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Summary

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Keywords: SDGs, Composite Index, Weighting, Correlation, Spectral Value Decomposition, Principal Component

JEL Classification: C4, O18, Q56

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A Methodological Approach to Measure the Agenda 2030 at Urban Level

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Abstract. In this paper we calculate the Italian Cities Sustainable Development Goals (SDGs) Composite Index potentially useful for policy analysis and dissemination of sustainable development at local level in Italy. Structured into several dimensions representing 16 out of 17 SDGs adopted by the United Nations at the end of September 2015, the index merges 53 available economic, social and environmental elementary indicators into a single composite dimension, highlighting a geographical and demographic heterogeneity within the country. By using the Spectral Value Decomposition technique, the index offers an urban focus of sustainability, showing some differences among the goals and the cities of Italy. Finally, it identifies the Goal concerning quality education and decent work and economic growth as the main key Goals for sustainability.

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1 Introduction

In August 2017 the Sustainable Development Solutions Network (SDSN) presented in New York the first US City Index on the Sustainable Development Goals (SDGs) at urban level (Prakash et al., 2017). This index was put beside the Global SDG Index (Sachs et al., 2018), underlining the specific role of cities. The SDGs recognize that sustainability is a universal goal and that all countries and communities can play an important role in achieving its Agenda. From a global point of view, cities are crucial for the achievement of sustainable development: they are relevant to assess the success or the failure of it, as they host more than half of the whole world's population and they are the main source of carbon emissions.

Using indicators to track progress is an integral part of the SDGs, which are included in an international framework agreed by world leaders in 2015[4], aiming to end poverty, fight inequalities and stop climate change.

Although important references exist in Italy to monitor sustainability at national level, there are no explicit references to single urban realities.

Numerous contributions that evaluate the country's positioning in the field of sustainability are available (see Cavalli, 2018 for a review). They range from the documents and data used to prepare the National Strategy for Sustainable Development (provided by the Ministry of Environment in December 2016), which presents the positioning of Italy compared to 17 SDGs and 169 targets, to the index developed by the UN-SDSN and by the Bertelsmann Foundation. This places Italy at the 29th place on 156 in the world in 2017, after Sweden, Denmark and Finland, but in the queue also to other countries like Slovak Republic, Hungary and Latvia. In particular, this tool shows for which Goal Italy is far from reaching the target (mainly Goal 14, 12, 13 and 9), and for which instead the country is on the path toward sustainability (Goal 1, 3, 4, 6, 11).

Among other contributions, the Organization for Economic Cooperation and Development (OECD, 2017) provides the state of the art for the SDGs in OECD countries, comparing the OECD well-being own framework to the Agenda 2030 and noticing that Italy has reached adequately 11 out of the 17 SDGs.

Despite the importance of understanding the positioning of one country in an international perspective, in order to have a complete picture to be used as a basis for the identification of a system of priorities, it is also important to understand the direction of the change and the speed of the progress towards the SDGs. In this regard Eurostat (2017) underlines the significant progress on some SDGs made by the EU (Goal 3, 7, 11, 12, and 15), but it also reminds that such progress is not sufficient to achieve the Agenda 2030[5].

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[4] https://www.un.org/sustainabledevelopment/development-agenda/

[5] To better understand the national situation, in 2017 the Italian Alliance for Sustainable Development (ASviS), established in 2016 to raise awareness and mobilize actions to pursue the SDGs, has stated that Italy is far from sustainability on unemployment, inequality and environmental issues, while it is improving in the fields of education, good health and food security, even if it continues to remain far away from the target for what concerns all these issues. Furthermore,

The process to reach targets or to reach the Goals of the Agenda depends also on the different policies adopted and their impacts. At this regard Campagnolo et al., (2018) developed a measure of the current well-being and the future sustainability, generating forecasts up to 2030 for 45 different geo-political areas (individual countries or macro-regions), based on the different hypotheses of policies adopted in a composite indicator (so-called Assessment, Projection and Policy of Sustainable Development Goals, APPS) that depends on a general equilibrium economic model. The results show that Italy stands at the 15th place among the 45 regions considered and, within the European Union, the Italian performance is better only compared to that of the Czech Republic, Spain and Greece.

While the studies that analyse countries in the context of the SDGs are numerous, nationally – but even internationally, with the only exception of the US – there are only few explicit references to urban realities. Several international organizations have created specific programs to develop and harmonize urban indicators worldwide; these include, among others (Alberti, 1996), the United Nations Centre for Human Settlements (UNCHS), the UN Commission on Sustainable Development, the World Bank, the OECD, the European Environment Agency (EEA), and the World Health Organization (WHO).

Considering the available international sources deep inside (Elmqvist et al., 2018), we can distinguish a first generation of urban indicators which was set during the 1960s when the World Bank launched the first World Development Indicators Series, aiming at monitoring urban achievement of the international development goals of that time (Wong 2006, 2014). After that, the Global City Indicators Program (GCIP) was introduced, which enabled cities to measure, report on, and improve their performance and quality of life, to facilitate capacity building, and to share best practices through an easy-to-use web portal. During the latest century, the Cities Data Book (CDB) was formulated by the Asian Development Bank as a comprehensive set of urban indicators able to improve urban management and performance measurement; in the same years, the Global Urban Indicators (GUI) database was established to monitor progress on the implementation of the UN-Habitat Agenda. As social and environmental indicators are concerned, Herva et. al (2011) review a series of environmental indicators developed in the last years that were found suitable to be applied at corporate level for the evaluation of production processes and products. The indicators reviewed in their paper were classified into four main groups: 1) Indicators of Energy and Material Flows; 2) Indicators with a Territorial Dimension; 3) Indicators of Life-Cycle Assessment; 4) Indicators of Environmental Risk Assessment. The definition of the environmental impact of economic activities has been gradually integrated with a broader concept, given that "sustainability" has also been including social elements. Therefore, Sirgy et. al (2004) and Prescott-Allen (2001) studied_community quality-of-life (QOL) indicators using Human Wellbeing Index (HWI) and Ecosystem Wellbeing Index (EWI) in their research, respectively. Further literature has been developed by following the SDGs, trying to define some SDGs indices (Sanchez et. al, 2018).

Italy is in delay in the adoption of fundamental strategies relating to energy, climate change and circular economy.

Even fewer are the sources available at local level, although when implementing the Agenda 2030 it is particularly important to define the strategies through the alignment of local or regional development plans with the Goals, the targets and the indicators of the Agenda 2030. For example, in October 2018 the Spanish SDSN Network, REDS, launched the SDG Spanish Cities Index, showing the progress of 100 Spanish cities towards the SDGs. Mazziotta and Pareto (2016) set some composite indices of well-being for Italian regions, as well as 110 Italian provinces, using 11 dimensions of well-being associated to 11 composite indices.

Locally adopting the Agenda is much more than reaching the target: in order to build a local strategy there is a need for the design, the sharing and the development of tools that photograph the "implementation status" of the SDGs in the main Italian municipalities; this to help local communities tackle the still unresolved challenges affecting single cities.

The present work is dedicated to filling in the gaps of the literature above: to do so, it identifies indicators related to the sustainability level of Italian cities, adopting the PCA method, trying to define a balanced structure of the data, as explained in Farnia (2019). The main results show that the main key Goals for sustainability are good education and decent work and economic growth.

This paper is organized as follows: chapter 2 is dedicated to the description of the composite index; chapter 3 explains the main results, while the 4th is the chapter of conclusions. The main sources and graphs are put in the appendix.

2 Composite Index

The Italian Cities SDGs Index is composed by 53 elementary indicators structured into 16 out of 17 SDGs; no data are available for Goal 14, “Life below water”. The list of the elementary indicators is shown in the Appendix (

Table 2) and Figure 1 graphically represents the composite index structure.

Such index does not measure the sustainability level of Italian urban reality; instead, it measures the Italian municipalities’ performance respect to the average. The reason is that only in 30% of our indicators a precise UN target (*sustainable* level) is available, and, on the other side, no *unsustainable* thresholds exist at all. We stress indeed the following: since, in a composite index, the distance to the target (upper bound) is rescaled on a [0,1] scale because of the presence of indicators with different units of measure, no rescaled distance based on a single point can be precisely computed. The choice of the lower bound plays indeed a crucial role in determining such distance and cannot depend on the data set – for example the 2.5 percentile (Prakash et al., 2017) – especially when we compare realities that are homogeneous, i.e. cities or regions belonging to the same country, or countries with similar wellbeing level (OECD, etc.).

Instead of working on 30% of indicators and setting as many lower bounds (difficult task), we have preferred to retain the whole set of indicators and build a fast, unsupervised composite index on standardized data. Therefore, the scores obtained in each dimension cannot reveal a sustainability level *per se*, but only a comparison between municipalities' performances in relation to an average value (set to zero).
Data have been merged in two levels: in the first level indicators have been aggregated within each Goal; in the second level the Goals have been aggregated into the *Sustainability Index*. The unevenly distribution of indicators among Goals (Goal 7 for example has only one indicator, while Goal 4 has 9) required a re-standardization of the value obtained to balance the Goal's influence on the final index. From a probabilistic point of view, Goals with fewer indicators exhibit a higher variance with respect to those formed by several, with a consequently greater influence on the final composite index.

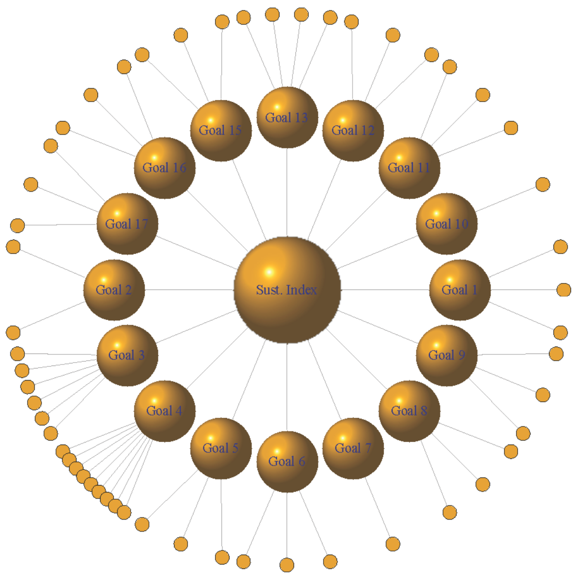

Figure 1 - Composite Index Structure

Moreover, the high dimensionality of the index has required the check for latent implications due to the multivariate distribution of data; it is mathematically proved (Wang and Stanley, 1970; Parulo et al., 2013) that not only the heterogeneous variance among indicators plays a central role on the aggregated value, but also the degree of correlations among them. With this aim, in order to identify the latent structure of data (see sub section 2.1), the Principal Component technique has been applied, clustering both indicators within each Goal and the Goals themselves. The weights attached to the indicators have been set in such a way to better represent the dimensions the data describe, favouring the ones that are statistically independent and, conversely, penalizing those that belong to the same dimension. In this way a balanced representation of data is guaranteed.

2.1 Criteria Weighting

Consider a composite index formed by p indicators x_i with $i = \{1,2, \ldots p\}$, that have been previously adjusted according to their polarity. If such indicators have been previously standardized too, their covariance matrix coincide with the correlation matrix (denoted with **R**). The Spectral Value Decomposition (SVD) allows to rewrite the correlation matrix in the following way:

$$\mathbf{R} = \mathbf{A}\boldsymbol{\Lambda}\mathbf{A}' \quad (1)$$

where $\boldsymbol{\Lambda}$ $(p \times p)$ is the diagonal matrix of eigenvalues of **R** and **A** $(p \times p)$ matrix of eigenvectors.

When in the data set some random variables are exactly linear dependent from others, it is possible to obtain the same correlation matrix **R** with a lower dimension in the matrix $\boldsymbol{\Lambda}$ $(k \times k)$ and $(p \times k)$, with $k < p$. If we define the total variance of the random vector **x** as the sum of the variance of its random variables, that is $trace\ (\mathbf{R}) = p$, we could form a new random vector **z** $(k \times 1)$ as a linear combination of **x** with the same total variance explained:

$$\mathbf{z} = \mathbf{A}'\mathbf{x} \quad (2)$$

$$Cov(\mathbf{z}) = \mathbf{A}'\mathbf{R}\mathbf{A} = \boldsymbol{\Lambda} \quad (3)$$

meaning that the elements of the random vector **z** are orthogonal. The total variance explained by the new random vector is:

$$trace\ (\boldsymbol{\Lambda}) = trace\ (\mathbf{A}'\mathbf{R}\mathbf{A}) = trace\ (\mathbf{R}) = p \quad (4)$$

The *principal component* represents the first element of the random vector **z** and it explains the maximum amount of the total variance of **R**, given that the eigenvalues of **R** have been rearranged in descending order.

It is worth underlining that the matrix **A** cannot be used directly in the construction of a composite index $y = \mathbf{w}'\mathbf{z}$, with $\mathbf{w} \geq \mathbf{0}$ a vector $(k \times 1)$ of weights; indeed, it could happen that an increment in the variable x_j leads to a negative direct effect in the composite index, because of the presence of negative elements in the matrix **A**:

$$\frac{\partial y}{\partial x_j} = \mathbf{w}'\mathbf{a}_{.j} < 0 \quad (5)$$

where $\mathbf{a}_{.j}$ represents the j-thcolumn of $\mathbf{A}'$.

For this reason, the utilization of PC, similarly to Factor Analysis, in the context of composite indices' construction requires a transformation and/or a rescaling of the eigenvector matrix. Hence, it is more correct to define such method as SVD based.

Although several techniques exist in literature, there is no consensus on which one is the best to use. The most commonly employed can be found in OECD (2005). However, this approach leads to two severe consequences: first, it could overweigh indicators that are correlated, penalizing those that are independent, leading consequently to an unbalanced composite index. The reason is that the initial weights of the indicators (represented by the proportion of variance explained in each component) are weighted again proportionally to the variance explained by the components. Second, the criterion adopted to retain the number of components (around 85% of total variance should be explained) could leave out components that in theory play a central role in the description of the data.
The following example will better explain the above two issues: suppose you are going to construct a composite index with three indicators, two of which are perfectly correlated, while the third is statistically independent from the others. In theory, one of the two correlated variable is redundant and it should be dropped in the composite index. If you are imposing equal weights, the composite index is unbalanced because one dimension (formed by the two correlated variables) is weighted twice with respect to the second one (formed by the independent variable). If you use the OECD approach, you obtain the same undesirable results.

$$\mathbf{R} = \begin{bmatrix} 1 & 1 & 0 \\ 1 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$$\mathbf{A} = \begin{bmatrix} 0.707 & 0 & 0.707 \\ 0.707 & 0 & -0.707 \\ 0 & 1 & 0 \end{bmatrix}$$

$$\mathbf{\Lambda} = \begin{bmatrix} 2 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 0 \end{bmatrix}$$

The number of components to retain is two, since the first one explains $\frac{2}{3}$ of the total variance and the second one an additional $\frac{1}{3}$.
The matrix $\mathbf{B}$ (with $b_{ij} = a_{ij}^2$) represents the proportion of the variance explained by each indicator for each component retained:

$$\mathbf{B} = \begin{bmatrix} 0.5 & 0 \\ 0.5 & 0 \\ 0 & 1 \end{bmatrix}$$

Following the OECD technique, the weight of the first two indicators is $\left(\frac{2}{3}0.5 + \frac{1}{3}0\right) = \frac{1}{3}$; the weight of the third indicator is $\left(\frac{2}{3}0 + \frac{1}{3}1\right) = \frac{1}{3}$.
To avoid this issue, you need to think differently: in some types of composite index, namely those for which condition 5) cannot be accepted, it is not recommended the technique that fits the data best. On the contrary, it is to prefer the one that best fits the dimensions data are explaining, in which indicators that are statistically independent are weighted more than those that belong to the same dimension. To this aim, when

using PCA technique, each component should have the same weight. To conclude, the optimal indicators' weights $\mathbf{w}^*$ $(p \times 1)$ are obtained averaging the proportion of variance explained by them in each component:

$$\mathbf{w}^* = \frac{1}{d}\mathbf{Bi} \tag{6}$$

where d represents the number of components retained.
According to 6), the weight of the first two indicators is $\left(\frac{1}{2}0.5 + \frac{1}{2}0\right) = \frac{1}{4}$ and the weight of the third indicator is $\left(\frac{1}{2}0 + \frac{1}{2}1\right) = \frac{1}{2}$.

Regarding the second issue – the number of components to retain: suppose that a composite index is formed by p indicators that are statistically independent. Given this assumption, each component explains $\frac{1}{p}$ of the total variance p and 20% of the initial set of indicators is wrongly discarded.
At first glance one could recommend retaining the number of components that simultaneously satisfy the following conditions: around 85% of the total variance should be explained and each eigenvalue is greater than one. Let λ_i the i-th eigenvalue and

$$C = \left\{k \middle| argmin_k f(k) = \left|\sum_{i=1}^{k} \lambda_i - \frac{8.5}{10}p\right|\right\},\ k = \{1, \dots, p\} \tag{7}$$

$$D = \{v|\lambda_v \geq 1\},\ v = \{1, \dots, p\} \tag{8}$$

the optimal number of components to retain d^* is given by:

$$d^* = max(k, v) \tag{9}$$

However, as Farnia (2019) shows, it is recommended to retain only those components whose eigenvalue are higher than the average.
The composite index y is hence a weighted average of the indicators belonging to it:

$$y = \mathbf{w}'\mathbf{x} \tag{10}$$

2.2 Final Goal's Influence on the Composite Index

In literature (Wang and Stanley, 1970; Parulo et al., 2013) the final influence of the i-th indicator on a composite index y (formed as linear combinations of some criteria) is expressed as the squared correlation between the two:

$$Influence_{x_i,y} = cor^2(x_i, y) \tag{11}$$

This allows us to better understand the real importance of a variable in a composite index, catching both the direct (weight/coefficient) and the indirect effect.

3 Results

Focusing on the recognized socio-economic disparities between the south and the north of the country, the Sustainability Index and its distribution across the regions confirms the gaps. According to equation (11), the key Goals to understand this result are those related to *quality education* (Goal 4) and *decent work and economic growth* (Goal 8). At level of elementary indicators, the key ones are NEET (young people aged 15-19 Neither in Employment nor in Education or Training) and the one related to the share of population that worked less than 20% of the time.
The overall influence of each SDG on the composite measure is reported in Table 1 and graphically represented in Figure 2.

Table 1 - Overall Influence of SDGs and their weights

Goal	Std. Infl.	Weight	Goal	Std. Infl.	Weight
Goal 4	0.137	0.044	Goal 12	0.047	0.085
Goal 8	0.136	0.041	Goal 9	0.044	0.051
Goal 5	0.103	0.038	Goal 6	0.040	0.102
Goal 2	0.087	0.051	Goal 7	0.036	0.099
Goal 1	0.084	0.048	Goal 11	0.028	0.080
Goal 17	0.081	0.041	Goal 13	0.018	0.065
Goal 3	0.079	0.057	Goal 10	0.011	0.086
Goal 16	0.072	0.052	Goal 15	0.000	0.060

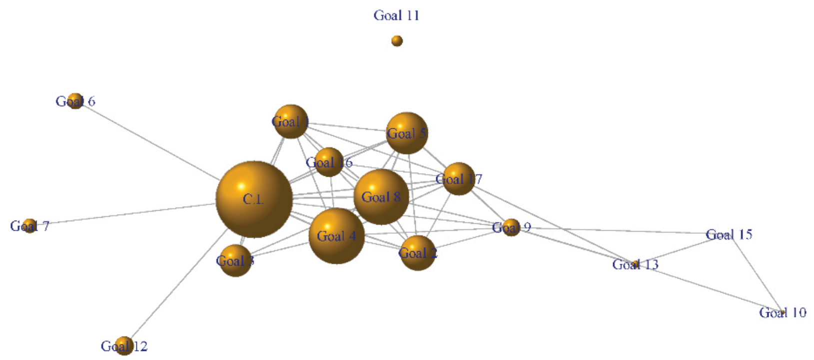

Figure 2 - Graph representation of the influence (sphere size) of SDGs on the composite index and the correlation ($|Cor(x,z)| \geq 0.35$) among them.

Although SVD technique tends to impose, at least for our data set, higher weights to less influencing Goals (see Figure 3 in Appendix), such results give a warning message and rise a challenge: three theoretically important Goals for sustainability as *life on land*

(Goal 15), *reduced inequalities* (Goal 10) and *climate actions* (Goal 13) are misrepresented in the SDGs structure; this could be the consequence both of the Italian's situation and of the numerically unbalanced distribution of the Goals among the social, economic and environmental pillars of sustainability. To avoid such risk, it is hence important to look at each specific Goal, as theoretically recommended by the Agenda 2030.

Given the importance of looking specifically at the SDGs to better understand the state of the art of the municipalities and their different specificities, rankings for each Goal have been provided (see Table 3 to Table 5 and their graphically representation in Figure 4 to Figure 6). It is always important to remember that the Agenda 2030 is a complex program that aims at avoiding trade-offs between the Goals, still recognizing the peculiarities of each single actor and the need of an integration between them. One of the points to focus the attention on, once the individual rankings have been obtained, is the high degree of diversification, which strongly – but not surprisingly – indicates the degree of heterogeneity of the Italian municipalities.

From a comparative perspective, as summarized in Bolzano is at the top of the ranking in the Goals linked to Poverty (Goal 1), to Sustainable cities (Goal 11). Milan (61st in the Sustainability Index) is the best performer in the SDGs related to Economic growth, Infrastructures and Innovation (Goal 8 and 9), it is on the podium in Goal 6 (Clean water and Sanitation), but at the same time it displays the worst result in SDG 10 (Economic inequality) and second to last in Goal 15 (Life on land). Belluno, Venezia and Padova, three Municipalities located in the North-East part of the country, are the best performers respectively in Goal 12 (Responsible production and consumption), 13 (Climate change) and 7 (Clean energy), while considering Terni and Rome (two Municipality in the centre part of Italy), they rank at the top in SDG 3 (Good health) and 5 (Gender equality), 17 (Partnership for the Goals) respectively. Finally, Matera and Enna, municipalities in the Southern part of the Country, are on the top of the ranking in SDG 15 (Life on land) and 16 (Peace).

The most effective reflexion that emerges from a comparative perspective is that there is no city reaching the full sustainability level in each one of the 17 SDGs acceptation – not even Bolzano, at the top of the ranking in different Goals, but showing a red-coloured light in Goal 7 (Clean energy). In the same vein, Milan, best performer in the SDGs related to Economic growth, Infrastructures and Innovation (Goal 8 and 9), displays the worst result in Goal 10 (Economic inequality) and second to last in Goal 15 (Life on land). Also, if numerous northern cities such as Belluno, Venezia and Padova are the best performers respectively in Goal 12 (Responsible production and consumption), 13 (Climate change) and 7 (Clean energy), on the other side Terni and Rome (cities of central Italy) rank at the top in SDG 3 (Good health) and 5 (Gender equality), and 17 (Partnership for the Goals) respectively. Finally, Matera and Enna, municipalities in the southern part of the country, are on the top of the ranking in SDG 15 (Life on land) and 16 (Peace).

All that said, these results confirm the complex picture and the need of tools to help the coordination and the intersection between policies, sectors and stakeholders to find innovative solutions to the challenges sustainable development addresses.

4 Conclusions

This paper offers a methodological approach that best suits the construction of composite indicators in the context of the SDGs. In the next future, when all the 269 elementary indices measuring sustainability will be available worldwide, there might be the need of a synthetic measure that best approximates the sustainability level of a country, region and city, and that mitigates the implicit issues generated by the multivariate distributions of the data. It is indeed highly probable that these 269 indicators do not explain as many as different dimensions.

To address the above issues, we applied the Principal Component technique, trying to define a balanced structure of the data, as explained in Farnia (2019). Our work offers the readers a list of indices (the sustainability index, and one for each Goal) for Italian municipalities. The results confirm the rift between the north and the south of the country, which flows in the fact that the same city could perform virtuously in some Goals, but still be in delay in others. Moreover, we have studied which Goal is, by construction, the most important for our measure; due to the number and types of indicators and the availability of data, the key Goals are those related to good education and decent work and economic growth. While, at single elementary indicators level, the key ones are the NEET one (young people aged 15-19 neither in employment nor in education or training) and the one related to the share of population that worked less than 20% of the time.

Another important point that arises from our results and our individual rankings is the high degree of diversification, which strongly – but not surprisingly – indicates the grade of heterogeneity of the Italian municipalities. Therefore, for each Goal we usually obtain different cities at the top of the ranking.

Future researches and developments can be devoted to the role of time in the index analyses. Further future prospects could be related to the definition of the targets and their impact on the synthetic index. Perhaps a further approach that does not depend on them could change the results in a more balanced index.

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6 Appendix

Table 2 - List of Indicators Considered (Goal and Polarity displayed)

Indicator	Source	Year	SDGs	Polarity
Elderly people dependence index	ISTAT	2017	1	negative
Economic distress	MEF	2013	1	negative
Individuals in low-working intensity families	ISTAT	2011	1	negative
Urban bio gardens	URBES	2013	2	positive
Obesity rate	ISS	2016	2	negative
Healthy life expectancy at birth	ISTAT	2016	3	positive
Healthy life expectancy at 65 years	ISTAT	2016	3	positive
Deaths and injuries in road accidents	ISTAT	2016	3	negative
Support to elderly people	ISTAT	2015	3	positive
Suicide rate	URBES	2011	3	negative
Infant mortality rate	URBES	2011	3	negative
Nursery services for children aged 0-36	ISTAT	2013	4	positive
Student literary competence	URBES	2013/14	4	positive
Student numerical competence	URBES	2013/14	4	positive
People with university degree	ISTAT	2011	4	positive
Population with low school license (isced 3)	ISTAT	2011	4	positive
Enrolled population at school aged 0-16	ISTAT	2011	4	positive
Schools with ramps for people with disabilities	URBES	2013	4	positive
School with technologies	MIUR	2015	4	positive
Population with pre-university education	ISTAT	2015	4	positive
Employment gender balance	ISTAT	2016	5	positive
Woman mayor in the last 10 years	DATI.GOV.IT	2016	5	positive
Women educational level compared to men	URBES	2011	5	positive
Water losses	ISTAT	2015	6	negative
Population connected to urban waste water treatment plants	ISTAT	2015	6	positive
Population served by sewerage	ISTAT	2015	6	positive
Solar PV installed	Legambiente	2017	7	positive

Average taxable income per capita	MEF	2015	8	positive
Neet (15-29)	URBES	2011	8	negative
Youngs aged 18-24 not enrolled in any educational course	URBES	2011	8	negative
Public transportation availability	Legambiente	2017	9	positive
Green firms	UNIONCAMERE	2015	9	positive
Connection infrastructure	Infratel	2015	9	positive
Gini index	MEF	2014	10	negative
Cycling road	Legambiente	2017	11	positive
People with no toilet	URBES	2011	11	negative
Pm 2.5 emission	ISPRA	2017	11	negative
Recycled waste	ISPRA	2016	12	positive
Urban waste	ISPRA	2016	12	negative
Incentive to recycling garden waste	ISPRA	2016	12	positive
Public transportation mobility	Legambiente	2017	13	positive
Bike sharing	ISTAT	2015	13	positive
Propensity to public transportation	ISTAT	2015	13	positive
CO2 emission	OECD	2008	13	negative
Share area utilization	SINAnet	2016	15	negative
Green urban areas per population	Legambiente	2017	15	positive
Ecolabel licenses	ISPRA	2017	15	positive
Political electoral participation	Ministero dell'In-terno	2013	16	positive
Tribunal efficiency	FPA	2012	16	negative
Firms rating	ISTAT	2015	16	positive
Broadband penetration rate	ISTAT	2011	17	positive
Propensity to association	ANCITEL	2015	17	positive
Social cooperatives	ISPRA	2015	17	positive

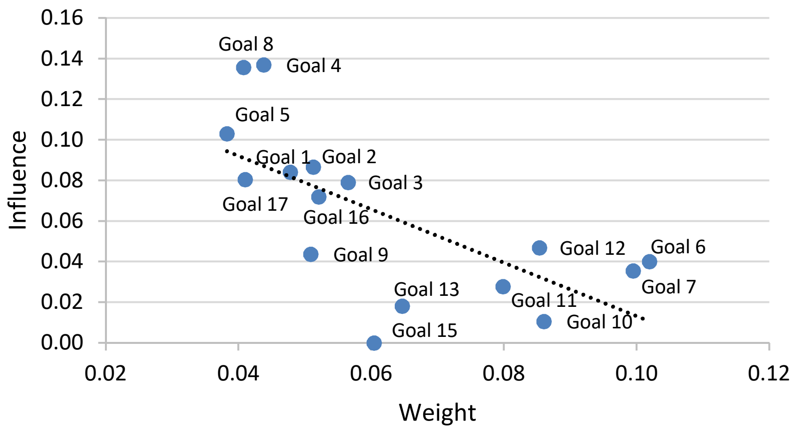

Figure 3 - Relation between overall Influence and Weights

Table 3 - Top and bottom 15 municipalities (Sustainability Index to Goal 5)

Municipality	S.I.	Municipality	Goal_1	Municipality	Goal_2	Municipality	Goal_3	Municipality	Goal_4	Municipality	Goal_5
Trento	2.30	Bolzano	1.83	Torino	5.61	Terni	1.91	Cremona	1.96	Roma	2.46
Cremona	1.51	Treviso	1.64	Parma	1.93	Treviso	1.89	Padova	1.85	Lodi	2.16
Bolzano	1.43	Pavia	1.27	Ferrara	1.43	Mantova	1.57	Trento	1.59	Torino	2.12
Padova	1.42	Rieti	1.16	Ravenna	1.18	Rimini	1.51	Udine	1.53	Ancona	2.06
Lodi	1.39	Padova	1.15	Pordenone	0.95	Forli'	1.49	Rovigo	1.51	Piacenza	1.87
Macerata	1.37	Brescia	1.15	Bologna	0.94	Siena	1.38	Bologna	1.44	Savona	1.76
Verbania	1.23	Trieste	1.14	Trento	0.91	Pordenone	1.38	Belluno	1.39	Vercelli	1.70
Forli'	1.21	Varese	1.13	Cremona	0.90	Perugia	1.37	Sondrio	1.35	Verbania	1.64
Mantova	1.18	Cremona	1.13	Belluno	0.90	Sondrio	1.29	Parma	1.33	Bologna	1.50
Verona	1.12	Lodi	1.05	Bolzano	0.87	Trento	1.23	Ancona	1.21	Alessandria	1.48
Ferrara	1.11	Firenze	1.05	Como	0.86	Macerata	1.23	Bergamo	1.20	Pavia	1.47
Bologna	1.10	Novara	0.99	Padova	0.85	Pistoia	1.23	Forli'	1.16	Pisa	1.35
Modena	1.02	Modena	0.98	Modena	0.83	Teramo	1.22	Pavia	1.15	Siena	1.17
Parma	0.99	Matera	0.96	Sondrio	0.82	Campobasso	1.20	Gorizia	1.11	Milano	1.06
Siena	0.93	Siena	0.95	Lecco	0.81	Pesaro	1.16	Macerata	1.11	Firenze	0.92
…	…	…	…	…	…	…	…	…	…	…	…
Catanzaro	-0.87	Alessandria	-0.99	Trapani	-0.97	Cremona	-0.91	Torino	-1.01	Messina	-0.97
Massa	-1.08	Lecce	-0.99	Agrigento	-0.97	Alessandria	-0.99	Caltanissetta	-1.13	Massa	-1.00
Brindisi	-1.12	Roma	-0.99	Messina	-0.97	Milano	-1.20	Brindisi	-1.18	Bari	-1.09
Caltanissetta	-1.15	Cosenza	-1.08	Matera	-0.98	Genova	-1.25	Alessandria	-1.18	Ragusa	-1.15
Frosinone	-1.32	Taranto	-1.19	Potenza	-0.98	Palermo	-1.35	Prato	-1.21	Enna	-1.23
Taranto	-1.33	Vibo valentia	-1.19	Campobasso	-1.41	Enna	-1.41	Massa	-1.30	Agrigento	-1.49
Benevento	-1.34	Crotone	-1.20	Reggio di calabria	-1.52	Catania	-1.49	Agrigento	-1.44	Taranto	-1.56
Agrigento	-1.51	Frosinone	-1.21	Catanzaro	-1.52	Messina	-1.55	Oristano	-1.44	Caltanissetta	-1.72
Vibo valentia	-1.56	Catania	-1.34	Cosenza	-1.52	Agrigento	-1.59	Taranto	-1.47	Palermo	-1.73
Palermo	-1.57	Sondrio	-1.51	Vibo valentia	-1.52	Pavia	-1.63	Trapani	-1.61	Catania	-1.80
Crotone	-2.14	Trapani	-1.60	Crotone	-1.52	Massa	-1.68	Messina	-1.70	Brindisi	-1.88
Messina	-2.19	Napoli	-1.69	Napoli	-1.75	Caltanissetta	-1.84	Crotone	-2.05	Foggia	-2.01
Trapani	-2.38	Palermo	-1.77	Salerno	-1.77	Roma	-2.20	Catania	-2.09	Napoli	-2.05
Napoli	-2.44	Agrigento	-4.01	Avellino	-1.77	Napoli	-2.87	Palermo	-2.47	Crotone	-2.06
Catania	-2.54	Messina	-4.55	Benevento	-1.77	Trapani	-3.12	Napoli	-2.91	Trapani	-2.10

Table 4 - Top and bottom 15 municipalities (Goal 6 to Goal 11)

Municipality	Goal_6	Municipality	Goal_7	Municipality	Goal_8	Municipality	Goal_9	Municipality	Goal_10	Municipality	Goal_11
Mantova	1.07	Padova	3.96	Milano	1.80	Milano	2.78	Vercelli	1.63	Bolzano	2.07
Milano	1.02	Macerata	3.66	Pavia	1.65	Trieste	2.19	La spezia	1.60	Oristano	2.03
Sondrio	1.01	Pesaro	3.56	Siena	1.64	Venezia	1.94	Pistoia	1.59	Verbania	1.73
Livorno	0.93	Verona	3.32	Padova	1.52	Treviso	1.58	Rieti	1.48	Pesaro	1.51
Torino	0.92	Oristano	2.27	Bergamo	1.47	Siena	1.57	Alessandria	1.48	Ravenna	1.44
Vercelli	0.92	Cosenza	2.16	Belluno	1.44	Cremona	1.52	Forli'	1.46	Sondrio	1.41
Teramo	0.91	Lodi	1.95	Treviso	1.20	Bologna	1.47	Terni	1.35	Ferrara	1.31
Genova	0.91	Pordenone	1.52	Trento	1.18	Genova	1.24	Ravenna	1.34	Mantova	1.30
Lecco	0.89	Trento	1.47	Parma	1.11	Trento	1.23	Nuoro	1.33	Lecce	1.19
Cremona	0.86	Como	1.02	Bologna	1.09	Parma	1.23	Asti	1.28	Forli'	1.17
Foggia	0.85	Cremona	0.92	L'aquila	1.07	Brescia	1.19	Taranto	1.28	Cremona	1.02
Varese	0.84	Bergamo	0.84	Varese	1.03	Mantova	1.19	Savona	1.22	Modena	1.00
Piacenza	0.82	Vicenza	0.82	Bolzano	1.02	Bergamo	1.06	Rovigo	1.21	Pistoia	0.99
Trento	0.81	Verbania	0.79	Lodi	0.98	Ancona	1.05	Livorno	1.20	Matera	0.89
Modena	0.81	Biella	0.73	Lecco	0.90	Firenze	1.00	Massa	1.18	Sassari	0.87
…	…	…	…	…	…	…	…	…	…	…	…
Taranto	-0.57	Vibo valentia	-0.70	Ragusa	-0.96	Macerata	-1.08	Firenze	-1.00	Asti	-1.06
Rieti	-0.62	Reggio di calabria	-0.72	Cosenza	-0.99	Teramo	-1.08	Pescara	-1.01	Biella	-1.07
Verona	-0.79	Campobasso	-0.72	Bari	-0.99	Grosseto	-1.08	Cagliari	-1.12	Vibo valentia	-1.09
Frosinone	-0.86	Napoli	-0.75	Agrigento	-1.02	Rovigo	-1.10	Catania	-1.13	Rovigo	-1.19
Campobasso	-1.06	Trieste	-0.75	Sassari	-1.04	Biella	-1.13	Palermo	-1.17	Varese	-1.19
Potenza	-1.15	Rovigo	-0.76	Foggia	-1.47	Salerno	-1.14	Como	-1.24	Benevento	-1.28
Pistoia	-1.17	Torino	-0.77	Caltanissetta	-1.59	Nuoro	-1.17	Varese	-1.27	Lucca	-1.33
Catanzaro	-1.26	Nuoro	-0.77	Brindisi	-1.70	Massa	-1.20	Brescia	-1.34	Terni	-1.35
Palermo	-1.47	Viterbo	-0.78	Messina	-1.80	Ragusa	-1.38	Treviso	-1.62	Como	-1.46
Lucca	-1.68	Varese	-0.78	Taranto	-1.86	Frosinone	-1.60	Padova	-1.79	Napoli	-1.85
Venezia	-1.93	Latina	-0.79	Crotone	-1.95	Caltanissetta	-1.74	Lecce	-1.82	Milano	-2.05
Pordenone	-1.95	Palermo	-0.80	Trapani	-2.41	Crotone	-1.81	Napoli	-1.82	Lecco	-2.44
Benevento	-3.02	Lucca	-0.81	Palermo	-2.52	Trapani	-1.87	Roma	-2.15	Torino	-2.64
Treviso	-4.20	Enna	-0.83	Napoli	-2.87	Enna	-1.87	Bergamo	-2.49	Reggio nell'emilia	-2.66
Catania	-4.85	Taranto	-0.83	Catania	-3.15	Vibo valentia	-1.89	Milano	-3.93	Messina	-3.07

Table 5 - Top and bottom 15 municipalities (Goal 12 to Goal 17)

Municipality	Goal_12
Belluno	1.68
Treviso	1.68
Trento	1.53
Novara	1.42
Pordenone	1.35
Nuoro	1.31
Macerata	1.28
Lodi	1.26
Teramo	1.22
Chieti	1.21
Mantova	1.18
Benevento	1.15
Gorizia	1.09
Asti	1.07
Cuneo	1.07
…	…
Potenza	-0.99
Avellino	-1.17
Brindisi	-1.32
Massa	-1.32
Foggia	-1.44
Vibo valentia	-1.45
Grosseto	-1.48
Brescia	-1.54
Cagliari	-1.61
Crotone	-1.70
Siena	-1.73
Pisa	-2.03
Trapani	-2.09
Catania	-2.57
Pesaro	-4.18

Municipality	Goal_13
Venezia	4.33
Milano	3.75
Roma	2.17
Bologna	2.00
Trieste	2.00
Siena	1.48
Firenze	1.45
Brescia	1.42
Genova	1.39
Torino	1.35
Cagliari	1.34
Trento	1.21
Parma	1.06
Rimini	0.90
Verona	0.89
…	…
Sondrio	-0.76
Lucca	-0.76
Massa	-0.80
Lecco	-0.82
Nuoro	-0.85
Catanzaro	-0.89
Taranto	-0.99
Vercelli	-1.07
Benevento	-1.08
Oristano	-1.16
Lodi	-1.19
Rovigo	-1.31
Gorizia	-1.36
L'aquila	-1.64
Viterbo	-2.35

Municipality	Goal_15
Matera	5.04
Nuoro	1.76
Trento	1.70
Potenza	1.68
Oristano	1.66
Sondrio	1.60
Enna	1.24
Sassari	1.24
Ragusa	1.08
Verbania	1.02
Caltanissetta	0.94
Cuneo	0.86
Cagliari	0.85
Agrigento	0.80
Gorizia	0.74
…	…
Cosenza	-0.79
Verona	-0.81
Parma	-1.04
Modena	-1.06
Udine	-1.08
Brescia	-1.31
Roma	-1.35
Napoli	-1.41
Bari	-1.43
Bologna	-1.71
Torino	-1.78
Pescara	-1.81
Firenze	-2.03
Milano	-2.38
Padova	-2.39

Municipality	Goal_16
Enna	3.05
Ferrara	2.45
Prato	1.70
Ravenna	1.54
Livorno	1.42
Trento	1.38
Rimini	1.37
Pescara	1.36
Mantova	1.21
Cuneo	1.20
Verona	1.17
Verbania	1.13
Bolzano	1.13
Milano	1.11
Torino	1.10
…	…
Ragusa	-1.01
Foggia	-1.03
Bari	-1.13
Brindisi	-1.13
Catanzaro	-1.21
Taranto	-1.22
Cagliari	-1.31
Napoli	-1.32
Trapani	-1.39
Agrigento	-1.62
Reggio di Calabria	-1.63
Matera	-1.79
Cosenza	-1.79
Oristano	-2.21
Messina	-2.92

Municipality	Goal_17
Roma	2.67
Firenze	2.35
Padova	2.26
Modena	2.10
Bolzano	2.02
Venezia	1.94
Trento	1.89
Siena	1.89
Potenza	1.12
Cagliari	1.10
Udine	1.03
Salerno	0.96
Cremona	0.94
Milano	0.93
Como	0.88
…	…
Frosinone	-0.96
Vercelli	-0.99
Ragusa	-1.10
Brindisi	-1.24
Imperia	-1.33
Enna	-1.37
Catania	-1.39
Catanzaro	-1.51
Massa	-1.54
Vibo valentia	-1.58
Agrigento	-1.88
Taranto	-1.97
Crotone	-2.00
Trapani	-2.34
Caltanissetta	-2.62

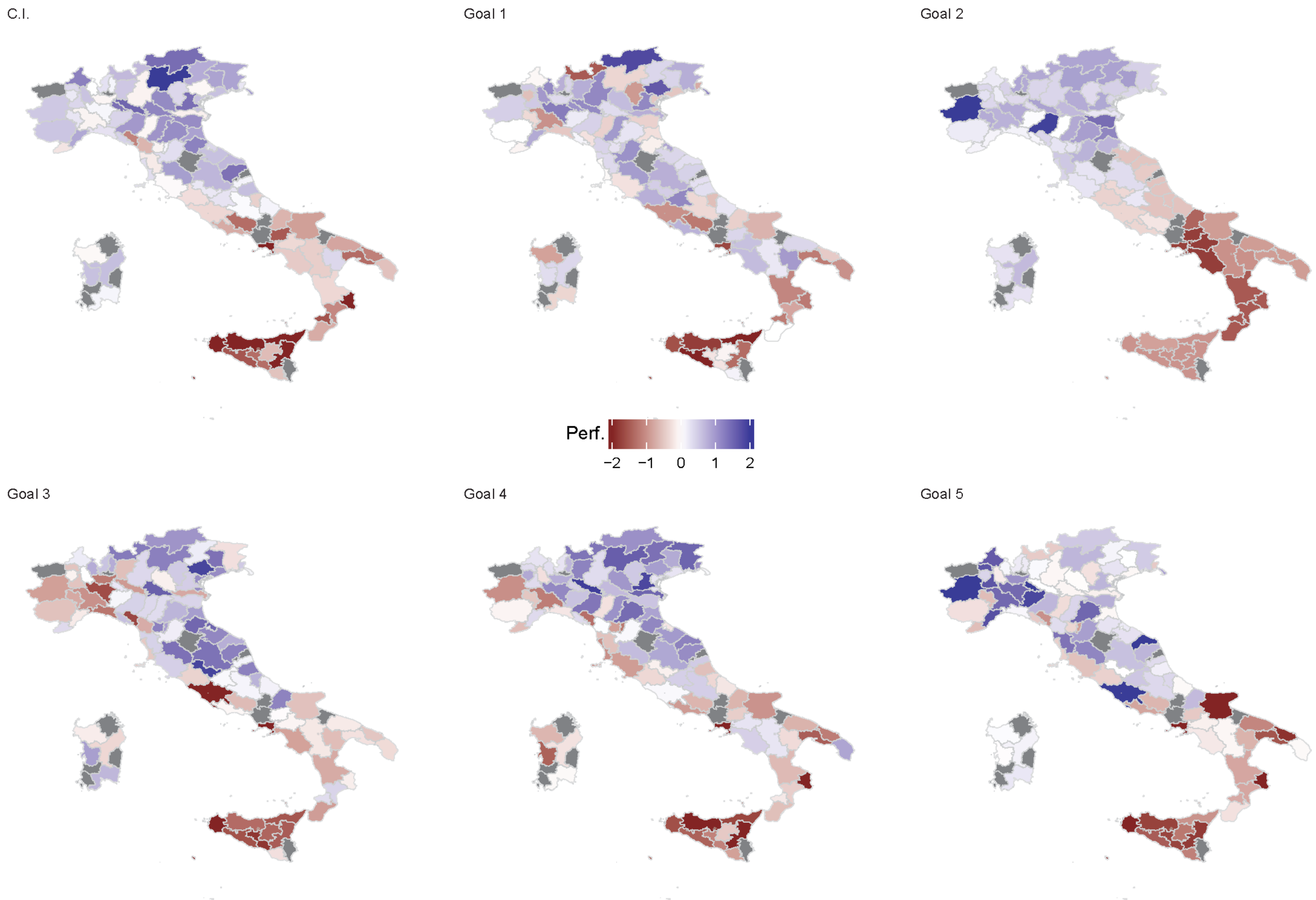

Figure 4 - Map visualization of municipality's performance for each dimension considered (Sustainability Index, Goal 1 to Goal 5)

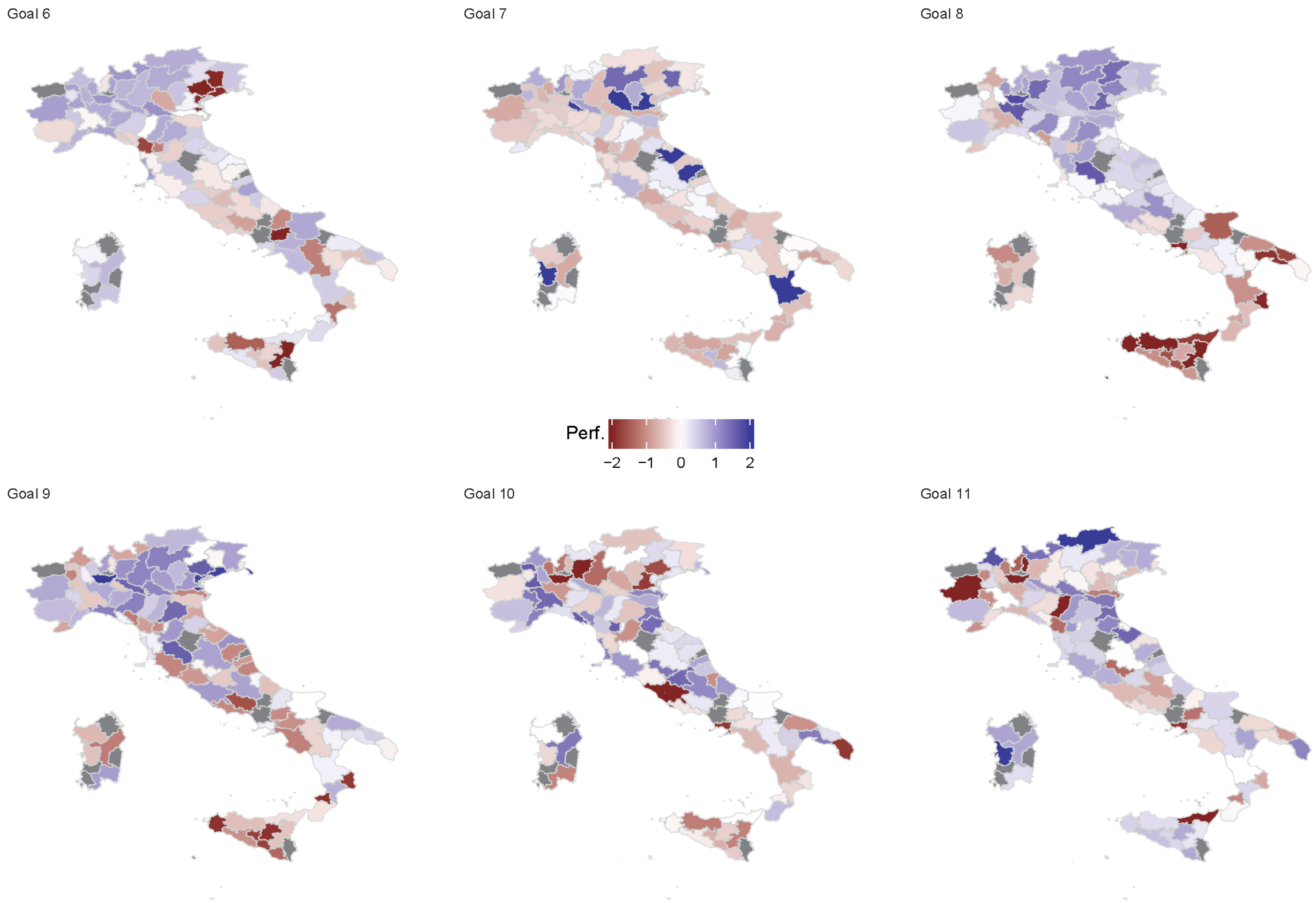

Figure 5 - Map visualization of municipality's performance for each dimension considered (Goal 6 to Goal 11)

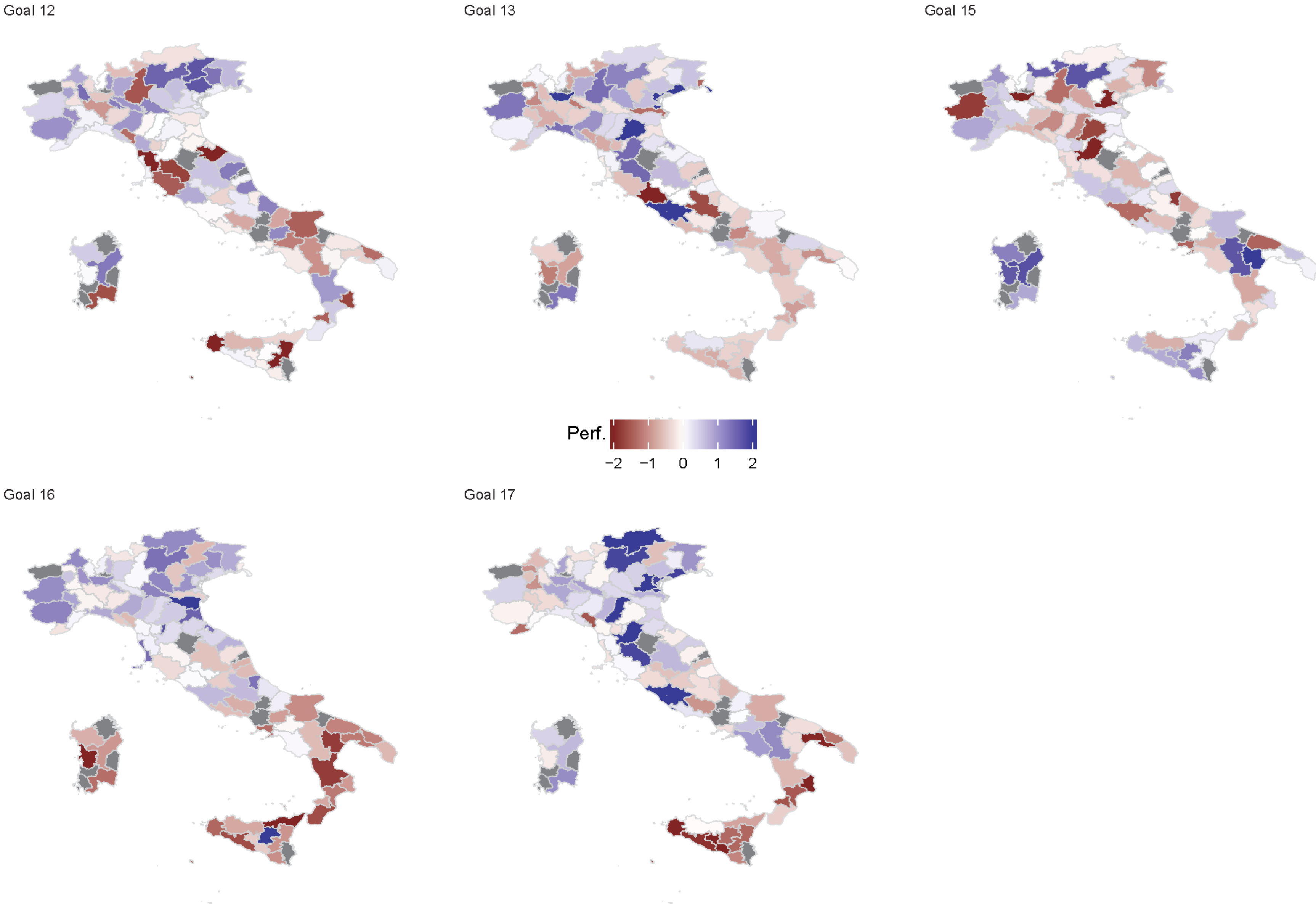

Figure 6 - Map visualization of municipality's performance for each dimension considered (Goal 12 to Goal 17)

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