

Spatial Statistical Model for the Analysis of Poverty in Italy According to Sustainable Development Goals

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Abstract. The "Sustainable Development Goals" indicate which changes nations and people of the world are committed to achieve, by virtue of a global consensus, obtained through a long, complex, and difficult path of dialogue and international and interdisciplinary collaboration. Ending poverty, in all its manifestations including its most extreme forms, through interconnected strategies, is the theme of Goal 1. Providing people all over the world with the support they need, as through promotion of social protection systems, is, in fact, the very essence of sustainable development. The objective of this work is the statistical analysis of the indicators useful for achieving the "No Poverty" Goal 1 through multidimensional statistical analysis methodologies (Totally fuzzy and relative) to understand which Italian regions need more government intervention.

Keywords: Sustainable development · Spatial statistical model · Fuzzy approach · Poverty

1 Introduction

The United Nations General Assembly on 25 September 2015 adopted the Report on the Sustainable Development Goals (SDGs) with the 2030 Agenda for Sustainable Development in which the global objectives to end poverty, protect the planet and ensure prosperity for all by 2030 are set.

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The contribution is the result of joint reflections by the authors, with the following contributions attributed to L. Mongelli (Sect. 1, 4), to A. Massari (Sect. 5), to P. Perchinunno (Sect. 3.1, 3.2) and to S. L'Abbate (Sect. 2and 3.3).

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collaboration; moreover, numerous references are aimed at the well-being of people and the equitable distribution of the benefits of intra and intergenerational development. Each goal has specific goals to achieve over the next few years. It is a system of indicators of great complexity that sees within it both consolidated indicators available for most countries, and indicators that are not currently produced or that have not yet been exactly defined at the international level. Statistics is called to contribute to progress towards sustainability by guaranteeing its own service, which consists in providing ever better evidence, to accompany every phase of the construction of sustainable development.

Istat, like the other National Statistical Institutes, is called by the United Nations Statistical Commission to play an active role of national coordination in the production of indicators for the measurement of sustainable development and the monitoring of its objectives. The 17 "Sustainable Development Goals (SDGs)" and the related 169 targets with which the three dimensions of sustainable development are declined, have extended the 2030 Agenda from the social pillar alone to the economic and environmental one, to these is added the institutional dimension. Every year Istat publishes the Report on the SDGs, the last update of the fourth Report dates to February 2022. The update summarizes 367 statistical measures (of which 338 are different) for 135 United Nations Inter Agency Expert Group (UN-IAEG) indicators, which constitute the global reference framework with the usual regional analysis, particularly useful for the observation of territorial imbalances. The Report offers a first representation of the impact of the pandemic on SDGs indicators. Below is a summary of the 17 objectives (Fig. 1).



Fig. 1. Sustainable Development Goals

Ending poverty, in all its manifestations including its most extreme forms, through interconnected strategies, is the theme of Goal 1. Providing people all over the world with the support they need, including through the promotion of social protection systems, is, in fact, the very essence of sustainable development.

The scientific research options have therefore been oriented towards a multidimensional approach, expanding the analysis to a wide range of indicators of living conditions and at the same time adopting tools that allow to adequately consider the complexities.

The objective of this work is the statistical analysis of the indicators useful for achieving the Goal 1 "*No Poverty*" goal through multidimensional statistical analysis methodologies (Totally fuzzy and relative) to understand which regions, at national level, need more government intervention.

2 Goal 1: No Poverty

Goal 1 "No Poverty" aims to end all forms of poverty in the world by 2030 [1]. Enabling people to lift them out of poverty require equal rights, access to economic and natural resources, technological resources, property, and basic services. It is also necessary to guarantee all the necessary aid to communities affected by climate-related disasters.

The statistical measures that populate this objective are twenty-one referring to eight UN-IAEG-SDGs indicators (Table 1).

Table 1. List of statistical measures disseminated by Istat, taxonomy with respect to the SDGs indicators relating to Goal 1 No poverty

1.1.1 Percentage of population below the international poverty line, by sex, age, employment status and geographical distribution
- Risk of poverty for those in employment (18 years and over) (Istat, 2019, percentage values)
1.2.1 Percentage of population living below the national poverty line, by sex and age
- Absolute poverty (incidence) (Istat, 2020, percentage values)
1.2.2 Percentage of men, women and children of all ages living in poverty (in all its dimensions) according to national definitions
- Risk of poverty or social exclusion (Istat, 2019, percentage values) - Severe material deprivation (Istat, 2019, percentage values) - Low work intensity (Istat, 2019, percentage values) - Risk of poverty (Istat, 2019, percentage values)
1.3.1 Percentage of population covered by social protection plans/systems by sex, distinguished between children, unemployed, elderly, persons with disabilities, pregnant women, infants, victims of accidents at work, poor and vulnerable
- Waiver of health services (Istat, 2020, percentage values)
1.4.1 Percentage of population/households with access to basic services

(*continued*)

Table 1. (*continued*)

- Overload of the cost of housing (Istat, 2019, percentage values) - Families very or quite satisfied with the continuity of the electricity service (Istat, 2020, percentage values) - People who cannot afford to adequately heat the house (Istat, 2019, percentage values) - Families who declare difficulties in connecting with public transport in the area in which they reside (Istat, 2020, percentage values) - Delivery of municipal waste to landfill (Ispra, 2019, percentage values) - Irregularities in water distribution (Istat, 2020, percentage values) - Households with fixed and/or mobile broadband connection (Istat, 2020, percentage values) - People aged 6 and over who use their mobile phones every day, per 100 people with the same characteristics (Istat, 2020, percentage values)
1.5.1 Number of deaths, missing and people affected by disasters per 100,000 people
- Number of deaths and people missing due to landslides (Ispra, 2018, N.) - Number of deaths and people missing due to floods/floods (Ispra, 2018, N.) - Number of injured by landslides (Ispra, 2018, N.) - Number of injuries from floods/floods (Ispra, 2018, N.)
1.a.1 Total Official Development Assistance (ODA) from all donors focusing on poverty reduction as a percentage of the beneficiary country's gross national income
- Official Development Assistance for Education, Health and Social Protection on bilateral ODA allocatable by sector (Ministry of Foreign Affairs and International Cooperation, 2019, percentage values)
1.a.2 Percentage of total government expenditure on essential services (education, health and social protection)
- Share of essential services (health, education and social protection) in general government expenditure (Istat, 2019, percentage values)

3 Methodological Frameworks

3.1 The Set of Indicators

For the purposes of this work, 11 indicators divided into 3 sets have been selected based on the following characterizations:

Set 1 - Indicators of economic poverty
Risk of poverty or social exclusion
Severe material deprivation
Low work intensity
Risk of poverty
Set 2 - Indicators related to the lack of basic services
Waiver of health benefits

(*continued*)

(*continued*)

Families who declare difficulties connecting with public transport in the area in which they reside
Landfilling of municipal waste
Set 3 - Indicators related to the lack of housing services
Overload of the cost of housing
Irregularities in water distribution
Families not satisfied with the continuity of the electricity service
Households without a fixed and/or mobile broadband connection

Let's now analyse in detail the values of the individual indicators detected in 2019 at national level and on the basis of the territorial distribution (Northeast, North West, Centre, South and Islands).

Regarding the first set relating to economic poverty, it should be noted that the indicator linked to the risk of poverty or social exclusion is a multidimensional indicator corresponding to the share of people who have at least one of the following situations:

1) people at risk of income poverty,
2) persons who are seriously materially deprived,
3) people living in families with a very low work intensity.

In 2019, 20.1% of people residing in Italy are at risk of poverty, 7.4% in conditions of severe material deprivation and 10.0% in low-work-intensive families.

The composite indicator built on these three components is equal to 25.6% (about 15 million and 390 thousand people), improving for the third consecutive year (27.3% in 2018, 28.9% in 2017, 30.0% in 2016).

The reduction is mainly attributable to the improvements marked by the indicator of low work intensity and that of severe material deprivation that have been significantly reduced in the last 3 years, while the risk of poverty is substantially stable in the three-year period 2016–2019.

At the level of territorial distribution, there is a clear difference between the Northern area (West and East) which has low levels of risk of poverty and social exclusion (respectively equal to 16.4 and 13.2%) and the South and the Islands with much higher values (respectively 41.6 and 43.6).

The same situation also occurs for the other indicators for which it emerges that the North and Central Italy have values below the average while the South values decidedly above the national average (Table 2).

Table 2. Set 1 indicators of economic poverty. Year 2019 (values%)

Division territorial	Risk of poverty or social exclusion	Severe material deprivation	Low work intensity	Risk of poverty
North West	16.4	4.1	6.0	12.4
Northeast	13.2	2.9	4.4	9.5
Center	21.4	5.5	7.6	15.3
South	41.6	12.7	14.8	33.7
Islands	43.6	15.4	22.8	36.8
Italy	**25.6**	**7.4**	**10.0**	**20.1**

Source: Istat. SDGs Report 2021. Statistical Information for the 2030 Agenda in Italy.

Regarding the lack of basic services, the spread of COVID-19 has had a significant impact on the lack of demand for health services. In 2019, 6.3% of people say they have given up a medical examination despite needing it, among them about half reported a problem related to COVID-19 as the cause. There are no major differences in territorial distribution.

Much higher is the percentage of families who declare difficulties in connecting with public transport in the area in which they reside which at national level is equal to 33.5% with peaks in the South equal to 42.3%. On the other hand, the territorial gap in the delivery of municipal waste to landfills is decidedly high, with values equal to 49.5% in the Islands, compared to a national average of 20.9% (Table 3).

Table 3. Set 2 indicators related to the lack of basic services. Year 2019 (values%)

Division territorial	Waiver of health benefits	Families who declare difficulties connecting with public transport in the area in which they reside	Landfilling of municipal waste
North west	5.4	31.1	10.1
Northeast	4.7	26.4	11.3
Center	6.9	33.1	29.3
South	7.3	42.3	22.4
Islands	8.0	36.3	49.5
Italy	**6.3**	**33.5**	**20.9**

Source: Istat. SDGs Report 2021. Statistical Information for the 2030 Agenda in Italy.

Regarding housing services at the national level, 8.7% of households in 2019 had an overload of the cost of housing, 8.6% irregularities in water distribution and 6.5% discontinuity of the electricity service. The percentage of households without a fixed

and/or mobile broadband connection is much higher (Table 4). At the level of territorial distribution, serious problems occur in the Islands about the overload of the cost of housing (14.8%) and the distribution of water (24%). The South also has values higher than the national average, while Central Italy has values above the average only regarding water distribution (9%) and continuity of electricity service (7.6%).

Table 4. Set 3 indicators related to the lack of housing services. Year 2019 (values%)

Division territorial	Overload of the cost of housing	Irregularities in water distribution	Families not satisfied with the continuity of the electricity service	Households without a fixed and/or mobile broadband connection
North west	8.4	3.0	6.5	25.3
Northeast	5.6	3.2	4.4	24.6
Center	6.8	9.0	7.6	22.3
South	10.3	12.9	8.1	29.7
Islands	14.8	24.0	9.9	30.1
Italy	**8.7**	**8.6**	**6.5**	**25.3**

Source: Istat. SDGs Report 2021. Statistical Information for the 2030 Agenda in Italy.

3.2 The Fuzzy Approach

The development of fuzzy theory initially stems from the work of Zadeh [2] and subsequently was conducted by Dubois and Prade [3]. The fuzzy theory develops starting from the assumption that each unit is not univocally associated with only one but simultaneously with all the categories identified based on links of different intensity (degrees of association).

The first measurement based on the fuzzy set theory, named TF (Totally Fuzzy), was suggested by Cerioli and Zani [4]. This logic can be applied to both continuous and ordinal variable cases. However, in the latter case, the maximum and minimum values can be determined by assuming the value of the lowest category as minimum and the highest as maximum.

Cheli and Lemmi [5] have proposed a generalization of this approach, called Totally Fuzzy and Relative (TFR). This method is also called "totally relative" because the value of the membership function is entirely determined by the relative position of the individual in the distribution of the population. The fuzzy TFR approach consists in defining the measurement of an individual's degree of belonging to the totality fuzzy, included in the interval between 0 (with an individual who does not demonstrate a clear belonging) and 1 (with an individual who demonstrates a clear belonging).

If we suppose to observe k indicators for each family, the function of belonging of the i-sima family to the blurred subset, can be defined as follows [4]:

$$f(x_{i.}) = \frac{\sum_{j=1}^{k} g(x_{ij}) \cdot w_j}{\sum_{j=1}^{k} w_j} \quad i = 1, \ldots, n \tag{1}$$

where $w_1,\ldots, w_k$ represent a generic system of weights. The $f(x_{i.})$ is in practice a global poverty index, while $g(x_{ij})$ measures the specific deprivation of the i-sima unit according to the j-th indicator. Following the Totally Blurred and Relative Approach (TFR) recently proposed by Cheli and Lemmi (1995), the function $g(x_{ij})$ is defined in terms of the partition function H (·) of the indicator X_j as follows:

$$g(x_{ij}) = \begin{cases} H(x_{ij}) & \text{if the risk of poverty increases with increasing of } x_j \\ 1 - H(x_{ij}) & \text{if the risk of poverty decreases with increasing of } x_j \end{cases}$$

The indices were chosen in order to identify different levels, related to the aspects of poverty [6, 7]. The indices were grouped into three sets characterized by different situations in the different components considered: economic poverty, lack of basic services, lack of housing-related services. The Total Fuzzy and Relative method was applied on the data of all the Italian regions obtaining a value of the individual w_i weights, which varies according to the level of importance in determining the degree of quality of the situation.

3.3 The Results of the Application of the Totally Fuzzy and Relative Approach

Once the sets of indicators were identified, the minimum, maximum and average values for each indicator of the different sets were detected (Table 5).

Table 5. Results of the application of the TFR method in relation to the distribution function and the weights of the various indices.

Indicators set	Indicators	Minimum	Maximum	Mean	Gmean	Weight w_j
Economic poverty	Risk of poverty or social exclusion	8.1	49.7	23.4	0.4	1.0
	Severe material deprivation	1.7	17.8	6.4	0.3	1.2
	Low work intensity	3.2	25.0	8.8	0.3	1.3
	Risk of poverty	6.1	41.4	17.9	0.4	0.9
Lack of basic services	Waiver of health benefits	3.2	11.7	6.4	0.5	0.7

(*continued*)

Table 5. (*continued*)

Indicators set	Indicators	Minimum	Maximum	Mean	Gmean	Weight w_j
	Families who declare difficulties connecting with public transport in the area in which they reside	13.3	55.9	30.8	0.6	0.5
	Landfilling of municipal waste	1.3	90.0	27.5	0.4	0.8
Lack of housing-related services	Overload of the cost of housing	3.7	16.7	7.5	0.4	1.0
	Irregularities in water distribution	1.4	31.2	8.5	0.4	1.0
	Families not satisfied with the continuity of the electricity service	2.1	11.7	6.2	0.5	0.7
	Households without a fixed and/or mobile broadband connection	18.8	33.3	25.5	0.6	0.6

Source: Our data processing Istat. Rapporto SDGs 2021.

For each set of indicators, the fuzzy value and its values attached to it have been calculated. Of particular interest is the analysis of w_i weights that indicate the relevance of the indicator on the considered set. As already specified, high values of this indicator denote a strongly discriminating condition in the determination of the result. In our case the values of the weights of the indicators relating to low work intensity ($w_i = 1.3$), and those relating to severe material deprivation ($w_i = 1.2$) are particularly discriminating.

In the third set relating to the lack of services related to housing, high values are found for overload of the cost of housing and irregularity in the distribution of water ($w_i = 1.0$). Conversely, the weights of the indicators relating to the difficulty of connecting with public transport in the area in which they reside (equal to $w_i = 0.5$) appear less discriminating.

As a result of the application, we have classified the Italian regions based on fuzzy values obtaining the classification illustrated in Table 6. Recall that high values are significant of regional situations of poverty, conversely low values are significant of situations of absence of difficulties.

Table 6. Composition in absolute values and percentages of regions by fuzzy class membership

Fuzzy value	Number of regions			%		
	Economic poverty	Lack of basic services	Lack of housing-related services	Economic poverty	Lack of basic services	Lack of housing-related services
0,0 ⊣ 0,2	10	3	4	50	15	20
0,2 ⊣ 0,4	2	4	5	10	20	25
0,4 ⊣ 0,6	2	2	4	10	10	20
0,6 ⊣ 0,8	3	6	5	15	30	25
0,8 ⊣ 1,0	3	5	2	15	25	10
Total	**20**	**20**	**20**	**100**	**100**	**100**

Source: Our data processing Istat. Rapporto SDGs 2021.

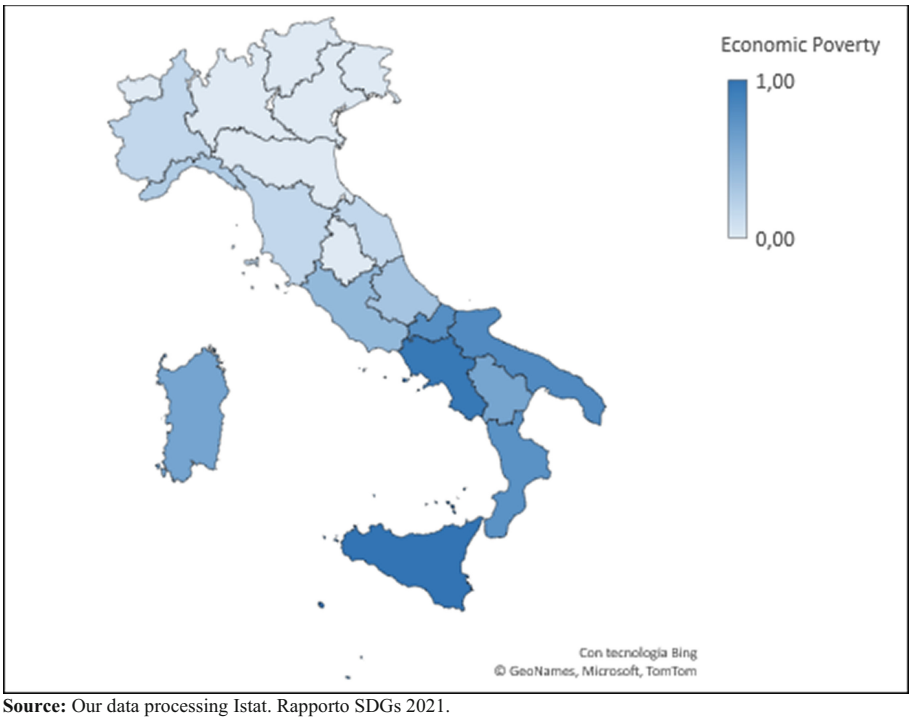
In particular, the percentage of regions with a high shortage of basic services (between 0.8 and 1) is higher (25%) than that which has a strong shortage of housing services (10%).

The same applies to regions with a high shortage of basic services (between 0.6% and 0.8) with a percentage of regions equal to 30% compared to 15% for regions with a high level of economic poverty.

4 Spatial Distribution of Fuzzy Values

In this paper, the representation of the values attributed to the individual geographic areas, corresponding to the regions, occurs through cartograms, associated with "natural" interval classes, defined within the distribution. By applying the *Total Fuzzy and Relative* method on the data of all Italian regions, as described in the previous section, three synthetic indices were obtained that describe the territorial distribution of the indicators.

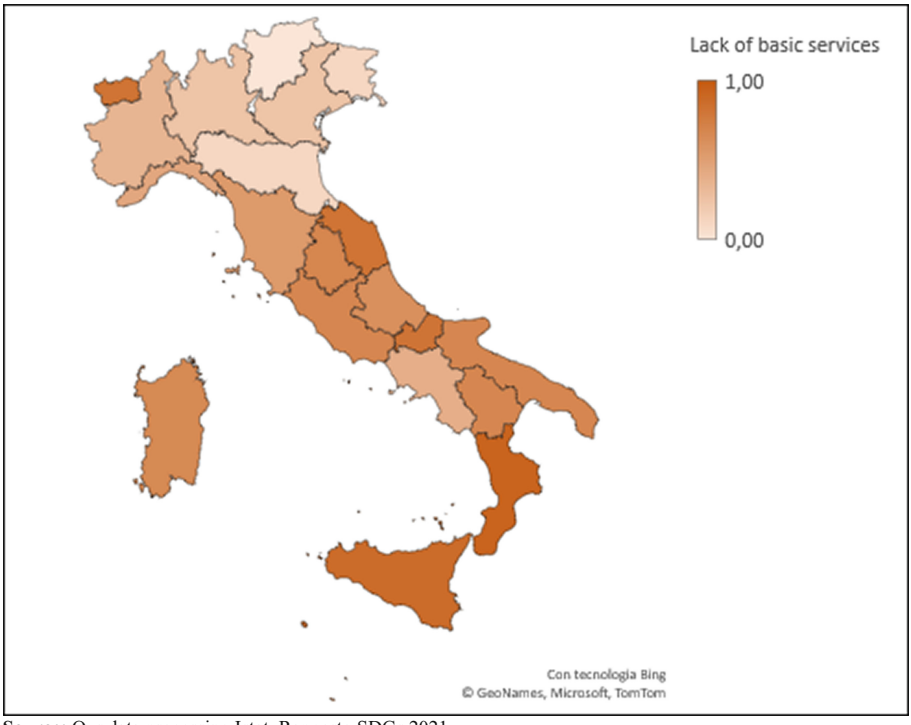
Regarding the set of indicators related to *economic poverty*, individuals with severe difficulties live mainly in the southern regions, Sicily, Campania and Puglia and have values between 1.0 and 0.8, followed by Molise, Calabria and Sardinia with values between 0.8 and 0.6. Economic poverty has average indicators between 0.6 and 0.4 in the Regions of Basilicata and Lazio and lows between 0.4 and 0.2 in Abruzzo and Liguria. The individuals who show less difficulty live in the other 10 regions all located in the Centre-North, as shown in Fig. 2.



Source: Our data processing Istat. Rapporto SDGs 2021.

Fig. 2. Spatial distribution economic poverty fuzzy value

Regarding the second set of indicators summarized as *a lack of basic services*, the territorial analysis by regions shown in Fig. 3 is particularly interesting. The regions in conditions of great difficulty with values between 1.0 and 0.8 are Calabria, Sicily, Valle d'Aosta, Marche, and Molise. The presence of Valle d'Aosta in this first group lies in the high value of the indicator that measures families who have had to give up health services. It is important to underline, however, that many have said that they have given up for reasons related to COVID-19, fear on the part of the population of contracting infections, closure of many outpatient facilities and suspension of the provision of postponable health services. Values between 0.8 and 0.6 are found in the regions of Umbria, Puglia, Basilicata, Lazio, Sardinia and Abruzzo, followed by the regions of Tuscany and Liguria with values between averages between 0.6 and 0.4. We find with values between 0.4 and 0.2 regions such as Campania, Piedmont, Lombardy and Veneto. We point out in the last group Friuli-Venezia-Giulia, Emilia-Romagna and Trentino-Alto-Adige regions where there are no complaints about shortages of basic services.

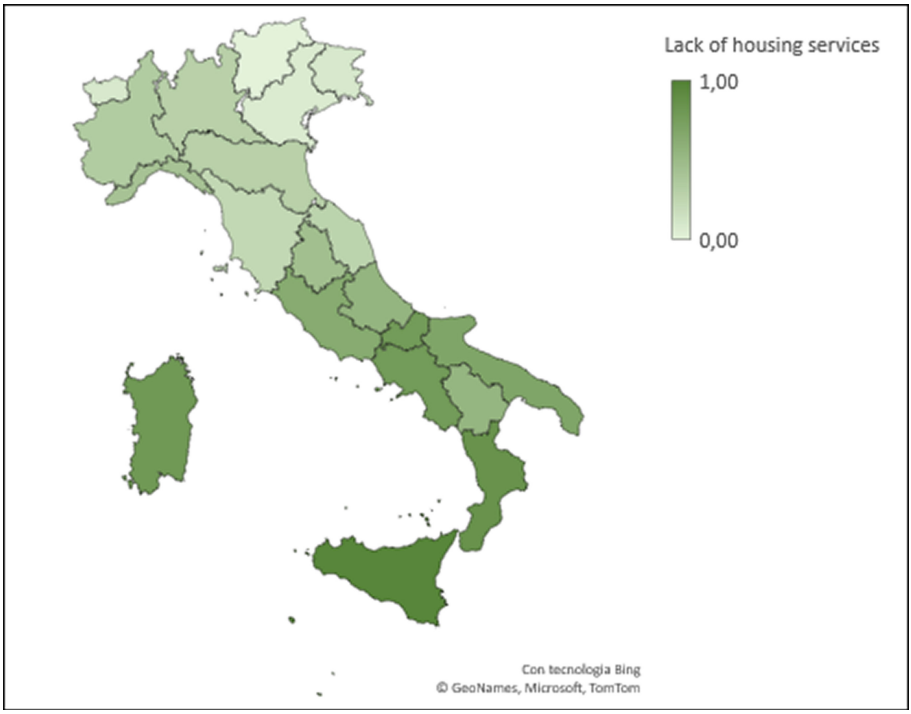


Source: Our data processing Istat. Rapporto SDGs 2021.

Fig. 3. Spatial distribution shortage of basic services fuzzy values

Finally, about the third set of indicators, summarized **in the lack of services related to housing**, we observe in Fig. 4 that the 2 regions with situations considered problematic by families are Sicily and Calabria with values between 1.0 and 0.8. With values between 0.8 and 0.6, there are regions such as Sardinia, Molise, Campania, Puglia and Lazio with always complex situations, but considered less problematic. Followed by 4 other regions, Abruzzo, Basilicata, Umbria and Liguria, with values ranging from 0.6 to 0.4. Lower shortage of housing-related services is highlighted by those who live in the regions of Piedmont, Lombardy, Emilia-Romagna, Marche and Tuscany, with values between 0.4 and 0.2. Almost no shortage is detected by the inhabitants in the regions of Valle d'Aosta, Friuli-Venezia Giulia, Veneto and Trentino-Alto Adige.

The overall analysis of the 3 sets of indicators reveals an overall interesting situation, where territorial differences are evident. The only aspect to highlight is the presence of the Trentino-Alto Adige and Friuli-Venezia Giulia regions in the lowest class, between 0 and 0.2, for all 3 sets of indicators analyzed.



Source: Our data processing Istat. Rapporto SDGs 2021.

Fig. 4. Spatial distribution shortage of services related to housing fuzzy values

5 Conclusions

The profound economic and social transformations that have taken place in recent years place the problem of poverty at the centre of a broad scientific debate. Poverty connotes a discomfort that does not necessarily end in the lack of monetary resources, but that involves a plurality of dimensions of a social and cultural nature such as education, health, housing and is concretized as a lack of equitable access to a plurality of essential goods and services.

Both in the academic literature and in international scientific reports, however, the multidimensional nature of poverty is emphasized, which entails the need to no longer resort to a single indicator but to a group of indicators, useful for better delineating the living conditions of the different subjects.

A first emerging idea from the present work is related to the ability to describe territorial phenomena through an integrated model, which starts from the construction of socio-economic indicators, of a multidimensional nature, and then adopts models capable of identifying areas at risk of discomfort. To enable people to lift them out of poverty, it is necessary to guarantee equal rights, to have access to economic and natural resources, technological resources, property and basic services.

The Sustainable Development Goals refer to different domains of development related to environmental, social, economic and institutional issues that go well with the Missions envisaged by the National Recovery and Resilience Plan (PNRR).

The Italian National Recovery and Resilience Plan (PNRR) is part of the Next Generation EU (NGEU) program, the 750-billion-euro package, consisting of about half of grants, agreed by the European Union in response to the pandemic crisis.

The main component of the NGEU programme is the Recovery and Resilience Facility (RRF), which has a duration of six years, from 2021 to 2026, and a total size of €672.5 billion (€312.5 billion grants, the remaining €360 billion loans at subsidised rates).

From the analysis of the data relating to the sets of indicators of Goal 1 it emerges that Italy has strong territorial gaps, with significant shortcomings in basic and housing services in the South and in the Islands. Among the objectives of the PNRR we find the need to repair the economic and social damage of the pandemic crisis and contribute to addressing the structural weaknesses of the Italian economy and the territorial gaps. This implies the need for increased targeted economic commitment to support regional policies.

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