MEASUREMENT OF THE "FIGHT AGAINST CLIMATE CHANGE" OBJECTIVE: EVIDENCE FROM EUROPEAN COUNTRIES

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Abstract. Sustainability is a complex multidimensional framework to be evaluated and measurement tools play a crucial role in this challenge. The 2030 Agenda for Sustainable Development, adopted by all United Nations Member States in 2015, declines sustainability through 17 objectives (17 Sustainable Development Goals, SDGs), to reach by 2030. Among all Goals, here we focus on climate change, that is on Goal 13 "Take urgent action to combat climate change and its impacts". With the aim of better monitoring and evaluating sustainability levels of countries and how far they are from achieving their goals, the current study proposes the use of a modified version of the Wroclaw taxonomic method. The proposed index is used to aggregate indicators belonging to Goal 13 for 18 European countries in 2020 and 2021. The effectiveness of the proposed method is assessed by comparing results with the classical indices used for measuring SDG progress.

1. Introduction

The main global challenge of this century is achieving sustainability, which requires the creation of innovative methods to measure and monitor progress. To ensure that a sustainable development is both understood and implemented, the 2030 Agenda – an ambitious and transformative plan for People, Planet, and Prosperity – has been adopted by all United Nations Member States in 2015.

The 2030 Agenda embodies all facets of sustainable development, emphasizing its pillars: social inclusion, economic development, and environmental sustainability. It operates through the identification of 17 Sustainable Development Goals (SDGs), supported by 169 targets and 240 indicators (see Bartram *et al*., 2018 for details).

Specifically, the 17 SDGs introduce crucial themes such as gender equality, protection of forests and oceans, promotion of peace and justice, fair work, urbanization and the fight against climate change (Biggeri *et al*., 2019).

The United Nations propose various indicators to monitor progress towards the goals[1]. However, given the actual inability to standardize the measurement of the

[1] https://undocs.org/en/A/RES/70/1

SDGs across countries, they can measure the SDGs using their own methodologies and indicators which may be different from those provided by the United Nations.

The challenge for countries is to define the objectives along with their respective sub-targets and indicators to be achieved through national policies.

Here, we focus on environmental sustainability analysed into SDG 13, a Goal aiming at combating the climate crisis by promoting actions at different levels.

As stressed by Butera (2011), climate change is a multidimensional phenomenon and its impact should be investigated considering all the factors jointly. In fact, the worsening of a single environmental factor can trigger reactions on others and, consequently, amplify its negative effects. This indirect and interconnected nature, not only complicates efforts to identify and measure controlling variables, but also makes the prediction of its biological, socioeconomic, and physical impacts challenging.[2]

SDG 13 is outlined in the 2030 Agenda through 5 sub-targets assessing the risks of climate change, adaptation measures, its integration into policies for mitigation, and educational awareness efforts. In turn, the 5 sub-targets are declined by mean of 8 indicators.

However, despite several progress in most of the SDG, the United Nations' Sustainable Development Report 2022 (United Nations, 2022) attaches to the SDG 13 a “code red warning” meaning that almost all countries are very far from the achieving of the target. For instance, considering all countries, Energy-related CO2 emissions increased by 6% in 2021, reaching highest level ever; global temperatures have arisen reaching more extreme weather and, estimates suggest that medium- to large-scale disasters will increase by 40% from 2015 to 2030. Thus, it seems that the planet is on the brink of a climate catastrophe and progress towards SDG 13 are unsatisfactory.

Also in the European context, although the EU's overall progress towards the SDGs is favorable, advancement on SDG 13 is moderate and considerably trails behind progress on other environmental goals. In fact, moving from global to European context, the scenario is quite similar: there is a string decline in emissions during the COVID-19 pandemic, which, in parallel with the global context, sees significant increases in 2021 (Sachs *et al*., 2023). Thus, the current situation remains critical, characterized by significant economic losses and challenges in managing the increasingly serious impacts of climate change.

In this context, it becomes crucial the adoption of appropriate tools capable of measuring a multidimensional and complex phenomenon such as climate change.

[2] https://ec.europa.eu/eurostat/web/products-flagship-publications/w/ks-04-23-184

According to Bidarbakht-Nia (2020), there are at least three different methods to measure progress on SDG. All methods consist in the construction of a synthetic index aiming at reducing complex systems into lower-dimension space, and allowing the performance of an individual unit to be evaluated across space and time (Mazziotta and Pareto, 2013).

The first one, has been developed by Sachs et al. (2017). It is a composite indicator that uses the arithmetic mean to aggregate elementary variables, resulting in a final sustainability score for each country based on their performance across the SDGs. To normalize elementary variables, the minimum of considered values among units is subtracted to the current value and then divided by the difference between the target value and the above-mentioned minimum. In other words, the current value is compared to the worst performer. The index gives a measure of how close the country is to the target

The second one, developed by UNESCAP (Bidarbakht-Nia, 2017) computes the progress of a country respect to the values achieved in 2000. The overall index is the arithmetic mean of normalized indicators. Here, for a given country, the normalization is obtained by divided the difference between the current values and the value achieved in 2000 by the difference between the target value and the 2000s-value. In this way, the index is a sort of share of total progress that the country needs to make.

Finally, OECD (2017) monitors SDG achievement by computing the arithmetic average of normalized indicators. Here, for each country, the normalization of each indicator is obtained as the ratio between the difference of the current value and the target and, at the denominator, the standard deviation of current values computed across countries. The main advantage of such approach is that it accounts for distributions.

As described above, the three methods use the arithmetic mean as aggregation procedure and, this introduces a compensatory effect that does not fully reflect the multidimensional nature of SDG measurement.

To address this limitation, we propose a modified version of the Wroclaw Taxonomic Method (hereafter, WTM) (Florek et al., 1951). We compute a non-compensatory composite indicator for 18 European countries over the years 2020 and 2021.

The WTM indicator is computed as a normalized distance of each European country from an ideal unit, that is, the unit which achieves the best performance on all the indicators (see Silvio-Pomenta,1973; Schifini *et al.*, 1980; Mazziotta *et al.*, 2010 for details).

The idea behind this method is to account for the distance with respect to an ideal unit that is a synonymous of reference value or goalpost (Ermini *et al.*, 2023).

The main novelty is to consider the country-specific target levels as goalposts and the resulting composite indicator represents the mean distance from the "most achievable" climate goals.

The rest of the paper is organized as follow: Section 2 describes data and the main characteristics and properties of the modified version of WTM. Section 3 highlights the main results of the computation of the index, comparing with the simple arithmetic mean. Section 4 concludes.

2. Data and methods

The empirical analysis is based on four elementary indicators included in the SDG 13 provided by EUROSTAT[3] (Table 1), namely 1) Net greenhouse gas emissions expressed in units of CO2 (*EMI*); 2) Climate economic losses measured in euros per capita (*LOS*), 3) Percentage of population covered by the Covenant of Mayors for Climate & Energy signatories (*COV*) and 4) Percentage of renewable energy consumption on the gross final energy consumption according to the Renewable Energy Directive (*REN*).

The analysis is carried out for 18 European countries: Belgium (BE), Bulgaria (BG), Czech Republic (CZ), Germany (DE), Greece (GR), Spain (ES), France (FR), Italy (IT), Luxembourg (LU), Netherlands (NL), Austria (AT), Poland (PL), Portugal (PT), Romania (RO), Slovenia (SI), Slovakia (SK), Finland (FI), and Sweden (SE), over the years 2020 and 2021.

Table 1 reports the target values in the target country to capture the distance from achieving SDG 13. Along this line, for the variables *EMI* and *REN*, country target levels are obtained from the 2019 National Energy and Climate Plans (NECP 2019) and the Regulation on the Governance of the Energy Union 2018/1999/EU, respectively. Best theoretical scenarios are used for the variables *LOS* (0 euro) and *COV (100%)*.[4]

Looking at the original formulation, the starting point of the WTM method is the computation of the Euclidean distance between the j-th indicator z_{ij} $j \in \{1, .., k\}$ of the i-th statistical unit $i \in \{1, ..., N\}$ from the ideal unit z_{oj}:

$$D_i = \sqrt{\sum_{j=1}^{k}\left(z_{ij} - z_{oj}\right)^2}. \tag{1}$$

[3] https://ec.europa.eu/eurostat/databrowser/explore/all/all_themes
[4] Data for the four variables and two years are available upon request.

The ideal unit is a hypothetical country which achieves the best performance on all the indicators. In this context, the ideal unit could be a vector with target values for each indicator.

Table 1 - *Target values of elementary indicators for 2020 and 2021.*

	Target			
	*EMI**	*COV**	*LOS**	*REN**
BE	-35	100	0	25
BG	0	100	0	27
CZ	-14	100	0	23
DE	-38	100	0	30
GR	-14	100	0	31
ES	-26	100	0	42
FR	-36	100	0	33
IT	-33	100	0	30
LU	-40	100	0	23
NL	-36	100	0	26
AT	-36	100	0	46
PL	-7	100	0	25
PT	-17	100	0	47
RO	-2	100	0	34
SI	-15	100	0	37
SK	-12	100	0	24
FI	-39	100	0	51
SE	-40	100	0	65

However, even if the definition of the 2030 Agenda (United Nations, 2015) makes it clear that targets are global in nature and universally applicable, the introduction of national targets is recommended. In fact, "*Targets are defined as aspirational and global, with each government setting its own national targets guided by the global level of ambition but taking into account national circumstances*" (United Nations, 2015, point 55).

Thus, each government should set its own targets, related to the global one, to stress the link between sustainable development. In this way, the definition of country-specific SDG targets implies their integration into the national strategic framework and stimulate a more efficient system of reporting and assessing the progress in achieving each relevant goal. In addition, the use of an own reference-point instead of a common one can be a useful instrument especially to evaluate the performance of a unit over time. This type of approach involving a unit-dependent point of view is not entirely new in the literature on the construction of composite indicators. Several scholars are introducing unit-dependent aggregation methods, Mauro et al. (2018) and and Biggeri et al. (2019) aggregate the indicators relative to different units with power means of different order.

Here, we modify the WTM to account for country-specific target levels, as follows:

$$D_i = \sqrt{\sum_{j=1}^{k}\left(z_{ij} - t_{ij}\right)^2}, \tag{2}$$

where t_{ij} represents the country-specific reference value.

We observe that, by definition, the distance between two points satisfies symmetry property. Therefore, the distance respect to the target gives the same results if a country exceeds or lacks a quantity c from the target since $[(t_{ij} - c) - t_{ij}]^2 = [(t_{ij} + c) - t_{ij}]^2$.

To address this issue, for all countries whose achievements exceed their respective targets, the value of the achievement is set equal to the target and, as a consequence, the distance is zero, that is:

$$z_{ij} = \begin{cases} t_{ij} & if\ z_{ij} \geq t_{ij} \\ z_{ij} & if\ z_{ij} < t_{ij} \end{cases} . \tag{3}$$

If the achievement of the target implies that the indicator value should be less than the target value, we simply modify Eq. (3), accordingly.

Finally, the Wroclaw indicator for each country *i*, can be computed as follows:

$$W_i = \frac{D_i}{d + 2\sigma(d)}. \tag{4}$$

Here the coefficient d is the arithmetic mean of all distances between each statistical unit *i* and the ideal unit and σ represents its standard deviation:

$$d = \frac{1}{n}\sum_{i=1}^{n} D_i \tag{5}$$

$$\sigma(d) = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(D_i - d)^2}. \tag{6}$$

The index in Eq. (4) ranges from 0 to 1, where 1 represents the greatest distance from achieving climate goals (i.e., worst scenario) and 0 means the achievement of the goals (i.e., best scenario).

The use of the WTM allows for comparisons between spatial and temporal units. Furthermore, it is a highly dynamic model, as the inclusion of new units does not alter the values of the indices already calculated (Ermini *et al.*, 2023).

3. Empirical findings

The WTM composite index measures the distance from achieving climate goals established by SDG 13 for the European context. It should be noted that the best performances are related to countries with lower index values, and, therefore, values close to zero.

As first step, we apply Eq. (3) for variable *COV* and *REN*, whereas, in the case of *EMI* and *LOS* indicators, we use the reverse.

Table 2 reports the results of the computation of WTM, according to Eq. (2), (4) and (6).

In 2020, Portugal was closest to achieving climate goals with a score of 0.332, while Greece had the worst score at 0.964 (Table 2a). In 2021, Italy showed the best performance with a score of 0.243, while Belgium was furthest from achieving climate objectives with a score of 0.911 (Table 2b).

Table 2 – *Wroclaw index values by country for the year 2020 (left side) and 2021 (right side).*

(a)

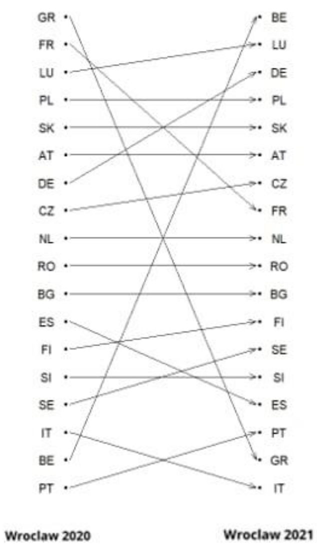
Country	WTM 2020
1. GR	0.964
2. FR	0.918
3. LU	0.893
4. PL	0.779
5. SK	0.741
6. AT	0.738
7. CZ	0.732
8. DE	0.725
9. NL	0.705
10. RO	0.651
11. BG	0.582
12. ES	0.524
13. FI	0.515
14. SI	0.489
15. SE	0.473
16. IT	0.456
17. BE	0.417
18. PT	0.332

(b)

Country	WTM 2021	Ranking in 2020
1. BE	0.911	17
2. LU	0.886	3
3. DE	0.822	8
4. PL	0.772	4
5. SK	0.732	5
6. AT	0.707	6
7. CZ	0.673	7
8. FR	0.670	2
9. NL	0.656	9
10. RO	0.601	10
11. BG	0.574	11
12. FI	0.491	13
13. SE	0.463	15
14. SI	0.458	14
15. ES	0.296	12
16. PT	0.278	18
17. GR	0.266	1
18. IT	0.243	16

Figure 1 depicts changes in country rankings over the two years 2020 (on the left) and 2021 (on the right). The countries are listed in descending order, with the first being the furthest from achieving climate goals and vice versa.

Figure 1 - *Ranking variation of Wroclaw index (2020 vs 2021).*



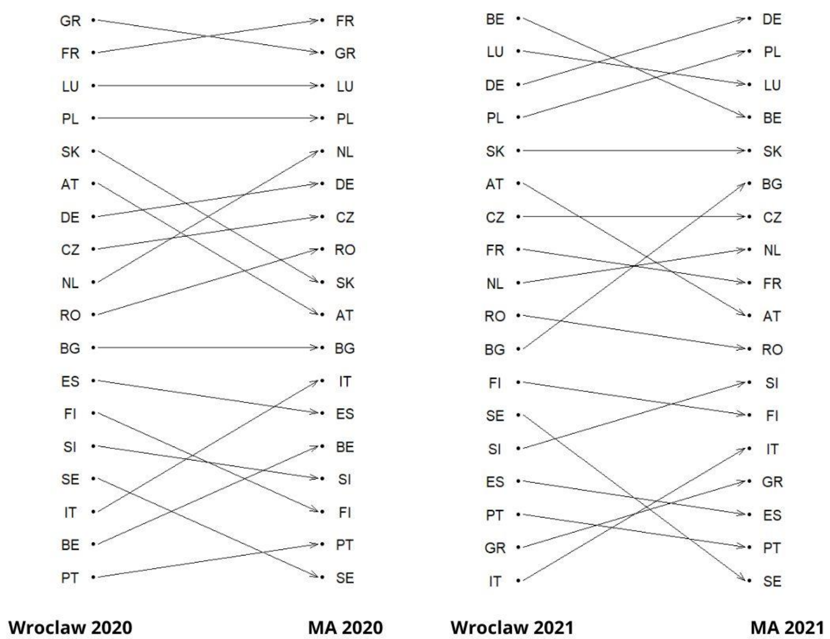
The WTM index reveals notable changes in the ranking from 2020 to 2021. Firstly, Greece moves from the last position to second place. Conversely, Belgium deviates significantly from its climate targets in 2021, becoming the country furthest from reaching them. These changes in the position deserve to be more in-depth investigated, looking at the specific policies adopted in the various countries over the years under analysis.

Countries showing substantial positive changes in the ranking include Italy, Spain and France. On the other hand, Germany and Belgium significantly worsen their positions, moving further away from achieving their objectives.

Poland, Slovakia, Austria, the Netherlands, Romania, Bulgaria, and Slovenia maintain their positions by slightly reducing their scores, thus getting closer to the established climate goals. In contrast, the Czech Republic, Luxembourg, Finland, and Sweden record a slight increase in their indices, leading to a drop in some positions in their ranking. For the Nordic countries, this decline can be attributed to the ambitious nature of their goals.

To ensure that this modified version of the WTM represents a significant contribution to measure the SDGs, the index obtained with this methodology is compared with the classical method used to compute SDG index, that is the arithmetic mean (MA). Although we are aware that AM has some disadvantages, first of all the compensability (perfect substitutability) among indicators since it assumes that the poor performance of one indicator can be completely compensated by the high performance of another. This can lead to misleading conclusions where high values in some indicators mask weaknesses in others. However, here we apply the AM, following Sachs et al. (2016) and Lafortune et al. (2018). More in detail, Sachs et al. (2016) propose as aggregation method for SDG indicators the AM for aggregation. Instead, Lafortune et al. (2018) apply to SDG indicators both the MA and the geometric mean obtaining quite similar rankings and for this reason they suggest using the MA to facilitate interpretation.

Figure 2 - *Ranking variation: Wroclaw Index vs Arithmetic Mean Index.*



The results are shown in Figure 2, listing countries in descending order from the worst to the best position. It is worth to note that the two indices yield different results when examining the ranking of countries. For example, Sweden, Finland, and Austria, among others, exhibit better overall performance associated with a higher MA index, despite still being far from achieving SDG 13.

Relying solely on the MA index could lead to misleading results for policymakers due to its compensatory effect, potentially causing them to decide not to intervene in countries where the achievement of sustainability remains distant.

4. Conclusions

Achieving sustainability is the major global challenge of this century, requiring innovative measurement methods. The 2030 Agenda, adopted by all UN Member States in 2015, outlines 17 Sustainable Development Goals (SDGs) with 169 targets and 240 indicators, covering social, economic, and environmental aspects. SDG 13 (Climate Action) aims to combat climate change through adaptation, mitigation, and awareness measures. Despite progress in some areas, the 2022 UN Sustainable Development Report issued a "code red warning" for SDG 13, as global CO_2 emissions hit record levels, temperatures continue to rise, and natural disasters are projected to increase by 40% between 2015 and 2030.

The simplest method to evaluate the achievement in SDG targets is the arithmetic mean that has the main disadvantage of hide poor performance in one indicator thanks to high performance of another.

To overcome compensability issues, this study proposes a modified Wroclaw Taxonomic Method (WTM) to compute a non-compensatory composite indicator for 18 European countries (2020–2021). The WTM method measures each country's normalized distance from an "ideal unit", representing the best possible performance across all indicators. Unlike traditional methods, this approach considers country-specific targets as reference points, offering a more realistic assessment to evaluate the country achievement of climate goal

However, this study has several limitations. The main issue is data availability, as SDG 13 for EU countries reports several missing values or missing country-specific targets that have reduced the number of analysed units. A further critical point concerns distance calculation from targets. In this study, when a country exceeded its target, it was assigned the target value, setting its distance to zero. However, this approach penalizes countries performing better than the benchmark. Future research should account for how much a country surpasses the target to provide a more comprehensive assessment and fairer rankings.

Since achieving sustainability is a global challenge, developing reliable and effective measurement methodologies remains crucial for understanding and addressing this multidimensional phenomenon.

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