Well-Being in Italy: A Comprehensive Statistical Analysis Beyond GDP

Najada Firza(✉) and Dante Mazzitelli

Department of Economics and Finance, University of Bari "Aldo Moro", Largo Abbazia Santa Scolastica, Bari, Italy
najada.firza@uniba.it

Abstract. The aim of this work is to analyze the variables responsible for long stays in patients with cardiovascular diseases to monitor the health of patients and better manage the financial resources of health facilities in relation to this problem. The United Nations 2030 Agenda for Sustainable Development indicators were developed to address the global economic, social and environmental crisis. These measures of sustainability aim to go beyond the traditional reliance on Gross Domestic Product as the only measure of prosperity. The Italian National Institute of Statistics collects indicators of societal well-being first using the Equitable and Sustainable Well-Being indicators and later adapting the system developed by the United Nations known as the Sustainable Development Goals. While the Equitable and Sustainable Well-Being System is specific to the Italian territory, the Sustainable Development Goals System is suitable for measuring and comparing sustainability at international level. We considered Environment, Economic well-being and Society of the Equitable and Sustainable Well-Being domains according to a three-way holistic framework. In this contest we put all Sustainable Development Goals indicators on this specific Equitable and Sustainable Well-Being domains to analyze Italy at regional level. Specifically, we used two independent methodologies: Fuzzy c-medoids clustering algorithm and Principal Component Analysis to investigate and to ranking each Italian Region in selected Equitable and Sustainable Well-Being domains. Our research provides a comprehensive overview of Italy's status in these Equitable and Sustainable Well-Being dimensions and provides valuable insights for local and national stakeholders, researchers and policy makers to identify regional challenges and formulate targeted intervention measures. The regional ranking resulting from our analyses for the Equitable and Sustainable Well-Being/Sustainable Development Goals areas is a valuable tool for measuring and monitoring progress towards these goals, facilitating ongoing monitoring and evaluation of progress, highlighting areas for improvement and guiding targeted interventions.

Keywords: SDGs · BES · Composite Indicators · PCA · Factor analysis · KPI

1 Introduction

Gross Domestic Product (GDP) is a useful measure for tracking a country's economic growth and comparing it with other countries over time. However, GDP presents some limitations that need to be emphasized (Bleys 2012). One key limitation is that GDP

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fails to consider critical factors such as environmental, social, human, and health aspects, which are integral components of economic activities (Costanza et al. 2009). Furthermore, several studies have demonstrated that relying solely on GDP as a measure of well-being has its drawbacks. For example, Talberth et al., argue that there is a threshold point beyond which increasing GDP (Talberth, Cobb et al. 2007) no longer results in higher levels of well-being. In fact, there are some factors not accounted by GDP (Max-Neef 1995) such as depletion of natural resources, growing income inequality and lack of quality leisure time.

There is a need to adopt alternative metrics to assess the overall well-being of society that extends beyond GDP.

Therefore, evaluating well-being has gained worldwide meaning, prompting the establishment of a global movement to proceed beyond GDP (Giovannini et al. 2018).

Moreover, going beyond GDP also means dealing sustainably with all areas of human development (Neumayer 2012).

To overcome the limitations of GDP, United Nations (UN) created the Sustainable Development Goals (SDGs) system. The 2030 Agenda of UN, consisting of the 17 SDGs, was developed to address global crises in the economic, social and environmental sectors. These goals comprise 169 specific targets aimed at ensuring a better future for current and new generations. The program underlines the need to address sustainability issues by going beyond the current model. Challenges such as inequality, climate change, and job automation are interconnected and require a committed global effort from the 192 signatory countries of the 2030 Agenda. The overarching aim of the SDGs is to track and promote progress toward achieving these goals. In Italy, the National Institute of Statistics (ISTAT) collects and publishes data on the Sustainable Development Goals (SDGs) every six months, as requested by the UN Statistical Commission (ASVIS Report 2022).

Prior to this activity, however, building on the observations of the CMEPSP[1] (Stiglitz et al. 2009), the EU Commission (2009) and OECD (Hall et al. 2010) developed guidelines to move beyond the GDP development model. ISTAT in Italy created a system of indicators for equitable and sustainable well-being (BES, that is 'Benessere Equo & Sostenibile') at the regional or provincial level. This system was inspired also by numerous studies on quality-of-life indicators (e.g. Maggino & Zumbo 2012) and integrates economic indicators with additional factors that highlight the multidimensional nature of well-being (Morrone 2013).

Since 2015, ISTAT has provided a composite index for each domain, producing an annual report on the well-being situation in Italy. This report aids the government's economic planning for public policies of well-being and sustainability.

The BES system is divided into 12 domains, which are further grouped into 130 indicators (D'Urso et al. 2022). It measures the well-being of a territory by integrating and complementing the GDP, providing an overview of the territory's health. (Alaimo 2018). As a result of those developments, the meaning of the SDGs and BES are closely linked to

[1] The *Commission on the Measurement of Economic Performance and Social Progress*, commonly known as the Stiglitz-Sen-Fitoussi Commission, was established by the French Government in 2008 to investigate alternative methods of measuring a nation's wealth and social progress beyond the limits of the one-dimensional GDP.

providing a reliable foundation for measuring sustainable development and well-being. The two sets of indicators are complementary, although only partially overlapping. It is worth noting that several BES indicators are directly included in the SDGs framework. The reason for choosing the BES system over the SDGs system is that the former is tailored to the specific situation of the Italian territory, while the latter, being an internationally approved system, omits many important local indicators. We believe that the SDGs system is flexible enough to allow the use of certain subsets that are just as useful as the pre-existing BES, and possibly other indicator systems that have not been considered here.

This work examines the relationship between BES and SDGs by analyzing the indicators shared by both domains at the regional level in Italy. The data used in this study was provided by ISTAT from 2004 to 2021. Specifically, we outlined at a regional scale the existence of general spatial patterns for different well-being factors. We divided the considered indicators into 4 macro-categories: economy, social, health and environment. By means of the fuzzy cluster c-medoids algorithm (FCMdd), we carried out a spatial analysis to group Italian regions in different clustering according to their common features for each considered macro-area. Then, through PCA and Factor Analysis, we built an index to rank the regions for each macro-category.

Finally, after the calculation of the composite indicator, we implemented a regional comparison. The article is organized as follows. In section "Materials and methods" we presented the dataset and the statistical techniques used in our research. In section "Results" we reported the main findings of our analysis. Finally, in section "Discussion" we argued our results.

2 Connection Between Well-Being and SDGs for a New Prospective of Development

The UN Agenda 2030 highlights the importance of a new development model compatible with the planet's resources that leverages an inclusive economic system in which levels of inequality are flattened. The availability of data beyond GDP measuring well-being and its sustainability is crucial for the development of new paradigms focused on well-being (Costanza et al. 2014). It is essential to improve the methodological harmonization of BES and SDGs data to create a more effective well-being assessment system at global level (Costanza et al. 2016).

According to Maggino (2017), a harmonization between the two systems is necessary because they have different purposes: BES serves as a system that portrays the well-being situation in various aspects within Italy and its regions, on the other hand, the SDG indicators have been specifically designed to set goals and targets, addressing a different purpose.

Furthermore, the harmonization of the two indicator systems will make data on sustainable development and well-being more accessible, underlining the importance of the information they provide. Consequently, this purpose will facilitate their use in policy planning as decision support for medium and long-term strategies promoting collective well-being.

It is important to note that while the SDGs act as simplified indicators applicable to all countries, the BES indicators follow an Italian approach and provide a wider range of measures for specific phenomena.

The matching between BES and SDGs, is also important to ensure uniform Italian policies at European level. This approach will allow for the creation of a global system that evaluates Italian well-being by considering different aspects and integrations.

3 Materials and Methods

In this publication we consider 4 of the 12 BES domains according to a conception of Gibson et al. (Gibson et al. 2005), which considers well-being as the intersection of the domains: Economy, Environment and Society. Our work considered the "Society" aspect, the *Health* domain which is one of the fundamental services in an advanced society and the *Quality of services* domain which is the emblem of services (Chalmin-Pui et al. 2021). To investigate how the two systems interact for the 4 BES domains, all the SDGs indicators that belong to these 4 domains were considered.

Specifically, the 25 indicators belonging to 8 SDGs (see Table 1) investigated the sustainable development of the Italian territory at a regional level, in a time window of 18 years (2004–2021). We carried out a spatial analysis considering the average of the BES indicators on the reference time interval because not all the considered variables have values on the reference time window analyzed. Our analysis includes 2 parts, one more qualitative and one more quantitative. Firstly, we applied the FCMdd algorithm to group the Italian regions with similar characteristics. In the second step, we built Key Performance Indicators (KPI), synthetic indicators based on PCA, factor analysis to assign a score to each region and rank them with respect to the 4 analyzed BES domain. The workflow of the implemented analysis is shown in Fig. 1.

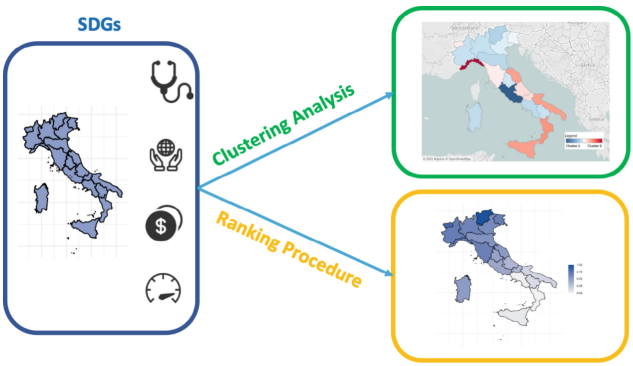


Fig. 1. The flowchart of the proposed methodology. We grouped all the SDGs of Italian Regions in 4 macro-areas: health, environment, economic well-being and quality of services. For each area we applied a clustering analysis based on the FCMdd algorithm and a ranking procedure exploiting factorial analysis, PCA (Key Performance Indicators).

3.1 Data Collection

The dataset for the SDGs at the regional level (2022 edition) used here was collected from the ISTAT public data warehouse (https://www.istat.it/en/well-being-and-sustainability/sustainable-development-goals/istat-indicators-for-sustainable-development). For additional information on the SDGs database, please refer to table S1 in the supplementary information section. The statistical measures of the SDGs exhibit synergies and interrelations with the BES indicators system. Specifically, 64 statistical measures from SDGs overlap with the BES system. We analyzed all SDGs indicators for 4 BES domains (SDGs ISTAT Report 2022). As Table 1 shows, the total number of SDGs indicators is 25 (there are 30 indicators in total but 5 of them do not have a time series and are not considered for the data analysis).

3.2 Exploratory Methods and Fuzzy c-Medoids

In the machine learning and data mining fields, data scaling and data normalization refer to the same preprocessing technique. Their purpose is to convert or transform the data into ranges and formats suitable for modeling and analysis. Models trained on scaled data typically exhibit much better performance than those trained on unscaled data, making data scaling a crucial step in data preprocessing. This process is especially important for methods that rely on distance measures, such as nearest neighbor classification and clustering (Cao, 2016). In methodology, two data scaling algorithms are extensively used: Z-score algorithm and Min-max algorithm. In this publication we used Min-max algorithm 0–1, instead of Z-score, because in the preliminary analyses our data (heterogeneous variables) revealed different discriminant power due to their different variance:

$$x' = \frac{x - \min(x)}{\max(x) - \min(x)}$$

Firstly, we used k-means with Euclidean distance as an exploratory analysis. As a confirmatory analysis to obtain more robust results we used fuzzy c-means (FCM) (Bezdek 1974, 1981). Fuzzy c-means is a generalization of the classical k-means method. Given an (n x p) matrix, X, where n and p are the number of units and variables, respectively, the aim is to partition the units into k groups, where each group is characterized by a prototype (centroid). Each row vector $x_i = [x_{i1}, x_{i2}, \ldots, x_{ip}]$ represents the *i-th* observation. The optimization problem of the FkM can be formalized by minimizing an objective function J as follows:

$$\underset{U,H}{min} J_{FkM} = \sum_{1=1}^{n} \sum_{g=1}^{k} u_{ig}^{m} \|x_i - h_g\|^2$$

where the (n x k) matrix U denotes the membership degree matrix, where each element $u_{ig} \in [0, 1]$ represents the membership degree of unit i to cluster g. The row-wise sum of U is equal to 1. The (k x p) matrix H denotes the prototype (centroid) matrix, where each row $h_g = \left[h_{g1}, h_{g2}, \ldots, h_{gp}\right]$ (g = 1,…, k) is prototype of cluster g. Finally, parameter m > 1 is used to tune the fuzziness of the obtained partition. The greater the

Table 1. The total number of SDGs indicators is 25 for 4 BES domains.

	Goal	Global indicator	Measured by	Years
HEALTH	3	3.4.1 - Mortality rate attributed to cardiovascular disease, cancer, diabetes or chronic respiratory disease	Healthy life expectancy at birth	2009-2021
	3	3.4.1 - Mortality rate attributed to cardiovascular disease, cancer, diabetes or chronic respiratory disease	Excess weight (standardized rates)	2005-2021
	3	3.a.1 - Age-standardized prevalence of current tobacco use among persons aged 15 years and older	Smoking (standardized rates)	2005-2021
	3	3.5.2 - Alcohol per capita consumption (aged 15 years and older) within a calendar year in litres of pure alcohol	Alcohol (standardized rates)	2007-2021
ENVIRONMENT	1	1.4.1 Proportion of population living in households with access to basic services	Submission of municipal waste to landfill	2004-2021
	11	11.6.2 Annual mean levels of fine particulate matter (e.g., PM2.5 and PM10) in cities (population weighted)	Air quality - PM2.5	2004-2021
	13	13.3.1 Extent to which (i) global citizenship education and (ii) education for sustainable development are mainstreamed in (a) national education policies; (b) curricula; (c) teacher education; and (d) student assessment	Concern about climate change	2004-2021
	6	6.3.1 Proportion of domestic and industrial wastewater flows safely treated	Wastewater treatment	2004-2021
	15	15.1.2 Proportion of important sites for terrestrial and freshwater biodiversity that are covered by protected areas, by ecosystem type	Protected areas	2004-2021
	7	7.2.1 Renewable energy share in the total final energy consumption	Electricity from renewable sources	2004-2021
	15	15.3.1 Proportion of land that is degraded over total land area	Soil sealing from artificial cover	2004-2021
ECONOMIC WELLBEING				
	10	10.1.1 - Growth rates of household expenditure or income per capita among the bottom 40 per cent of the population and the total population	Gross disposable income per capita	2004-2020
	10	10.1.1 - Growth rates of household expenditure or income per capita among the bottom 40 per cent of the population and the total population	Net income inequality (s80/s20)	2004-2020
	1	1.2.2 - Proportion of men, women and children of all ages living in poverty in all its dimensions according to national definitions	Risk of poverty	2004-2021
	1	1.2.2 - Proportion of men, women and children of all ages living in poverty in all its dimensions according to national definitions	Severe material deprivation	2004-2021
	1	1.2.2 - Proportion of men, women and children of all ages living in poverty in all its dimensions according to national definitions	Low labor intensity	2004-2021
	1	1.4.1 - Proportion of population living in households with access to basic services	Housing cost overcharge	2004-2021
QUALITY OF SERVICES	Goal	Global indicator	Measured by	Years
	3	3.8.1 - Coverage of essential health services	Beds in residential social-welfare and social-health facilities	2009-2019
	16	16.6.2 - Proportion of population satisfied with their last experience of public services	Difficulties in accessing some services	2006-2020
	1	1.4.1 - Proportion of population living in households with access to basic services	Irregularities in water distribution	2006-2021
	11	11.2.1 - Proportion of population that has convenient access to public transport, by sex, age and persons with disabilities	Seat-km offered by the Tpl	2004-2020
	11	11.2.1 - Proportion of population that has convenient access to public transport, by sex, age and persons with disabilities	Frequent users of public transportation	2005-2021
	1	1.3.1 - Proportion of population covered by social protection floors/systems, by sex, distinguishing children, unemployed persons, older persons, persons with disabilities, pregnant women, newborns, work-injury victims and the poor and the vulnerable	Waiver of health care benefits	2017-2021
	3	3.c.1 - Health worker density and distribution	Doctors	2012-2021
	3	3.c.1 - Health worker density and distribution	Nurses and midwives	2013-2020

value of m, the forther away from 1 and 0 the membership degrees are (Ferraro, 2021). For m $\rightarrow$ 1 FkM reduces to the k-means (kM) algorithm. Empirical results depend on the selection of this parameter, which is commonly chosen between 1.5 and 2 in practice (Pal and Bezdek, 1995). Among the various proposals for robust fuzzy clustering methods, we use the Fuzzy c-medoids (FCMdd). Its method consists in replacing the centroids with the medoids. The FCMdd, known as a partition clustering algorithm like the k-means algorithm is used for grouping the Italian regions. This algorithm partitions simultaneously object by considering multiple dissimilarity matrices. Its design aims to provide a fuzzy grouping and profile for each fuzzy cluster, as well as to learn the specific relevance weights for each dissimilarity matrix to optimize an objective function. Each element x_i, belonging to a cluster j, is assigned a random membership weight u_{ij}. Through an iterative process, the algorithm dynamically moves the cluster medoids z_j to minimize an objective function, which is defined as the sum of distances between each point and each cluster center:

$$\min_{U,H} J_{FCMdd} = \sum_{i=1}^{M}\sum_{j=1}^{N} u_{ij}^{m}\|x_i - z_j\|^2$$

where the medoid of cluster j is represented by z_j, and M denotes the total number of instances in the dataset. N represents the desired number of clusters specified by the researcher. To calculate the distances between the cluster centers and each observation in the sample, we used the Euclidean distance metric. The FCMdd procedure was employed to assign membership to each Italian region within a specific cluster. Finally, we computed the silhouette coefficient to choose the optimal number of clusters within the dataset. This coefficient evaluates the quality of clustering by measuring the proximity of each point in a cluster to the points in neighboring clusters.

3.3 The Key Performance Indicators

For each analyzed macro-area, we built a synthetic indicator to rank the Italian regions. These indicators, called Key Performance Indicators (KPI), are based on both Principal Component Analysis (PCA) and Factor Analysis (FA). FA is a statistical method that identifies the underlying dimensions of a dataset. In its exploratory approach, PCA is commonly used (but not exclusively) to extract these dimensions. PCA is a multivariate analysis technique that can examine, summarize, and simplify a set of observed characteristics (see, e.g., Delvecchio 2010; Mulaik 2010). This simplification involves reducing the complexity of the data by using linear combinations. In our work we implemented the procedure named "backward elimination." This method involves selecting components with eigenvalues above a certain threshold and removing items with low communality. Communality represents the proportion of variance explained by the extracted solution. We set a threshold of 0.5 on the communality value. The elimination process begins with the items having the lowest values and proceeds until all variables present a communality value greater than the selected threshold. Under these conditions, for the 4 BES domain we chose a few components explaining over 70% of the total variance. We summarized our setups in Table 2.

Table 2. The number of principal components selected and corresponding percentage of cumulate variance.

Macro-area	Number of selected components	Cumulate % of variance
Health	1	77
Environment	3	78
Economics wellbeing	2	97
Quality of services	2	80

In general, the Key Performance Indicators (KPI) encompass a collection of metrics that gauge the efficiency, level, and quality of services. These indicators play a crucial role in determining the overall value of a service and aim to identify a comprehensive set of information that can effectively evaluate the performance and competitiveness of a particular service or process. The KPI is defined as:

$$KPI = \frac{\sum_{i=1}^{N} c_i v_i}{\sum_{i=1}^{n} c_i}$$

where c_i are the communality values of each original variable v_i multiplied by the sign of its main factorial weight. Furthermore, we normalized KPI values between 0 and 1.

4 Results and Discussion

In this work we developed an analysis framework to study all 25 indicators belonging at 8 SDGs Goals and 4 BES domain (see table 1 for further details), at the Italian regional level for a time window of 18 years. We initially carried out a clustering analysis using the FCMdd which outlined, for the macro-areas Health, Environment and Economic Well-being, the existence of two distinct clusters (see the upper panel of Fig. 2). Notably, the Economic Well-being BES domain, our findings confirmed the existence of two blocks of regions: Northern and Southern ones. Italy is a country that has historically highlighted a multitude of territorial differences that find their origin in the so-called NORTH-SOUTH gap (Alaimo & Maggino 2020). We are obviously talking about social and economic inequalities which were further marked by the crisis resulting from the pandemic situation. Mapping the territory is the first step in monitoring it and can support and guide policies by giving them a factual basis, starting with the National Recovery and Resilience Plan (PNRR)[2]. Our analyses also confirmed the results of the ISTAT SDGs 2022 Report: the radar chart referring to Economic Wellbeing in Fig. 3 shows very different trends for the two clusters, underlining the deep economic gap between

[2] For more information: https://www.italiadomani.gov.it/content/sogei-ng/it/en/home.html.

Northern and Southern Italy. Among the 5 indicators examined within the Economic Well-being of BES domain, "*the risk of poverty*" emerges as the indicator that most prominently underscores the regional disparity between the North and South in our analyses. As highlighted in the methods section, our analysis proceeded through the construction of an index with the use of PCA to assign each region a ranking for 4 BES domains. This ranking confirms the findings obtained with FCMdd highlighting a North-South gradient for the Economic Wellbeing area. Our results are exactly in line with ISTAT SDGs 2022 Report: in the Autonomous Province of Bolzano, 10% of the resident population faced the risk of poverty or social exclusion, while in Campania, this indicator reached half of the population (50.2%). Similarly high percentages, exceeding 40%, were observed in other southern regions such as Calabria and Sicily. In contrast, some northern regions (Trentino Alto Adige, Valle d'Aosta, Emilia-Romagna, and Marche) displayed percentages below 15% (ISTAT SDGs 2022 Report). We can state that regional gaps have diminished in the last two years. Nevertheless, there is no evident trend of convergence in the last decade (ISTAT SDGs 2022 Report).

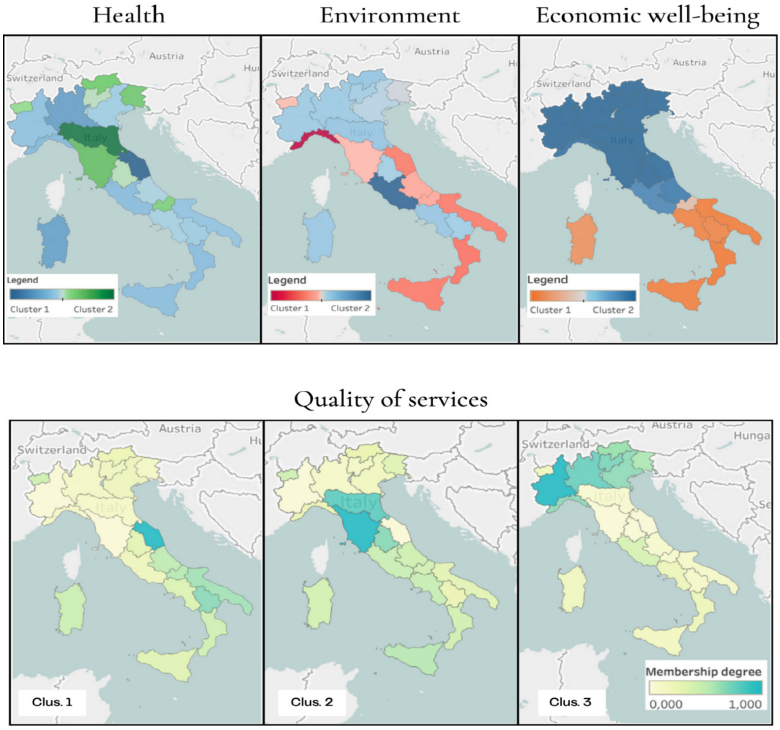


Fig. 2. (The upper panel) The clustering analysis using the FCMdd algorithm which confirmed, for the macro-areas Health and Economic Well-being, the existence of two distinct blocks: Northern regions and Southern ones. (The lower panel) The cluster analysis performed for the macro-area Quality of services suggested the existence of three clusters.

For the other two BES domains (Health and Environment) the FCMdd didn't find a clear geographic pattern.

First, we can say that the trend of the data for each region was strongly influenced by the pandemic, because the values in 2020 and 2021 never returned to the previous ones. This is one of the reasons why the analyses and the division of the regions into groups, especially in the other three BES areas considered, do not always follow a clearly defined criterion. FCMdd segmented the Health domain into two clusters, using the four common BES/SDGs variables.

Notably, two of these variables (*excess weight* and *smoking*) show similar values in both clusters. A paradox arises for the other two features of this domain: regions with *the highest life expectancy at birth* also demonstrate the highest recorded *alcohol consumption.* From a methodological perspective, it is noteworthy that the two independent analyses (FCMdd and KPI) do not align. As is known in the literature (Dubes, 1993), the results obtained with the cluster method are very sensitive to the number of variables used. Therefore, in our analysis the use of only 4 variables leads to a clustering not very robust (silhouette value < 0.5) as reported in Table 3. Additionally, the subjective nature of cluster selection is evident, given the close silhouette values for $k = 2$ and $k = 3$.

Table 3. Cluster validation: Average silhouette coefficients for different values of k.

Dimensions of well-being	$k = 2$	$k = 3$	$k = 4$
Health	0,43	0,40	0,28
Environmental	0,34	0,31	0,29
Economic	0,75	0,65	0,62
Quality of Services	0,57	0,58	0,50

Conversely, the KPI analysis, which categorizes regional rankings in the Health domain, yields more understandable results. Regarding the "life expectancy" variable, it's essential to acknowledge that the analyses were influenced by data regarding the Covid period (Eurostat, March 2023[3]).

Life expectancy at birth in 2021 did not return to 2019 levels, although in the North the indicator recovered 0.8 years in 2020, reaching 82.9 years. Instead in the South in 2021 the loss of life expectancy at birth appeared more pronounced than in 2020 (0.5 years less on 2020), reaching 81.3 years (ISTAT SDGs Report 2022).

Our ranking data shows a good agreement with the study of Eurostat about the life expectancies in Italy. The autonomous provinces of Trento and Bolzano are among the European areas with the highest life expectancies at birth (Eurostat, November 2023[4]). Conversely, Sicily and Campania have lower life expectancies, with averages of 83.3 years for women and 79.2 and 78.7 years for men, respectively. Nevertheless,

[3] https://ec.europa.eu/eurostat/en/web/products-eurostat-news/w/ddn-20230316-1.

[4] https://ec.europa.eu/eurostat/en/web/products-eurostat-news/w/ddn-20231106-1.

all Italian regions overcame the EU average, which stands at 82.9 years for women and 77.2 for men (Eurostat, November 2023[5]).

Both the clustering analysis and the KPI highlight a critical environmental situation in Italy. However, the results of the two independents analyze do not agree very much. The clustering results report a lack of statistical significance, given the low silhouette values (shown in Table 3), probably because the environmental variables used are uninformative and contradictory. In future analysis we will add other variables to improve the robustness of our results.

To add further considerations about the Environmental well-being indicator we can show the panel B of Fig. 3. It is evident that 5 northern regions (Piedmont, Lombardy, Veneto, Emilia Romagna and Friuli) present more critical situation related to environmental issues. These regions, show a worst air quality linked to the presence of high concentrations of particulate matter (in particular PM 2.5) with an average value of "Annual means level of particulate matters in cities" equal to 95.3 much higher than the average Italian value of 84.8.

Furthermore, these regions present a more critical hydrogeological situation. Instead, the 4 regions with the least environmental problems are equally distributed between the North (Valle d'Aosta and Trentino) and the South (Molise and Basilicata). These regions have a greater concentration of mountains and a higher average altitude (1164 m) than the national average value (293 m) [https://it-ch.topographic-map.com/map-lk69m/Italia/], moreover they are among the region with lower degree of urbanization [https://www.istat.it/it/archivio/137001].

Instead, the cluster analysis performed on the BES domain "Quality of services" suggested the existence of three clusters as shown in the lower panel of Fig. 2. Lighter shades of color in Fig. 2, indicate a higher fuzzy degree.

Compared to the other two groups, the first group has low scores for two variables related to public transport (seat/km, public transport users), higher scores for irregularity of water supply and Waiver's health services, while the difficulty of access to services is on par with the second group. The second group is characterized by the highest number of doctors in the region, the lowest number of nurses and the lowest number of beds compared to the other groups. The third group is characterized by the highest number of beds and nurses and the lowest number of doctors. In addition, it also has the lowest number of people abandoning healthcare, the lowest number of irregularities in water distribution and the lowest number of difficulties in accessing services.

All outcomes can be compared with the KPI results of the ranking created and with the ISTAT 2022 SDGs Report: The persistence of the pandemic has led to a homogenization of areas in terms of the extent to which health services are foregone, with a more significant increase in the northwest, northeast and center.

According to the ISTAT SDGs Report in 2021, 9.4% of families report that the water supply in their homes is irregular (8.9% in 2020). Irregularities affect all regions in a heterogeneous way, with higher intensity in the South, where they are perceived by 1.5 million families (63.9% of the total), and especially in Sicily (29.0%) and Calabria (28.8%). In the north-west and north-east, the figures are low (3.1% and 3.5% respectively), while in the center less than one in ten families report irregularities in service.

[5] https://ec.europa.eu/eurostat/en/web/products-eurostat-news/w/ddn-20231106-1.

In this regard, Italy is characterized by an accentuated fragmentation of management, especially in those areas of the country where integrated water supply has not been fully implemented (in particular Calabria, Molise, the autonomous provinces of Trento and Bolzano, Sicily and Valle d'Aosta), which may slow down the achievement of a wide coverage of the territory by water security plans (SDGs ISTAT Report 2022).

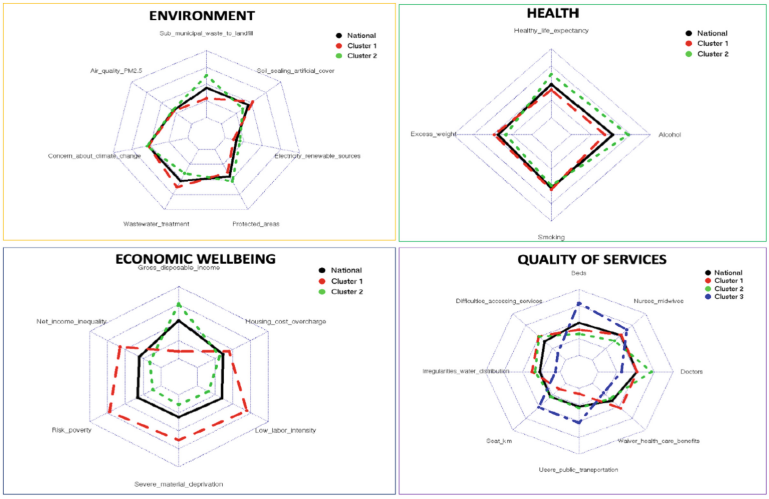


Fig. 3. Radar plot for each cluster of the four macro-categories analyzed. The black line indicates the national average.

Figure 3 displays radar charts for the 4 BES domains considered in which average values of the features of each cluster are compared with the national average value. The graph relating to the environment highlights how the trends of the variables of the two clusters are compatible except for 2 features: "Submission of municipal waste to landfill" where in cluster 2 there is a higher percentage of waste sent to landfill compared to cluster 1; "Wastewater treatment" where in cluster 1 there is on average a greater quantity of treated wastewater.

From the radar chart relating to the Health category, we can see that group 2 has an excess weight which is on average lower than the national average associated with a higher life expectancy despite a slightly higher alcohol consumption. The radar chart referring to Economic Wellbeing shows two very different trends for the two clusters, underlining the profound economic differences between Northern and Southern Italy. However, in the Quality of Services area we notice very different situations for the 3 clusters, for group 3 indicated by the dotted blue line where it is possible to notice the low presence of doctors in contrast with the wider availability of hospital beds.

As displayed the result of the index we calculate in Table 4, in the 4 considered macro-areas, the most virtuous regions in the Ranking of the Italian Regions are Valle d'Aosta and Trentino Alto Adige, while those with the greatest deficits in terms of Economy, Health and Quality of Services are Sicily, Calabria and Campania.

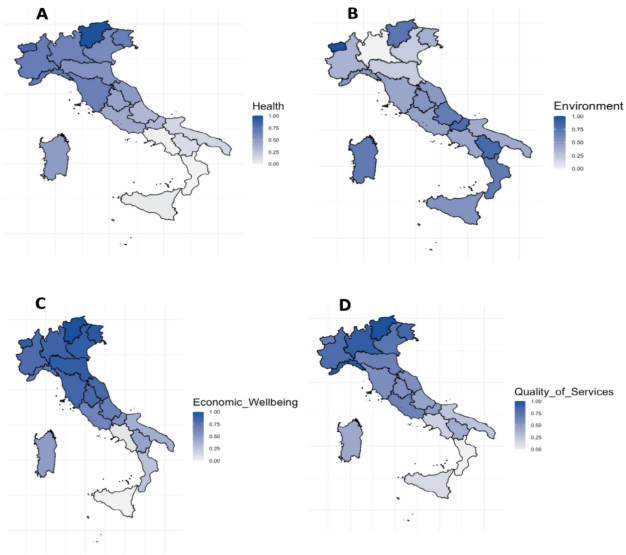


Fig. 4. Geographical distribution of KPI for the 4 considered BES domain.

Table 4. Ranking of the Italian Region in the 4 considered macro-areas.

Position	Health	Environment	Economic wellbeing	Quality of Services
1	Trentino A. A.	Aosta Valley	Trentino A. A.	Trentino A. A.
2	Aosta Valley	Basilicata	Friuli V. G.	Liguria
3	Liguria	Molise	Aosta Valley	Lombardy
4	Piedmont	Trentino A. A.	Emilia Rom	Friuli V. G.
5	Friuli V. G.	Calabria	Veneto	Piedmont
6	Tuscany	Sardinia	Lombardy	Veneto
7	Lombardy	Abruzzo	Tuscany	Aosta Valley
8	Veneto	Sicily	Marche	Emilia Rom
9	Emilia Rom	Umbria	Umbria	Lazio
10	Marche	Liguria	Piedmont	Tuscany
11	Sardinia	Marche	Liguria	Marche
12	Umbria	Lazio	Abruzzo	Umbria
13	Lazio	Tuscany	Lazio	Molise
14	Molise	Campania	Molise	Abruzzo
15	Abruzzo	Apulia	Sardinia	Sardinia

(*continued*)

Table 4. (*continued*)

Position	Health	Environment	Economic wellbeing	Quality of Services
16	Apulia	Friuli V. G.	Basilicata	Basilicata
17	Basilicata	Piedmont	Apulia	Apulia
18	Sicily	Veneto	Calabria	Campania
19	Campania	Emilia Rom	Campania	Calabria
20	Calabria	Lombardy	Sicily	Sicily

5 Conclusion

In this paper, we implemented two independent analyses to examine the Italian situation using BES and SDGs indicators. The two analyses show two different perspectives: the more qualitative clustering algorithm and the more quantitative composite indicators based on KPI (PCA and factor analysis).

Both methods underline the strong existence of the North-Sud gap for macro-area: Economic Well-being how widely reported in literature.

In the two other BES areas (Health, Quality of Services), there does not appear to be any agreement between the two methods considered. While the KPI still underlines a North-South divide, the results obtained with the FCMdd show a rather confusing situation. These differences can be attributed to the small number and low information content of the variables used for clustering, which is underlined by the silhouette values found.

A separate discussion must be held for the environment, where the KPI does not show a clear geographical trend indicating a critical situation in the northern regions due to environmental pollution.

The results of the KPI procedure confirm that 5 northern regions are at the bottom of the ranking. Indeed, the northern regions are on average more polluted than the southern ones and have a more critical hydrogeological situation.

The 4 least polluted regions are evenly distributed between the North (Valle d'Aosta and Trentino) and the south (Molise and Basilicata).

Our analyses show that the Italian framework is complex, multidimensional and contradictory.

The use of publicly available ISTAT data and widely recognized statistical techniques ensures a high degree of replicability, enabling future researchers or policymakers to apply the same framework to updated datasets or to different territorial contexts within or beyond Italy. However, several methodological limitations must be acknowledged. First, the limited number of indicators per BES domain, particularly in Health and Quality of Services, reduces the richness and discriminative power of the analyses, as reflected in the low silhouette values of the clustering. Second, discrepancies between the two analytical methods (e.g., conflicting patterns in regional classification) point to the sensitivity of results to methodological choices and the need for caution in interpretation. Lastly, the KPIs' reliance on aggregation may obscure localized nuances and heterogeneities. Future

developments should aim at expanding the indicator set, integrating higher-frequency or disaggregated data, and testing advanced machine learning models for improved granularity and accuracy. Moreover, incorporating participatory or qualitative inputs could enrich the understanding of regional well-being and better align the analysis with the 2030 Agenda's ambition of "leaving no one behind."

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