Indicators for Monitoring Sustainable Development Goals: An Application to Oceanic Development in the European Union

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Key Points:

- The SDG framework would benefit from the (complementary) inclusion of composite indicators (CIs).
- CIs support the identification of synergies and trade-offs, providing policy guidance in achieving sustainable development.
- Analysis of SDG 14 (Ocean) for EU coastal states to demonstrate the inclusion of CIs.

Abstract

The 2030 Agenda for Sustainable Development includes a set of 17 Sustainable Development Goals (SDG) with 169 specific targets. As such, it could be a step forward in achieving efficient governance and policies for global sustainable development. However, the current indicator framework with its broad set of individual indicators prevents straightforward assessment of synergies and trade-offs between the various indicators, targets, and goals thus heightening the significance of policy guidance in achieving sustainable development. With our detailed analysis of SDG 14 (Ocean) for European Union coastal states, we demonstrate how the (complementary) inclusion of composite indicators that aggregate the individual indicators by applying a generalized mean can provide important additional information and facilitate the assessment of sustainable development in general and in the SDG context in particular. Embedded in the context of social choice theory, the generalized mean varies the specification of substitution elasticity and thus allows a) for a straightforward distinction between a concept of weak and strong sustainability and b) for straightforward sensitivity analysis. We show that while in general the EU coastal states have a fairly balanced record at the SDG 14 level, certain countries like Slovenia and Portugal with a fairly balanced and a fairly unbalanced showing, respectively, rank very differently in terms of the two concepts of strong sustainability.

1 Introduction

On 25 September 2015, the 193 members of the United Nations General Assembly adopted the 2030 Agenda for Sustainable Development. This agenda includes a set of 17 Sustainable Development Goals (SDG) with 169 specific targets (UN 2015). Part of the sustainable development strategy is a set of global indicators used to monitor and assess progress over and against both the overall goals and the specific targets. The Inter Agency and Expert Group on SDG Indicators (IAEG-SDGs) established by the UN Statistical Commission (UNSC) at its 46th session (3-6 March 2015) is responsible for the development of the global indicator framework in conjunction with the UN Statistical Commission. Initially numbering 300, the proposed indicators have undergone an inclusive, open and transparent consultation process in which countries, regional and international agencies, civil society, academia, and the private sector were invited to comment and express their views (UN 2015, IAEG-SDG 2015). This discourse has generated adjustments, deletions and replacements in the initial indicator set providing the basis for a final proposal of 230 SDG indicators presented at the 47th session (8-11 March 2016) of the UN Statistical Commission (UN 2016).

The large number of indicators is considered necessary to fulfill the criteria of being useful in a management context and for the purpose of (statistical) capacity building (UN 2015, 2016). At the same time, the large number of indicators amplifies the effort needed to evaluate the overall success in achieving sustainable development. Not surprisingly, one major concern in the current discussion about the monitoring process is that clear policy guidance towards achieving an SDG is potentially blurred by the number of targets and the even larger number of indicators. This could lead to arbitrary application of management measures focusing on less critical or more easy-to-achieve targets to the detriment of others (Loewe and Rippin 2015). At all events, we can confidently expect the 230 indicators to be further refined and adjusted in the future. The work plan of the expert group for the next few years explicitly contains the task of developing procedures for the methodological review and revision of the current indicator base (UN 2016). While for the initial set of 300 indicators a color classification (green, yellow, and grey) was used to reflect progress on indicator development and agreement, the current version distinguishes between three different tiers for the indicators, reflecting the degree of methodological development and data availability (UN 2016). About one third of the indicators (78) have been classified as tier III (*indicators for which there are no established methodology and standards or methodology/standards are being developed/tested,* IAEG-SDG 2016a), thus indicating the challenges faced by the IAEG-SDGs over the course of the next year(s). At the 48th session of the UNSC, the IAEG-SDGs will report on developments and adjustments regarding data availability and methodology (not restricted to tier-III indicators).

Part of the work program for the IAEG-SDGs is to further analyze interlinkages across goals and targets and to identify multi-purpose indicators (IAEG-SDG 2016b). Given this aim, it is surprising that relatively little attention appears to have been devoted to conceptual issues with regard to the measurement of synergies and trade-offs between targets and goals. A particularly urgent question is how the overall sustainability of development is to be assessed. Surprising here is the opposition to composite indices in favor of the use of a large number of stand-alone indicators as the backbone of SDG operationalization, based on the argument that such an approach results in clear(er) policy recommendations. This argument can be disputed—notably with regard to the aim of guiding policy towards sustainable development. Pintér et al. (2005) and Kopfmüller et al. (2012) argue that a small set of indicators has greater relevance for decision-makers. However, facing such a large set of goals (and even larger set of targets), it seems highly unrealistic to plump for a number of (headline) indicators that decision-makers will have no trouble keeping in mind. Clearly, the statistical requirement of selecting indicators that are (simply) measurable, robust, and comparable is a strong argument for avoiding more complicated composite indicators.

However, using composite indicators as complements to the single indicators could support the overall assessment process without necessitating any significant changes to the current indicator base. Of course, the individual indicators remain the backbone of the indicator framework, as they serve the detailed assessment of specific policy measures. But the composite indicators allow for an explicit assessment of trade-offs between policies. Policies often affect various indicators in opposite ways (e.g., job creation versus nature conversation), making it practically impossible to provide policy advice based on indicator sets (given that no policy exists that would improve all indicators). The current outline of the indicator framework for the SDGs (i.e., an indicator set without explicit treatment of trade-offs) could be interpreted as an assessment approach dedicated to a concept of strong sustainability, according to which sustainable development requires that all indicators be maintained at least at their current level. That would, for example, imply that in a situation where all indicators improve except for one (which in itself would be an unlikely success), the goal of sustainable development would technically not be achieved.

Facing these competing aims, this paper discusses the extent to which the inclusion of additional, scientifically sound composite indicators can improve the validity and policy relevance of the current SDG measurement and assessment framework. We discuss the degree to which different concepts of sustainable development are already implicitly embedded in the proposed framework, arguing that the debate about the inclusion or omission of certain indicators is a discussion about weights given to specific targets and is indeed very similar to the choices that have to be discussed in the case of constructing composite indicators. Specifically, we analyze in detail the indicators related to SDG 14: *Conserve and sustainably use the oceans, seas* *and marine resources for sustainable development.* We take this as an example enabling us to discuss the use and advantages of composite indicators and emphasize the challenges faced by IAEG-SDGs, the UN Statistical Commission, and further stakeholders during the development of the overall indicator framework. We apply the proposed approach to assess the sustainability of ocean and maritime development of the EU's coastal states and show how sustainable development assessment can benefit from the additional consideration of composite indicators.

2 Concepts and Methods

Sustainable development requires that wealth, in a comprehensive sense, should not decrease over time (Arrow et al. 2003). Phrased in terms of the famous formulation of the United Nations World Commission on Environment and Development, it requires that a development be achieved "which meets the needs of the present generation without compromising the ability of future generations to meet their needs" (Brundtland et al. 1987). However, no single or ideal approach exists for selecting a measurement framework to characterize such developments. In general, arrival at a sound theoretical concept of sustainability will be the starting point for the design of the measurement framework. This concept will be the yardstick first for the selection of the indicators and second for their aggregation to form composite indicators (e.g., OECD 2008)

In (economic) academic literature, the capital approach is probably the most prominent approach for thinking about sustainability issues. It is based on the idea that the resource assets (capital stocks) left behind will determine the well-being of future generations (UNECE 2014). More formally, non-decreasing comprehensive wealth requires that the production potential of nature and the economy—the endowment with capital stocks—be constant or incremental over time (e.g., Pearce 1993, Smith et al. 2001, Arrow 2003, Dasgupta 2009). Here, the term production also includes natural and non-market production. Accordingly, this concept is based on a broad definition of capital stocks encompassing not only man-made (economic) capital but also human capital, social capital and, in particular, environmental capital stocks. Although the term "capital stock" needs to be used with a degree of circumspection in debates taking place outside academia (Radermacher 2005), it represents a sound concept for formalizing issues of (dis)investment in the context of (natural) resources and is squarely and firmly rooted in economic theory. The concept has been adopted, for example, in the Report by the Commission on the Measurement of Economic Performance and Social Progress (the Stiglitz-Sen-Fitoussi Report, Stiglitz et al. 2010), in the Reports of the UNECE/Eurostat/OECD Working Group on Statistics for Sustainable Development, and in the European Seventh Environmental Action Program to 2020 (UNECE 2014). More generally, one could argue that the extended coverage of the SDGs in comparison to the Millennium Development Goals (MDGs) reflects a broader understanding of capital foundation, including in particular the natural capital base, as a factor for achieving greater wealth and reducing poverty.

2.1 Indicator selection

In terms of its practical implementation, the capital approach faces some challenges that have not yet been fully addressed. Even though the United Nations System of Environmental-Economic Accounting (SEEA) provides formal definitions and guidance for measuring natural capital stocks, the (physical) quantification of stock size and the quality of many natural resources is very uncertain and rough and ready (e.g., Fenichel and Abbott 2014). This holds in particular for the multitude of oceanic resources (e.g., Visbeck et al. 2014).

Consequently, the capital approach is often interpreted as an organizing framework requiring the identification and selection of non-monetary (physical) indicators to approximate the size of capital stocks and their changes over time (e.g., Radermacher and Steuerer 2014). However, there exist no unambiguous rules for selecting indicators that will function as a measure for capital stocks (Böhringer and Patrick 2007). Ideally, the selection of indicators starts by determining a large set of potential indicators from which the most appropriate are selected in accordance with well-defined and broadly accepted methods (e.g., Alfsen and Greaker 2007), a process supported by empirical studies on the historical influence of the indicator on the desired objective, the historical influence of policy measures on the indicator, and correlations between the various indicators (e.g., Schultz et al. 2008).

In selecting indicators for measuring capital stocks, a further classification is provided by the pressure-state-response (PSR) framework (OECD 1993). In a nutshell, the PSR framework distinguishes between a) indicators that measure human activities (such as nutrient pollution) exerting *pressure* on natural systems, b) indicators that measure the *state* of environmental systems, such as the eutrophication level of a lake (which is affected by pressures), and c) indicators that measure human responses to changes in pressures or states (such as the establishment of a regulatory framework or other policy instruments to limit pollution). In the capital approach, capital stocks are measured by state variables, so the capital approach would require state indicators. However, pressure and response indicators can be included to approximate the dynamics of the capital stocks. This approach is taken, for example, by the Ocean Health Index (OHI) (Halpern et al. 2012, 2015). The OHI measures scores for ten ocean-related societal goals. The overall score is the arithmetical mean of the present status score (measured by state indicators) and the likely future status score. The likely future status assesses the prevailing trend (over the last five years), ecological and social pressure on the status (measured by pressure indicators), and the ecological factors and social initiatives determining the resilience of the corresponding oceanic resource (measured by response indicators).

True, the SDG indicator framework lacks a clear foundation in the capital approach and a well-defined distinction between pressure, state, and response indicators, but given the normative character of the overall framework (e.g., Beisheim et al. 2015), a unanimously supported scientific solution is not likely to materialize. For that reason, the only viable alternative was to organize indicator selection as an inclusive, open, and transparent process—as done by the IAEG-SDGs and the UNSC. Nevertheless, the transparency of the selection process should not blind us to the fact that selection is an intense negotiation process between the various interest groups involved, a process that has to cope with the limitations imposed by data availability and also necessitates discussion about appropriate weightings for indicators. We discuss this aspect in more detail in the next section.

For our assessment of sustainable oceanic development in the EU coastal states we select indicators based on the preliminary indicator set proposed for SDG 14 by the UN Statistical Commission at their 46th session. In addition, we take account of the comments made in the open consultation on the proposed indicators, the final set of proposed indicators at the 47th session, and the preliminary tier classification (UN 2015, IAEG-SDGs 2015, UN2016, IAEG-SDGs 2016c). The main focus of our analysis is on the complementary use of composite indicators to facilitate the assessment of sustainable development. Accordingly, we provide a detailed assessment of the proposed indicators in the Supplementary Material S1.

2.2 Indicator assessment and aggregation: Composite indicators

With a set of (non-monetary) indicators as proxies for capital stocks, it still remains an open question how sustainable development should be assessed when certain indicators increase while others decrease. Obviously, situations in which all indicators increase can easily be identified as sustainable development. Likewise, unsustainable development is easily identified as such when all indicators decrease. However, the typical situation is that while some indicators increase, others decrease. In such a situation, sustainable development assessment is not straightforward. With an indicator set of the kind found in the current outline for the SDGs, qualitative assessment and discussion are required for an assessment of the overall development. Such a qualitative assessment includes an implicit weighting of indicators. It also includes implicit assumptions on the substitution possibilities between the targets measured by the different indicators. These substitution possibilities determine how an increase in one indicator can compensate for a decrease in another. Consequently, the assessment based on indicator sets involves various normative judgements and decisions that are seldom made transparent or set out as such.

Using composite indicators comprising indicators for several targets demands an explicit treatment of these trade-offs, some kind of weighting scheme and an explicit specification of substitution possibilities. The explicit specification of potential substitution then paves the way for a clear distinction between *weak* and *strong* sustainability. In theory, the concept of weak sustainability allows for unlimited substitution and requires that the (weighted) aggregate of the various indicators does not decline (e.g., Pearce et al. 1989). By contrast, the concept of strong sustainability does not allow for any substitution between the various targets at all.

Aggregation into a composite indicator involves dealing with the different measurement units of the individual indicators that make them non-comparable (e.g., *Gross Nutrient Balance in kg/ha* versus *CO_2 Emissions in kg per capita*). Comparability can be achieved by transforming the individual indicators, thus making for greater flexibility in aggregating them. Various methods for the transformation and normalization of individual indicators exist (e.g. OECD 2008), one of them being the Min-Max transformation to obtain indicators in a fixed range, or the related Distance-to-Reference transformation, where the best (max) value is replaced by an exogenous reference value. In compiling the OHI index, Halpern et al. (2012, 2015) opt for a combination of these two approaches. They assume that goal-specific scaling factors exist (derived either from goal-specific maximum values among countries or exogenous reference values), obtaining ratio-scale, full-comparable indicators (goal scores range between 0 and 100). Obviously, one needs to keep in mind the sensitivity of the indicators to the transformation process. In addition, selection of the transformation should take into account the data properties and the objectives of the measurement (Ebert and Welsch 2004). In the context of the SDG indicator framework, information for the normalization scheme can be obtained from agreed target values for specific SDG targets and indicators.

Given that all selected indicators I_i are ratio-scale measurable and fully comparable (as a result of the normalization), meaningful aggregation into a *CI* is achieved by applying weighted generalized means (Blackorby and Donaldson, 1982):

$$CI(a_i, I_i, \sigma) = \left(\sum_{i=1}^{N} \alpha_i I_i^{\rho}\right)^{\frac{1}{\rho}}, \tag{1}$$

with weights $\alpha_i > 0$, for the individual indicators. The exponent ρ determines the substitution possibilities between the different indicators, determining how fare the distribution of scores across the various indicators influences the overall score. Specific values of ρ yield various special cases of the generalized mean, for example the arithmetical mean for $\rho = 1$ (Hardy et al. 1934). To relate the application of the generalized mean to social choice theory and the parameter ρ is usually specified as

$$\rho = \frac{\sigma - 1}{\sigma} \qquad \text{with } 0 \leq \sigma \leq \infty \tag{2}$$

where parameter σ quantifies the *elasticity of substitution* between the different indicators, thus providing the constant elasticity of substitution (CES) function (Solow 1956, Arrow et al. 1961, Armington 1969). The elasticity of substitution is the elasticity of the ratio of the two indicators with respect to the marginal rate of substitution (MRS) which expresses by how much one indicator has to increase to just offset a decrease of the other one, thus keeping the CI constant. Increasing values for σ reflect improved substitution possibilities and hence a weaker sustainability concept. Consequently, we obtain a full class of specific functional forms for the *CI* depending on σ. We denote these by $CI(\sigma)$ for the case of a given set of indicators and weights. Figure 1 displays the resulting *CIs* for three special cases for σ and illustrates the corresponding substitution possibilities and sustainability concepts.

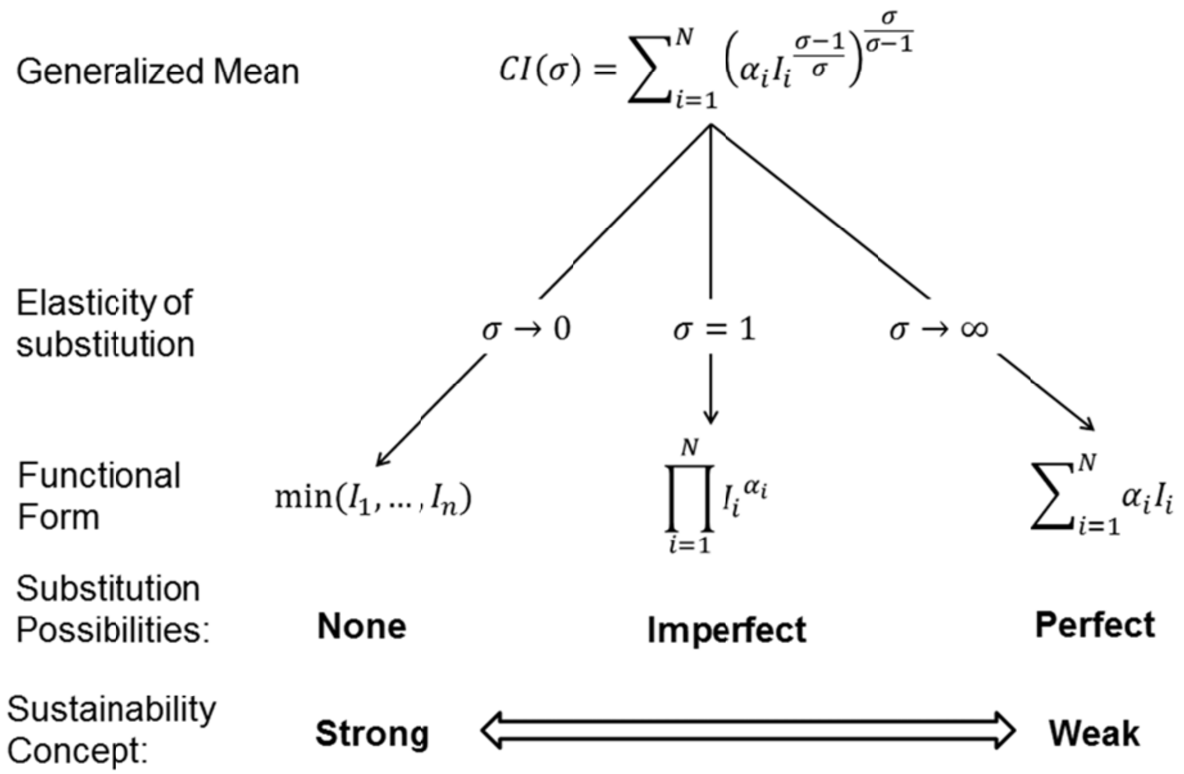

Figure 1: Special instances of the generalized mean in the context of sustainable development assessment.

Except for the special case where all individual indicator scores are equal ($I_i = \bar{I}$), we have

$$CI(\sigma \to 0) < CI(\sigma = 1) < CI(\sigma \to \infty). \qquad (3)$$

The distinction between the three special cases in Figure 1 allows straightforward classification of existing sustainability assessments. One could argue that the current SDG indicator framework espouses a concept of strong sustainability. Without the inclusion of additional composite indicators, the treatment of trade-offs remains unresolved, requiring technically that all indicators be at least maintained at the current level to achieve sustainable development. Accordingly, the overall assessment would theoretically be governed by the indicator that performs worse. By contrast, several existing *CIs* and an assessment like the OHI implicitly assume infinite elasticity of substitution by applying the arithmetical mean and accordingly espouses a concept of weak sustainability with unlimited substitution possibilities (Rickels et al. 2014). Under such a concept the distribution of scores over the different indicators only has any bearing on the value of the *CI* to the extent that the weights may differ.

Obviously, the two concepts at the left and right of Figure 1 represent two extreme cases. In reality, the appropriate level of substitution potential can be expected to lie between these two extremes and is likely to differ depending on the characteristics of the underlying capital stocks (e.g., Bateman et al. 2011). A prominent example of an *intermediate CI* is the Human Development Index (HDI). The HDI assumes a substitution elasticity of 1 and is computed as the geometric mean of three sub-indicators reflecting the areas health, education, and economic development. Consequently, the HDI is less optimistic about the substitution possibilities than the OHI. Opting even more determinedly for strong sustainability than the HDI requires choosing a substitution elasticity value below 1 (e.g., Gerlagh and van der Zwaan 2002, Heal 2009, Bateman et al. 2011, Traeger 2013). In their study of the human-climate system, Sterner and Persson (2008) propose using $\sigma = 0.5$.

However, the different aspects and dimensions of sustainable development reflected by the indicator set do not necessarily share a unique substitution elasticity. Taking jobs in the fishery and marine tourism sectors as an example, one would probably argue that the substitution possibilities between these two aspects of the economic dimension are higher than between jobs and the degree of biodiversity. In the face of varying degrees of substitution potential among different indicators, aggregation can be improved by constructing a nested/multi-layered composite indicator for measuring sustainable development with different substitution possibilities at different layers. The OHI is an example of such a nested composite index, where the 10 goal scores are themselves *CIs* aggregating several indicators to measure the status, trend, pressure, and resilience of specific aspects of ocean health. The goal status score for *Clean Waters* is obtained as the geometric mean of the absence of trash, chemical, nutrient, and pathogen pollution (Halpern 2015). Consequently, the substitution possibilities are considered to be more restrictive within the calculation of the individual goal score (*CI: Clean Waters*) than for the overall score (*CI:* OHI), which is obtained by the arithmetical mean. Even though this may be justified for this specific goal, in general it appears to be more reasonable to first aggregate those indicators with better substitution possibilities and assume less optimistic substitution elasticities at the top level of aggregation (Dovern et al. 2014).

In general, there does not exist one *true* value for σ, and different underlying objectives of the measurement framework also require different values for σ. Even though the process of designing a (possibly nested) composite indicator can be supported by empirical analysis (e.g., correlation or principal component analysis), the final decisions about the specification of the substitution possibilities require normative assessment. However, this is no different from the selection of individual indicators. Furthermore, the specification of σ is clearly linked to the underlying sustainability concept and in contrast to adjusting weights for individual indicators determines the extent to which the overall balance of scores across indicators is reflected in the *CI* score. Furthermore, the restriction of this influence to one parameter, σ, provides a straightforward resource for sensitivity analysis.

In our assessment of sustainable oceanic development in EU coastal states, we demonstrate the complementary inclusion of *Ci*s by using the generalized mean for the aggregation of the individual indicators selected. For those indicators not yet available as ratio-scale, fully comparable indicators we apply distance-to-reference transformation (for indicators with exogenous given target values) and Min-Max transformations (for the remaining indicators) (OECD 2008). Details on indicator-specific transformation and the scaling factors applied can be found in Table S1 in the Supplementary Material.

For the *CI* we apply a nesting structure. The SDG framework with its assignment of indicators to targets provides a clear proposal for the nesting structure, having first an indicator level, second a target level, and third an SDG level. The second and third levels are assessed by means of *CIs*. Where more than one indicator is selected (i.e. a sub-indicator level), we also calculate *CIs* for the indicator level. Following Dovern et al. (2014), we assume that the substitution possibilities are upwardly decreasing in the nesting structure, with good substitution potential at the indicator and target levels (corresponding to a concept of weak sustainability) and poor substitution potential at the SDG level (corresponding to a concept of strong sustainability). It should be noted that the sensitivity of the results arises in particular from the distinction between strong and weak sustainability (i.e., $\sigma < 1$ and $\sigma \geq 1$, respectively). Accordingly, we define the default value as $\sigma = 10$ for those aggregation levels corresponding to a concept of weak sustainability. Following Sterner and Persson (2008), we include an alternative calculation at the target level with $\sigma = 0.5$. Instead of selecting a specific value for substitution elasticity at the SDG level, we follow Rickels et al. (2014) and carry out a Monte Carlo analysis (N=10,000), assuming that σ is uniformly distributed between 0 and 1. This provides information about the sensitivity of the results to the *degree* of sustainability strength, and we compare the ranking information thus obtained with the ranking information obtained from concept of weak sustainability. As our analysis focuses on the influence of the substitution analysis, we assume equal weighting of the indicators for each aggregation step. The structure of the *CI: Sustainable oceanic development in the European Union* is displayed in Figure 2, including information about the applied elasticity of the substitution at the different levels.

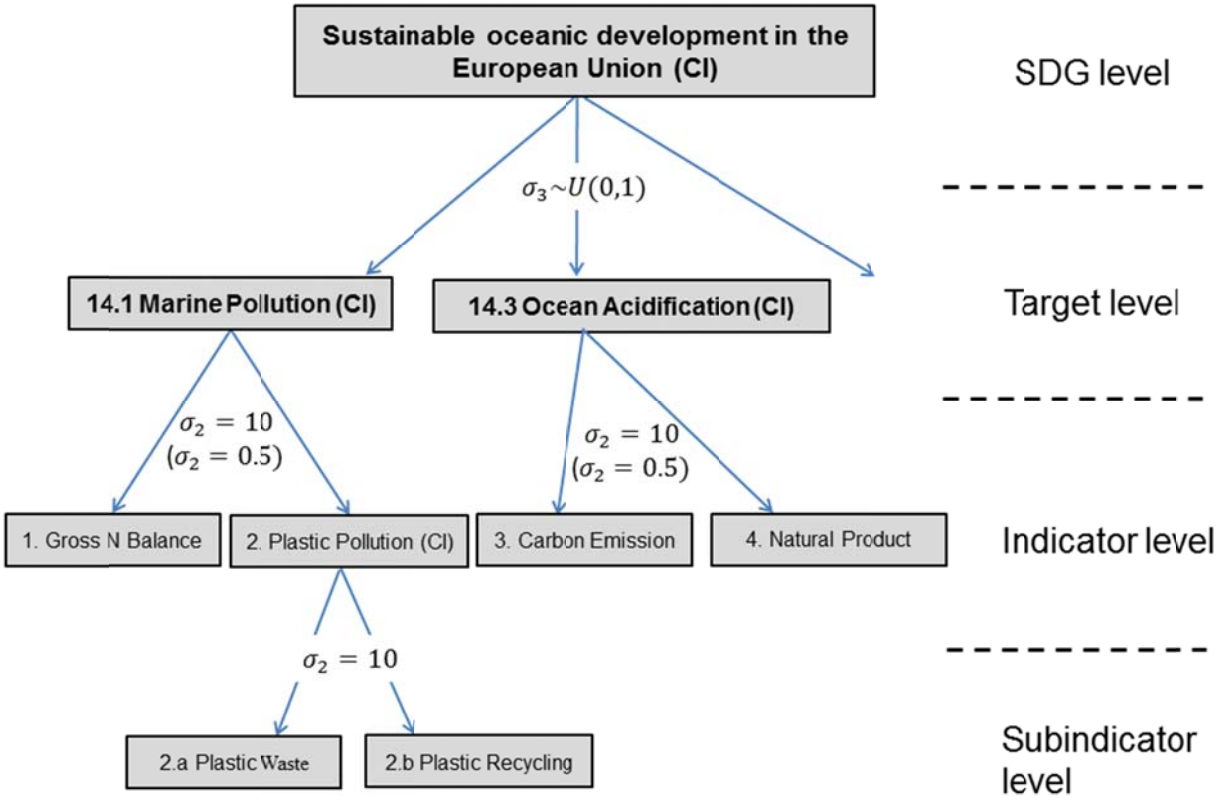

Figure 2: Applied nesting structure for assessment of sustainable oceanic development in the EU

3 Applying the Ocean SDG to the European Union's Coastal States

To illustrate the challenges encountered in selecting appropriate indicators and the possibility of using composite indicators, we now discuss an indicator framework for measuring sustainable oceanic development in EU coastal states.

3.1 Indicator selection for sustainable oceanic development

SDG 14: *Conserve and sustainably use the oceans, seas and marine resources for sustainable development* contains 10 targets (14.1-14.7 and 14.a-14.c), each associated with two indicators as proposed by the UNSC at its 46th session. Table 1 summarizes these indicators proposed by the UN Statistical Commission and our selection of 17 indicators for the assessment of sustainable oceanic development in EU coastal states. For each target to which indicators are assigned the table also includes a brief title in parentheses that we use in the subsequent analysis for ease of reference to the specific targets. Supplementary Material Text S1 provides detailed information about the current debate on indicator selection in the IAEG-SDG process and about our selection of indicators. Table S1 in the Supplementary Material also contains information about the data source, the time period covered, and the reference value applied for the transformation. Since adequate data history is available for only about half of the selected indicators, we restrict our investigations in the next section to the current state of oceanic sustainable development in the EU's coastal states.

Table 1: Overview of Indicators

Indicators proposed by the UN Statistical Commission (2015) at the 46th session	**Indicators used in this study to assess sustainable oceanic development in EU coastal states**
Target 14.1 By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution. **(Pollution)**	
14.1.1 Fertilizer consumption (kg/ha of arable land)	*1. Gross N Balance*
14.1.2 Metric tons per year of plastic materials entering the ocean from all sources	*2.a Plastic Waste Generation* *2.b Recovery Rate of Plastic Packaging*
Target 14.2 By 2020, sustainably manage and protect marine and coastal ecosystems to avoid significant adverse impacts, including by strengthening their resilience, and take action for their restoration in order to achieve healthy and productive oceans.	
14.2.1 Percentage of coastline with formulated and adopted ICM/MSP plans	*No indicator selected*
14.2.2 Ocean Health Index	*No indicator selected*
Target 14.3 Minimize and address the impacts of ocean acidification, including through enhanced scientific cooperation at all levels. **(Acidification)**	
14.3.1 Average marine acidity (pH) measured at agreed suite of representative sampling stations	*3 Carbon emission*
14.3.2 Coral Coverage	*4 Natural Product (OHI)*
Target 14.4 By 2020, effectively regulate harvesting and end overfishing, illegal, unreported and unregulated fishing and destructive fishing practices and implement science-based management plans, in order to restore fish stocks in the shortest time feasible, at least to levels that can produce maximum sustainable yield as determined by their biological characteristics. **(Overfishing)**	
14.4.1 Fish species, threatened	*5 Fish Species, threatened*
14.4.2 Proportion of fish stocks within biologically sustainable limits	*6 Fish stock biomass above BMSY*
Target 14.5 By 2020, conserve at least 10 per cent of coastal and marine areas, consistent with national and international law and based on the best available scientific information. **(Protection and Conversion)**	
14.5.1 Percentage area of each country's EEZ in MPA Percentage area of ABNJ in MPA Percentage area of global ocean under MPA	*7 Percentage area of each country's EEZ in MPA*
14.5.2 Coverage of protected areas	*8 Biodiversity (OHI)*
Target 14.6 By 2020, prohibit certain forms of fisheries subsidies which contribute to overcapacity and overfishing, eliminate subsidies that contribute to illegal, unreported and unregulated fishing and refrain from introducing new such subsidies, recognizing that appropriate and effective special and differential treatment for developing and least developed countries should be an integral part of the World Trade Organization fisheries	

subsidies negotiation **(Fish Subsidies)**	
14.6.1 Dollar value of negative fishery subsidies against 2015 baseline	*9 Government financial transfers to Marine Capture Fisheries relative to Gross Value Added*
14.6.2 Legal framework or tax/trade mechanisms prohibiting certain forms of fisheries subsidies	*10 Landings exceeding Total Allowed Catch*
Target 14.7 By 2030, increase the economic benefits to small island developing States and least developed countries from the sustainable use of marine resources, including through sustainable management of fisheries, aquaculture and tourism. **(Economics)**	
14.7.1 Fisheries as a % of GDP	*11 Coastal Livelihoods & Economics (OHI)*
14.7.2 Level of revenue generated from sustainable use of marine resources	*12 Tourism & Recreation (OHI)*
Target 14.a Increase scientific knowledge, develop research capacity and transfer marine technology, taking into account the Intergovernmental Oceanographic Commission Criteria and Guidelines on the Transfer of Marine Technology, in order to improve ocean health and to enhance the contribution of marine biodiversity to the development of developing countries, in particular small island developing States and least developed countries. **(Scientific Capacities)**	
14.a.1 Number of researchers working in this area	*13 Number of Marine Monitoring Stations relative to EEZ*
14.a.2 Budget allocated to research in the field of marine technology	*14 TAC Exceedance of Scientific Advice*
Target 14.b Provide access for small-scale artisanal fishers to marine resources and markets. **(Small Scale Fisheries)**	
14.b.1 By 2030, X% of small scale fisheries certified as sustainable; Y% increase in market access for small scale fisheries	*15 Artisanal Fishing Opportunities (OHI)*
14.b.2 By 2030, increase by X% the proportion of global fish catch from sustainably managed small scale fisheries	*16 Fish stock harvest level below FMSY*
Target 14.c Ensure the full implementation of international law, as reflected in the United Nations Convention on the Law of the Sea for States parties thereto, including, where applicable, existing regional and international regimes for the conservation and sustainable use of oceans and their resources by their parties. **(Marine Agreements)**	
14.c.1 Adoption of a legal framework and number of associated court cases	*17 Participation rate in International Marine Agreements*
14.c.2 Number of countries implementing either legally or programmatically the provisions set out in regional seas protocols	

3.2 Indicator assessment and aggregation for sustainable oceanic development

Assessment at indicator level provides important insights on sustainable oceanic development. Accordingly, we show the normalized scores for the indicator level in Figure 3. By transforming all indicators such that higher score indicates better performance (i.e. a high score in the carbon indicator means less carbon emission), the figure provides a quick impression of the relative strengths and weaknesses of the countries covered. The figure includes the average of all EU country scores together with the scores for Denmark, Germany, and France. The results indicate, for instance, that overall the EU has large potential for increasing its efforts in assigning MPAs and that Germany has relatively strong potential for making marine tourism more sustainable. The results also show that France performs relatively well with respect to avoiding carbon emissions, in particular relative to Denmark. One possible explanation for France's good showing (in terms of per-capita carbon emissions) is its fairly high degree of carbon-free nuclear power generation. Such insights are a motivation to look more closely at the original data and the country results, and possibly also to review whether the chosen indicator is appropriate.

A number of other insights can be obtained by analyzing and comparing the standardized indicator levels of the countries. However, the complexity of such an analysis as shown in Figure 3 increases with the number of indicators included, amplifying to extract clear information. Furthermore, even with the small number of countries in Figure 3 it is difficult to assess whether for example France or Germany is more successful in oceanic sustainable development (except in the rare cases that one country has higher scores than another country for every indicator). Accordingly, we now turn to assessment at the target level and the central concern of this article: concentration of information by means of composite indicators.

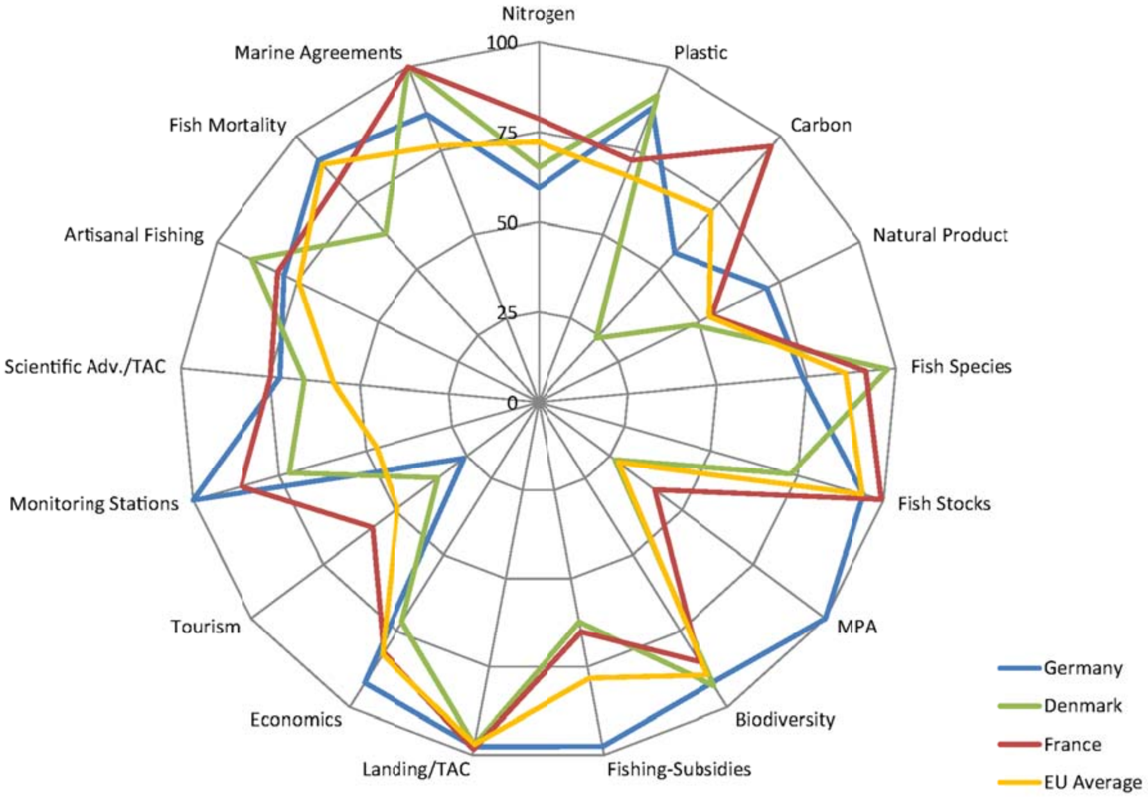

Figure 3: SDG 14 indicator scores for selected EU coastal states and EU average

Figure 4 shows the target scores (14.1 to 14.7 and 14.a to 14.c plus brief titles) obtained with the generalized mean for the individual indicators associated with the targets. For target 14.c (Marine Agreements) only one indicator has been selected (see Table 1), so in this case the scores at indicator and target level coincide. As set out in Section 2.2, we aggregate the indicators at the target level with $\sigma_2 = 10$, assuming that at this level of oceanic development there are sufficient substitution possibilities to justify a weak sustainability concept. The argument is that indicators assigned to targets measure a rather similar aspect of sustainable oceanic development. Nevertheless, in addition to the analysis in the left panel (a) of Figure 3 with the default value, the right panel (b) displays the results obtained from a concept of strong sustainability ($\sigma_2 = 0.5$). Both panels show the EU average target scores and the scores for selected countries (Portugal, Sweden, Italy).

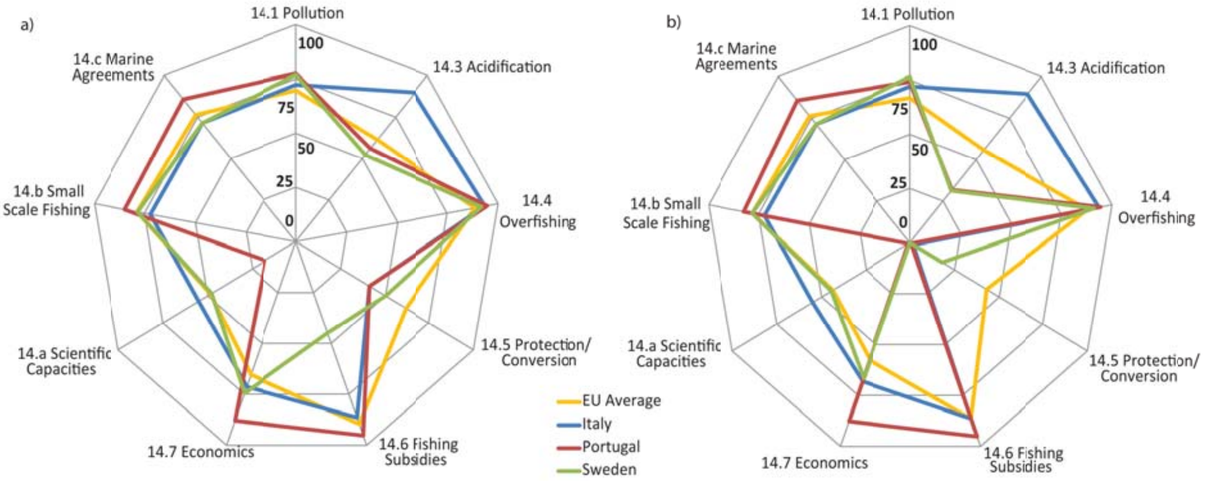

Figure 4: SDG 14 target scores for selected EU coastal states and EU average. Left panel a) for a concept of weak sustainability ($\sigma_2 = 10$) and right panel b) for a concept of strong sustainability ($\sigma_2 = 0.5$)

As expected, the target scores under a concept of weak sustainability (left panel) are higher than under a concept of strong sustainability (right panel) (see (3) in Section 2.2). The relatively slight differences between the EU average scores in left and right panel suggest that the indicators assigned to the targets measure rather similar aspects or show sufficient correlation to justify a concept of weak sustainability (on average). Furthermore, the EU average scores show that one area for potential improvement is Scientific Capacity (measured in terms of marine monitoring stations and the degree to which TAC follows scientific advice), whereas the EU performs surprisingly well in connection with the targets Reducing Overfishing and Fishing Subsidies.

The comparison of the target scores for the selected countries under the two sustainability concepts reveals inconsistent performance in connection with the target Scientific Capacities by Portugal and the target Protection and Conversion by Portugal and Italy. The low target score in Protection and Conversion is explained by the very low scores for indicator 7 (*percentage area of each country's EEZ in MPA)* with 0.98 and 0.36 for Italy and Portugal, respectively. Under a concept of strong sustainability with limited substitution possibilities, the two countries cannot compensate for this low score with the rather good scores in the other indicator assigned to this target (*biodiversity* (OHI)) with 87 and 88 for Italy and Portugal, respectively. Consequently, it is the application of a concept of strong sustainability that reveals the imbalance in this dimension of ocean health. However, one could also argue that the share of MPA serves the purpose of achieving a good biodiversity status, so countries achieving good biodiversity by other means or favorable environmental conditions should not be punished disproportionally by low target scores due to the absence of a policy considered desirable. Consequently, we assume that at this aggregation level a concept of weak sustainability is sufficient. Nevertheless, sensitivity analyses with low substitution possibilities also provide robustness checks—revealing, say, data errors that might otherwise elude detection in aggregations with high or even perfect substitution possibilities. However, even though the information in Figure 4 is less profuse (9 target scores versus 17 indicator scores in Figure 3), it still remains difficult to assess overall performance in sustainable oceanic development. For that reason, we now turn to assessment at the SDG level.

For aggregation at SDG level, we stick to the default value for substitution elasticity at the target level ($\sigma_2 = 10$) but assume that the aggregation of different dimensions of ocean sustainability as reflected by the targets is more complex and requires a concept of strong sustainability. The strong sustainability concept is reflected by values for σ_3 below 1 in the Monte Carlo sensitivity analysis. Table 2 displays the results of the Monte Carlo Simulation, including information about the average SDG score and rank in combination with the standard deviations (columns 2 to 5). For comparison, Table 2 also includes the score and rank under the assumption of perfect substitution possibilities (columns 6 and 7).

Table 2: SDG 14 scores for EU coastal states

	Imperfect Substitution Possibilities				**Perfect Substitution Possibilities**	
	$\boldsymbol{\sigma_3 \sim U(0,1)}$				$\boldsymbol{\sigma_3 \to \infty}$	
Countries	**Av._Score**	**Std.**	**Av._Rank**	**Std.**	**Score**	**Rank**
Germany	75.99	4.61	1.26	0.44	81.01	1
France	75.59	2.70	1.74	0.44	80.20	2
Belgium	71.19	4.54	3.63	0.48	77.31	3
Lithuania	70.36	6.94	3.68	1.12	74.81	6
Slovenia	67.10	3.21	6.06	1.74	70.89	12
Italy	64.54	7.55	6.88	1.54	72.56	9
Ireland	64.19	7.72	7.19	1.93	75.46	4
Finland	65.56	3.98	7.86	1.91	73.99	7
Spain	62.26	9.45	10.18	2.44	75.31	5
United Kingdom	62.17	7.93	11.12	0.95	72.88	8
Latvia	60.42	11.65	11.16	3.81	72.35	10
Netherlands	62.58	4.49	11.16	2.51	69.65	14
Romania	61.68	7.31	12.00	0.27	69.38	15
Poland	61.12	5.24	12.61	2.14	68.08	16
Sweden	58.67	4.17	14.60	2.57	65.32	20
Denmark	58.67	7.68	14.87	0.34	70.63	13
Estonia	49.37	8.45	17.81	0.97	61.64	21
Malta	46.95	11.82	18.05	0.21	65.77	18
Portugal	45.82	14.28	18.14	0.98	71.16	11
Croatia	41.76	13.52	20.00	0.00	65.72	19

Cyprus	31.19	10.52	21.58	0.88	58.93	23
Bulgaria	27.54	14.58	21.90	0.30	60.36	22
Greece	24.28	16.78	22.53	0.82	67.39	17
EU average	*65.79*	*4.67*			*71.08*	

By construction, the score obtained under perfect substitution possibilities (i.e. the arithmetical mean) is higher than the score obtained under limited substitution possibilities (see (3) in Section 2.2). However, the ranking information is comparable. Figure 5 shows the ranking obtained for the two sustainability concepts (including the ±1 standard deviation error bars obtained from the Monte Carlo Simulation). Without any influence from the sustainability concept, all countries would be aligned along the 45° line. Here we see countries above and below the 45° line. Countries below that line perform fairly consistently across goals, implying that they obtain a better ranking (and relative score) under a concept of strong sustainability. Countries above the line perform rather inconsistently, implying that they achieve a higher ranking if they can compensate for poor scores in connection with certain targets by good scores in others (concept of weak sustainability). An example of the former case is Slovenia, ranking about 6 places better under a concept of strong than under weak sustainability. By contrast, Portugal with its rather inconsistent performance (see Figure 4a) ranks about 7 places worse under strong than under weak sustainability. In general, though, all countries are fairly close to the 45° degree line, indicating that for target scores obtained under weak sustainability overall performance is quite consistent.

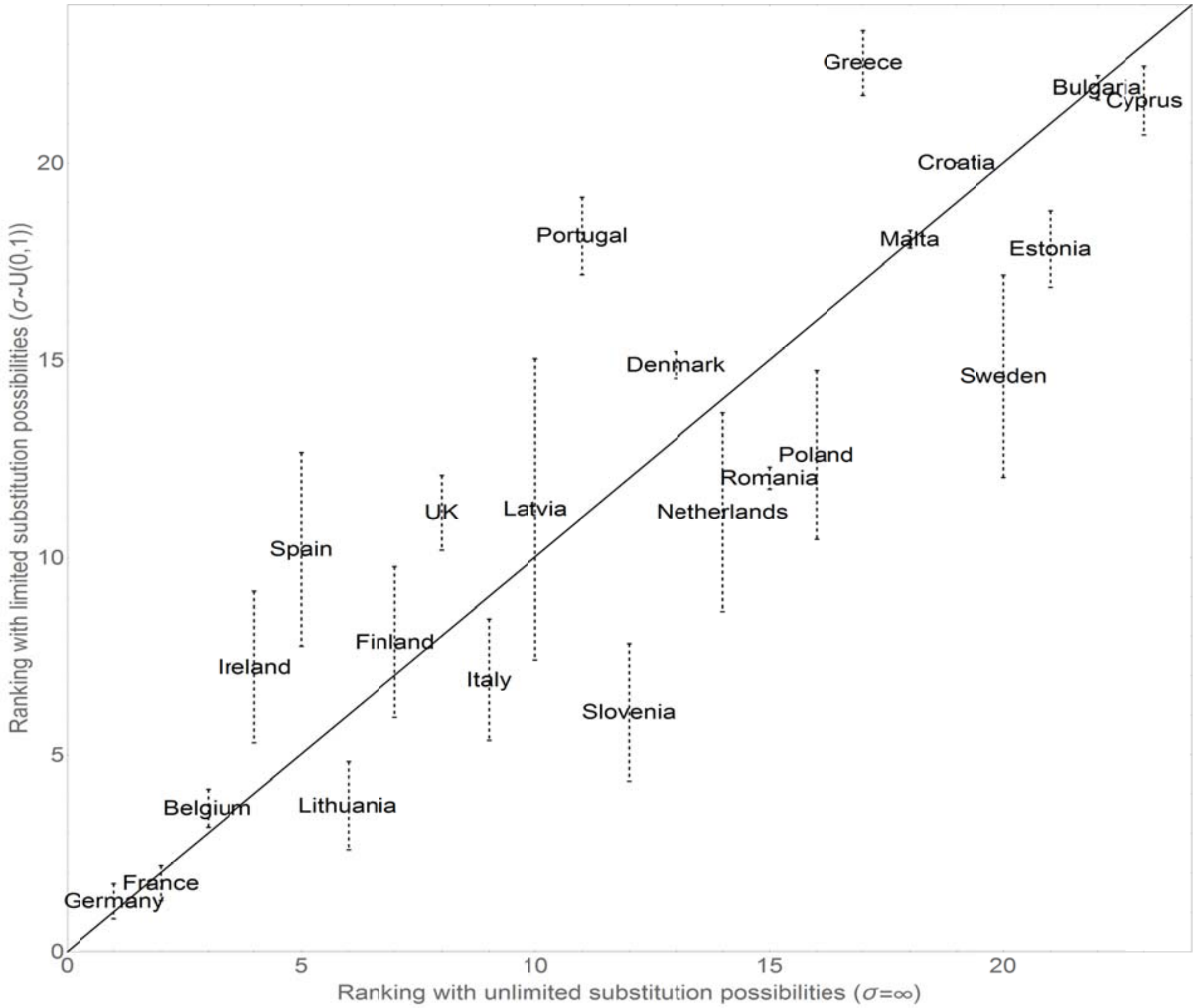

Figure 5. Comparison of SDG 14 scores for EU coastal states with unlimited substitution possibilities (weak sustainability) and with limited substitution possibilities (strong sustainability). The data point is the middle of the respective country's name; error bars indicate ±1 standard deviation.

4 Discussion and Conclusion

The 2030 Agenda for Sustainable Development includes a set of 17 Sustainable Development Goals (SDG) with 169 specific targets. It could be a step forward in achieving efficient governance and policies for global sustainable development. To live up to the expectations placed in them, the SDGs have to be integrated into international and national policies, with proper coordination, monitoring, and assessment of sustainable development policies in general. An essential element will be the global indicator framework to monitor and assess progress over and against both the overall goals and the specific targets and to guide policy towards sustainable solutions. Unlike previous top-down approaches, the development of the overall agenda and also the indicator framework has been, and is still, organized to include opinions and expertise from different experts, partners, and stakeholders. Consequently, the indicator framework has good prospects of achieving a reasonable compromise between the diverging goals of statistical measurability, scientific consistency, and political relevance.

However, the current framework with its broad set of individual indicators prevents straightforward assessment of synergies and trade-offs between the various indicators, targets, and goals, complicating the identification of policies leading to sustainable development. The current approach with a large set of indicators could actually be interpreted as a concept of strong sustainability which—if strictly followed—might in fact hinder the application of effective policies. For example, despite potential conservation benefits, closing a certain fishery for a limited period of time might violate the concept of strong sustainability because social or economic capital stocks would shrink.

In this paper have we demonstrated how the complementary inclusion of composite indicators aggregating the individual indicators can provide important additional information and facilitate assessment of sustainable development in general and in particular in the SDG context. We have analyzed SDG 14 in more detail: *Conserve and sustainably use the oceans, seas and marine resources for sustainable development.* We have also selected indicators related to the indicators proposed by the UN Statistical Commission at their 46th session for EU coastal states and applied generalized resources to calculate composite indicators, notably at the SDG target and overall SDG level.

The individual indicators selected for EU coastal states are important in comparing and assessing the influence of marine policies across states and time. However, they do not permit straightforward identification of the extent to which overall balanced marine policy is achieved. Looking back and forth between the composite indicators and the individual indicators provides important insights on the appropriateness of the selected indicators, possible data problems, and potentially unbalanced sustainable developments. Our distinction between fairly high and rather low substitution possibilities, for example, revealed unbalanced performance by Portugal and Italy in connection with target 14.5 (Protection and Conversion), thus raising the question whether at this stage of assessment a concept of weak or strong sustainability would be more appropriate. Obviously, the specification of substitution possibility cannot solely be based on scientific reasoning, but requires normative judgement and decision. Nevertheless, we have demonstrated by our analysis at the SDG level that variation in substitution elasticity allows for a straightforward sensitivity analysis. We have shown that in general the EU coastal states make a relatively balanced showing at the SDG 14 level, while certain countries like Slovenia and Portugal are consistent/inconsistent in performance and are hence allotted very differently rankings under the two concepts of sustainability.

One major argument brought forward against the use of composite indicators is that no scientifically sound weighting scheme exists (e.g., UNECE 2014). However, the same criticism applies to the design of any indicator set: including an additional indicator effectively results in a reduction of the weightings given to all or some of the existing indicators, while the opposite is true when certain indicators are excluded. Neglected indicators have no weight, and the relative weightings of other indicators change. Thus in qualitative terms, the decisions and specifications for constructing composite indicators are no different from the overall process of selecting and dumping indicators in the alternative approach, tasks that also implicitly involve a weighting decision. Once target values and baselines (for tracking indicators) are agreed on for specific indicators, scaling schemes are already implicit, and, as mentioned above, the specification of the substitution elasticity allows for a) straightforward distinction between a concept of weak and strong sustainability, and b) straightforward sensitivity analysis.

In any assessment framework, maximum transparency in connection with its overall design is of the utmost importance. Transparent and explicit communication of the transformation, weighting, and aggregation schemes applied for composite indicators provides clear information and rules for the assessment of trade-offs. By contrast, a set of indicators without any further specification invites prioritization and emphasis of those indicators with a fairly good showing (i.e., adjusting the implicit weighting scheme *ex post*). For that reason, the additional inclusion of composite indicators may be helpful in detecting arbitrary application of management measures focusing only on areas (indicators) that are less critical or easier to achieve.

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