The FEEM Sustainability Index: An Integrated Tool for Sustainability Assessment

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Abstract The FEEM Sustainability Index (FEEM SI) proposes an integrated methodological approach to quantitatively assess sustainability performance across countries and over time. Three are the main features of this approach: (1) the index considers sustainability based on economic, environmental and social indicators simultaneously; (2) the framework used to compute the indicators, i.e. a Computable General Equilibrium (CGE) model, allows to generate projections on

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the future evolution of sustainability; and (3) the methodology used for the normalisation and aggregation of the indicators delivers a unique and comprehensive measure of sustainability. These features along with the multi-regional nature of the CGE model consent to perform policy evaluations and sustainability assessments for different countries or regions in the world. This chapter offers a methodological overview of the FEEM SI approach. To illustrate the potential of the methodology for the measurement of sustainability, the chapter also illustrates results from a climate policy scenario. In the mitigation scenario considered Annex I and Non-Annex I countries taking action towards climate change achieve the lower end of the pledges proposed at the 15th UNFCCC Conference of the Parties in Copenhagen. For countries putting into practice the policy, the environmental sphere more than offsets the related costs (economic pillar), leading to an overall improvement in sustainability. At world level, the outcome is positive even though carbon leakage in countries that are not acting reduces the effectiveness of the policy and the sustainability performance.

Keywords Sustainability · Composite indicators · Computable general equilibrium model · Climate policy

1 Introduction

Sustainable development is a paradigm that considers several aspects of growth in a comprehensive framework. The Bruntland Report (WCED 1987) defines it as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". Two are the main concepts comprised in this paradigm: (1) the simultaneous achievement of economic, social and environmental sustainability, and (2) the intra/intergenerational equity.

The most recent evolution of the sustainability debate refers to the analysis developed by Stiglitz, Sen and Fitoussi (Commission on the Measurement of Economic Performance and Social Progress 2009). This tries to define more concretely the concept of sustainable development and clarify the methodological approaches in this field. The "Rio + 20" conference (June 2012) assessed the main achievements in sustainable development in the last 20 years, providing further guidelines with main focus on the green economy and the effective integration of sustainable development within all levels of institutional governance. The outcome of the conference underlined the importance of tracking sustainability, as suggested by the statement that "progress towards the achievement of the goals needs to be assessed and accompanied by targets and indicators, while taking into account different national circumstances, capacities and levels of development" (UN 2012).

A valid tool to measure sustainability is a set of indicators (Parris and Kates 2003; Singh et al. 2009). Thanks to their synthetic properties, indicators are widely used in policymaking and public communication. Further, substantial efforts have been devoted to create lists of indicators that address the concept of sustainable development in a comprehensive way (United Nations' Commission on Sustainable Development- UNCSD; European Union's Sustainable Development Strategy—EU SDS; World Bank's World Development Indicators—WDI). Research has focused mostly on expanding the sustainability dimensions considered or on the selection of appropriate indicators. There have also been a few attempts at aggregating indicators to indices, which are generally focused on a specific area of sustainability. Many aggregate measures are nowadays used in policymaking and assessments. Examples are: (1) the HDI—Human Development Index (UNDP 1990), (2) GS—Genuine Savings (Yusuf et al. 1989), (3) the ISEW—Index of Sustainable Economic Welfare (Daly and Cobb 1989), and (4) the EPI—Environmental Performance Index (Yale and Columbia Universities 2010). These aggregate indices generally focus on one precise aspect of sustainability.

The indicators' aggregation procedure is a controversial issue. However, an index built with a transparent aggregation methodology and complementary to its single components can be very useful for summarising a wide range of information. Such an index facilitates policy design, assessment and implementation, and allows to explore the trade-offs and relationships among indicators.

In this context, the Fondazione Eni Enrico Mattei (FEEM) has been working on developing a new tool for sustainability assessment—the FEEM Sustainability Index (FEEM SI)—since 2006.[1] A first version was released in 2009 while the updated structure for its second release (2011) is presented in this chapter. The index summarises and merges information derived by a selection of relevant sustainability indicators offering a more comprehensive account of sustainability.

The FEEM SI is an aggregate index composed of a set of indicators that captures the main elements of sustainable development (socio-economic and environmental components). The index uses a specific aggregation methodology that considers the interactions among indicators by relying on subjective experts' evaluations. As it is built in a recursive-dynamic Computable General Equilibrium (CGE) model, the FEEM SI can be used to analyse and compare sustainability across different policy scenarios. This allows including in the analysis the intertemporal aspects of sustainability. While the nature of the macroeconomic model implies some drawbacks (e.g., the absence of indicators disconnected from economic activity), the modelling framework provides a coherent context for calculating indicators with comparability across countries, time and alternative scenarios.

To illustrate the potential of the methodology to measure sustainability, this chapter also illustrates results from a climate policy scenario. In the mitigation scenario considered Annex I and Non-Annex I countries taking action towards climate change achieve the low pledges proposed at the 15th UNFCCC Conference of the Parties in Copenhagen (December 2009). The results show that, for countries putting into practice the policy, the environmental sphere more than

[1] The complete overview on methodology and results is available at: www.feemsi.org. See also Carraro et al. (2012).

offsets the related costs (economic pillar), leading to an overall improvement in sustainability performance. At world level, the outcome is positive even though carbon leakage in countries that are not acting reduces the effectiveness of the policy and the sustainability outcome.

The structure of the chapter is as follows. Section 2 describes the composition of the FEEM SI and its indicators. Section 3 presents the CGE approach and the necessary extensions of both the database and the model to compute the indicators. Section 4 illustrates the normalisation and aggregation methodology. Section 5 presents the main results for a baseline scenario while Sect. 6 considers the effects of a climate policy on sustainability. Section 7 concludes.

2 The FEEM SI Structure

The list of indicators included in the FEEM SI has been determined after a thorough analysis of the sustainable development literature. The selection process has been further refined to consider only indicators manageable in the framework of the macroeconomic model used for scenario building. The world coverage requires data availability for the entire world at country or macro-region scale. The specific methodology applied to define future sustainability limited the choice to indicators that can be directly linked to economic measures present in the model.

Figure 1 illustrates the structure of the FEEM SI and includes all indicators selected for the index construction. Along with the wide definition of sustainability, the structure of the tree considers its three main pillars: economic, social and environmental. For each of these dimensions, the FEEM SI tree covers the main areas of sustainability assessment: economic growth drivers, GDP per capita, economic exposure; population density, well-being, social vulnerability; energy, air quality, and natural endowments.

Table 6 of Annex I summarises the indicators selection and describes the indicators, including their affiliation to a particular area of sustainability, definition, implementation in the model and relevant references to the literature.

3 Modeling Framework

Processing sustainability indicators within the framework of a CGE model has a number of advantages. One of the main features of CGE models is to consider the interactions existing within and across productive systems in a consistent framework. This contributes to increase the comparability of the different indicators. Further, as argued by Böhringer and Löschel (2006), CGE models also allow performing a trade-off analysis among different components of sustainability. This feature is especially useful in analysing the effects of a policy implementation. An intervention in one dimension of sustainability in a specific country will influence

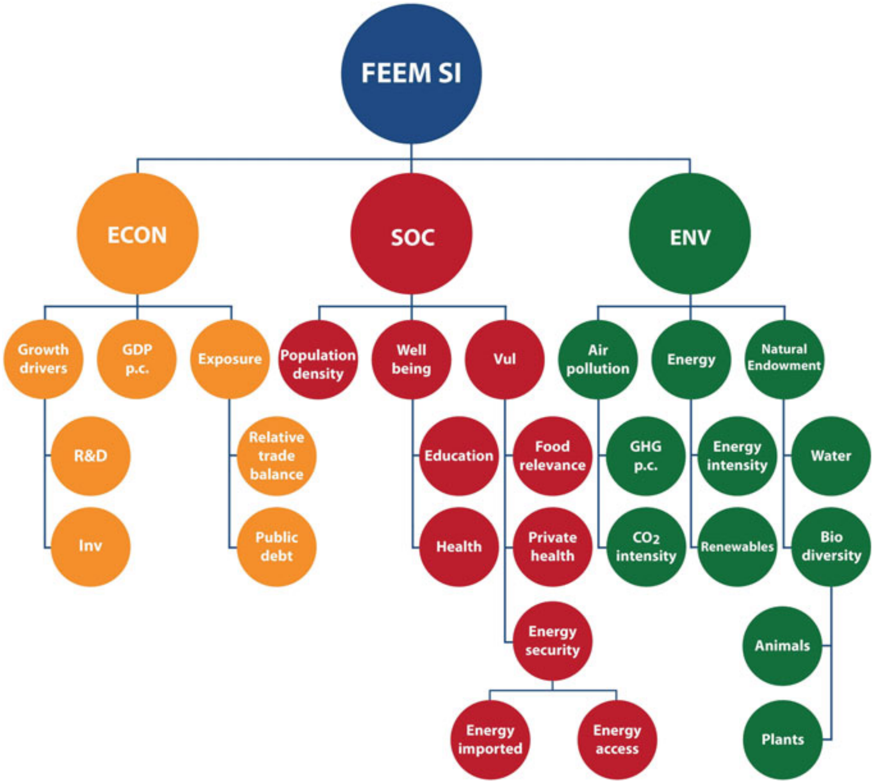

Fig. 1 FEEM SI 2011 indicators' tree

other aspects of sustainability in that country as well as in other countries. Finally, when using a dynamic CGE model, it is also possible to make projections of the indicators and thus perform a scenario analysis of future sustainability under different policy proposals.

The main difficulty in using a quantitative economic model is to link environmental and social indicators to economic variables computed in the model. This reflects a limited flexibility in defining a full set of indicators. Some of these indicators, which are not directly connected to specific economic activities, may play a role in assessing sustainability but can hardly be modelled to depict their future evolution.

The CGE model used—ICES-SI[2]—is an ideal framework for the construction of a policy-oriented sustainability index. The model allows to compute indicators related to different productive sectors and calculating the index for each region in the world (either at national or macro-regional level). Furthermore, its dynamic

[2] A detailed description of the model tailored to be used for sustainability indicators is in the FEEM SI Methodological report (FEEM 2011) and Carraro et al. (2012).

framework generates scenarios that can be used to calculate the index in the future under different policy assumptions.

Within the CGE framework, industries are modelled as a representative cost-minimizing firm with nested production functions in which primary factors and intermediates are combined to produce the final output. A representative household in each region receives income, defined as the service value of the national primary factors (natural resources, land, labour, and capital). Demand for production factors and consumption goods can be satisfied either by domestic or foreign producers that are not perfectly substitutable (Hertel 1997). The dynamic of the model is driven by two sources: one exogenous and the other endogenous. The first stems from exogenously imposed growth paths for some key variables (population, labour stock, labour productivity and land productivity). The second concerns the endogenous process of capital accumulation, according to which capital stock is cumulated through time taking into account endogenous investment decisions.

ICES-SI is based on the GTAP 7 database (Narayanan and Walmsley 2008), which presents a snapshot of 2004 world economic flows. The world economy is divided in 40 countries or macro-regions in which countries are at a similar stage of development or have similar characteristics (see Table 7 in Annex I). Within each country/macro-region, the economy is represented by 20 sectors (see Table 8 in Annex I). In order to perform the analysis on future sustainability trends throughout the world, the ICES-SI sectoral details have been enhanced by adding new variables and equations to the model. This allows increasing its flexibility in capturing as many as possible dimensions of sustainable development.

A number of indicators are sector-specific in the sense that they refer to their share of expenditure or production over GDP (i.e. Health or Education expenditure are used as indicator for the social pillar) or output of a subset of productive sectors (i.e. Renewables demand over total energy demand). Some sustainability indicators focus on sectors that are not represented in the original GTAP 7 database. In order to increase the informative purpose of the Index, the original database has been modified to increase the sectors specification. Research and Development (R&D), Education, Private and Public Health, and Renewables have been included in the model using data on trade flows, production and consumption from different sources (Table 1).[3] These new sectors have an endogenous evolution coherent with the exogenous assumptions on primary factors' productivity.

Other indicators focus on variables that are not part of the ICES-SI model, namely use of water, biodiversity, access to electricity and inhabitable land. The above variables have been linked to the model with additional equations that allow simulating their future behaviour coherently with the endogenous path of ICES-SI. Table 2 reports the way in which the new indicators are linked to the model and main sources for data collection with relation to the base year.

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[3] These sectors were extracted from more aggregate sectors by using the SplitCom facility (Horridge 2008) and constructed using data from relevant sources.

Table 1 Additional sectors for FEEM SI

New sector	Original GTAP7 sector	Main reference sources
R&D	"Other business services"	World Bank (2010a)
Education/private health/ public health	"Other generative services"	World Bank (2010b), WHO (2010)
Renewables	"Electricity"	IEA (2005), EC (2008), Ragwitz et al. (2007), GTZ (2009), IEA country profiles, REN21 (2011) renewable energy policy network for the 21st century (www.ren21.net)

Table 2 Additional sectors for FEEM SI

New indicator	Model variable link	Main reference sources
Water	Water services demand by agriculture, industry and households	FAO's aquastat database
Biodiversity	CO_2 emissions	World conservation union IUCN (2010), Thomas et al. (2004)
Electricity access	GDP per capita	IEA (2010), World Bank (2010b)
Inhabitable land	Population	FAO (2011); FAO and IIASA (2000)

The Water sector in GTAP7 refers to infrastructure whose services by agriculture, industry and households were used to consider the exploitation of water, keeping constant the available total renewable water resources in each country. Biodiversity has been assumed to decline with increases in carbon dioxide emissions. Reducing GDP per capita gap with respect to developed countries allows reproducing an increase in access to electricity in developing countries. Finally, growing population raises the pressure over the inhabitable land.

The physical energy flows underlying the database (production, consumption and trade of energy) and the Kyoto GHG emissions (CO_2, CH_4, N_2O, PFCs, HFCs, SF_6) (Lee 2008; Rose and Lee 2008), are included to consider GHG per capita, energy intensity and CO_2 intensity. They evolve coherently with economic flows.

4 Normalisation and Aggregation Procedure

The output of the ICES-SI model provides the initial values for the indicators that are then normalised and aggregated. The idea of having comparable indicators and one index to assess the overall level of sustainability, across countries and time, requires two main steps.

To begin with, it is necessary to express all indicators, characterised by different measure units, in a common measurement scale. According to the OECD's *Handbook on constructing composite indicators* (2008), "normalisation is required prior to any data aggregation as the indicators in a data set often have different measurement units". Several normalisation techniques exist in literature. The FEEM SI normalisation method uses a mixed strategy. First, a *re-scaling* procedure is applied to all indicators to obtain values in the range [0, 1], where 0 defines extremely unsustainable and 1 fully sustainable performance. Second, a step-wise *benchmarking* function is defined for each indicator in order to consider intermediate levels of performance.

The use of a benchmarking procedure is appropriate in the case of indicators for which a policy target or a minimum/maximum threshold exists for the extremely unsustainable or fully sustainable levels for the indicators respectively. This method allows comparison through time and across countries, whilst supplying a policy-based normalisation, which is particularly suitable for the construction of the FEEM Sustainability Index. Rather than subtracting mean and dividing each indicator by its standard deviation, we supply a benchmark for sustainable targets. Therefore, our index aims for absolute sustainable level of each indicator and country rather than their relative positions to the highest or lowest levels of each indicator. Since the purpose of creating a sustainability index is not only to identify best and worst practices, but also to give an appraisal of the relative distance to the sustainable target, the FEEM SI indicators are normalised according to a benchmark function, which passes through five reference levels.[4]

To avoid the discontinuity of a step function, each level has been "linearised" taking the mean values of two subsequent intervals and interpolating them, thereby creating a continuous step function (Fig. 2). The intervals are defined considering both relevant literature and official statistics to derive the most appropriate benchmarks for each indicator.

When all indicators are expressed in the [0,1] range through normalization, the next step is the aggregation of all indicators in one general index. This is a three-stage procedure considering: (1) evaluation elicitation, (2) aggregation of single preferences in a representative profile of weights, and (3) index computation combining weights and normalised indicators.

The first stage is the definition of weights to be associated to each indicator. To this purpose, an experts' elicitation with an "ad hoc" questionnaire is performed. The questionnaire is prepared in such a way that experts were asked to evaluate all possible scenarios of the indicators being at their best or worst levels, i.e. all the combinations of BEST and WORST values, as well as how they would evaluate intermediate conditions. Firstly, they are asked to evaluate all possible conditions when only one sustainability indicator is completely sustainable (i.e., best), but the remaining ones are completely unsustainable (i.e., worst). Secondly, they are asked

[4] The complete description of the normalization and benchmarking procedure as well as the benchmark selection is in Chap. 3 of the FEEM SI Methodological report (FEEM 2011).

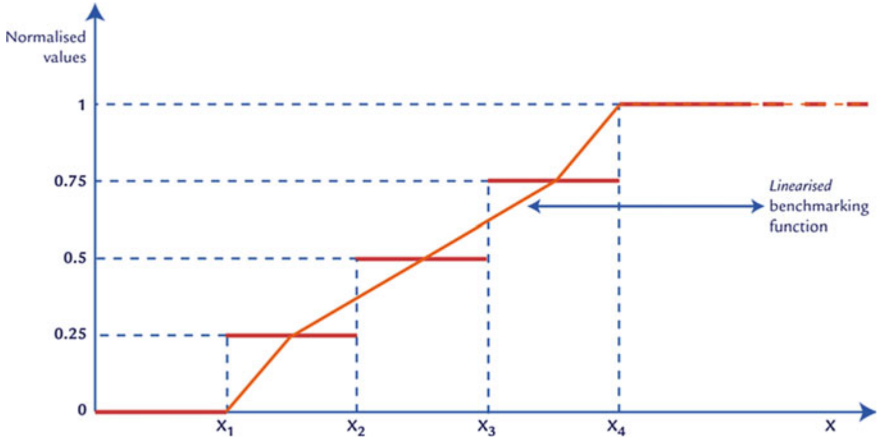

Fig. 2 The benchmarking function

to evaluate all possible combinations when two sustainability indicators are completely sustainable (i.e., best) and the remaining one is completely unsustainable (i.e., worst). Similar types of questions allow evaluating the indicators located under each node in the decision tree.

In the second stage, a non-linear aggregation methodology is applied to aggregate divergences in respondents and to compute a consensus measure. This allows to derive a 'representative' weight assigned to each sustainability indicator and tree's node, relying upon the *metric distance* measure (i.e., if the evaluation of an expert is in agreement with other experts, then this expert's valuation gets higher weight. Thus, if an expert's valuation of sustainability indicators is extremely different from other experts, a relatively lower weight is assigned to this type of expert valuation).

The third stage concerns the aggregation of indicators, combining normalised indicators' values and their weights created in the previous step. The aggregated Sustainability Index is constructed through a non-linear aggregation methodology, the Choquet integral, which accounts for the possible interactions among sustainability indicators (see Murofushi and Soneda 1993; Murofushi et al. 1994; Grabisch 1995, 1996; Marichal and Roubens 2000; Grabisch et al. 2003 for the detailed Choquet integral aggregation procedure and its characteristics).[5] For the aggregation, the decision tree should be read from bottom (leaves) to top (final node) and the tree respects the three main pillar structure which is quite standard in most sustainability studies (see e.g., UN CSD 2005; Global Reporting Initiative framework, GRI 2006, 2010; Krajnc and Glavic 2005), with the final node producing the aggregate index. Finally, economic, social and environmental

[5] See Meyer and Ponthière (2011) for a recent application of the Choquet integral to construct a ranking of multiattribute hypothetical societies by eliciting individual preferences on different dimensions of living conditions.

sustainability levels for each country are obtained and those are aggregated to obtain the final FEEM SI values.

This approach gives an innovative direction to the current literature on aggregate indicators. For example in a recent review, Singh et al. (2009) summarises forty-one sustainability indicators and majority of those indices are either aggregated through equal weight assignment (e.g., Environmental Sustainability Index, Human Development Index, Sustainability Performance Index, etc.) or weights given by experts (e.g., Index of Environmental Friendliness) to each sustainability indicator. However, none of those indices allows for the interactions between different sustainability indicators. In other words, those aggregation methodologies do not account for synergies or redundancies when indicators are aggregated. In the construction of FEEM SI, the Choquet integral aggregation is able to address specifically the inter-relations across indicators, thus overcoming the limitations of other aggregation methodologies.

In addition, the questionnaire tailored to elicit experts' evaluations of the sustainability indicators also releases important key characteristics where one can obtain information about the experts' attitude towards the sustainability concept. For example, one of the key aspects that can be derived through the Choquet integral is the "andness" degree. An "andness" degree close to 1 indicates that the decision maker tends to be non-compensative, meaning that she/he would not accept that a good performance in one indicator compensates for a negative one in another. On the contrary, an "andness" degree close to 0 indicates that the decision maker is satisfied even if only one indicator is at "best" level. Given the nature of the problem at hand, it seems more likely that decision makers evaluating the hierarchical structure of the FEEM SI tree should be more inclined towards "andness", as sustainability implicitly requires a balanced development across its different components.[6]

5 Baseline Scenario and Sustainability

The framework described in the previous sections has been applied to a baseline scenario for the period 2005–2020, which gives insights on the evolution of overall sustainability as well as its pillars in a no policy scenario. This scenario is used as reference to analyse the effect of alternative policy scenarios. The baseline scenario replicates the historical trends of main economic variables in the period 2004–2009 and then reproduces an intermediate growth level scenario. The main sources of exogenous dynamic are presented in Table 3. In order to create this scenario the baseline is built according to a set of exogenous drivers, mainly population, labour stock and land productivity. Additional variables such as labour

[6] For a detailed description of the aggregation procedure see Cruciani et al. (2012).

Table 3 Main variables and reference sources in the baseline scenario

Variable	Reference source
Population	UN world population prospect (2010 revision)—medium fertility variant
Fossil fuel prices	Eurelectric (2011)
GDP	2005–2009 = WDI World Bank (2010a)
	2010–2020 = MMC_G10 scenario med pop—medium growth—fast convergence (Conv) developed within the RoSE project[a] + IMF (2010) for downscaling at country level
Energy intensity	2005–2009 = IEA (2010)
	2010–2020 = endogenous
CO_2 emissions	2005–2009 = IEA (2010)
	2010–2020 = endogenous
Public debt	IMF (2010)

[a] "RoSE—Roadmaps towards Sustainable Energy Futures: A Model-Based Assessment of Scenarios for Decarbonising the Energy System in the twenty first Century". Germany

Fig. 3 World map of sustainability in 2011

productivity and total factor productivity are then calibrated to replicate the selected reference GDP growth rate.[7]

The FEEM SI and its indicators are then calculated for each country/macro-region and for each year until 2020. The map (Fig. 3) represents the global picture for the world in 2011. As expected, the most developed countries show higher sustainability than less developed ones. This is mainly explained with the good performances of rich countries in the social pillar.

Figure 4 compares the scores of each pillar (economic, social and environmental) and the aggregate index for the best and worst countries. The scores for the top-three countries are similarly high in the three main components of

[7] The baseline calibration and validation is detailed in Chap. 5 of the FEEM SI Methodological report (FEEM 2011).

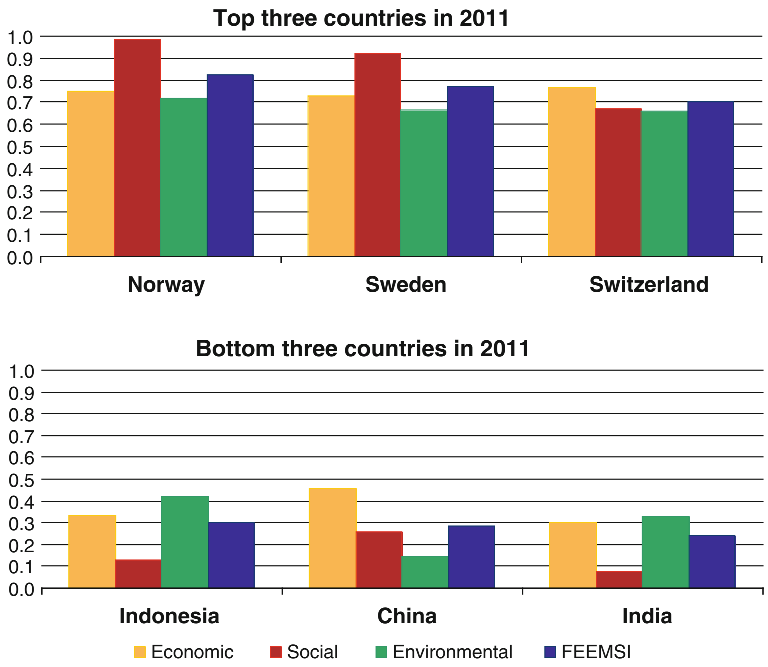

Fig. 4 FEEM SI and sustainability pillars for the top and bottom countries

sustainability. Norway is at the top of the ranking with the highest scores for the social and environmental components. Switzerland is second with a slightly higher economic performance but lower social welfare. Sweden performs slightly less than Norway in all dimensions. Looking at the bottom-three countries, the components are very unequally distributed. Indonesia has a higher value for the environmental dimension than the other two regions. On the other side, China has the highest score in the values of economic and social pillars, while reaching the lowest score in the environmental one. Finally, India reaches the lowest levels in the score of economic and social pillars.

Table 4 illustrates the position of the 40 countries/macro-regions in 2011 and 2020, as well as the changes in the ranking. The results illustrate that no dramatic changes occur in the period under consideration. Benelux (+7 positions from 2011 to 2020), Germany (+5) and Italy (+3) benefit the highest advancements in the sustainability ranking; conversely, United States (−6) and Russia (−5) downgrade mostly, along with a reduction in their overall level of sustainability, since their economic growth determines a significant deterioration of the environmental pillar.

The purpose of a Sustainability Index is to consider economic, social and environmental indicators simultaneously and offer additional and more complete information for welfare assessment beyond what GDP per capita can do. Figure 5 sketches the correlation between GDP p.c. and the FEEM SI. On average, the higher the GDP p.c., the higher the value of FEEM SI. However, the sustainability

Table 4 World sustainability ranking (2020 with respect to 2011)

Rank 2011	Country	FEEM SI 2011	Δ Rank	FEEM SI 2020	Country	Rank 2020
1	Norway	0.82	=	0.85	Norway	1
2	Sweden	0.77	=	0.81	Sweden	2
3	Switzerland	0.70	−1	0.74	Austria	3
4	Austria	0.69	1	0.70	Switzerland	4
5	Finland	0.66	=	0.68	Finland	5
6	Denmark	0.65	=	0.68	Denmark	6
7	Canada	0.64	=	0.67	Canada	7
8	France	0.63	=	0.65	France	8
9	Ireland	0.62	−1	0.63	New Zealand	9
10	New Zealand	0.61	1	0.62	Ireland	10
11	USA	0.55	−6	0.58	Germany	11
12	Australia	0.55	=	0.58	Australia	12
13	Brazil	0.55	−2	0.56	Benelux	13
14	UK	0.53	=	0.55	UK	14
15	RoEurope	0.53	−1	0.54	Brazil	15
16	Germany	0.53	5	0.54	RoEurope	16
17	Portugal	0.52	−2	0.53	USA	17
18	RoLA	0.51	=	0.53	RoLA	18
19	Spain	0.50	−2	0.53	Portugal	19
20	Benelux	0.50	7	0.51	RoEU	20
21	Russia	0.49	−5	0.50	Spain	21
22	RoEU	0.49	2	0.50	Italy	22
23	Mexico	0.49	−2	0.49	Korea	23
24	Korea	0.48	1	0.49	Japan	24
25	Italy	0.47	3	0.48	Mexico	25
26	Japan	0.46	2	0.48	Russia	26
27	Turkey	0.45	=	0.48	Turkey	27
28	MiddleEast	0.45	=	0.47	MiddleEast	28
29	Poland	0.43	=	0.44	Poland	29
30	SouthAfrica	0.43	=	0.43	SouthAfrica	30
31	Greece	0.40	=	0.43	Greece	31
32	RoAfrica	0.40	=	0.40	RoAfrica	32
33	RoWorld	0.39	=	0.39	RoWorld	33
34	SEastAsia	0.37	=	0.36	SEastAsia	34
35	RoFSU	0.37	=	0.36	RoFSU	35
36	NorthAfrica	0.34	=	0.34	NorthAfrica	36
37	RoAsia	0.33	=	0.34	RoAsia	37
38	Indonesia	0.30	−1	0.32	China	38
39	China	0.29	1	0.32	Indonesia	39
40	India	0.24	=	0.29	India	40

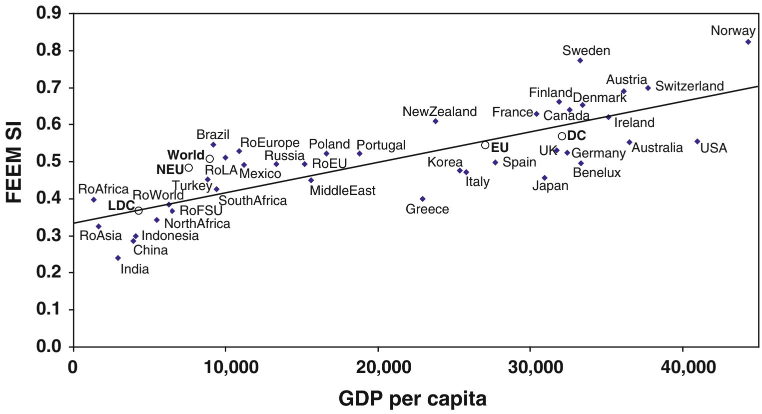

Fig. 5 FEEM SI and GDP p.c. correlation

performance of countries with similar GDP p.c., such as Benelux and Sweden, can be very different.

Differences emerge in comparing the ranking of GDP p.c. and of the FEEM SI. For example, USA and Australia, with the 2nd and 4th highest GDP p.c. in the world respectively, are only at 11th and 12th positions according to the FEEM SI ranking. This is due to the low performance in environmental sustainability not compensated by the good economic and social performance. Other rich countries are significantly worse off when looking at FEEM SI value, such as Japan, Italy and Greece, while Sweden, Finland, France have the reverse relationship (FEEM SI makes them better off than GDP ranking). A stronger relation between GDP p.c. and FEEM SI rankings characterises the 10 bottom countries; a low GDP p.c. is normally associated to a low overall sustainability performance. Nevertheless, the other indicators considered in the FEEM SI skew the GDP p.c. ranking. For instance, India (38th according to GDP p.c.) becomes the worst performer (40th according to FEEM SI) because of its poor performance in social and environmental sustainability. Conversely, the Rest of Africa (RoAfrica) benefits from the relatively good environmental performance connected to the relatively low importance of energy-intensive industry.

6 The Effect of Climate Policy on Sustainability

Climate change is one of the main challenges for humankind in this century. Designing and implementing an effective climate policy offers a valid option to deal with this phenomenon. Nevertheless, curbing CO_2 emissions implies economic costs that often discourage a binding commitment in this field. The FEEM

Table 5 CO_2 emissions growth and reduction targets in 2020 with respect to 1990

Region	Baseline CO_2 growth (%)	CO_2 target (%)	Policy scenario CO_2 growth (%)
Annex I—Leading Regions			
Australia	62	13	13
New Zealand	102	−10	−10
Japan	21	−25	−25
EU27	2	−20	−20
USA	36	−3	−3
Canada	26	3	3
Switzerland	15	−20	−20
Norway	32	−30	−30
Russia	9	−15	−15
Turkey[a]	123	–	191
Non-annex I—leading regions			
Korea (Rep. of)	207	115	115
China[b]	376	–	375
India[b]	367	–	357
Indonesia	335	222	222
Mexico	108	46	46
Brazil	279	142	142
South Africa	83	20	20
Annex I	21	−12	−10
Non-annex I	317	289	289
Rest of the World	115	–	155
WORLD	94	–	75

[a] Annex I country with no target
[b] China and India's targets are originally stated in terms of carbon intensity reduction with respect to 2005

SI, reflecting the broad concept of sustainability, allows analysing the benefits of a climate policy in a more comprehensive way.

The analysis focuses on a mitigation scenario in which Annex I and Non-Annex I countries taking action towards climate change achieve the low pledges proposed at the 15th UNFCCC Conference of the Parties in Copenhagen (December 2009). All countries implement a unilateral emission reduction through a carbon tax or a carbon intensity target (China and India). The only exception is represented by EU27, whose Member States are allowed trading emission permits among them (but not with the rest of the world) replicating the Emission Trading Scheme in force since 2005. For sake of simplicity, the policy only refers to CO_2 emissions and is applied uniformly to all productive sectors. Table 5 reports the Copenhagen targets, and percentage change in both baseline and policy case for leading countries.

Looking at the main aggregates in Table 5, Annex I countries, which in the baseline scenario increase emissions in 2020 by 21 % with respect to 1990, reduce their emission levels by 10 % in the policy scenario. Non Annex I countries also contribute to the policy since their emissions grow less than in the baseline (289 vs. 317 %). The Rest of the World, with no commitments, increases its emissions

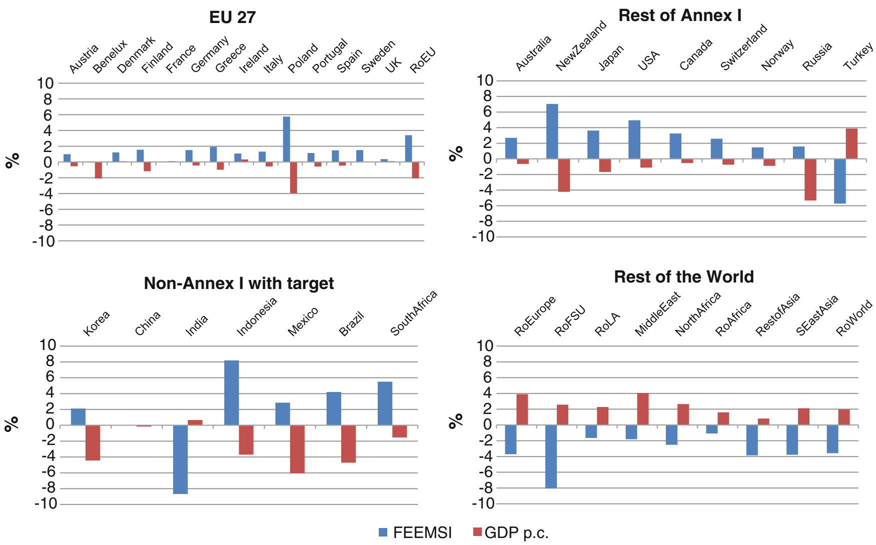

Fig. 6 FEEM SI and GDP p.c. % change in 2020 (climate policy vs. baseline)

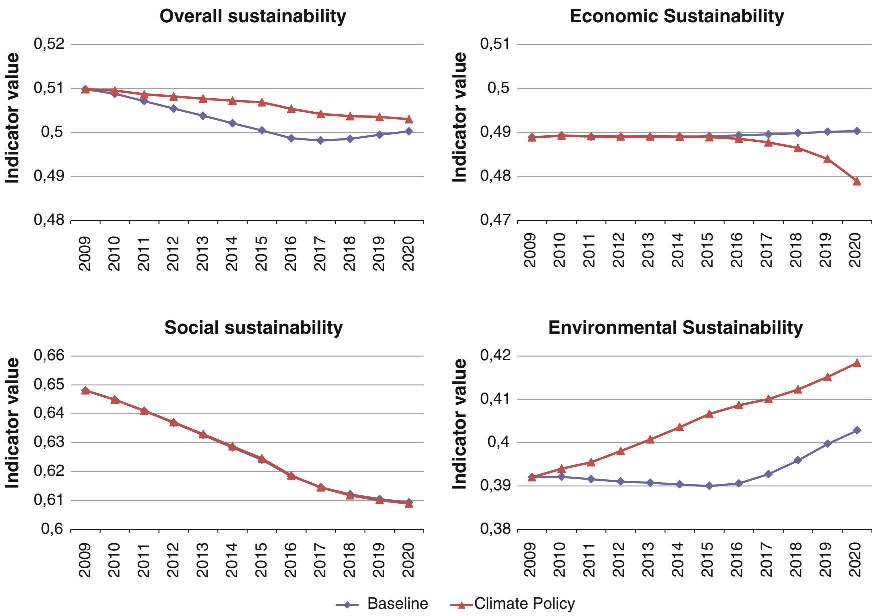

Fig. 7 Changes in World sustainability by pillar (climate policy vs. baseline)

from 115 to 155 %. At world level, emissions after the mitigation policy are lower than in the baseline scenario, growing 75 % instead of 94 %.

Figure 6 shows the implications of the climate policy for sustainability and mitigation costs of several aggregates. In EU27, Poland and RoEU display the main GDP losses, but also the highest improvement in sustainability. These two countries contribute more than the others to the EU abatement, given their low mitigation costs. Benelux also has a significant economic loss, but in this case the impact on sustainability is negligible. Germany, Sweden and Ireland show an increase in sustainability at very low cost, given the already good environmental performance. Among other Annex I countries, the highest costs are undertaken by Russia and New Zealand.

The related positive impact on sustainability is differentiated: high for New Zealand but quite low for Russia. USA, Australia and Canada have a significant increase in sustainability with low economic loss, meaning once again that the initial stage of technological development matters. Turkey not having any commitment would experience an improvement of economic conditions, but with a substantial reduction in its sustainability due to the increased environmental degradation.

Almost all Non-Annex I countries show important economic costs to achieve their own targets (especially Mexico, Brazil and Korea). Indonesia has the strongest increase in sustainability. India earns in GDP terms but with a drop in sustainability, while China has a negligible loss with no impact on sustainability. In both cases the economic result depends on lack of stringency of the target (almost achieved in the baseline). Overall, costs are higher for Non-Annex I than for Annex I countries. Rest of the World macro-regions are all better off with respect of GDP since they do not have any emissions target and can increase their output due to the carbon leakage effect; but at the same time their sustainability decreases due to environment degradation.

The implication of the climate policy for sustainability at world level by pillar is depicted in Fig. 7. The overall sustainability declines less than in the baseline scenario. The downward trend is justified by the significant decrease in the social pillar (as in the baseline), almost unaffected by climate policy. However, the increase in the environmental pillar more than compensates the decline in the economic pillar after 2015, when the policy becomes more costly. The mitigation policy improves world sustainability. Moreover, this positive result could be stronger if a higher number of signatories committed to an emission reduction target, reducing the carbon leakage effect.

7 Conclusions

This chapter presented a methodological tool for sustainability measurement built in a CGE model: the FEEM SI. Most policy-makers and stakeholders recognise the importance to go beyond the economic dimension in measuring sustainable development. While many highlight the opportunity to change the development pattern through qualitative approaches, there is an increasing interest in quantifying the level of sustainable development.

The FEEM SI summarises a set of indicators reflecting the main aspects of sustainability. It uses a normalisation procedure based on re-scaling and benchmarking to reconcile all indicators to a common scale. The indicators' aggregation requires the elicitation of experts' evaluations through an "ad hoc" questionnaire in order to derive weights, and a non-linear aggregation procedure of weights and indicators values.

The FEEM SI offers projections on the trend of countries' sustainability across the world in the next future and allows considering different scenarios besides the current situation. This requires the use of a recursive-dynamic CGE model as basic framework for the index in which the overall coherence is guaranteed by economic interrelations among countries.

The FEEM SI results show a heterogeneous situation, in which advanced economies have a satisfying level of sustainability while developing countries still show a significant gap. Looking in detail at the determinants of this result, it emerges that a high performance in each sustainability dimension is a necessary condition to reach the overall sustainability.

In the baseline scenario, world sustainability slightly decreases mainly due to a significant reduction in the economic and social components. In the climate policy scenario, sustainability in signatory countries increases since the costs and the subsequent reduction in economic performance are more than offset by the improvement of the state of environment. Both mitigation effectiveness and sustainability at world level can be seriously compromised because of carbon leakage. These results suggest that a higher level of sustainability could be achieved if a higher number of signatories committed to an emission reduction target.

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A.1 Annex I

See Tables 6, 7 and 8

Table 6 Indicators' description

Dimension	Name	Indicator	Long description	Literature reference
Economic	R&D	R&D expenditure/GDP (%)	This indicator assumes a positive relationship between investment in R&D and growth, by maintaining that increased investment in R&D can bring more R&D output that will eventually lead to more innovation and increased productivity	EU SDS—UN CSD—WDI
	Investment	Net investment/capital stock (%)	Investment is one of the main drivers of economic sustainability, allowing for capital accumulation, which boosts economic growth. This indicator is weighted considering the country specific capital stock	EU SDS—UN CSD
	GDP per capita	GDP PPP/population	It is a measure of the per capita value of all market goods and services produced within a country. GDP p.c. is the typical indicator used to define the average well-being in a country	EU SDS—UN CSD—WDI
	Relative trade balance	Trade balance/market openness	The relative trade balance measures the degree of a country's exposure in the global commodities markets. It considers the net export value and weights it with the country specific market openness (exports + imports). Relying relatively more upon exports is a signal of strong competitiveness	–
	Public debt	Government debt/GDP (%)	Public debt has an important role on the future perspective of a country's economy. It depends on current government choices on expenditure and taxation, and on previously accumulated debt	WDI—UN CSD—IMF
Social	Population density	Population/country surface	Population density evaluates the population concentration in a specific country or macro-region (excluding uninhabitable areas). It represents the pressure on the available living space and resources for each individual	UN CSD—WDI
	Education	Education exp./GDP (%)	Expenditure in education constitutes an investment in human capital. The role of education in improving future economic conditions and enhancing mobility as well as gender equality is supported by several studies	EU SDS—WDI
	Health	Total health exp./GDP (%)	The generalised access to basic health services is a major concern throughout the world. Monitoring the growth of expenditures in health by summing public and private expenditures allows to measure the degree of support on this issue	WDI
	Food relevance	Food cons./private exp. (%)	This indicator is used as a proxy for the poverty level. In fact, according to Engel's law, the higher the proportion of national income spent on food the lower the level of a country's welfare	–
	Energy imported	Energy imported/energy cons. (%)	This is an indicator of energy security. The higher the energy dependence from abroad, the higher the risks deriving from changes in energy prices and political instability in energy-rich countries	WDI
	Energy access	Population with access to electricity/total population (%)	Access to energy is important with reference to living conditions and future prospectives of well-being. This indicator considers the share of population having access to electricity. It allows capturing the intra country aspect of energy security, being more focused on distribution of energy resources than on availability at the country level	WDI
	Private health	Private health exp./total health exp.(%)	Monitoring the balance between public and private contribution to the health sector is essential for sustainability because it determines the availability of primary service to the whole society. The higher the share of private health expenditure, the lower the ability of poorer people to access to the health care	WDI

(continued)

Table 6 (continued)

Dimension	Name	Indicator	Long description	Literature reference
Environmental	GHG per capita	Kyoto GHGs emissions/population	The greenhouse gases are considered as described in the Annex I of the Kyoto Protocol. Emission per capita is a measure of the burden that the society imposes on climate and environment	EU SDS—UN CSD—WDI
	CO_2 intensity	CO_2 emissions/total primary energy cons.	This indicator is fundamental to monitor the improvement of the environmental performance of production and consumption activities, the latter playing a major role in the release of carbon dioxide into the atmosphere	EU SDS—UN CSD—WDI
	Energy intensity	Total primary energy supply/GDP PPP	This indicator aims to assess the evolution of energy use efficiency	EU SDS—UN CSD—WDI
	Renewables	Renewable cons./total primary energy cons.(%)	The gradual reduction of fossil fuel use is an important step towards security and sustainability of energy systems. The higher the share of green energy, the higher the environmental performance of the energy sectors	EU SDS—UN CSD—WDI
	Plants	Endangered species/total species (%)	This indicator represents an alarm signal of the general worsening of habitats. It provides a comparable measure of endangered Plant species throughout the world, by considering the number of endangered species over the number of total known species present in that country	EU SDS—UN CSD—WDI
	Animals	Endangered species/total species (%)	As in the previous indicator, it also represents an alarm signal of the general worsening of habitats. It is calculated in the same way but focusing on animal biodiversity	EU SDS—UN CSD—WDI
	Water	Water use/total available water (%)	Human pressure on water, is an important indicator of resource pressure. It is estimated as water consumed in a country (for agriculture, industry and private uses) over the total renewable water resources available in that specific country	UN CSD—WDI

Table 7 Regional aggregation

No.	Macro-Regions	Countries
1	Australia	Australia
2	NewZealand	New Zealand
3	Japan	Japan
4	Korea	Korea
5	China	China, Hong Kong, Taiwan
6	India	India
7	Indonesia	Indonesia
8	SEastAsia	Malaysia, Philippines, Singapore, Thailand, Vietnam
9	RoAsia	Afghanistan, Bangladesh, Bhutan, Brunei Darassalam, Cambodia, Democratic Republic of Korea, Lao People's Democratic Republic, Macau, Maldives, Mongolia, Myanmar, Nepal, Pakistan, Sri Lanka, Timor East
10	USA	USA
11	Canada	Canada
12	Mexico	Mexico
13	Brazil	Brazil
14	RoLA	Argentina, Bolivia, Chile, Colombia, Ecuador, Paraguay, Peru, Uruguay, Venezuela, Falkland Islands (Malvinas), French Guiana, Guyana, Suriname, Costa Rica, Guatemala, Nicaragua, Panama, Belize, El Salvador, Honduras, Saint Vincent and the Grenadines, Trinidad and Tobago, Turks and Caicos, Anguilla, Antigua & Barbuda, Aruba, Bahamas, Barbados, Cayman Islands, Cuba, Dominica, Dominican Republic, Grenada, Guadeloupe, Haiti, Jamaica, Martinique, Montserrat, Netherlands Antilles, Puerto Rico, Saint Kitts and Nevis, Saint Lucia, Virgin Islands (British), Virgin Islands (U.S.)
15	Austria	Austria
16	Benelux	Belgium, Luxembourg, Netherlands
17	Denmark	Denmark
18	Finland	Finland
19	France	France
20	Germany	Germany
21	Greece	Greece
22	Ireland	Ireland
23	Italy	Italy
24	Poland	Poland
25	Portugal	Portugal
26	Spain	Spain
27	Sweden	Sweden
28	UK	UK
29	RoEU	Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Slovakia, Slovenia, Bulgaria, Romania
30	Switzerland	Switzerland
31	Norway	Norway
32	RoEurope	Albania, Andorra, Bosnia and Herzegovina, Croatia, Faroe Islands, Gibraltar, Iceland, Liechtenstein, Macedonia, the former Yugoslav Republic of, Monaco, San Marino, Serbia and Montenegro

(continued)

Table 7 (continued)

No.	Macro-Regions	Countries
33	Russia	Russia
34	RoFSU	Belarus, Ukraine, Moldova, Republic of, Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, Uzbekistan, Armenia, Azerbaijan, Georgia
35	Turkey	Turkey
36	MiddleEast	Bahrain, Islamic Republic of Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Occupied Palestinian Territory, Oman, Qatar, Saudi Arabia, Syrian Arab Republic, United Arab Emirates, Yemen
37	NorthAfrica	Algeria, Egypt, Libyan Arab Jamahiriya, Morocco, Tunisia
38	RoAfrica	Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Cape Verde, Central African Republic, Chad, Comoros, Congo, Democratic Republic of the Congo, Cote d'Ivoire, Djibouti, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mauritius, Mayotte, Mozambique, Niger, Nigeria, Reunion, Rwanda, Saint Helena, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, Somalia, Sudan, Swaziland, Tanzania, Togo, Uganda, Zambia, Zimbabwe
39	SouthAfrica	SouthAfrica
40	RoWorld	American Samoa, Cook Islands, Fiji, French Polynesia, Guam, Kiribati, Marshall Islands, Micronesia, Federated States of, Nauru, New Caledonia, Norfolk Island, Northern Mariana Islands, Niue, Palau, Papua New Guinea, Samoa, Solomon Islands, Tokelau, Tonga, Tuvalu, Vanuatu, Island of Wallis and Futuna, Bermuda, Greenland, Saint Pierre and Miquelon

Table 8 Sectoral aggregation

No	Sectors
1	Food
2	Forestry
3	Fishing
4	Coal
5	Oil
6	Gas
7	Petroleum products
8	Other electricity
9	Renewables
10	Nuclear
11	Biofuels
12	Energy intensive industries
13	Other industries
14	Water
15	Market services
16	Public services
17	R&D
18	Education
19	Private health
20	Public health

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