SDG COMPOSITE INDICATORS FOR MEDITERRANEAN COUNTRIES: A NEW THEORETICAL APPROACH

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1. Introduction

The definition and construction of composite indicators is an appealing research strand. The increasing interest is also proved by the increasing number of papers devoted to this topic according to "Google Scholar" since 2020 there are about 8,000 items (papers, articles, reports and so on) that contain the expression "composite indicators" that is about the same number of works published between 2001 and 2012 (8440).

One of the reasons for this rise lies in its ability of producing rankings used to compare countries' performances and monitoring progress.

In a very general way, composite indicators are defined as a function of indicators and weights, where weights usually reflect a sort of relative importance, in the simplest case, they are constructed by averaging normalized country values (Saisana, 2014).

Since September 2015, the "2030 Agenda for Sustainable Development" has become a referent point for scholars interesting in analysing and monitoring progress toward sustainable development. The Agenda includes 17 Sustainable Development Goals (SDGs) which must be reached before the end of 2030. Goals include poverty/well-being in a broad sense (Goal 1, Goal 2, Goal 3, Goal 6, Goal 8, Goal 10 and Goal 16), education (Goal 4), gender disparities (Goal 5), energy, climate change and innovation (Goal 7, Goal 9 and Goal 13), sustainability in city and consumption (Goal 11 and Goal 12), life below water and on land (Goal 14 and Goal 15) and partnerships (Goal 17).

Each Goals typically is defined by means of 8-12 targets, which, in tourn has between 1 and 4 indicators.

Annually, all countries' performances are tracked and reported by Sachs et al. (2016) on behalf of Bertelsmann Stiftung and the Sustainable Development Solutions Network (SDSN) (2021). The report analyses 193-member states of the United Nations. Beside the dashboard values, authors also derive a composite indicator by Goals as well as an overall indicator. More in detail, the arithmetic mean is used to aggregate indicators relating to each Goal in turn, before 'averaging' the results into a single metric.

After this first attempt of aggregation, literature account for additional tries. For instance, Lafortune et al. (2018) use the arithmetic mean (CES function), the minimum (Leontief production function) and the geometric mean (Cobb-Douglas production function) for aggregating SDGs. Guijarro (2018) proposes a parametric weighting scheme for the calculation of the SDG Index based on the multicriteria Goal Programming (GP) approach. Finally, Biggeri et al. (2019) introduce an adjusted SDG Index based on the Multidimensional Synthesis of Indicators (MSI) method with the twofold objective of overcoming the perfect substitutability problem of the arithmetic mean and of avoiding the tendency of geometric mean approach to collapse to zero.

Recently, there is an increasing interest in monitoring SDG for some World sub-area. For instance, Otekunrin et al. (2019) compute a composite index to describe the status of African countries on the attainment of Sustainable Development Goals (SDGs). Lynch and Sachs (2021) provide an up-to-date benchmarking of the progress of the United States and the 50 states towards the Sustainable Development Goals. Similarly, the Sustainable Development Solutions Network (SDSN, 2021) publish a report on the progress of the European Union (EU), its member states, and other European countries.

Thus, this paper aims at merging these new strands of the literature: in one hand the use of new aggregation techniques and, on the other hand, the increasing interest in monitoring SDG progress for a specific geographical area. We apply the new aggregation method proposed by Marini and Ciommi (2022) for constructing composite indicators. The method allows to penalize countries that display a larger variability by introducing a penalty factor that considers the horizontal heterogeneity among indicators. More recently, the method has been extended by Mariani et al. (2022) from the Arithmetic and Geometric mean to all possible members of the power mean. Accordingly, we focus on the so-called Penalized Geometric Mean (hereafter pGM) and we compare results with the classical geometric mean (hereafter GM) and also with the Arithmetic Mean (hereafter AM). Hence, these composite indicators are used to compare the performance of 17 Mediterranean countries, partitioned into 9 European Mediterranean countries (MCs), namely Croatia, Cyprus, France, Greece, Italy, Malta, Portugal, Slovenia and Spain and 8 non-European Mediterranean countries (nMCs), namely Algeria, Egypt, Israel, Jordan, Lebanon, Morocco, Tunisia, and Turkey.

The rest of the paper is organized as follow. Section 2 briefly reviews the notation introduced in Mariani and Ciommi (2022) and describes the data used in the proposed application. Section 3 illustrates the results and Section 4 concludes.

2. Methods and data

Let n be the number of units (countries, in our case) and k be the number of indicators. Thus, data can be represented by a rectangular matrix, X whose entries x_{ij}, $i=1,\dots,n$ and $j=1,\dots,k$ denote the value of indicator j for country i. Let I denotes the normalized matrix, that is the matrix of normalized values obtained according a given method that ensure data to be in a fixed interval.[1] Thus $\underline{I_i}$ is a generic row of matrix I representing the normalized profile of country i. Then, according to Mariani et al. (2022), the p-order generalized mean is:

$$M_p(\underline{I_i}) = \left(\frac{1}{k}\sum_{j=1}^{k} I_{ij}^{p}\right)^{1/p} \qquad p \in \mathbb{R} \text{ and } p \neq 0 \tag{1}$$

where the geometric mean is a special case of the power mean for $p \to 0$.

As stressed in Mariani and Ciommi (2022), the so-called penalized Geometric Mean (pGM), is the solution of an optimization problem:

$$\min_{a\in\mathbb{R}} F(a) \quad where\ F(a) = \frac{1}{k}\sum_{j=1}^{k}\big(h_0(I_{ij}) - h_0(a)\big)^2 \tag{2}$$

The function $h_0(\cdot)$ is the Box–Cox function of order zero (Box and Cox, 1964)[2] defined as:

$$h_0(x) = \ln(x) \qquad x \in \mathbb{R}_+ \tag{3}$$

Mariani and Ciommi (2022) demonstrate that, for each unit i, the solution of problem (2) is the classical geometric mean $\mu_{0,i} = (\prod_{j=1}^{k} I_{ij})^{1/k}$. This quantity can be written in terms of the Box-Cox function as follow:

$$\mu_{0,i} = h_0^{-1}\Big(\frac{1}{k}\sum_{j=1}^{k} h_0(I_{ij})\Big) \tag{4}$$

Moreover, the error made by approximating the normalized indicators I_{ij} with $\mu_{0,i}$ coincides with the (biased) sample variance of I_{ij}. We denote this quantity as S_i^2. Since the magnitude of those variances depend on the size of the mean, we divide

[1] Here, we are not interested in the kind of normalization procedure.

[2] The Box-Cox transformations is a parametric family of transformations, from x to $x^{(\lambda)}$ that can be used with non-negative responses.

the normalized indicators by the corresponding geometric mean: $\tilde{I}_{ij} = {I_{ij}}/{\mu_{0,i}}$ and consequently, S_i^2 can be re-written as:

$$\tilde{S}_{0,i}^2 = \frac{1}{k}\sum_{j=1}^{k}(\ln(\tilde{I}_{ij}))^2 \quad (5)$$

Thus, keeping this in mind, the penalized geometric mean for unit i (pGM) is defined as follow (Mariani and Ciommi, 2022):

$$pGM^{\pm} = \mu_{0,i} h_0^{-1}(\pm \tilde{S}_{0,i}^2) = \mu_{0,i} e^{\pm \tilde{S}_{0,i}^2} \quad (6)$$

where the sign $\pm$ represents the well-known polarity. As shown in equation (6), pGM is just the product between the geometric mean $\mu_{0,i}$ and a penalty factor $h_0^{-1}(\pm \tilde{S}_{0,i}^2)$ that allows us to discriminate between unit with the same geometric mean but different geometric mean reliability. That is, in the case of positive (negative) polarity, the penalty factor gives smaller (larger) value to the units for which the geometric mean is less reliable.

To illustrate the appealing of this penalized geometric mean, we focus on Sustainable Development Goals and, in particular, we use data from Sachs et al. (2021). Data refers to 2021. The report includes 91 global indicators as well as 30 additional indicators for OECD countries. It provides both original values and normalized data. Here, we use the second one in order to keep the five-step decision tree discussed in Sachs et al. (2021). Moreover, using already normalized data allows us to compare the results of our penalyzed geometric mean with the so-called SDG index, that is an index computed by aggregating indicators within and across SDGs. Both the SDG for each Goal and the overall SDG are computed by means of the arithmetic mean, giving equal weights to each indicator and Goal, respectively.

As stressed by Sachs et al. (2021), to obtain normalized, the original data are scaled though a sort of min-max method, where the minimum and the maximum for each indicator are fixed as specific targets. Thus, using our notation, I_{ij} represents the normalized data. We compute a further step consisting in rescaling the normalized data form range [0,100] to [0,1] where 0 denotes worst possible performance and 1 is the optimum. This re-scale procedure allows us to limit the range the composite indicator in the interval [0,1].

As reported by Sachs et al. (2021), the Report includes countries having data for at least 80 percent of the variables included. Since dataset still presents several missing values, we add two additional and more restrictive criterions, that are, for each Goal, 1) we remove variable with more than 50% of missing value, 2) then, we remove country with more than 50% of missing value. In this way, from the original

193 countries, we range between 125 (for Goal 14) to 165 (Goal 2, 3, 5-9, 12 and 13). Nevertheless, even if a two-stage procedure to trait missing data has been adopted, for some indicators and some Goals there still remain unobserved data. For this reason, following Lafortune et al. 2018, for each Goal[3] l, $l=1,\dots,17$, and for each country i, the aggregation takes into account the effective number of indicators j for which that country has data.

3. Results and Discussions: the case of Goal 2

Among the 17 SDG, we focus on Goal 2: “End hunger, achieve food security and improved nutrition and promote sustainable agriculture”, in-brief called “zero-hunger” Goal. Aim of Goal 2 is to ensure that everyone everywhere has enough good-quality food to lead a healthy life. UN has defined 8 Targets and 14 Indicators for SDG 2.[4]

We focus on Goal 2 since it is one of the Goal most effected by the global pandemic. For instance, moving from 2014 to 2019, the number of undernourished people has increased passing from 507 million to 650 million, and, in 2020, an additional 70-161 million people are likely to have experienced hunger as result of the pandemic.[5] Moreover, two billion people in the world do not have regular access to safe, nutritious and sufficient food. In 2019, 144 million children under the age of 5 were stunted, and 47 million were affected by wasting.[6]

Table 1 reports a description of the variables for Goal 2 as well as the lower bound and the upper bound used in the normalization step as collected by Sachs et al. (2021). Moreover, after applying the above-mentioned procedure to remove missing data, the Goal 2 collects data for 165 countries and the aggregation step is made by mean of 8 variables. In fact, among the 9 variables listed in Table 1, *yieldgap* has been removed from the analysis since it has only 27 observations and 28 countries have been dropped due to missing data. Moreover Table 1 reports both the number of the original missing values and the number of missing values after the selection procedure (in brackets).

Even if we are interested in Mediterranean countries, we compute the composite indicators for all countries, and we select the Mediterranean ones. For 17 Mediterranean countries we distinguish between European Mediterranean countries

[3] The procedure is general. Here Goals play the role of domains, according to the OECD (2008) notation.
[4] See https://sdg-tracker.org/zero-hunger for the complete list of Targets and Indicators for this Goal
[5] See https://sdgs.un.org/goals/goal2
[6] https://www.un.org/sustainabledevelopment/wp-content/uploads/2016/08/2_Why-It-Matters-2020.pdf

(MCs) and non-European Mediterranean countries (nMCs). Croatia, Cyprus, France, Greece, Italy, Malta, Portugal, Slovenia, and Spain belong to the first group, whereas for the second group we consider Algeria, Egypt, Israel, Jordan, Lebanon, Morocco, Tunisia, and Turkey.

Table 1 – *Analysed SDG Targets for Goal 2*

Code	SDG sub-indicator	Missing (After sel.)	Lower Bound (=0)	Upper Bound (Optimum, =100)	Justification for Optimum
undernsh	Prevalence of undernourishment (%)	47 (19)	42.3	0	SDG Target
stunting	Prevalence of stunting in children under 5 years of age (%)	30 (2)	50.2	0	SDG Target
wasting	Prevalence of wasting in children under 5 years of age (%)	30 (2)	16.3	0	SDG Target
obesity	Prevalence of obesity, BMI ≥ 30 (% of adult population)	30 (2)	35.1	2.8	Average of best performers
trophic	Human Trophic Level (best 2-3 worst)	34 (6)	2.47	2.04	Average of best performers
crlyld	Cereal yield (tonnes per hectare of harvested land)	30 (2)	0.2	7	Average of best performers
snmi	Sustainable Nitrogen Management Index (best 0-1.41 worst)	30 (2)	1.2	0	Technical Optimum
yieldgap	Yield gap closure (% of potential yield)	166 (Drop)	28	77	Average of best performers
Pestexp	Exports of hazardous pesticides (tonnes per million population	80 (52)	250	0	Technical Optimum

Our elaboration on Sachs et al. (2021).

For each country, we compute the Arithmetic Mean, the Geometric Mean and the Penalized Geometric Mean. Table 2 reports some basic statistics for the three methods for all countries (All) and for the selected Mediterranean ones (Medit).

Table 2 – *Basic statistics.*

	Arithmetic Mean		Geometric Mean		Penalized Geometric Mean	
	All	Medit	All	Medit	All	Medit
Min	0.2332	0.5510	0.2172	0.5178	0.1840	0.4523
Max	0.8246	0.7499	0.8106	0.7220	0.7830	0.6644
Range	0.5914	0.1989	0.5935	0.2042	0.5990	0.2121
Sd. dev	0.1069	0.0577	0.1077	0.0585	0.1112	0.0617
Coeff.var	0.1817	0.0907	0.1918	0.0969	0.2197	0.1150

Our elaboration.

Table 3 reports the comparisons between the standard SDG index computed according to Sachs et al. (2021) methodology, that is, by using the Arithmetic mean (AM), the classical Geometric mean (GM) and our methodology (pGM), both in terms of values and rank. Then, for GM and pGM, the magnitude of the decrease (or increase) with respect to the standard SDG Index (AM) is reported in percentage terms. Finally, the rank difference between pGM and AM is provided.

Table 3 – *Comparisons.*

	Values			Reduction		Rank			Rank diff
	AM	GM	pGM	GM on AM	pGM on AM	AM	GM	pGM	pGM vs AM
CYP	0.59	0.55	0.47	-6.93	-20,53	94	102	110	16
DZA	0.57	0.54	0.50	-3.78	-11,32	114	109	99	-15
EGY	0.64	0.61	0.56	-4.51	-13,69	49	56	60	11
ESP	0.64	0.61	0.54	-5.20	-15,64	56	61	74	18
FRA	0.74	0.70	0.61	-5.42	-17,10	10	11	23	13
GRC	0.66	0.63	0.58	-4.19	-12,57	39	38	45	6
HRV	0.75	0.72	0.66	-3.73	-11,41	6	7	6	0
ISR	0.62	0.58	0.51	-6.17	-18,31	69	81	96	27
ITA	0.71	0.68	0.62	-3.97	-12,24	19	19	18	-1
JOR	0.60	0.56	0.48	-6.42	-19,63	90	98	105	15
LBN	0.57	0.54	0.49	-4.76	-14,34	111	108	103	-8
MAR	0.62	0.60	0.56	-3.61	-10,79	65	62	58	-7
MLT	0.67	0.64	0.57	-4.89	-14,75	34	35	48	14
PRT	0.64	0.60	0.50	-7.13	-21,68	53	71	98	45
SVN	0.59	0.55	0.45	-7.61	-22,93	97	107	120	23
TUN	0.55	0.52	0.45	-6.04	-17,93	118	121	122	4
TUR	0.65	0.62	0.56	-4.47	-13,63	42	50	55	13

Our elaboration.

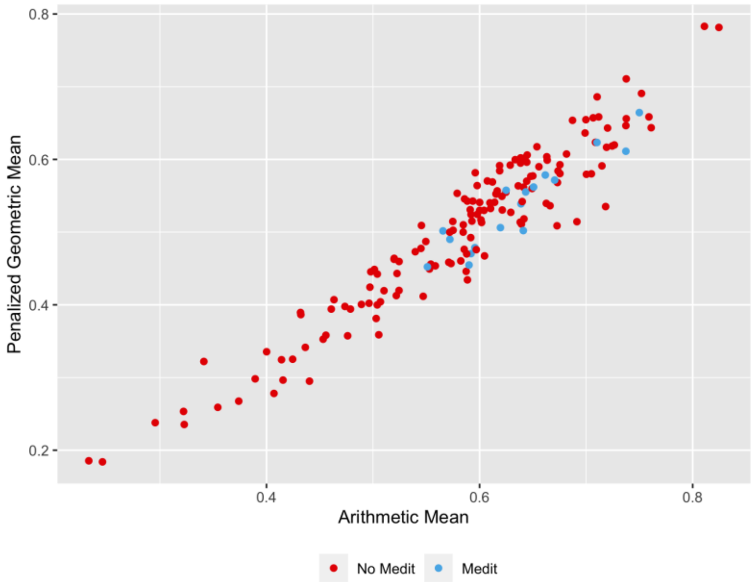
By analyzing the results for all Countries, the comparisons between Penalized Geometric Mean and Geometric Mean shows an absolute average ranking difference of 8.582 (position). The 95% of countries change their ranking position and the 82% of countries change at least 2 positions. Looking at Mediterranean Countries, Algeria (DZA) exhibits the largest improvement (from position 109 according to GM to position 99 with pGM), whereas Portugal (PRT) and Israel (ISR) register the largest worsening: Portugal moves from position 71 to position 98 and Israel loses 15 positions (from 81 to 96).

The comparisons between Penalized Geometric Mean and Arithmetic Mean reveals a higher absolute average ranking difference (about 12.90). The 98% of countries change their ranking position and the 88% of countries change at least 2 positions. Among Mediterranean Countries, Algeria improves of 15 positions (from 114 of the AM to 99 according the pGM) whereas Portugal and Israel are the most penalized in the position: 45 (from 53 according to the AM to 98 using pGM) and 27 (from 69 to 96), respectively.

What it is interesting is that countries with the largest improvement and worsening are the same.

Figure 1 reports the values of the penalized Geometric Mean (pGM) (vertical axis) versus the Arithmetic Mean (horizontal axis). Mediterranean countries are in blue, whereas the rest of the World is in red. The distribution of data exhibits a convexity meaning that the penalized Geometric Mean penalizes more countries with lower values.

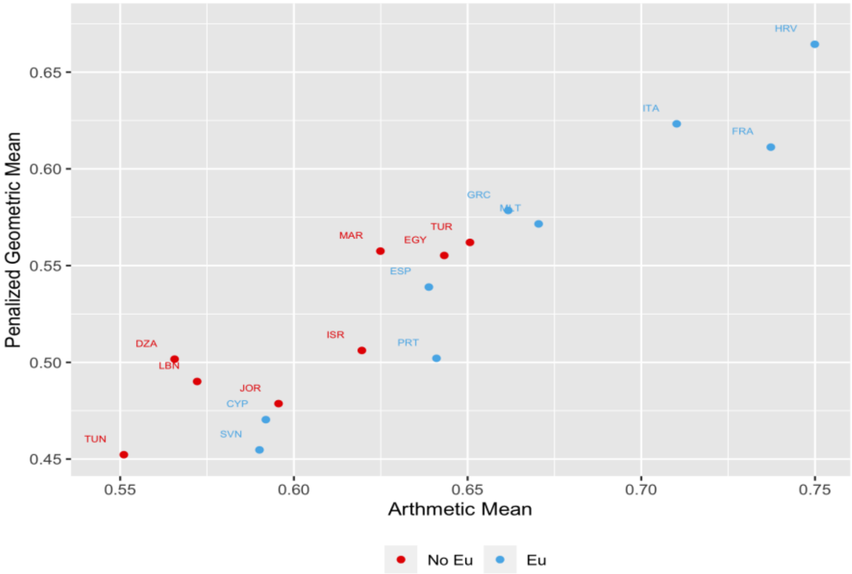
Figure 1 – *Penalized Geometric Mean vs Arithmetic Mean.*



Our elaboration.

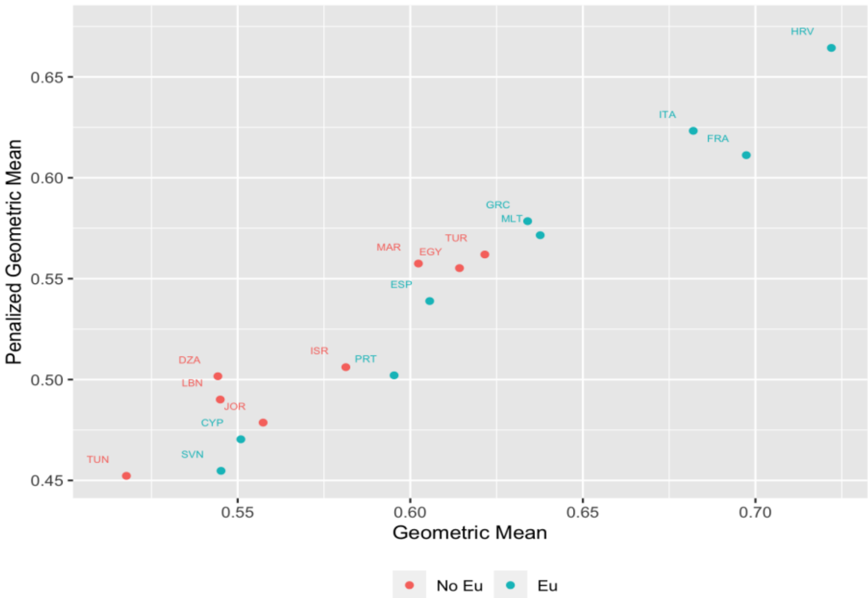
By combining results of Table 2 with Figure 1, what emerges is that the values of Mediterranean Countries are higher than the most of Worldwide countries. To better investigate those differences, we focus on Mediterranean Countries, and we compare the results of the penalized Geometric Mean (horizontal axes) with the Arithmetic mean (Figure 2) and the Geometric Mean (Figure 3).

Figure 2 – *Penalized Geometric Mean vs Arithmetic Mean for Mediterranean Countries.*



Our elaboration.

Figure 3 – *Penalized Geometric Mean for Mediterranean Countries vs Geometric Mean.*



Our elaboration.

Both figures show that non-European countries (red dots in Figure 2 and Figure 3) have, on average, worse performances respect to European Countries (blue dots), in fact they are distributed in the part of the graph on the left. Among European Countries, Cyprus (CYP) and Slovenia (SVN) display performance like the no-European ones whereas, among the no-European Countries, Turkey (TUR), Egypt (EGY) and Morocco (MAR) are ranked better than some European Countries such as Spain (ESP) or Portugal (PRT).

This can lead to some considerations concerning the Goal 2: in one hand, Cyprus and Slovenia are more similar to the no-European Countries than to European one, on the other hand, Turkey, Egypt and Morocco can be considered European Countries since their values are similar to those of Spain and Portugal. Moreover, unexpectedly, Croatia is the country with the highest performances, higher than France and Italy that are respectively ranked at the second and third position among Mediterranean Countries.

4. Conclusions and Further research

In this work we have analysed a particular member of the class of composite indicators obtained penalizing the p-order generalized mean with a factor that accounts for the (horizontal) variability of the sub- indicators introduced in Mariani et al. (2022), the so-called penalized Geometric Mean (pGM).

This index has several advantages: i) it allows for a discrimination among units with same generalized mean; ii) it accounts for the degree of (horizontal) variability experienced by each unit; iii) it is based on the minimum information loss principle, usually used for constructing composite indicators; iv) it manages way the interaction between sub-indicators in a more flexible.

This is a first attempt and further research will be conducted. For instance, we want to extend the analysis conducted for Goal 2 to all 17 Goals and, consequently, computing the analogous of the overall SDG Index aggregating the 17 SDG indices through the pGM methods (second stage aggregation).

Moreover, we believe that in some context could be of potential interest to add weighs reflecting a sort of relative importance of the sub-indicators. For this reason, it is necessary to develop a weighted version of the penalized Geometric Mean.

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SUMMARY

SDG composite indicators for Mediterranean countries: a new theoretical approach

Composite indicators provide summary picture of multidimensional phenomena, and the corresponding rankings facilitate evaluations and comparisons over time and space.

Standard composite indicators often assume compensability among indicators. We argue that the compensability hypothesis needs to be restricted especially when analyzing economic, social and environmental aspects.

Among all the member of the new family of composite indicators made by penalized versions of the generalized means introduced by Mariani et al (2022), we focus on the penalized Geometric Mean (pGM). This index is defined by means of a penalty factor that accounts for the (horizontal) variability of the normalized indicators opportunely scaled and transformed via the Box-Cox function.

To illustrate the appealing of our proposal, we compute penalized Geometric Mean and we compare it with the Arithmetic Mean and the Geometric Mean. We focus on data referring to the Sustainable Development Goals (SDGs) (Sachs et al., 2021). More in datail, among the 17 Goals, analyse Goal 2: "End hunger, achieve food security and improved nutrition and promote sustainable agriculture", the so-called "Zero Hunger" and we compute the three indices for world-wide Countries with a focus on 17 Mediterranean Countries.

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