity is a condition for sustainability), average of the six Governance indicators of the World Bank (condition for development of all people in freedom and harmony, within the framework of international rules and laws).

The Environmental Wellbeing dimension is populated with six indicators that describe: emissions of SO₂, a proxy for air pollution in its effects on nature (condition for ecological health), size of protected areas (condition for perpetuating the function of nature in all its aspects), annual water withdrawal as percentage of renewable water sources (measure of sustainable use of renewable water resources in order to prevent depletion of resources), ecological footprint minus carbon footprint, a proxy for consumption (as a measure of the use and depletion of material resources), renewable energy (as a measure of sustainable use of renewable energy resources in order to prevent depletion of fossil resources and to reduce GHG emissions), CO₂ emissions per capita, a proxy for greenhouse gases (a measure of main contribution to climate change, causing irreversible effects).

Finally, the Economic Wellbeing is described by five indicators: organic farming (a measure for progress of transition to sustainability), genuine savings (a measure for the true rate of savings, essential for sustainability), gross domestic product (a partial measure for the growth of the economy), unemployment in the labour force (with the rationale that access to the labour market is a condition for wellbeing for all people), and public debt (a measure of a country's ability to make independent decisions with respect to budget allocation).

The 21 indicators (or indices³) that populate the SSI-2012 framework come from fifteen sources: Food and Agriculture Organization (FAO), World Health Organization (WHO)-Unicef Joint Monitoring Programme, WHO, UN Population Division, Yale and Columbia University, UNESCO, World Economic Forum, World Bank, United Nations Environment Programme–World Conservation Monitoring Centre (UNEP-WCMC), FAO global information system on water and agriculture (Aquastat), Global Footprint Network, International Energy Agency (IEA), Research Institute of Organic Agriculture (FiBL), International Monetary Fund (IMF), International Labour Organization (ILO) and Central Intelligence Agency (CIA) World Factbook.

Figure 1. Revised Framework for the SSI



Source: Sustainable Society Index SSI-2012

³ Some of the indicators are already aggregate measures (indices), namely: Clean Air, Clean Water, Education, Gender Equality, Good Governance, Air Quality, Consumption, Genuine Savings, Gross Domestic Product.

Revised SSI framework: what has been changed

In an iterative process between the JRC and the SSI team, the framework has been revised in order to achieve a conceptual and statistical coherence and arrive at SSI components that are relatively balanced. Box 1 summarizes the adjustments that were made to the framework. The assessment of the revised framework will be thoroughly discussed in Section 4.

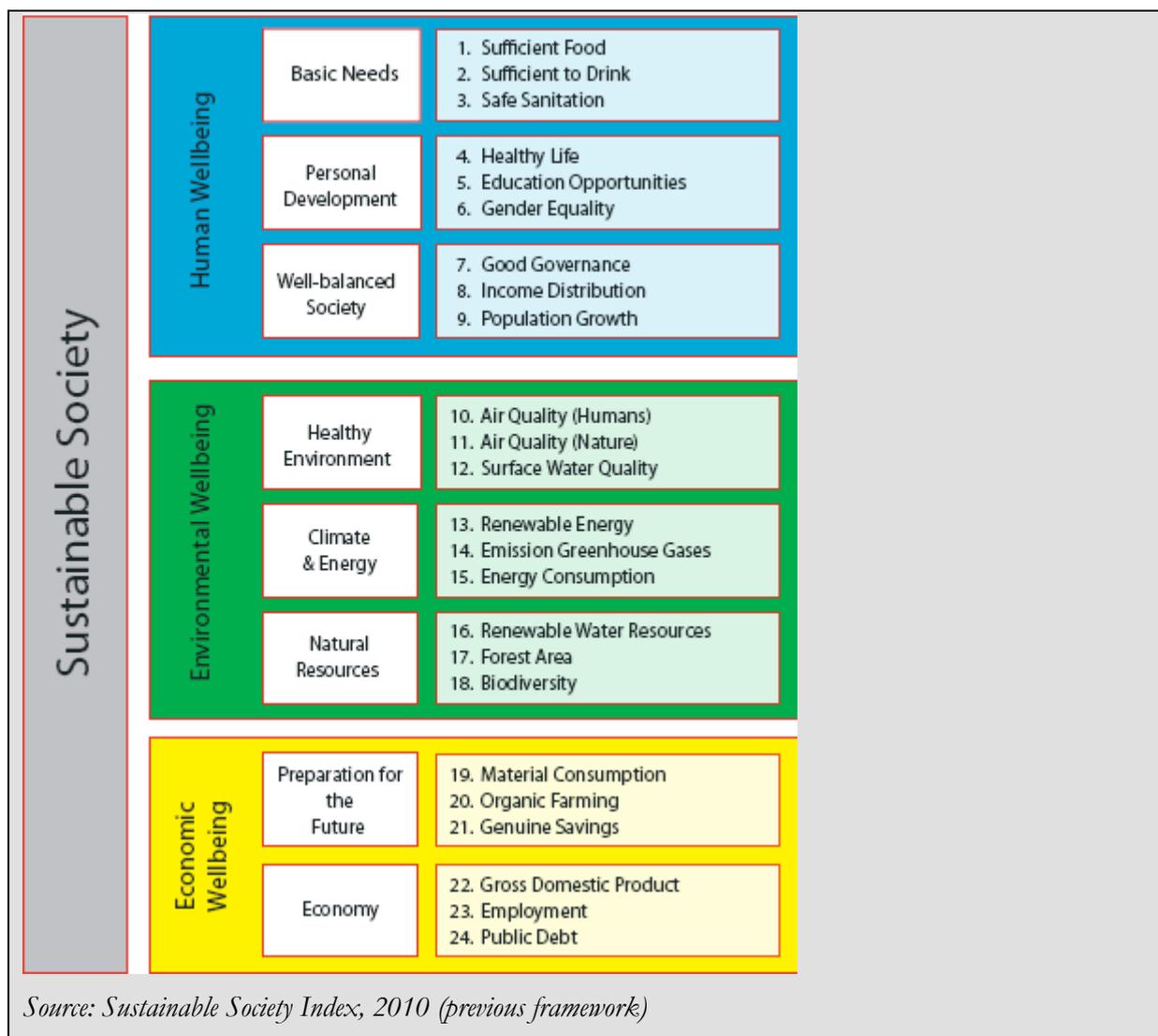
Box 1. Revised SSI-2012 framework – changes compared to the previous framework

1. Air Quality (humans) is now allocated to the Human Wellbeing dimension and renamed Clean Air, to avoid possible confusion with Air Quality (nature), which is renamed Air Quality.
2. Surface Water Quality is now allocated to the Human Wellbeing dimension and renamed Clean Water.
3. Clean Air and Clean Water make up, together with Healthy Life, a new category Health, which is part of Human Wellbeing.
4. Consumption⁴ is now allocated to the Environmental Wellbeing.
5. Forest Area has not been included because of the strong negative correlation with Environmental Wellbeing.
6. The sub-indicator Threatened Species of the indicator Biodiversity appeared to have a nearly random correlation with its category. In addition, given the difficulties with the collection of reliable data, this sub-indicator is not included. Hence, Biodiversity is now only expressed by Protected Areas.

Besides these changes which were done in close cooperation with the JRC, the SSI team made some more changes to the framework:

1. Population Growth is not included, so as to keep the framework as simple as possible, not to have too many indicators in Human Wellbeing compared to Environmental Wellbeing and since countries usually don't set policies on this issue.
2. Energy Consumption has been left out – in spite of being a valuable policy indicator – due to the overlap with Emission of Greenhouse Gases.
3. The third category of Human Wellbeing is now renamed Personal & Social Development.
4. The 6 indicators which make up Environmental Wellbeing, are distributed over three, partly renamed categories: Nature & Environment, Natural Resources and Climate & Energy.

⁴ After directional adjustment, see Section 3 for more details



Developing the SSI required many assumptions and compromises related to the framework; here we elaborate on three. First, the SSI is limited to eight policy categories primarily for parsimony and ease of communication while maintaining a structure complementary to other ecosystem benefit typologies. One should recognise that this structure significantly influences the results. Certainly, it is not the only possible structure. Yet, the current SSI structure is both conceptually and statistically sound (as we will discuss in detail in Section 4).

3. Sustainable Society Index - Methodology

The SSI-2012 framework with the eight categories and the three Wellbeing dimensions aims to picture the global landscape of societies with respect to their sustainability level. This section reviews the methodological revisions made by the JRC together with the SSI team in order to build the SSI components. The development of an overall index will be discussed at a next stage, separately. The calculation of the SSI categories and Wellbeing dimensions can be outlined in five key steps:

Step 1. Raw data for the selected indicators are first checked for reporting errors and for outliers that could strongly bias the results are treated.

Step 2. Missing data are estimated using expert knowledge.

Step 3. Indicators are normalized by the min-max method, taking the direction of their effect into account.

Step 4. Equal weights are assigned to the indicators within categories and within the Wellbeing dimensions.

Step 5. Country scores on the eight SSI categories are calculated as simple geometric averages of the underlying normalized indicators. Country scores on the three SSI Wellbeing dimensions are also calculated as simple geometric averages of the underlying categories.

Next, we describe in more detail each of those steps.

Step 1: Selection of indicators and data checks

Candidate indicators were selected for their relevance to a specific Wellbeing dimension (based on literature review) and for their timeliness. In all cases, the covariance structure of the dataset was taken into account in order to match the conceptual with the statistical grouping of indicators into categories and dimensions (see Section 4 for more details). To represent a fair picture of country differences, indicators were denominated (e.g., by dividing by total area, or total population or gross national income, or other units) as appropriate and where needed.

Data values outside the 1.5 interquartile range were checked for reporting errors.⁵ Indicators that could bias the overall results were identified as those having a skewness (absolute) greater than 2 and kurtosis greater than 3.5⁶. Given that in all cases, there were more than five points in each indicator that were distorting the distribution, these indicators were treated by nonlinear transformations (best distribution fitting). This was the case for Income Distribution, Organic Farming, Genuine Savings, GDP, Employment, and Public Debt. After this step, all transformed indicators had skewness and kurtosis values within the specified ranges.

Step 2: Missing data

The dataset used for the development of the SSI has an excellent data coverage: over 90% data availability per year. Few data gaps were filled in by expert judgment of the SSI team in consultation with relevant experts.

Step 3: Normalisation

The indicators are expressed in different units (percentages, tonnes, and other), have different ranges and variances, and thus a normalization to a common scale is required. The methods that are most frequently used are standardization (or z-scores) and rescaling.

Standardization: $\frac{x_i - \text{mean}(x)}{\text{std}(x)}$

This method converts the indicators to a common scale of mean zero and standard deviation of one. Therefore it rewards exceptional behavior, i.e. above-average performance of a given indicator yields higher scores than consistent average scores across all indicators.

Re-scaling: $\frac{x_i - \min(x)}{\max(x) - \min(x)}$

This approach is easier to communicate to a wider public, given that it normalizes indicators to an identical range [0, 1], where higher scores represent better achievement. A key advantage of this method over standardization, at least in the context of the SSI framework, is that re-scaling widens the range of an indicator, which is an advantage for those indicators with a small range of values, as it allows differentiation between countries with similar levels of performance.

⁵ The interquartile range is the difference between the upper (75% of values) and the lower (25% of values) quartiles.

⁶ Groeneveld and Meeden (1984) set the criteria for absolute skewness above 1 and kurtosis above 3.5. The skewness criterion was relaxed to account for the small sample.

However, this method is not appropriate in the presence of extreme values or outliers, which can distort the normalized indicator. To control for this, in step 1 above the necessary treatment was made to avoid that extreme values could bias the results. The minimum and maximum values needed for the re-scaling were determined in most cases based on “natural” minimum and maximum values instead of observed minimum and maximum over 2006-2012. For example, the Gender Gap Index, which is the proxy for Gender Equality under the Human Wellbeing dimension, is by construction expressed in a 0-1 scale. Thus, the 0 and 1 values were respectively the minimum and maximum values during the normalization here, although the observed minimum and maximum values over 2006-2012 across the 151 countries were 0.46 and 0.85 respectively.

The direction of the indicators’ effect was taken into account at this stage. For indicators where higher raw values are desirable, the formula was $\frac{x_i - \min(x)}{\max(x) - \min(x)} \times 9 + 1$. For indicators where lower raw values are desirable, the formula was: $\frac{\max(x) - x_i}{\max(x) - \min(x)} \times 9 + 1$.

At this stage all normalised indicators are expressed in a 1-10 scale. We avoided values lower than 1 for reasons that will be explained in the aggregation step (see Step 5 below).

Step 4: Weights

The SSI categories and Wellbeing dimensions are calculated using equal weights for the underlying components. There are no highly correlated indicators (all Pearson correlations coefficients are lower than 0.82). We anticipate here that assigning equal weights to the indicators does not necessarily guarantee an equal contribution of the indicators to an index. We will discuss this point thoroughly in Section 4.

Step 5: Aggregation

The most popular aggregation methods in the relevant literature are the arithmetic and geometric means. The arithmetic mean has been traditionally used to compute most of the well-known indices in the international scene and all previous versions of the SSI. Some counter arguments for the use of the arithmetic mean are: (a) perfect substitutability, i.e. poor performance in one indicator can be fully compensated by good performance in another, (b) no penalty for an

unbalanced performance: the arithmetic mean does not penalize the differences in values between indicators, i.e. it does not reward balanced achievement in all indicators, (c) no impact of poor performance: the arithmetic mean does not consider that the lower the performance in a particular indicator, the more urgent it becomes to improve achievements in that indicator.

Next, we provide a better understanding of the three arguments above by considering one of the eight SSI categories (see Table 2). The Basic Needs category is composed of Sufficient Food, Sufficient to Drink and Safe Sanitation. To make the case we consider two countries, Ghana with (normalized) values 10.0, 8.6, and 1.4 and Senegal with values 8.1, 7.2, and 5.2 respectively. These two countries have very similar scores (roughly 6.7 points) in the Basic Needs category if the arithmetic average is used (assuming equal weights for the three indicators). However, the arithmetic mean does not penalize the more uneven performance of Ghana with respect to Senegal (see differences in standard deviations). Instead, the geometric mean penalizes Ghana for the uneven performance, whereby its aggregate score is reduced from 6.7 (arithmetic mean) to 4.9 points (geometric mean), whilst the score of Senegal remains practically unaffected. Furthermore, if Ghana improves in Sufficient to Drink by 1 point, then the geometric mean increases from 4.9 to 5.1. Instead, if Ghana improves by 1 point on the aspects that is most weak, namely on Safe Sanitation, then the geometric mean increases from 4.9 to 5.9. If the arithmetic mean is used, improvement on either indicator (be it Sufficient to Drink or Safe Sanitation) gives the same mean score (7 points).

Table 2. Rationale for the use of geometric mean in the SSI development

Scores in 2012	Ghana	Senegal
Sufficient Food (normalized)	10.0	8.1
Sufficient to Drink (normalized)	8.6	7.2
Safe Sanitation (normalized)	1.4	5.2
Standard deviation (of the three indicators above)	4.6	1.5
Arithmetic mean (score)	6.7	6.8
Geometric mean (score)	4.9	6.7
Arithmetic mean (score, scenario A)	7.0	
Geometric mean (score, scenario A)	5.1	
Arithmetic mean (score, scenario B)	7.0	
Geometric mean (score, scenario B)	5.9	

Notes: Scenario A assumes that Ghana improves by 1 point on Sufficient to Drink, the other two indicators remain unchanged. Scenario B assumes that Ghana improves by 1 point on Safe Sanitation, the other two indicators remain unchanged.

Upon these conceptual considerations, the aggregation formula for the SSI components was changed from arithmetic to geometric mean. The geometric mean of the SSI indicators (or

categories), as opposed to the arithmetic mean, produces lower scores, with the largest changes occurring in countries with uneven performance across indicators. Given that the geometric mean requires strictly positive values, and because indicator values close to 0 would bring the aggregate score close to zero, we have preferred to normalize the indicators in the 1-10 scale (Step 3 above).

4. Conceptual and statistical coherence

The SSI-2012 framework is the result of an iterative process between the JRC and the developing team, in order to match the results of the statistical analysis with conceptual justifications. This section delves into the conceptual and statistical coherence in the revised SSI framework.

Principal component analysis and cross-correlation analysis

Principal component analysis (Bryant and Yamond, 1995; Johnson and Wichern, 1992) confirms that there is a single latent dimension in each SSI category, which captures between 41% and 86% of the total variance in the underlying indicators (see Table 3)⁷. More variance is explained in the more homogenous categories—Basic Needs, Climate & Energy – whilst less variance is captured by the more heterogeneous categories— Economy. For conceptual reasons that were explained in the previous section, full compensability is not desirable in a sustainability concept, hence the SSI categories are calculated as simple geometric means of the underlying normalized indicators. This choice receives statistical justification, at least in terms of the total variance explained, given that the amount of variance explained by the SSI category is in all cases very similar to the maximum variance that could have been explained by a linear function.

⁷The first principal component is a weighted average of the indicators, whereby the indicators receive statistically driven weights based on the covariance matrix. An important property of the first principal component is that it captures the maximum possible variance in the underlying indicators that could have been explained by any weighted average of the underlying indicators.

Table 3. Variance explained by the SSI categories and the first principal component

SSI categories	Variance explained by the first principal component	Variance explained by the SSI category
Basic Needs	83%	81%
Health	68%	66%
Personal & Social Development	60%	50%
Nature & Environment	58%	55%
Natural Resources	57%	41%
Climate & Energy	86%	84%
Transition	62%	59%
Economy	41%	36%

A more detailed analysis of the correlation structure within and across the SSI categories confirms the expectation that the indicators are more correlated to their own category than to any other category and all correlations within a category are significant and positive (see Table 4). These results have two implications: from a statistical point, no-reallocation of the indicators into different categories is needed, and no trade-offs are present in this framework as all correlations are significant and positive.

At the dimension level, Human Wellbeing appears very homogenous, whereby a single latent factor is identified that captures 82% of the variance in the three categories (see Table 5). In the Environmental and Economic Wellbeing dimensions, there is also one latent dimension identified that captures respectively 58% and 69% of the variance of the underlying categories. Again, as was the case for the categories above, the SSI Wellbeing dimensions, which for conceptual reasons are calculated as simple geometric means of the underlying categories, they explain a similar amount of variance compared to the first principal component. Also the cross-correlation analysis confirms the expectation that the categories are more correlated to their own Wellbeing dimension than to the other dimensions and all correlations within a dimension are significant and positive (see Table 6). These results have two implications: from a statistical point, no-reallocation of the categories into different Wellbeing dimensions is needed, and no trade-offs are present at this aggregation level as all correlations are significant and positive.

Table 4. Coherence test in the SSI framework

SSI categories	SSI Indicators	SSI categories							
		I	II	III	IV	V	VI	VII	VIII
I.Basic Needs	Sufficient Food	0.82	0.71	0.59	-0.15	-0.50	-0.71	0.45	0.54
	Sufficient to Drink	0.90	0.72	0.58	-0.14	-0.41	-0.76	0.45	0.53
	Safe Sanitation	0.97	0.79	0.64	-0.22	-0.51	-0.81	0.46	0.58
II.Health	Healthy Life	0.87	0.87	0.70	-0.12	-0.52	-0.79	0.55	0.62
	Clean Air	0.75	0.87	0.62		-0.57	-0.73	0.48	0.52
	Clean Water	0.40	0.68	0.52	0.20	-0.10	-0.32	0.51	0.28
III.Personal & Social Development	Education	0.80	0.82	0.71		-0.45	-0.73	0.55	0.56
	Gender Equality	0.47	0.57	0.52			-0.34	0.48	0.34
	Income Distribution	0.35	0.37	0.81		-0.22	-0.41	0.33	0.19
	Good Governance	0.62	0.76	0.76		-0.48	-0.56	0.68	0.54
IV.Nature & Environment	Air Quality	-0.37	-0.17	-0.13	0.62	0.27	0.50	0.12	-0.21
	Biodiversity				0.84	0.13	0.12	0.25	
V.Natural Resources	Renewable Water Resources	-0.24			0.43	0.58	0.38	0.15	
	Consumption	-0.46	-0.61	-0.46		0.70	0.40	-0.50	-0.48
VI.Climate & Energy	Renewable Energy	-0.79	-0.65	-0.52	0.33	0.47	0.96	-0.34	-0.54
	Greenhouse Gases	-0.75	-0.75	-0.72	0.16	0.59	0.87	-0.45	-0.62
VII.Transition	Organic Farming	0.44	0.59	0.58	0.24	-0.29	-0.37	0.94	0.30
	Genuine Savings	0.28	0.29	0.32	0.17		-0.19	0.54	0.29
VIII.Economy	GDP	0.80	0.86	0.73		-0.60	-0.79	0.59	0.68
	Employment	0.23	0.21	0.21		-0.20	-0.21	0.15	0.61
	Public Debt		-0.12						0.48

Notes: The numbers in grey are the Pearson correlation coefficients of the indicators with their own SSI category. Correlation coefficients that are non-significant at the 99% level are not reported.

Table 5. Explained variance by the SSI dimensions

SSI dimensions	Variance explained by the first principal component	Variance explained by the SSI dimension
Human Wellbeing	82%	82%
Environmental Wellbeing	58%	57%
Economic Wellbeing	69%	67%

Table 6. Correlation structure in the SSI Framework (category level)

SSI Category	Human Wellbeing	Environmental Wellbeing	Economic Wellbeing
Basic Needs	0.90	-0.74	0.63
Health	0.94	-0.60	0.72
Personal & Social Development	0.88	-0.55	0.65
Nature & Environment		0.62	0.16
Natural Resources	-0.52	0.73	-0.39
Climate & Energy	-0.81	0.89	-0.56
Transition	0.64	-0.26	0.88
Economy	0.60	-0.51	0.75

Pearson correlation coefficients that are not significant at the 99% level are not reported.

Implicit weights

The SSI team assigned equal weights to the indicators not necessarily on the grounds that they are all worth the same, but due to lack of a clear reference in the literature as to the importance of each indicator in determining sustainability.

This sub-section will analyze the impact of the equal weights assumption on the variance of the SSI category (or Wellbeing) scores by means of the implicit weights. Despite the equal nominal weights assigned to the indicators within the SSI categories, the implicit weights of the indicators are not necessarily equal. The implicit weights are a function of the nominal weights, the data correlation structure and the indicators' variances. We calculate the implicit weights using a non-linear measure, the kernel estimate of the Pearson correlation ratio⁸. If indicators are supposed to be equally important in classifying countries with respect to an SSI category, then their implicit weights should not differ too much. The same argument holds for the importance of categories in determining the variance of the Wellbeing scores. Results are overall reassuring. In most SSI categories the underlying indicators have similar implicit weights in classifying countries within each category, though some indicators are slightly more important than others (see Table 7). In few cases, though, as for the Transition category, the implicit weight for the indicator on Genuine Savings is much lower than that for Organic Farming. Should one aim for an equal

⁸ Paruolo et al., 2013, discuss four properties of the Pearson correlation ratio (else termed first order sensitivity measure), which render the correlation ratio a suitable measure of the indicators' implicit weights (else termed effective weights): (a) it offers a precise definition of importance, that is 'the expected reduction in variance of an index that would be obtained if a variable could be fixed'; (b) it can be used regardless of the degree of correlation between variables; (c) it is model-free, in that it can be applied also in non-linear aggregations; (d) it is not invasive, in that no changes are made to the index or to the correlation structure of the indicators.

contribution of these two indicators to the overall variance of the Transition scores, then the nominal weight assigned to the Genuine Savings should be more than half (as it is the case now). Similar remark holds for the impact of Public Debt on the variance of the Economy scores, which is currently lower than that of the GDP and Employment. Again, the nominal weight assigned to Public Debt should be much higher than one-third (as it is the case now) in order for Public Debt to have a similar implicit weight to the other two indicators in the category. Before deciding whether to adjust the nominal weights of the indicators in order for their implicit weights to be similar, an analysis of the marginal weight was conducted.

Table 7. Implicit weights of the SSI indicators and categories

	Indicator #.1	Indicator #.2	Indicator #.3	Indicator #.4
Basic Needs	0.64 [0.64, 0.72]	0.82 [0.78, 0.87]	0.96 [0.95, 0.97]	
Health	0.79 [0.75, 0.84]	0.79 [0.74, 0.83]	0.48* [0.48, 0.63]	
Personal & Social Development	0.53 [0.48, 0.60]	0.28* [0.23, 0.32]	0.68 [0.64, 0.80]	0.63 [0.59, 0.73]
Nature & Environment	0.44 [0.36, 0.54]	0.72 [0.70, 0.81]		
Natural Resources	0.37 [0.33, 0.46]	0.50 [0.47, 0.62]		
Climate & Energy	0.94 [0.91, 0.96]	0.94 [0.73, 0.95]		
Transition	0.89 [0.85, 0.92]	0.32* [0.30, 0.47]		
Economy	0.47 [0.36, 0.64]	0.44 [0.44, 0.65]	0.21* [0.17, 0.33]	
	Category #.1	Category #.2	Category #.3	Category #.4
Human Wellbeing	0.91 [0.76, 0.92]	0.85 [0.85, 0.89]	0.74 [0.72, 0.78]	
Environmental Wellbeing	0.38* [0.38, 0.54]	0.59 [0.53, 0.68]	0.81 [0.77, 0.89]	
Economic Wellbeing	0.76 [0.75, 0.83]	0.5 [0.48, 0.57]		

Notes: Numbers represent the kernel estimates of the Pearson correlation ratio (η^2) and were calculated using the approach suggested in Paruolo *et al.*, 2013. Min-max estimates for the η^2 are reported in brackets and derive from the choice of the smoothing parameter. Indicators that have much lower contribution to the variance of the relevant SSI category or Wellbeing dimension than the equal weighting expectation are marked with an asterisk. The order of the indicators is the same as in Figure 1. For example, the Basic Needs category is built on three indicators, where the first indicator (Sufficient Food) has an η^2 value equal to 0.64, which is the expected reduction in the variance of the SSI category scores if that indicator could be fixed. Similarly, the Human Wellbeing is built on three categories, where the first category (Basic Needs) has an η^2 value equal to 0.91.

Marginal weights

The implicit weights discussed previously relate to the impact of the indicators on the variance of the categories scores, and measure the expected reduction in the variance of the SSI category scores that would be obtained if an indicator could be fixed. In this respect, looking at the implicit weights is important, if one assumes that the aim of the SSI categories is merely to rank countries. However, this is not the case. In fact, the SSI-2012 report places emphasis on benchmarking country performance with respect to a perfect 10 score for a fully sustainable society.

Hence, in the SSI context, analysing the marginal weights of the indicators and the categories becomes more relevant. The marginal weights of the indicators express the elasticity (or sensitivity) of the SSI categories to changes in one indicator, keeping others unchanged. Here, elasticity is calculated with respect to a 10% increase in any indicator, while all other indicators remain unchanged. We will look into it both with respect to the SSI categories and to the SSI Wellbeing dimensions.

Overall, the marginal weights of the indicators on the SSI categories scores do not differ too much (see Table 8). For example, the Basic Needs scores are slightly more sensitive to changes of Safe Sanitation, then Sufficient to Drink, and then Sufficient Food. A 10% increase on Sufficient Food yields an average⁹ increase of 1.62% in the category scores. On the other hand, a 10% increase on Safe Sanitation yields the highest average increase of 2.13% in the Basic Needs scores. It is worth noting is that countries with lower scores on an indicator have much more incentives to improve on that indicator compared to countries with already very good performance, which is attributable to the use of the geometric mean for the aggregation of the indicators. For example, countries in the low tertile¹⁰ of the distribution on Safe Sanitation that increase by 10% their score would see an increase in their Basic Needs scores by 3.23% on average, compared to those that are in the top tertile on Safe Sanitation, which would only increase their Basic Needs scores by 0.29%. The Natural Resource's scores are, on average, more sensitive to changes in Consumption than to Renewable Water Resources. A 10% increase¹¹ in Consumption yields an average increase of 4.88% in the Natural Resources scores, an impact

⁹ across all 151 countries analyzed

¹⁰ A tertile contains one third of the countries analyzed .

¹¹ This should be read here as a decrease in the Consumption, because the marginal effects are calculated after the normalization, where the direction of the effect of an indicator is taken into account, so that higher values are desirable in all indicators.

which is constant for all countries. On the other hand, a 10% increase on Renewable Water Resources yields an average increase of 2.80% in the Natural Resource scores, an increase which is ten times higher for countries in the low tertile (4.88%) than for countries in the high tertile (0.44%). It is also worth mentioning that a 10% change in four indicators – Gender Equality, Good Governance, Air Quality, Consumption– has marginal effects that are constant across all countries.

Table 8. Marginal weights (%) of the indicators in the eight SSI categories

SSI Categories	SSI Indicators	Low tertile	Medium tertile	Top tertile	Average
Basic Needs	Sufficient Food	3.23	1.67	0.00	1.62
	Sufficient to Drink	3.23	2.24	0.10	1.84
	Safe Sanitation	3.23	2.92	0.29	2.13
Health	Clean Air	3.23	3.23	3.20	3.22
	Clean Water	3.23	3.23	0.28	2.23
	Healthy Life	3.23	3.23	2.90	3.12
Personal & Social Development	Education	2.41	2.41	1.69	2.17
	Gender Equality	2.41	2.41	2.41	2.41
	Income Distribution	2.41	2.41	2.29	2.37
	Good Governance	2.41	2.41	2.41	2.41
Nature & Environment	Air Quality (Nature)	4.88	4.88	4.88	4.88
	Biodiversity	4.88	4.88	2.36	4.03
Natural Resources	Renewable Water Res.	4.88	3.11	0.44	2.80
	Consumption	4.88	4.88	4.88	4.88
Climate & Energy	Renewable Energy	4.88	4.88	4.62	4.79
	Greenhouse Gases	4.88	4.88	1.81	3.84
Transition	Organic Farming	4.88	4.88	4.62	4.79
	Genuine Savings	4.88	4.88	4.35	4.70
Economy	GDP	3.23	3.23	2.53	2.99
	Employment	3.23	3.23	3.08	3.18
	Public Debt	3.23	3.23	1.76	2.73

Notes: The marginal weights of the indicators express the elasticity (or sensitivity) of the SSI categories to changes in one indicator, keeping others unchanged. Here, elasticity is calculated with respect to a 10% increase in any indicator. Elasticity is averaged across all 151 countries or by tertile of the indicator distribution.

We next look at the elasticity of the SSI Wellbeing dimensions with respect to changes in the underlying SSI categories (see Table 9). In this case, there are no variations in the marginal weights neither with respect to the SSI category nor with respect to the level of a country's performance. To be more specific, in the Human Wellbeing dimension, a 10% increase in the Basic Needs yields an increase of 2% in the Human Wellbeing scores, which is constant across all 151 countries. On the other hand, a 10% increase on either Health or Personal & Social

Development yields an increase of 3% in the Human Wellbeing scores, again constant across all countries. In the Environmental Wellbeing dimension, a 10% increase in either Nature & Environment, or Natural Resources, or Climate & Energy yields an increase of 3% in the Environmental Wellbeing scores. Finally, in the Economic Wellbeing dimension, a 10% increase in either Transition or Economy yields an increase of 5% in the Economic Wellbeing scores. These results imply that the SSI categories have an equivalent impact to the scores of their own Wellbeing dimension. For the completeness of reporting, the elasticity of the SSI Wellbeing dimensions to changes in the underlying indicators is in general lower compared to that of the SSI categories. The marginal effects of changes in the underlying indicators are roughly three times lower on the Wellbeing dimensions than on the respective category scores.

Table 9. Marginal weights (%) of the categories on the three SSI dimensions

SSI dimension	SSI Category	Elasticity
Human Wellbeing	Basic Needs	2%
	Health	3%
	Personal & Social Development	3%
Environmental Wellbeing	Nature & Environment	3%
	Natural Resources	3%
	Climate & Energy	3%
Economic Wellbeing	Transition	5%
	Economy	5%

Notes: The marginal weights of the categories express the elasticity (or sensitivity) of the SSI dimensions to changes in one category, keeping others unchanged. Here, elasticity is calculated with respect to a 10% increase in any category.

The discussion so far on the marginal weights of the SSI indicators or categories makes clear one point. Whilst some indicators appeared to be less influential in determining the variance of the respective category scores, for example Public Debt within the Economy category, from the point of view of the marginal effects, the structure of the SSI is balanced.

Had the objective of the SSI components been to merely provide a ranking of countries, then the few imbalances seen in Table 7 would have necessitated some methodological refinements (for example adjusting the nominal weights from equal to unequal). However, since the primary aim of the SSI components is to benchmark country performance with respect to a perfect 10

score, looking at the marginal weights, which convey exactly this piece of information is more relevant in this context. Upon all these considerations, the SSI team, together with the JRC decided not to alter the nominal weights for the indicators but to keep them equal.

5. Measuring sustainability with a single number?

The SSI-2012 framework has been carefully revised in order to make sure that the categories and the Wellbeing dimensions are to the possible extent balanced in their underlying components, as discussed above. A further challenge was related to aggregating the SSI components into an overall index, a temptation particularly appealing for media communication. However, in the context of measuring sustainability in a broad sense along human, environmental and economic aspects, an all-inclusive number needs to be carefully considered.

In fact, from a statistical point, it is not recommended to combine the SSI components into an overall index by calculating an average (be that geometric or another partially compensatory approach) for the following reason. There are significant negative correlations between Natural Resources or Climate & Energy with any of the other SSI categories (see Table 10). These negative correlations are a sign of a trade-off, whereby many countries that have poor performance on Natural Resources or Climate & Energy have good performance on all other categories and vice versa. The trade-offs are also evident at the Wellbeing level. The Human Wellbeing scores have a high association to the Economic Wellbeing scores ($r=0.73$, $n=604$), but a strong negative correlation to the Environmental Wellbeing scores ($r=-0.69$, $n=604$). It appears, thereafter, that the Human and Economic Wellbeing go hand-in-hand in many countries, but at the expense of the Environmental Wellbeing. Fortunately, this is not the case for all countries. For example, Costa Rica and Qatar have a similar level of Human Wellbeing close to 6.5 points, but Costa Rica manages to attain also a good level of Environmental Wellbeing at 6.9 points, contrary to Qatar that has the lowest level of Environmental Wellbeing (1.2 points) among the 151 countries included in the SSI. One interesting result that emerges from Figure 3 is that all countries that score more than 5 points in the Environmental Wellbeing score less than 5 points on the Economic Wellbeing and vice versa. The only exceptions are Dominican Republic, Latvia and Switzerland. In particular Switzerland is the only country (of the 151 countries included) that manages to achieve a high Economic Wellbeing with a moderate performance in the Environmental Wellbeing. All other countries that perform well in the Economic Wellbeing seem to do so at the expense of the Environmental Wellbeing.

To what extent economic growth promotes resource depletion and increase in waste production and hence increased damage to the environment, is an ongoing debate. Some economists argue that economic growth will eventually lead to an improvement in the environment, despite some past increases in environmental degradation correlated with economic growth. The international literature suggests that there is an inverted shaped relationship (Environmental Kuznets Curve, or simply EKC) between economic growth and the change of environmental quality, whereby technological improvements, manufactures and industries are determinants of economic growth, but, on the other hand, critical factors of environmental quality (Cole et al., 1997; Daly and Cobb, 1989; Ekins, 1997; Kuznets, 1955).

In fact, Figure 3 confirms the inverted shaped relationship between economic and environmental wellbeing. Generally speaking, recent experience has shown that governments do not begin to commit themselves to major expenditures on the environment until environmental damage has already become very serious. Maybe this applies to the formulation and implementation of environmental policies. Except for few countries, most developing nations still have economic growth corresponding to a degradation of environmental wellbeing. Similar conclusions are drawn from an international team at a recent publication in Nature, which discusses a measure of the economic wellbeing and its negative association to the ocean's wellbeing. Yet, variation at country level around these relationships shows that all possible combinations of human progress exist, and it is from this point that best practices need to be taken on board by other countries.

Table 10. Correlations among the eight SSI categories

	I	II	III	IV	V	VI	VII	VIII
I. Basic Needs	1.00	0.81	0.65	-0.21	-0.51	-0.83	0.49	0.60
II. Health	0.81	1.00	0.74		-0.49	-0.74	0.63	0.57
III. Personal & Social Development	0.65	0.74	1.00		-0.42	-0.64	0.63	0.46
IV. Nature & Environment	-0.21			1.00	0.24	0.30	0.26	
V. Natural Resources	-0.51	-0.49	-0.42	0.24	1.00	0.56	-0.30	-0.41
VI. Climate & Energy	-0.83	-0.74	-0.64	0.30	0.56	1.00	-0.40	-0.61
VII. Transition	0.49	0.63	0.63	0.26	-0.30	-0.40	1.00	0.37
VIII. Economy	0.60	0.57	0.46		-0.41	-0.61	0.37	1.00

Pearson correlation coefficients that are not significant at the 99% level are not reported.

Figure 2. Human Wellbeing versus Environmental Wellbeing (SSI-2012)

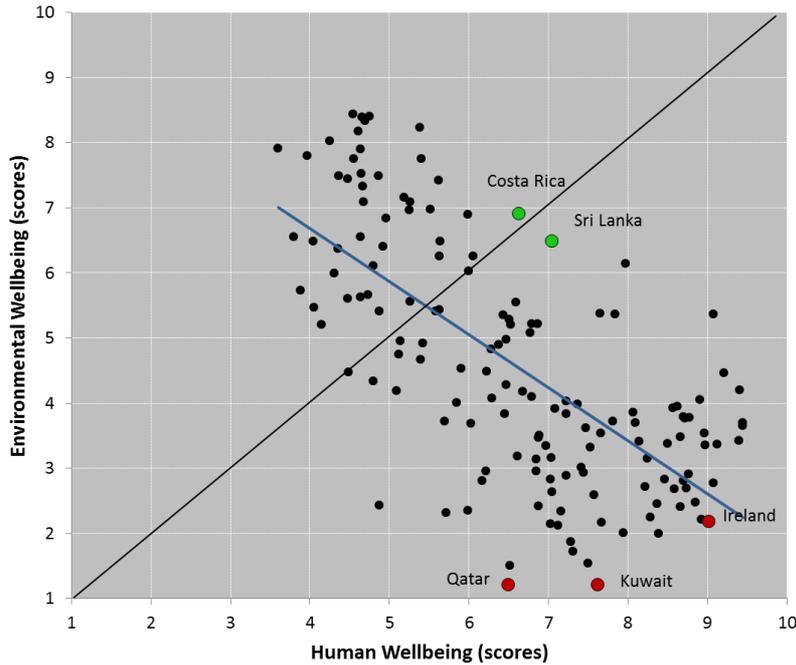
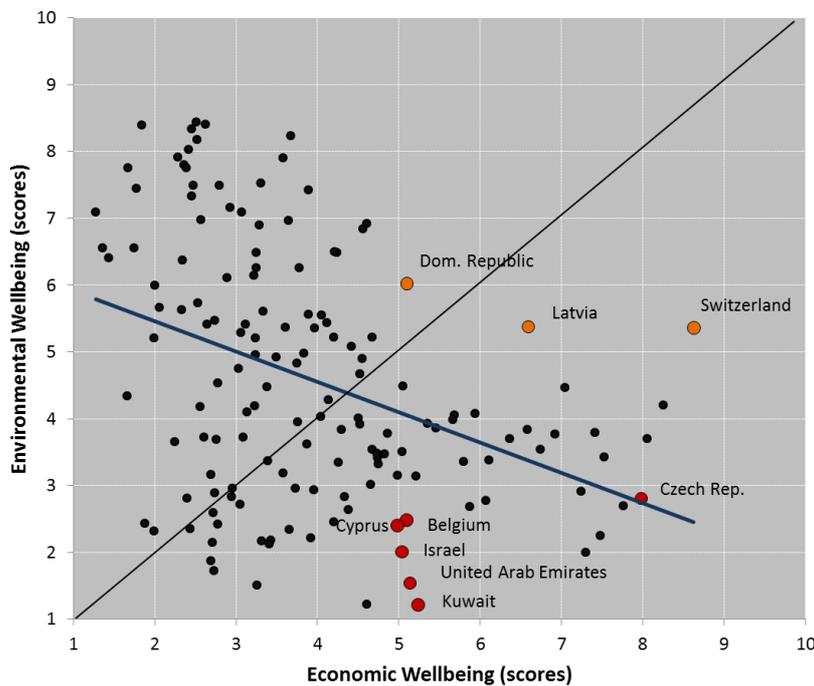


Figure 3. Economic Wellbeing versus Environmental Wellbeing (SSI-2012)



Upon these considerations related to the trade-offs among the SSI categories and dimensions, the JRC recommendation is not to aggregate the SSI components into an overall index. Instead, the focus should be given to the SSI categories and Wellbeing dimensions, which are well-structured, and do not present any trade-offs within. Despite these suggestions, the aggregation into a single number of sustainability may be irresistible to some. To anticipate this, the SSI

developing team, for purely indicative reasons, could calculate an overall index by using the geometric average of the eight categories. In that case, the SSI index has positive (though moderate to low) correlations to all indicators and categories. Instead, the geometric average of the 21 indicators or the three wellbeing dimensions would result in an index that has negative correlations to some of these components.

There is ongoing testing by the JRC on alternative aggregation methods of partial or non-compensatory nature (such as the Copeland or Arrow-Raynaud approaches) for the purposes of calculating a single sustainability number per country. Results will be reported at a later stage.

6. Impact of modeling assumptions on the SSI results

This section will assess the uncertainty of the SSI Wellbeing rankings attributed to the normalization and the weights assigned to the indicators, which are the two judgments in the development process that cannot be fully justified neither by theoretical reasons, nor by the data properties¹². In the present analysis the data are assumed to be error-free since the SSI team already undertook a double-check control and eventual errors and typos were corrected during this phase (see Step 2 in Section 3).

An important remark is that the uncertainty analysis cannot inform on the quality of the SSI framework. This was the aim of the analysis carried out in Section 4. Instead, the results in this section can only provide information on the validity of inferences associated with the country ranks on the SSI Wellbeing dimensions, which are the only full rankings presented in the SSI-2012 report (p.94-98).

The uncertainty analysis of the SSI-2012 rankings on the three Wellbeing dimensions was based on a Monte Carlo experiment. This type of assessment aims to anticipate criticism that the country ranks associated with indices are frequently presented as if they were calculated under conditions of certainty, while this is, by definition of the index, not the case (Saisana et al., 2005; Saisana et al., 2011). The Monte Carlo simulation (20,000 runs) related to the issue of normalisation and weighting of the indicators. Although there are arguments in favour of the min-max method for normalizing the indicators versus the z-scores approach (see Section 3), an

¹² Note that the estimation based on expert judgment of the missing data is not at all influential on the SSI results given the very small proportion of missing data (less than 10%). The previous sections also offered conceptual justification for the use of the geometric averaging versus the arithmetic averaging formula.

argument in favour of the z-scores approach is that all normalized indicators have the same variance, and thereafter the implicit weights are only a function of the correlation structure between the indicators (assuming equal nominal weights as it is the case here). Hence, the z-scores approach for normalising the indicators versus the min-max was tested. At the same time, different sets of weights of the indicators were randomly sampled from uniform distributions centred in the reference values ($\pm 25\%$ of the reference value). The choice of the range for the weights' variation has been driven by two opposite needs: on one hand, the need to ensure a wide enough interval to have meaningful robustness checks; on the other hand, the need to respect the rationale of the SSI that no indicator dominates any Wellbeing dimension. Given these considerations, limit values of uncertainty intervals have been defined as shown in Table 11. For example, the Human Wellbeing dimension is made of three categories with 3, 3 and 4 indicators respectively. The calculation of the Wellbeing score as the geometric average of the three categories implies that every indicator from the first or second category is assigned a weight of $1/3/3$ ($=1/9$), and every indicator that belongs to the third category is assigned a weight of $1/3/3$ ($=1/12$). Consequently, we tested 2 models based on either min-max versus z-scores normalisation, which combined with 10,000 simulations to account for the uncertainty in the weights for the indicators, amount to altogether 20,000 simulations for each SSI Wellbeing dimension.

The main results of the uncertainty analysis are provided in Figure 4 to Figure 6. Countries are ordered from best to worst according to their reference rank in the SSI Wellbeing dimension (black line), the dot being the simulated median rank. Error bars represent, for each country, the 90% interval across all 20,000 Monte Carlo simulations. For more transparency, Table 12 reports the original country ranks, the simulated median and the 90% confidence interval for the simulated rank for the three SSI Wellbeing dimensions. Our intention is to be explicit about on which countries the simulated interval either does not include the reference rank or is too wide to allow for a reasonable inference or the median rank is very different from the reference rank. Overall, country ranks in all three Wellbeing dimensions provide a representative picture of a country's performance that is not driven by the modelling assumptions on the normalization and weighting of the underlying indicators: 90% of the countries shift with respect to the simulated median less than ± 1 position in any of the SSI Wellbeing dimensions. Hence, country ranks on the three SSI Wellbeing dimensions depend solely on the indicators used and not on the methodological judgments made during the aggregation. Simulated 90% intervals across all 20,000 simulations are narrow enough for many countries to allow for meaningful inferences to be drawn. Few countries have relatively wide intervals (more than 20 positions): no country on

the Human Wellbeing; Norway, North Korea, Iceland and Uruguay in the Environmental Wellbeing; twenty two¹³ countries on the Economic Wellbeing. These relatively wide intervals are due to compensation of low performance on some indicators with a very good performance on other indicators in a given Wellbeing dimension. These countries have been flagged herein as part of the uncertainty analysis in order to give more transparency in the entire process and to help appreciate the SSI results on the Wellbeing dimensions with respect to the choices made during the development phase.

Table 11. Uncertainty parameters (normalization, weights)

	Type of uncertainty	Reference	Alternative
	Uncertainty in the normalization	Min-max	z-scores
	Uncertainty in the weights	Value	Distribution assigned for uncertainty analysis ($\pm 25\%$ reference value)
Human Wellbeing	Sufficient Food	0.111	U[0.083, 0.139]
	Sufficient to Drink	0.111	U[0.083, 0.139]
	Safe Sanitation	0.111	U[0.083, 0.139]
	Clean Air	0.111	U[0.083, 0.139]
	Clean Water	0.111	U[0.083, 0.139]
	Healthy Life	0.111	U[0.083, 0.139]
	Education	0.083	U[0.063, 0.104]
	Gender Equality	0.083	U[0.063, 0.104]
	Income Distribution	0.083	U[0.063, 0.104]
	Good Governance	0.083	U[0.063, 0.104]
Environmental Wellbeing	Air Quality (Nature)	0.167	U[0.125, 0.208]
	Biodiversity	0.167	U[0.125, 0.208]
	Renewable Water Resources	0.167	U[0.125, 0.208]
	Consumption	0.167	U[0.125, 0.208]
	Renewable Energy	0.167	U[0.125, 0.208]
	Greenhouse Gases	0.167	U[0.125, 0.208]
Economic Wellbeing	Organic Farming	0.250	U[0.188, 0.313]
	Genuine Savings	0.250	U[0.188, 0.313]
	GDP	0.167	U[0.125, 0.208]
	Employment	0.167	U[0.125, 0.208]
	Public Debt	0.167	U[0.125, 0.208]

¹³ Dominican Republic, Belgium, Spain, United Kingdom, Hungary, France, Uganda, Sri Lanka, Egypt, Canada, Portugal, Ireland, Japan, Sierra Leone, United States, Greece, Tajikistan, Lebanon, Oman, Trinidad and Tobago, Jamaica, Uzbekistan.

To get a better understanding of these results, we study the dominant pair-wise comparisons, namely those comparisons where one country is better than another country on all indicators underlying an SSI Wellbeing dimension. For these dominant cases, the comparison is never reversed at any methodological configuration (be that a weighting vector or aggregation function or combination thereof). In the Human Wellbeing dimension, which is composed of 10 indicators, out of the 11,325 pair-wise comparisons involving the entire set of 151 countries¹⁴, only 17% are dominant. Similarly, in the Environmental Wellbeing (made of 6 indicators) and Economic Wellbeing dimension (made of 5 indicators) there are 14% and 8% dominant pair-wise comparisons respectively. Overall, these results suggest that the indicators underlying each SSI Wellbeing dimension cover different issues related to that dimension and explain why the Human Wellbeing country ranks are more robust than the Environmental Wellbeing ranks, which in turn are more robust than the Economic Wellbeing ranks. For comparison, in the 2011 Human Development Index (made of four indicators¹⁵), out of the 17,391 pair-wise comparisons involving 187 countries, almost 64% are dominant, which explains why the HDI would appear to be more robust to different methodological configurations than any of the SSI Wellbeing dimensions.

Yet, the robustness of an index should not be interpreted as an indication of the index quality but is instead a consequence of the index dimensionality. In other words, robustness is to some extent the flip side of redundancy: a very high correlation between indicators will lead to an index ranking that is practically not affected by the methodological choices, so the index will be both robust and redundant. Similarly, a low correlation among indicators would imply that the methodological choices are very important in determining country rankings, and thus that the index is unlikely to be robust to these choices.

Overall, country ranks on the three SSI Wellbeing dimensions are found to depend mostly on the indicators used and not on the methodological judgments made during the aggregation, while at the same time the SSI Wellbeing dimensions cover multiple aspects of sustainability.

¹⁴ There are $151 \times 150 / 2 = 11,325$ different pair-wise comparisons, without considering the reflexive comparisons of a country with itself.

¹⁵ The four indicators in the Human Development Index 2011 are: life expectancy at birth (weight 1/3), income (weight 1/3), mean years of schooling (weight 1/6) and expected years of schooling (weight 1/6).

Figure 4. Uncertainty analysis results for the Human Wellbeing

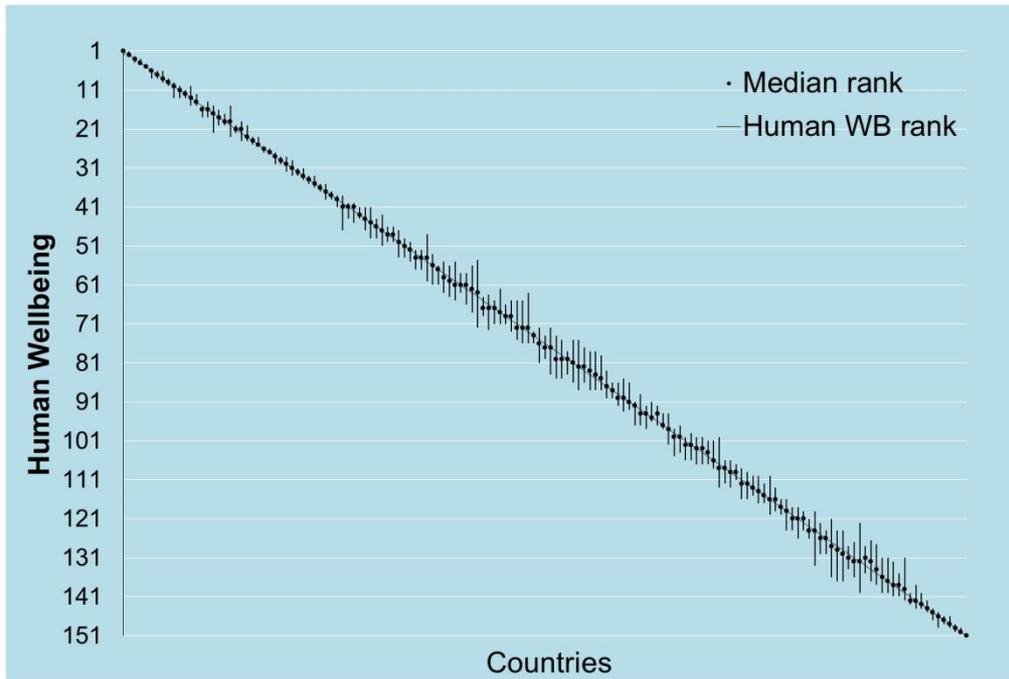


Figure 5. Uncertainty analysis results for the Environmental Wellbeing

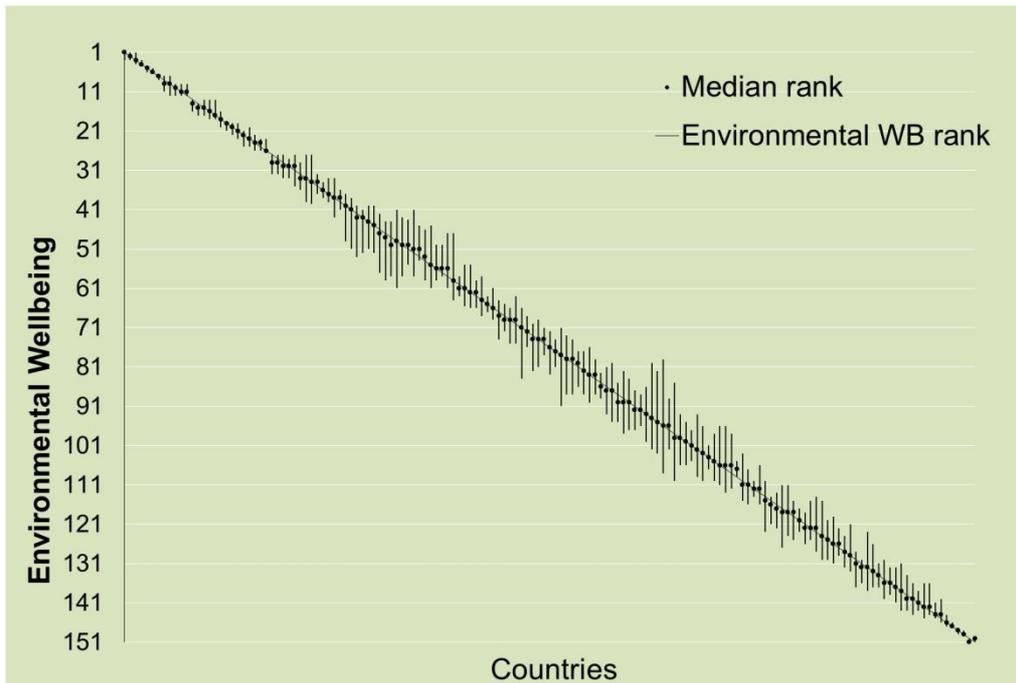


Figure 6. Uncertainty analysis results for the Economic Wellbeing

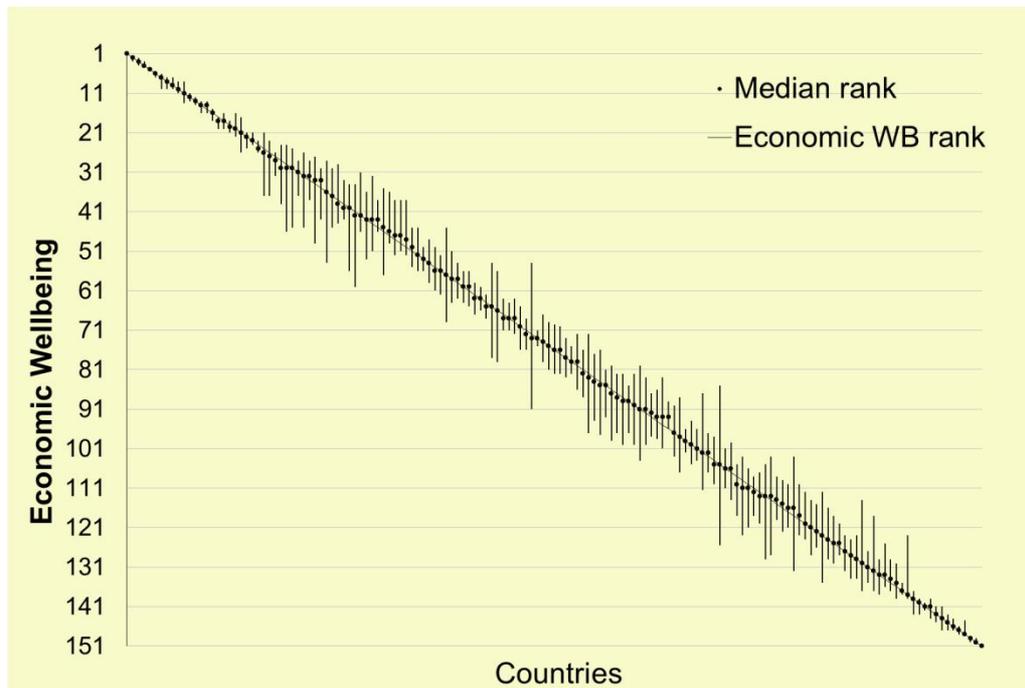


Table 12. Country ranks of the SSI Wellbeing dimensions (simulations)

	Human Wellbeing Simulations			Environmental Wellbeing Simulations			Economic Wellbeing Simulations		
	SSI rank	Median	90% c.i.	SSI rank	Median	90% c.i.	SSI rank	Median	90% c.i.
Albania	36	36	[35 ,37]	36	36	[34 ,38]	96	93	[89 ,96]
Algeria	53	54	[52 ,57]	79	79	[73 ,88]	63	63	[60 ,66]
Angola	140	139	[131 ,142]	16	16	[13 ,18]	145	145	[143 ,147]
Argentina	55	54	[48 ,60]	86	87	[81 ,93]	15	14	[13 ,16]
Armenia	72	72	[65 ,76]	76	76	[72 ,83]	97	97	[90 ,103]
Australia	28	28	[27 ,30]	145	144	[140 ,146]	9	9	[7 ,10]
Austria	5	5	[5 ,5]	70	69	[63 ,75]	11	11	[8 ,14]
Azerbaijan	84	83	[78 ,88]	87	87	[80 ,95]	54	54	[48 ,59]
Bangladesh	107	108	[100 ,113]	62	62	[55 ,66]	81	82	[76 ,88]
Belarus	45	45	[41 ,49]	109	107	[105 ,109]	38	39	[29 ,44]
Belgium	14	14	[12 ,15]	130	131	[128 ,137]	30	30	[25 ,45]
Benin	134	132	[127 ,137]	9	9	[7 ,12]	80	79	[72 ,86]
Bhutan	105	104	[101 ,107]	49	49	[41 ,61]	98	98	[88 ,107]
Bolivia	111	112	[108 ,116]	44	44	[40 ,51]	68	68	[64 ,71]
Bosnia-Herzegovina	44	44	[41 ,47]	129	129	[121 ,133]	115	114	[108 ,119]
Botswana	109	109	[106 ,113]	66	66	[61 ,69]	48	47	[38 ,52]
Brazil	77	77	[72 ,84]	45	45	[40 ,52]	62	63	[59 ,67]
Bulgaria	33	33	[31 ,34]	104	104	[101 ,107]	39	40	[33 ,43]
Burkina Faso	131	132	[127 ,136]	13	14	[13 ,16]	88	89	[82 ,100]
Burundi	119	119	[116 ,124]	32	33	[29 ,36]	149	149	[149 ,150]
Cambodia	110	109	[107 ,111]	5	5	[5 ,6]	75	75	[69 ,81]
Cameroon	113	113	[110 ,115]	23	23	[20 ,25]	77	76	[70 ,82]
Canada	12	12	[11 ,13]	139	140	[134 ,143]	66	66	[56 ,79]
Central African Republic	148	148	[146 ,149]	10	10	[9 ,12]	134	133	[125 ,136]
Chad	150	150	[149 ,150]	28	29	[27 ,32]	146	146	[144 ,147]
Chile	64	63	[55 ,72]	108	106	[98 ,112]	55	56	[50 ,61]
China	98	98	[94 ,102]	80	79	[74 ,88]	50	48	[38 ,52]
Colombia	92	92	[91 ,97]	34	34	[27 ,40]	71	72	[68 ,76]
Congo	143	143	[140 ,144]	39	38	[36 ,41]	140	140	[139 ,143]
Congo. Dem. Rep.	151	151	[151 ,151]	8	9	[7 ,11]	137	137	[135 ,138]
Costa Rica	75	76	[72 ,81]	24	24	[22 ,26]	45	43	[38 ,46]
Cote d'Ivoire	130	131	[128 ,134]	3	3	[1 ,4]	144	144	[141 ,147]
Croatia	35	35	[33 ,36]	85	86	[83 ,89]	24	25	[23 ,26]
Cuba	47	47	[43 ,51]	97	96	[89 ,102]	69	68	[63 ,72]
Cyprus	21	21	[20 ,22]	134	134	[131 ,137]	35	33	[30 ,43]
Czech Republic	19	19	[17 ,20]	122	122	[115 ,125]	4	4	[3 ,4]
Denmark	17	17	[15 ,22]	126	126	[119 ,131]	5	5	[5 ,5]
Dominican Republic	94	94	[92 ,98]	38	38	[33 ,43]	29	30	[24 ,46]
Ecuador	73	72	[63 ,76]	59	59	[47 ,64]	51	50	[45 ,55]
Egypt	48	48	[46 ,50]	117	118	[111 ,127]	65	65	[54 ,78]
El Salvador	88	88	[86 ,90]	64	64	[58 ,68]	73	73	[71 ,75]
Estonia	30	30	[28 ,32]	138	138	[131 ,143]	7	7	[6 ,10]
Ethiopia	137	137	[131 ,140]	1	1	[1 ,3]	126	125	[120 ,128]
Finland	4	4	[3 ,4]	103	103	[96 ,110]	6	6	[6 ,7]
France	11	11	[10 ,13]	99	99	[93 ,106]	41	42	[34 ,60]
Gabon	102	102	[99 ,106]	35	34	[32 ,37]	92	91	[83 ,100]
Gambia	132	132	[122 ,140]	42	43	[40 ,53]	136	135	[130 ,139]
Georgia	80	80	[78 ,84]	54	53	[46 ,59]	101	101	[96 ,104]
Germany	10	10	[9 ,13]	107	106	[96 ,113]	21	21	[17 ,26]
Ghana	114	114	[110 ,117]	19	19	[19 ,21]	106	106	[101 ,111]
Greece	27	27	[26 ,27]	120	120	[117 ,123]	105	105	[85 ,126]
Guatemala	104	103	[100 ,107]	17	17	[13 ,18]	67	68	[63 ,71]
Guinea	133	131	[128 ,135]	27	29	[27 ,32]	150	150	[149 ,150]
Guinea-Bissau	125	126	[122 ,130]	2	2	[1 ,3]	120	120	[112 ,124]
Guyana	100	100	[97 ,104]	92	92	[88 ,96]	99	99	[96 ,102]
Haiti	149	149	[148 ,150]	40	40	[37 ,49]	124	124	[116 ,129]

	Human Wellbeing Simulations			Environmental Wellbeing Simulations			Economic Wellbeing Simulations		
	SSI rank	Median	90% c.i.	SSI rank	Median	90% c.i.	SSI rank	Median	90% c.i.
Honduras	101	102	[100 ,106]	30	30	[28 ,33]	56	56	[52 ,62]
Hungary	22	21	[19 ,24]	101	101	[97 ,105]	40	40	[34 ,56]
Iceland	1	1	[1 ,2]	96	96	[79 ,108]	138	138	[123 ,139]
India	116	116	[110 ,120]	65	65	[63 ,67]	103	102	[97 ,107]
Indonesia	85	84	[78 ,88]	53	51	[45 ,54]	64	65	[62 ,68]
Iran	70	69	[65 ,73]	115	116	[114 ,121]	74	74	[67 ,79]
Iraq	99	100	[98 ,105]	137	137	[132 ,141]	142	141	[139 ,144]
Ireland	9	9	[8 ,10]	140	140	[136 ,144]	82	83	[72 ,97]
Israel	37	37	[35 ,39]	144	144	[141 ,145]	33	32	[28 ,38]
Italy	25	25	[23 ,25]	83	83	[76 ,90]	25	26	[21 ,37]
Jamaica	74	74	[73 ,76]	75	74	[71 ,78]	123	123	[112 ,135]
Japan	6	6	[6 ,8]	106	106	[96 ,111]	84	85	[76 ,98]
Jordan	62	61	[58 ,66]	142	142	[136 ,145]	116	115	[109 ,122]
Kazakhstan	56	56	[53 ,61]	136	136	[132 ,139]	76	76	[70 ,82]
Kenya	122	121	[119 ,124]	15	15	[13 ,17]	127	127	[123 ,132]
Korea, North	93	94	[89 ,97]	95	95	[82 ,103]	111	112	[108 ,118]
Korea, South	24	24	[23 ,25]	127	126	[122 ,129]	20	20	[16 ,22]
Kuwait	43	43	[41 ,44]	151	150	[150 ,151]	26	27	[23 ,37]
Kyrgyz Republic	78	80	[74 ,85]	57	56	[50 ,58]	94	93	[86 ,99]
Laos	96	94	[92 ,97]	25	24	[23 ,26]	89	89	[85 ,97]
Latvia	42	41	[40 ,45]	50	50	[43 ,58]	14	14	[13 ,16]
Lebanon	54	54	[52 ,57]	119	118	[115 ,125]	113	113	[105 ,129]
Liberia	126	126	[124 ,130]	41	41	[38 ,51]	139	139	[137 ,143]
Libya	52	52	[50 ,55]	146	146	[144 ,147]	117	116	[110 ,121]
Lithuania	34	34	[33 ,35]	93	93	[86 ,100]	16	16	[15 ,18]
Luxembourg	16	16	[14 ,18]	118	118	[111 ,124]	10	10	[8 ,11]
Macedonia	65	67	[64 ,69]	100	100	[95 ,106]	32	32	[26 ,45]
Madagascar	139	138	[135 ,141]	43	43	[41 ,52]	86	87	[80 ,99]
Malawi	108	108	[106 ,112]	12	11	[9 ,12]	133	133	[129 ,138]
Malaysia	58	59	[55 ,63]	84	83	[79 ,88]	49	47	[38 ,51]
Mali	120	121	[118 ,124]	48	50	[44 ,58]	119	118	[110 ,123]
Malta	40	41	[38 ,47]	141	141	[138 ,143]	87	88	[82 ,97]
Mauritania	123	124	[121 ,126]	71	71	[66 ,84]	148	148	[145 ,148]
Mexico	87	87	[83 ,90]	77	77	[74 ,81]	19	20	[18 ,21]
Moldova	67	67	[65 ,71]	102	102	[93 ,109]	37	37	[30 ,45]
Mongolia	91	91	[86 ,93]	123	122	[114 ,128]	132	132	[118 ,137]
Montenegro	38	38	[37 ,39]	51	50	[44 ,55]	78	78	[73 ,83]
Morocco	76	77	[74 ,80]	110	111	[103 ,115]	79	79	[75 ,82]
Mozambique	144	144	[142 ,145]	7	7	[7 ,8]	131	131	[127 ,135]
Myanmar	124	124	[119 ,133]	37	37	[33 ,39]	107	106	[100 ,114]
Namibia	117	116	[113 ,119]	74	74	[69 ,81]	95	93	[83 ,101]
Nepal	135	134	[128 ,138]	6	6	[5 ,6]	125	125	[118 ,130]
Netherlands	8	8	[6 ,9]	124	124	[115 ,130]	18	18	[16 ,20]
New Zealand	13	13	[10 ,15]	78	78	[71 ,91]	22	22	[21 ,25]
Nicaragua	112	112	[109 ,116]	20	20	[19 ,22]	100	100	[94 ,105]
Niger	146	146	[145 ,149]	46	47	[42 ,57]	112	113	[107 ,120]
Nigeria	141	142	[140 ,143]	14	15	[14 ,17]	108	110	[105 ,118]
Norway	2	2	[1 ,2]	94	94	[80 ,102]	3	3	[2 ,4]
Oman	51	51	[49 ,54]	147	147	[146 ,147]	114	113	[103 ,128]
Pakistan	115	115	[112 ,117]	61	61	[55 ,66]	93	92	[87 ,98]
Panama	86	85	[79 ,88]	63	62	[59 ,66]	47	46	[36 ,49]
Papua New Guinea	138	138	[132 ,141]	69	69	[66 ,75]	85	85	[81 ,93]
Paraguay	103	103	[100 ,107]	47	48	[44 ,59]	61	60	[56 ,65]
Peru	89	90	[86 ,92]	68	69	[65 ,72]	31	31	[28 ,37]
Philippines	68	68	[62 ,71]	56	56	[50 ,59]	59	58	[54 ,63]
Poland	26	26	[26 ,27]	105	105	[98 ,110]	17	18	[17 ,20]
Portugal	23	23	[20 ,24]	82	82	[77 ,88]	72	73	[54 ,91]

	Human Wellbeing Simulations			Environmental Wellbeing Simulations			Economic Wellbeing Simulations		
	SSI rank	Median	90% c.i.	SSI rank	Median	90% c.i.	SSI rank	Median	90% c.i.
Qatar	81	81	[75 ,86]	150	151	[150 ,151]	44	43	[32 ,51]
Romania	50	50	[47 ,54]	81	80	[77 ,86]	23	23	[21 ,24]
Russia	59	60	[56 ,64]	128	128	[124 ,132]	52	52	[45 ,56]
Rwanda	129	130	[124 ,137]	18	18	[16 ,20]	129	129	[123 ,134]
Saudi Arabia	57	57	[56 ,61]	143	142	[136 ,144]	83	84	[77 ,94]
Senegal	106	106	[101 ,108]	22	22	[21 ,25]	122	122	[115 ,126]
Serbia	39	39	[38 ,41]	91	92	[87 ,97]	121	121	[114 ,128]
Sierra Leone	147	147	[146 ,148]	31	30	[27 ,35]	91	91	[80 ,104]
Slovak Republic	18	18	[16 ,20]	90	90	[84 ,97]	12	12	[11 ,13]
Slovenia	20	19	[15 ,23]	88	90	[85 ,95]	8	8	[7 ,10]
South Africa	90	90	[85 ,94]	116	117	[113 ,122]	104	105	[98 ,110]
Spain	31	31	[29 ,33]	112	112	[110 ,114]	34	33	[27 ,49]
Sri Lanka	60	61	[55 ,65]	29	30	[27 ,33]	57	57	[45 ,69]
Sudan	145	145	[144 ,147]	58	56	[47 ,61]	141	141	[140 ,142]
Sweden	3	3	[3 ,4]	73	74	[70 ,82]	2	2	[2 ,3]
Switzerland	7	7	[6 ,8]	52	51	[41 ,58]	1	1	[1 ,1]
Syria	66	67	[64 ,73]	133	133	[126 ,137]	110	111	[106 ,121]
Taiwan	29	29	[28 ,30]	131	132	[130 ,136]	58	58	[51 ,64]
Tajikistan	97	97	[94 ,98]	67	68	[64 ,74]	109	111	[103 ,123]
Tanzania	127	128	[121 ,136]	4	4	[3 ,4]	128	128	[124 ,134]
Thailand	71	72	[65 ,75]	55	55	[45 ,61]	42	42	[31 ,46]
Togo	136	136	[131 ,140]	11	11	[9 ,12]	147	147	[146 ,148]
Trinidad and Tobago	61	61	[58 ,63]	111	111	[107 ,116]	118	116	[103 ,132]
Tunisia	49	48	[46 ,50]	114	115	[110 ,123]	43	43	[36 ,53]
Turkey	69	69	[66 ,71]	113	112	[106 ,116]	27	28	[26 ,32]
Turkmenistan	79	80	[75 ,85]	149	149	[148 ,149]	90	90	[82 ,100]
Uganda	118	118	[116 ,120]	26	26	[23 ,26]	46	45	[35 ,57]
Ukraine	63	62	[56 ,68]	121	122	[118 ,126]	53	53	[50 ,56]
United Arab Emirates	46	46	[44 ,49]	148	148	[148 ,149]	28	30	[24 ,39]
United Kingdom	15	16	[15 ,18]	89	90	[82 ,98]	36	36	[28 ,54]
United States	32	32	[31 ,33]	125	125	[120 ,130]	102	102	[87 ,112]
Uruguay	41	41	[40 ,44]	98	99	[85 ,110]	13	13	[12 ,14]
Uzbekistan	95	95	[91 ,96]	135	136	[130 ,140]	130	130	[114 ,137]
Venezuela	83	82	[77 ,86]	72	72	[68 ,76]	60	60	[56 ,64]
Vietnam	82	82	[75 ,88]	60	61	[58 ,63]	70	70	[65 ,76]
Yemen	121	121	[118 ,126]	132	132	[123 ,138]	143	143	[141 ,145]
Zambia	142	142	[138 ,144]	33	33	[27 ,39]	135	134	[129 ,137]
Zimbabwe	128	129	[124 ,137]	21	21	[19 ,23]	151	151	[151 ,151]

7. SSI and variability

This section analyses the relationship between an SSI Wellbeing score and the variability of the underlying indicators, i.e. what the relationship is, if any, between an SSI Wellbeing score and a balanced performance in the underlying indicators. While country scores on the SSI Wellbeing dimensions provide a quantitative indication of societies' achievement, changes in the variability convey information on the quality of the changes: an increase in a Wellbeing score may be achieved by improving performance in specific indicators, but also by reducing gaps in performance between indicators. An additional piece of information from this type of analysis is that countries with high variability are compensating very poor performance in some indicators with high performance in other indicators. This compensation is moderated by the use of the geometric mean, yet not eliminated. In order to measure the variability of the underlying indicators we will calculate their coefficient of variation, which is the ratio of the standard deviation across the indicators' scores for a given country in a Wellbeing dimension and a country's score on that dimension.

As can be seen in Figure 7, generally countries with higher levels of Wellbeing performance exhibit less variability since they tend to achieve high values in all the underlying indicators. The opposite holds generally true for countries with lower levels of achievement, see the scissors' pattern. This reflects the fact that countries with lower levels of achievement generally display larger discrepancies in performance between indicators, and that focusing only on particular indicators while allowing performance gaps between them yields only marginal results. In the Human Wellbeing dimension, Qatar and Indonesia have similar scores (close to 6.5) but very different profiles in the underlying indicators (see Figure 8). In fact, as the variability indicates, Qatar has the highest compensation, whereby a very poor performance on Income distribution is partially compensated by very high performance on several indicators. On the other hand, the performance of Indonesia is more balanced in the Human Wellbeing dimension. A similar comparison can be made for the Environmental Wellbeing dimension (see Figure 9), whereby Sri Lanka and Zambia have similar average performance on that dimension, but the performance of Sri Lanka is much more balanced, whilst Sri Lanka's weak aspect is the poor Air Quality which is partially compensated by very good performance on almost all the other indicators in that dimension. Finally, a similar comparison for the Economic Wellbeing can be made between Austria and Uruguay, countries that despite their similar Economic Wellbeing scores have notable differences in their performance within the dimension (Figure 10).

Figure 7. SSI Wellbeing scores and the variability of their underlying indicators

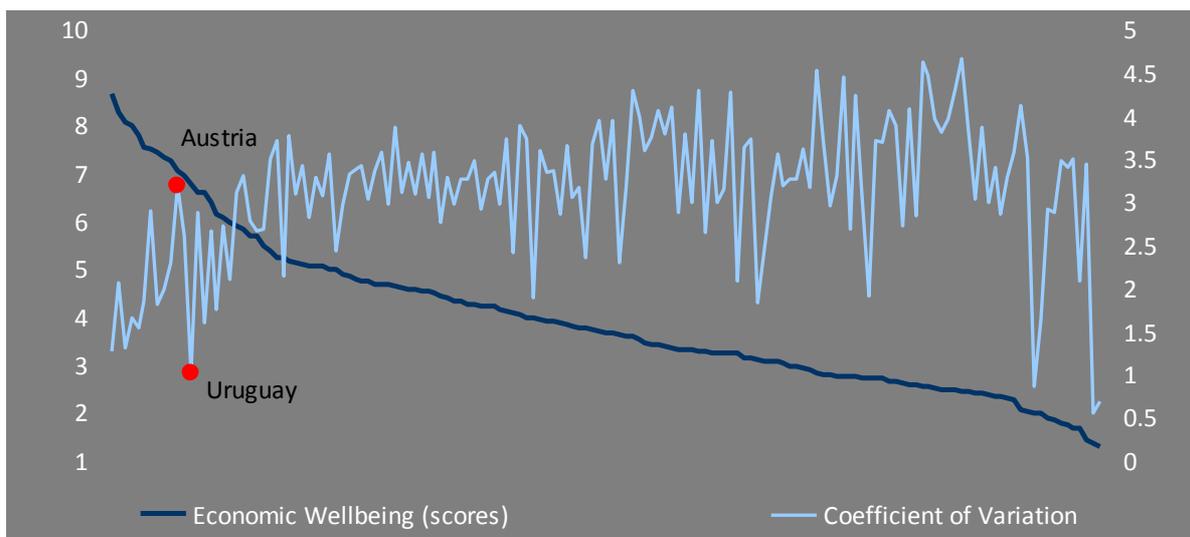
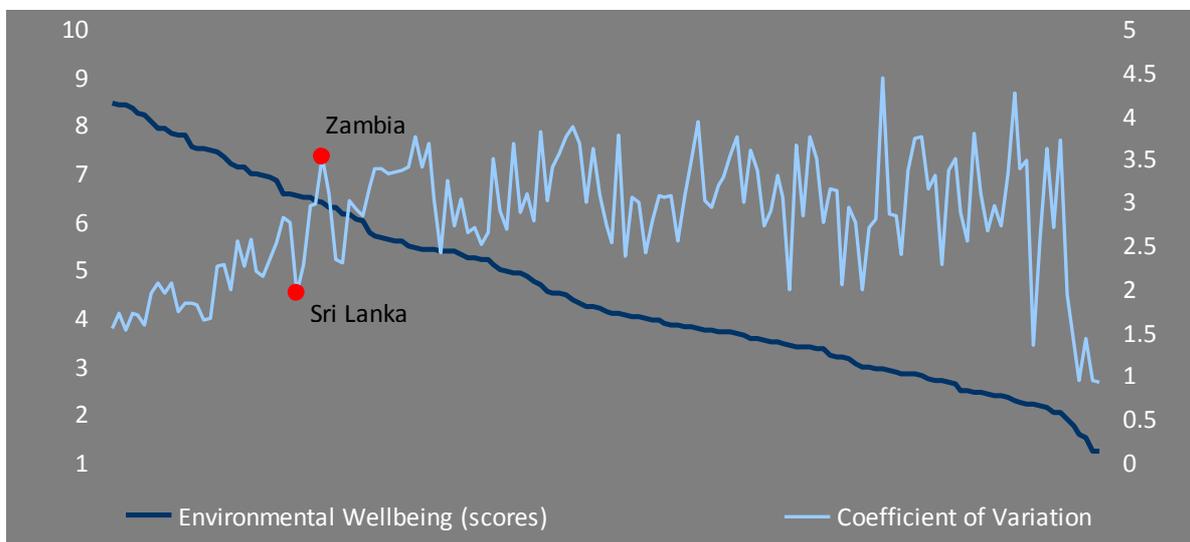
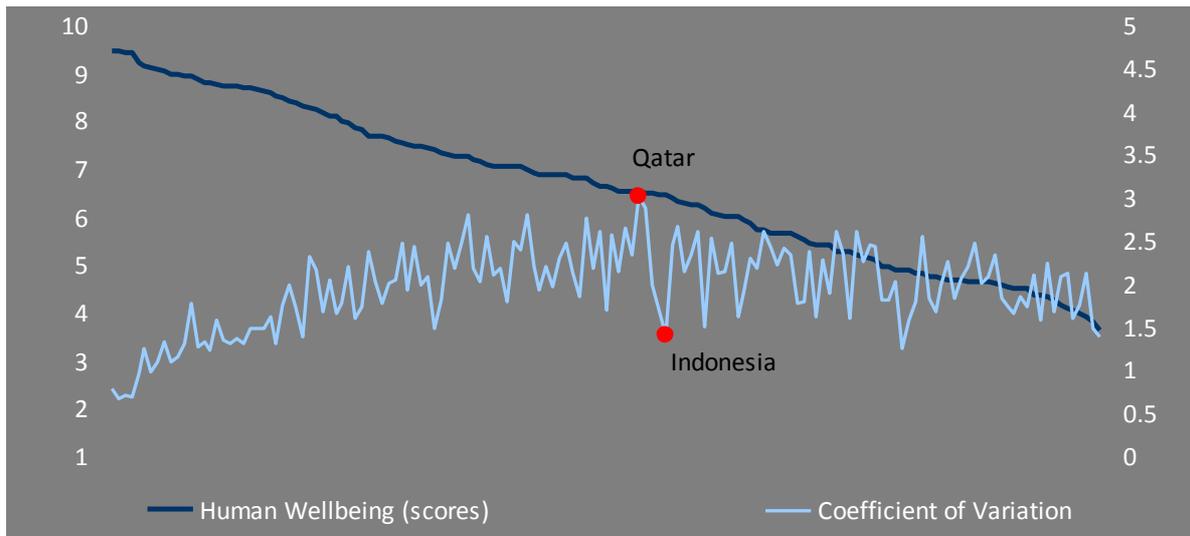


Figure 8. Human Wellbeing: country profiles for Qatar and Indonesia

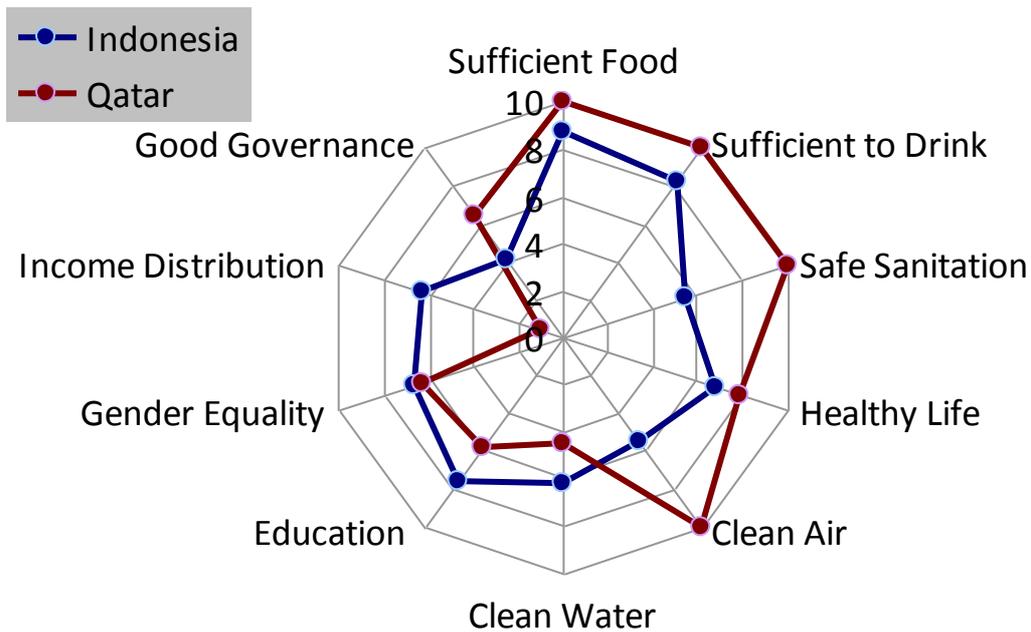


Figure 9. Environmental Wellbeing: country profiles for Sri Lanka and Zambia

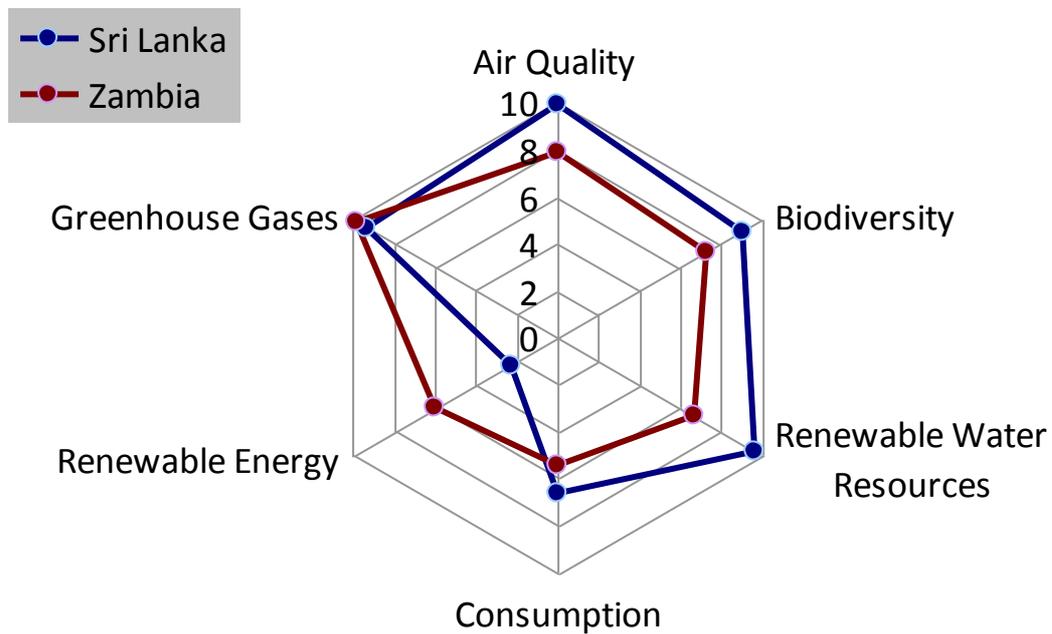
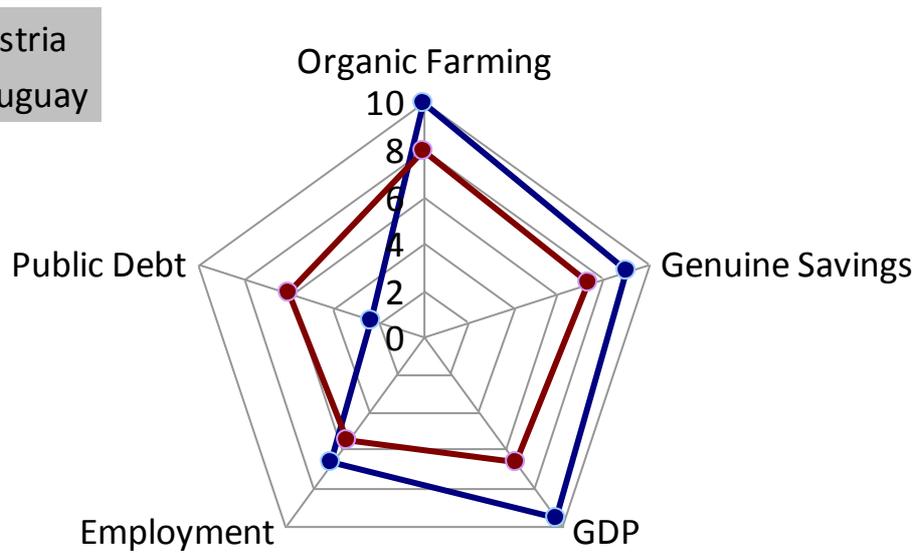


Figure 10. Economic Wellbeing: country profiles for Austria and Uruguay



These results only confirm that countries with similar scores on a Wellbeing dimension do not necessarily have the same performance on the underlying categories of sustainability. Hence, it is important to delve into the SSI components in order to identify where and why some sustainability policies work well or not.

8. Conclusions

The Sustainable Society Foundation in the Netherlands has been developing since 2006 the Sustainable Society Index (SSI) that aims to be a comprehensive and quantitative method to measure and monitor the health of coupled human-environmental systems at national level worldwide. The SSI framework departs from a purely protectionist approach that would aim to maintain natural systems with minimal human impact. It aims instead to describe societal progress along all three directions: human, environmental and economic. To this end, the SSI comprises eight policy categories and three Wellbeing dimensions (Human, Environmental, Economic) and is calculated for 151 countries accounting for 99% of the world population.

The Econometrics and Applied Statistics Unit at the European Commission Joint Research Centre (JRC) in Ispra-Italy was invited by the Sustainable Society Foundation to audit and refine the SSI. The JRC analysis was based on an in-house quality control process¹⁶ that aims to ensure the transparency of the SSI methodology and the reliability of the results. The JRC recommendations on the revision of the framework together with fine-tuning suggestions related to indicator calculation formulas were taken into account in the final version of the SSI model. In this way, the development of the SSI-2012 moved from a one-way design process to an iterative process with the JRC with a view to arrive at a balanced index, where no indicator dominates the results and no indicator is only cosmetic to the framework.

This report touched upon the necessity for going beyond GDP in order to assess societal progress, presented the new SSI-2012 framework, the revisions made with respect to the previous framework and the rationale behind the selection of the indicators. A total of 21 indicators were selected from fifteen sources, such as the Food and Agriculture Organization, World Health Organization, UNESCO, World Economic Forum, World Bank and International Monetary Fund.

The revised methodology used to calculate the SSI components includes data quality issues (missing data, possible outliers), choice of normalization, weighting and aggregation formula. Raw data are first checked for reporting errors and outliers that could strongly bias the results are treated. The indicators are normalized using the min-max method in 1-10 scale (10 = most sustainable score) and aggregated into eight SSI categories by simple geometric mean. Three SSI

¹⁶The JRC analysis was based on the recommendations of the OECD (2008) Handbook on Composite Indicators, and on more recent research from the JRC. The JRC conducts auditing studies of composite indicators upon request of the index developers. For more information visit: <http://composite-indicators.jrc.ec.europa.eu>

Wellbeing dimensions are calculated as the geometric mean of the underlying categories. In the SSI-2012, the aggregation formula was changed from an arithmetic to a geometric mean, because the latter formula: (a) implies only partial substitutability, i.e. poor performance in one indicator cannot be fully compensated by good performance in another, (b) rewards balance by penalizing uneven performance between indicators, (c) provides incentives for improvement in the weak dimensions: the geometric mean considers that the lower the performance in a particular indicator, the more urgent it becomes to improve achievements in that indicator.

The statistical coherence of the SSI framework is first assessed by analyzing the covariance structure within and across the categories and the dimensions. The analysis confirms that the SSI is well-structured, as the indicators are more correlated to their own category than to any other category and all correlations within a category are significant and positive. Same conclusion is drawn at the dimension level. Second, an assessment of the implicit weights via non-linear methods (kernel smoothing regression) reveals that in most SSI categories the underlying indicators have similar implicit weights in classifying countries within each category, though some indicators are slightly more important than others. A few imbalances were found within the Transition and the Economy category. Before deciding whether to adjust the nominal weights of the indicators whose implicit weight was much lower than what would have been expected given the equal nominal weights, the marginal weights (sensitivity of SSI categories to 10% change in the underlying indicators keeping all other indicators fixed) were analysed. It was found that the marginal weights of the indicators on the SSI categories scores do not differ too much. All things considered, had the objective of the SSI components been to merely provide a ranking of countries, then the few imbalances in the implicit weights would have necessitated some methodological refinements (for example adjusting the nominal weights from equal to unequal). However, since the primary aim of the SSI components is to benchmark country performance with respect to a perfect 10 score, looking at the marginal weights, which convey exactly this piece of information is more relevant in this context. Upon all these considerations, the SSI team, together with the JRC decided not to alter the nominal weights for the indicators but to keep them equal.

A robustness analysis of country ranks for each SSI Wellbeing dimension was conducted to assess to what extent the results depend on the selected set of indicators or on the methodological judgments (normalization and weighting) made during the development of the SSI. Overall, country ranks in any of the SSI Wellbeing dimensions were supported by the simulations, whereby 90% of the countries shift less than ± 1 position with respect to the

simulated median. These results suggested that the SSI provides a reliable picture of the countries' performance, that is not driven by methodological assumptions. Some countries with wide intervals in the simulations were flagged in order to give more transparency in the entire process and to help appreciate the uncertainty in the SSI results for those countries.

Key results on the world landscape of societies' achievements confirmed the inverted shaped relationship between economic and environmental wellbeing (known as Environmental Kuznets Curve). The Environmental Wellbeing had a strong and negative correlation to the Human Wellbeing and to the Economic Wellbeing. It appeared, thereafter, that the Human and Economic Wellbeing go hand-in-hand in several countries, but often at the expense of the Environmental Wellbeing. Fortunately, this was not the case for all countries. Furthermore, while country scores on the SSI wellbeing dimensions provided a quantitative indication of societies' achievement, changes in the wellbeing variability conveyed information on the quality of the changes: an increase in a Wellbeing dimension may be achieved by improving performance in specific indicators, but also by reducing gaps in performance between indicators. Countries with higher levels of Wellbeing performance exhibited less variability since they tended to achieve high values in all the underlying indicators. The opposite held generally true for countries with lower levels of achievement (scissors' pattern). This reflected the fact that countries with lower levels of achievement generally displayed larger discrepancies in performance between indicators, and that focusing only on particular indicators while allowing performance gaps between them would yield only marginal results. Results also showed that countries with similar scores on a Wellbeing dimension do not necessarily have the same performance on the underlying categories of sustainability. Hence, it is important to delve into the SSI components in order to identify where and why some sustainability policies work well and where they do not.

All things considered, the Sustainable Society Index appears to be a comprehensive and quantitative method to measure and monitor the health of coupled human-environmental systems at national level worldwide. The SSI framework goes beyond a purely protectionist approach that would aim to maintain natural systems with minimal human impact. It aims instead to describe societal progress along all three dimensions: human, environmental and economic, which build on 21 (simple or composite) indicators. Undoubtedly, the SSI is not the only way to monitor sustainability. But it is a conceptually and statistically sound tool, that is widely applicable for ongoing assessment of the human-environmental systems and a key benchmark against which to compare future progress and inform comprehensive societal

policies. As with any indicator, the SSI assesses rather than models current and future conditions, and so it cannot predict the future. However, it can be used to simulate the consequences of a range of potential actions, providing a powerful tool to inform decisions about how to achieve human and economic growth without compromising the environmental wellbeing.

In a nutshell, all JRC's recommendations have been implemented in the new update of the SSI-2012, and the overall conclusions of this audit are:

1. *The revised SSI framework is conceptually coherent:*

- the indicators are more correlated to their own category than to any other category;
- all correlations within a category are significant and positive;
- the same conclusions are drawn at the dimension level.

2. *The revised SSI framework meets the statistical requirements set by JRC:*

- in most SSI categories the underlying indicators have similar implicit weights in classifying countries within each category;
- few imbalances were found within the Transition and the Economy category;
- the marginal weights of the indicators on the SSI categories scores do not differ too much;
- the robustness analysis of country ranks for each SSI Wellbeing dimension showed that the SSI provides a reliable picture of the countries' performance, that is not driven by methodological assumptions.

3. *The SSI is well suited to assess nations' development towards sustainability in its broad sense: Human, Environmental and Economic Wellbeing:*

- the SSI framework goes beyond a purely protectionist approach that would aim to maintain natural systems with minimal human impact;
- it describes societal progress along all three dimensions: human, environmental and economic, built on 21 indicators;
- it is a conceptually and statistically sound tool, that is widely applicable for on-going assessment of the human-environmental systems;
- it can be used to simulate the consequences of a range of potential actions, providing a powerful tool to inform decisions about how to achieve human and economic growth without compromising the environmental wellbeing.

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31. Human Development Index (HDI, 2011) <http://hdr.undp.org/en/statistics/>
32. Human Sustainable Development Index (HSDI, 2010) <http://ourworld.unu.edu/en/the-2010-human-sustainable-development-index/>
33. EU Regional Human Development Index (2010) http://ec.europa.eu/regional_policy/sources/docgener/focus/2011_02_hdev_hpov_indices.pdf
34. Environmental Sustainability Index (ESI, 2005) <http://www.yale.edu/esi/>
35. Environmental Performance Index (EPI, 2012) <http://sedac.ciesin.columbia.edu/data/set/epi-environmental-performance-index-pilot-trend-2012>
36. Commitment to Development Index (CDI, 20012) http://www.cgdev.org/section/initiatives/active/cdi/non_flash/

37. Index for Sustainable Economic Welfare (ISEW) - Genuine Progress Indicator (GPI) <http://ideas.repec.org/a/eee/ecolec/v44y2003i1p105-118.html>
38. Ecological Footprint http://www.footprintnetwork.org/en/index.php/GFN/page/footprint_science_introduction/
39. Human Wellbeing Index (HWI) <http://www.wilsoncenter.org/event/the-wellbeing-nations-developing-tools-for-measuring-sustainable-development>
40. Ecosystem Wellbeing Index (EWI) <http://cmsdata.iucn.org/downloads/wonback.pdf>
41. Wellbeing Index (WI) <http://cmsdata.iucn.org/downloads/wonback.pdf>
42. Wellbeing Stress Index (WSI) <http://cmsdata.iucn.org/downloads/wonback.pdf>
43. Sustainability Rating (2011) https://www.credit-suisse.com/publications/annualreporting/doc/2011/csg_crr_2011_en.pdf#page=69
44. Australian SAM Sustainability Index (AuSSI, 2012) http://www.sustainability-index.com/images/aussi-guidebook_tcm1071-337256.pdf
45. FEEM Sustainability Index (FEEM SI methodology report 2011) <http://feemsi.org/>
46. Welfare Index (2010) http://www.academia.edu/233979/Beyond_GDP_Welfare_across_Countries_and_Time
47. American Human Development Index (2011) <http://hdr.undp.org/en/statistics/>
48. Environmental Vulnerability Index (EVI, 2005) http://vulnerabilityindex.net/evi_2005.htm
49. Environmental Degradation Index (EDI, 2006) <http://marno.lecture.ub.ac.id/files/2012/06/KEBERLANJUTAN-LINGKUNGAN.pdf>
50. Canadian Index of Wellbeing (CIW, 2011) <http://ciw.ca/reports/en/Reports%20and%20FAQs/CIW-HowAreCanadiansReallyDoing-FINAL.pdf>
51. Best Performing Cities (2011) <http://bestcities.milkeninstitute.org/>
52. European Cities Monitor (2011) http://www.berlin-partner.de/fileadmin/chefredaktion/pdf/studien-rankings/2011_en_European-Cities-Monitor.pdf
53. European Smart Cities (2011) <http://www.smart-cities.eu/ranking.html>
54. European Green City Index (2010) <http://www.siemens.com/press/en/events/corporate/2009-12-Cop15.php>
55. Happy Planet Index (2012) <http://www.happyplanetindex.org/data/>
56. Living Planet Index (2012) http://awsassets.panda.org/downloads/1_lpr_2012_online_full_size_single_pages_final_120516.pdf
57. Most Livable Cities (2012) https://www.eiu.com/public/topical_report.aspx?campaignid=Liveability2012
58. European Economic Sustainability Index (EESI, 2010) http://www.epc.eu/documents/uploads/pub_1127_eesi.pdf
59. Alternative Country Risk Rating (IRPA, 2008) http://web.undp.org/developmentstudies/docs/indices_2008_bandura.pdf

(all links above were accessed on Dec. 31, 2012)

About the authors

Michaela Saisana has been a Scientific Officer at the Joint Research Centre (JRC) of the European Commission (Italy) since 1998. She has audited more than 60 composite indicators, upon request of their developers, including Yale and Columbia University, World Economic Forum, Harvard School of Economics, INSEAD, World Intellectual Property Organization, Bertelsmann Foundation, New York Medical College, University of S. Carolina- Criminology and Criminal Justice, World Justice Project, Transparency International and others. She is offering regularly courses on the development and robustness assessment of composite indicators to the academia, international organizations, and European Commission officials. She is a principal author of the 2008 OECD/JRC Handbook on Composite Indicators, co-author of the book *Global Sensitivity Analysis: The Primer* (2008), and developer and moderator of the JRC Information server on composite indicators. Her publications deal with sensitivity analysis, composite indicators, multicriteria analysis, multivariate analysis, multi-objective optimization, and air quality modelling and forecasting (20 peer-reviewed publications, 50 working papers). In 2004 she won the European Commission – JRC Young Scientist Prize in Statistics and Econometrics, awarded by the then Commissioner for Research Janez Potočnik. She has a PhD and an MSc in Chemical Engineering from the National Technical University of Athens (received with Awards from the Technical Chambers of Greece).

Dionisis Th. Philippas has been a researcher for the last five years at the University of Patras (Greece) and since 2012 a post-doc researcher at the Unit of Econometrics and Applied Statistics at the Joint Research Centre of the European Commission. His primary research topic is mainly in financial innovation, associated with Economics and Financial Econometrics, indicators and time series, in the presence of risk and abrupt changes. He also examines various issues related to asset pricing and market behavior (volatility, information asymmetries, financial engineering, and non-linear systems). He has taught various modules (Quantitative Analysis, Applied Statistics, Microeconomics, Technical analysis, etc.) to the academia and he has presented his research to a number of international conferences. Moreover, he has professional experience as a financial analyst, seminar trainer, and consultant for the private sector on finance-related projects. His publications deal with financial innovation, financial markets and risk, information entropy, forecasting, multivariate analysis, and performance of indicators, (4 peer-reviewed publications, 4 working papers, 1 published book as a syllabus for Greek universities, and 2 published handbooks). He has a Ph.D. in Financial Econometrics from the Department of Business Administration at the University of Patras (Greece) and an M.Sc. in Economics from the Department of Economics at the University of Athens.

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Abstract

The JRC analysis on the Sustainable Society Index (SSI), conducted upon request of the SSI developers, was based on an in-house quality control process that aims to ensure the transparency of the SSI methodology and the reliability of the results. In this way, the development of the SSI-2012 moved from a one-way design process to an iterative process with the JRC with a view to arrive at a balanced index, where no indicator dominates the results and no indicator is only cosmetic to the framework. Key results on the world landscape of societies' achievements confirmed the inverted shaped relationship between economic and environmental wellbeing (known as Environmental Kuznets Curve). The Environmental Wellbeing had a strong and negative correlation to the Human Wellbeing and to the Economic Wellbeing. It appeared, thereafter, that the Human and Economic Wellbeing go hand-in-hand in several countries, but often at the expense of the Environmental Wellbeing. Fortunately, this was not the case for all countries. This report discusses how the SSI appears to be a comprehensive and quantitative method to measure and monitor the health of coupled human-environmental systems at national level worldwide by going beyond a purely protectionist approach that would aim to maintain natural systems with minimal human impact. Undoubtedly, the SSI is not the only way to monitor sustainability. But it is a conceptually and statistically sound tool that is widely applicable for ongoing assessment of the human-environmental systems and a key benchmark against which to compare future progress and inform comprehensive societal policies. As with any indicator, the SSI assesses rather than models current and future conditions, and so it cannot predict the future. However, it can be used to simulate the consequences of a range of potential actions, providing a powerful tool to inform decisions about how to achieve human and economic growth without compromising the environmental wellbeing.

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