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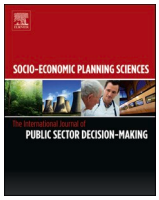

Adopting the fuzzy approach to analyze food poverty in Italy: A study on vulnerable households using household budget survey data

Ilaria Benedetti, Federico Crescenzi *, Tiziana Laureti, Luca Secondi

Department of Economics, Engineering, Society and Business Organization, University of Tuscia, Via Del Paradiso, 47, 01100, Viterbo, Italy

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ABSTRACT

Besides international efforts to address poverty and hunger, there are still many disparities among households, therefore innovative approaches and techniques are required to address the multiple facets of poverty, especially food poverty.

Given the complexity in defining this phenomenon, the fuzzy approach based on an expenditure-related metric is adopted as it provides valuable insights into the Italian food poverty situation thus improving the results generally provided using by the classical binary (or crisp) set theory.

By considering the equivalised household food expenditure obtained from the 2021 Italian Household Budget Survey data, the fuzzy set approach is used to measure food poverty paying particular attention to vulnerable households at a detailed territorial level. The results show that food poverty is lower in the Northern-Central regions than in Southern Italy and highlight the vulnerability of families with children and single-parent households.

1. Introduction

The concept of food security is defined as "a situation that exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life". Therefore, as it affects a significant proportion of the world's population, addressing it is a major global challenge [1]. The United Nations (UN) estimates indicate that approximately 2.3 billion people worldwide lacked adequate access to nutritious food in 2020 [2].

The 2008 global economic crisis significantly affected food security in developed countries thus increasing food insufficiency and reliance on food aid organisations [3,4]. Furthermore, the Covid-19 pandemic, the economic turmoil and the ongoing Russia-Ukraine war have exacerbated the global food security crisis thus leading to a rapid escalation in food prices [5]. As low-income households tend to spend a greater proportion of their income on food, high food prices could mean that the poorer the households, the more likely they are to be at risk of food poverty.

The issue of food poverty in developed countries has attracted much attention in recent decades, as it can endanger public health and social well-being [6]. Although food poverty and food insecurity may appear to refer exclusively to developing countries, they are now becoming more and more common in developed countries as well [7,8] and are driven by factors such as economic inequality, low household income [9] and in some cases the presence of food deserts [10]. Through their economic, social and food policies, governments establish the overall conditions for their citizens to access adequate food and to obtain the required incomes to purchase it [11].

Despite the implementation of various strategies to alleviate food poverty and numerous measures and indicators to describe its complex nature, inequalities remain across and within countries thus highlighting the need of novel approaches to solve the emerging issues [12].

At European level, in 2022 the statistical office of the European Union (Eurostat) estimated that approximately 8.3% of the EU population was unable to afford and consume a meal containing meat, fish or a vegetarian alternative every two days, with an increase equal to one percentage point compared to 2021 (Eurostat, 2023a).

In Italy poverty affects a considerable portion of the population and according to data provided by the Italian National Institute of Statistics (ISTAT), in 2021 approximately 2.6 million households (10.1% of the population) were living in relative poverty (ISTAT, 2023), which seriously affected households with children, single-parent families (15.7%) and those residing in the Southern regions and Italian islands.

* Corresponding author.
E-mail addresses: i.benedetti@unitus.it (I. Benedetti), federico.crescenzi@unitus.it (F. Crescenzi), laureti@unitus.it (T. Laureti), secondi@unitus.it (L. Secondi).

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Furthermore, 4.5% of Italian households experienced severe material deprivation, as they could not afford essential foods such as meat, chicken, fish or vegetarian equivalents every two days.

Bearing the above issues in mind, it is essential to conduct studies aimed at measuring food poverty for Italian households, by focusing specifically on sub-national territorial levels and considering various household types.

In Italy very few studies have been conducted on food poverty issues. To the best of our knowledge, Campiglio and Rovati [13] carried out the first quantitative and qualitative survey on food poverty in Italy, referring to official statistical information and data provided by the 8000 non-profit organisations belonging to the *Banco Alimentare* network which regularly provide food aid to almost one and a half million people. More recently, Marchetti and Secondi [14] proposed a consumption-based analytical approach using HBS data to estimate the At-Risk-of-Food-Poverty (AROFP) rate and food insecurity index at sub-national levels and to study the inequalities between poor and non-poor households.[1]

In this context, the aim of this paper is to contribute to current literature by proposing a fuzzy approach as a novel methodology to analyze food poverty in Italy at regional level and at detailed sub-domains. The approach adopted is not related exclusively to the usual dichotomy between poor and non-poor but considers the state of deprivation as a continuum, represented by fuzzy sets [15], to which all members of the population belong, but to different extents, i.e. by the grade of membership.

It is important to note that this is the first time the fuzzy approach has been applied to assess food poverty. Compared to a binary condition [16], the main advantage of using the fuzzy approach is that it offers a nuanced understanding of poverty and combines the principles of fuzzy logic and relative measures [17]. Originally introduced by Cerioli and Zani [18] and further discussed by other academics (e.g. Refs. [19,20]), this method, enables the introduction of uncertainties in the analysis thus providing a more realistic picture of poverty than traditional binary classifications.

From an applied economic perspective, our paper is an in-depth analysis of food poverty at the sub-domain level. More specifically, it highlights the disparities in food poverty across specific households taking into consideration the region (NUTS2 territorial units) where they reside which is a planned domain of the Italian HBS. Furthermore, the various types of households, such as single-parent households or families with children, were considered to gain a better understanding of poverty issues within the broader socio-economic framework. Applying the fuzzy methodology using detailed household data provides valuable insights into the incidence of food poverty among different demographic groups and geographic areas in Italy.

By using the 2021 Italian HBS microdata, the effectiveness of using the fuzzy approach to capture the complexities of food poverty dynamics and informing evidence-based policy interventions is clearly illustrated and can offer policy makers insights when implementing evidence-based interventions.

The remainder of the paper is structured as follows. Section 2 presents the framework of the analyses, highlighting the state of the art, the existing approaches to measure food poverty and the need of further research. Section 3 describes the method used while, Section 4 illustrates the main aspects of the Italian HBS and the data used to measure food poverty. Section 5 presents the results obtained using both the binary and the fuzzy approach. Section 6 provides a discussion of the findings, compares the results and the various potential applications of the proposed approach for policy planning. In Section 7 some conclusions are drawn.

[1] Similarly to the concept of the At-Risk-of-Poverty used to measure relative poverty in the European Union [59], the AROFP rate is based on specific food poverty lines established at a national level.

2. The framework of the analysis

While the concept of food (in)security is clearly defined in literature (e.g. Refs. [1,2]), little is known regarding the concept of food poverty since it is sometimes confused with food insecurity [21].

In developed countries, economic access to food, which is linked to income levels, expenditure and market price trends, is particularly relevant. According to Campiglio and Rovati [13], the paradox of "scarcity in abundance" takes on a specific connotation in the case of food insecurity and poverty, which are significantly widespread in most developed countries where a percentage of the population facing food shortages coexists with food waste [22], overproduction and abundant food availability [23]. Therefore, it is essential to address economic disparities in order to reduce food insecurity and improve the economic dimension of food poverty since food consumption plays a pivotal role in well-being and socio-economic development [24,25].

According to the 2021 estimates published by Eurostat [26], "Food and non-alcoholic beverages" represent the second-largest household expenditure category across Member States, equal to approximately 14.3% of total household expenditure. However, considerable heterogeneity is observed across European countries, with the highest shares registered in Romania (24.8%), Lithuania (20.4%), Bulgaria (20.1%) and Estonia (19.9%). Contrastingly, the lowest shares were observed in Ireland (8.3%), Luxembourg (9.0%) and Austria (10.9%). A recent empirical analysis based on European household survey microdata shows that expenditure on food covers most of total budget of poorer households, with lower-income households allocating over 30% of their budget to food compared to less than 15% for higher-income households [27]. This result indicates that food is a considerable financial burden for households, and particularly affects lower income families, thus emphasizing the importance of addressing economic disparities in order to alleviate food poverty and improve overall well-being for all citizens.

Prior to the turn of the Millennium, the methodology most commonly used in developed countries to assess food poverty was based on macro-economic indicators, including Gross Domestic Product (GDP) or other measures obtained from national accounts. Over the past decade, several new indicators have been developed to measure food poverty that account for the effects of specific variables, including income-related metrics such as budget shares that decrease as income increases, as well as nutritional indicators, for example the percentage of undernourished children. Other complex measures have been developed to take into account the multifaceted dimensions of food poverty, including the Global Food Security Index, the World Hunger Index, the Multidimensional Poverty Index [21]. More specifically, the indicators concerning the economic accessibility to food or economic vulnerability [28] based on household income or food expenditure, offer valuable insights into the economic and social factors that contribute to food poverty and related insecurity within a population.

According to Engel's law which states that an increase in the income of a family decreases the proportion of the income spent on food, even though the total amount of food expenditure is increasing, the share of food expenditure is seen as an important indicator of economic well-being and household food security [29].

To the best of our knowledge, the most recent Italian analytical study focusing on economic access to food and food poverty was carried out by Marchetti and Secondi [14] using data from the HBS and providing estimates at NUTS3 levels for the 107 Italian provinces. On observing the distribution of the estimated AROFP among the regions, the authors found that food poverty appears to be widespread among Italian regions and is not only concentrated in the Southern regions as could be expected considering the existing North–South divide in Italy. Moreover, by exploring the empirical distributions of the equivalent expenditure on food for 11 food categories, the highest level of inequalities between poor and non-poor households were found to be for vegetables, meat and fish expenditure. In addition to the methodological aspects, some researchers have focused on socio-cultural factors influencing families in

food poverty.

Brannen and O'Connell [30] draws on a comparative study that examined food poverty in low-income families with children aged 11–15 years in the UK, Portugal and Norway following the 2008 financial crisis. It demonstrates how a multi-tiered research design facilitates the analysis of the complex conditions in which undocumented migrant parents sought to sustain and feed their families and how food and food poverty were experienced by these children and their parents.

The ongoing conflict between Russia and Ukraine raises important issues related to food and food security in Europe, particularly in terms of food access and agricultural commodity prices [31].

Low-income households in densely populated areas, which represent a vulnerable category face greater challenges due to rising food prices, leading to increased consumer food deprivation [32]. In this perspective, it is essential to note that food poverty is a multifaceted issue influenced by a range of socio-economic factors, including education, gender, age and household composition [33]. Moreover, women appear to be particularly vulnerable to food poverty, since it is influenced by education levels and household composition to a certain extent [11].

In Italy, poverty affects a large proportion of the population. The ISTAT poverty report, highlights that in 2022 the disparities in poverty were exacerbated in households with children for whom poverty rates appeared to increase according to the number of children in the household. Furthermore, the phenomenon is affected by several additional factors, including regional location, family structure and primary income sources.

Families with children and teenagers under 16 years old living in Southern regions are more disadvantaged and have a relative poverty rate equal to 19.3% compared to 6% in the Central and North-Eastern Italy and 5.4% in the North-West. Furthermore, single-parent households have a higher relative poverty rate equal to 15.7% compared to 5.5% for couples without children.

In view of the aforementioned considerations, it is essential to carry out a comprehensive analysis into the food poverty phenomenon in Italy taking into account the diverse family structures and regional peculiarities in order to develop tailor-made policies and interventions.

3. Towards a fuzzy measure of food poverty

This section begins with the introduction of the definition of the at-risk-of-food-poverty threshold proposed by Marchetti and Secondi [14]. The definition of a poverty line (or a poverty threshold) is in fact of paramount importance in the development of the fuzzy measure of poverty that will follow afterwards.

A food (relative) poverty line is defined as a food expenditure threshold below which a household is considered to be at risk of food poverty. This poverty line is estimated as

$$\hat{\tau} = 0.6 \times \widehat{Me}(\tilde{y}_i, i = 1, \ldots, n) \tag{1}$$

where $\tilde{y}_i, i = 1, \ldots n$ represents the equivalised household food expenditure, and $\widehat{Me}(u_i, i = 1, \ldots, n)$ is an estimator of the median based on the empirical cumulative distribution function.

The proportion of household at-risk-of-food-poverty is then estimated as

$$AROFP = \frac{\sum_i w_i I(\tilde{y}_i < \hat{\tau})}{\sum_i w_i} \tag{2}$$

Where w_i is the sampling weight of unit i, and $I(u < x)$ is equal to 1 if $u < x$ and 0 otherwise. For the calculation of the equivalised food expenditure, we used the Carbonaro equivalence scale [34] while [14] used the square root scale [35].

From this point onwards, let $\mathscr{A}$ be the set of food-poor households. It is evident that households are binary classified to be poor or not poor - equivalently assigned or not assigned to the set $\mathscr{A}$ - according to the rule in the numerator of Equation 2. In fuzzy logic, the statement: a is a member of $\mathscr{A}$, is not necessarily true or false, instead, a belongs to $\mathscr{A}$ according to a certain degree in the unit interval $[0,1]$. Consequently, in a population U of N individuals, each element of the population has a degree of belonging to the set of people $\mathscr{A}$ who are deprived with respect to a generic poverty predicate. The function that assigns to each element of the population its membership degree to $\mathscr{A}$ is called membership function. When the degree of membership is equal to zero, the unit does not belong at all to the set, while it fully belongs to the set when the value of the membership function is equal to 1. It is noteworthy that the fuzzy approach represents a generalisation of the binary approach, provided that we consider a membership function $\mu(\tilde{y}_i) = 1$ if $\tilde{y}_i < \tau$ and 0 otherwise.

Among the various membership functions have been proposed in literature (see Ref. [36], or [37] and references therein for a good review of the existing functions) in this paper we consider the membership function introduced by Betti et al. [19], given by

$$\begin{aligned}\mu(y_i) &= (1 - F_Y(y_i))^{\alpha-1}(1 - L_Y(y_i)) = \\ &= \left(\frac{\sum_{j=i+1}^{n-1} w_j \middle| y_j > y_i}{\sum_{j=2}^{n-1} w_j \middle| y_j > y_1}\right)^{\alpha-1} \left(\frac{\sum_{j=i+1}^{n-1} w_j y_j \middle| y_j > y_i}{\sum_{j=2}^{n-1} w_j y_j \middle| y_j > y_1}\right)\end{aligned} \tag{3}$$

where F_Y is the empirical cumulative distribution function of Y, L_Y is the Lorenz curve, and w_i is the sampling weight of household i. The rationale for this choice of membership function can be explained by its definition in terms of the empirical cumulative density of the equivalised food expenditure and the Lorenz curve. Indeed, the majority of fuzzy membership functions proposed in the literature do not include a mathematical formulation that considers statistical functionals or economic functions (see Ref. [37]). Moreover, the parameter $\alpha \geq 2$ controls the steepness of the function and can be set iteratively so that the average of μ equals an official measure of deprivation such as the Head Count Ratio ([37]), or in this study the value obtained from Equation 2. Although it is certainly of interest to study the entire membership function, it is often more interesting to study the average of the function at different sub-domains (i.e. geographical domains, sub-populations, etc …). In this case, an estimate can be easily obtained as a weighted average of the membership values of the households in each domain.

In addition, the variance of the expected value of μ can be estimated by means of Jackknife Repeated Replications [38]. Let est be a full-sample estimate of any complexity. We use the subscript m to indicate a sample PSU and l to indicate its stratum; $a_l \geq 2$ is the number of PSUs in stratum l. Let $est_{(lm)}$ be the estimate produced using the same procedure after eliminating primary unit i in stratum h and increasing the weight of the remaining $(a_l - 1)$ units in the stratum by an appropriate factor g_l. Let $est_{(l)}$ be the simple average of the $est_{(lm)}$ over the a_l sample units in l. The variance of est is then estimated as:

$$var(est) = \sum_l \left[(1 - f_l) \times \sum_m g_{(lm)} \left(est_{(lm)} - est_{(l)}\right)^2\right]$$

where $(1 - f_l)$ is the finite population correction, and it is usually ~ 1 for samples in typical social surveys. While it is possible to consider $g_{(lm)}$ to be independent from a particular m in a given stratum l, so that:

$$g_{(lm)} = \frac{a_l}{(a_l - 1)}$$

it is more appropriate to use [38].

$$g_{(lm)} = w_l \Big/ (w_l - w_{lm})$$

where $w_l = \sum_m w_{lm}$, with $w_{lm} = \sum_m w_{lmi}$ as the sum of sample weights of ultimate units i in primary selection units m. This means that in each replicate (lm) the weights for individual units are redefined and re-scaled as follows:

- for unit i not in stratum l: $w'_{lmi} = w_{lmi}$;
- for unit i in stratum l but not in PSU m: $w'_{lmi} = g_{(lm)} \times w'_{lmi}$;
- for unit i in stratum l and in PSU m: $w'_{lmi} = 0$.

Where $g_{(lm)}$ acts as a correction factor for unequal probabilities, reducing the contribution of observations which have higher (first-order) selection probabilities in the sample, and thus make smaller contributions to the variance. The inverse of this correction to selection probability is the corresponding correction to weight (g_{lm}).

4. Data

In accordance with [39–41], we employed consumption expenditure data collected through HBS to measure food poverty, as they can provide a more accurate description of household material living conditions compared to income measures. Consequently, the HBS conducted by ISTAT serves as the primary data source, providing comprehensive insights into consumption expenditure patterns of households residing in Italy. It assesses changes in the level and composition of household consumption expenditure based on their primary social, economic, and territorial characteristics. Moreover, it is used for official estimates of relative and absolute poverty in Italy [42], as well as the measurement of inflation across household expenditure categories. In accordance with Eurostat guidelines, the survey employs the harmonised international classification of expenditure categories (Classification of Individual Consumption by Purpose – COICOP) to ensure comparability with international standards. The sampling design is a two-stage process, with municipalities and households selected in the first stage. Municipalities are stratified within each geographical region (planned domain) based on two variables: municipal type and demographic size. A sample of households is drawn from each sampled municipality, constituting the final sampling units, with a total of 32,500 families sampled each year. In this study, we used the microdata file for public use available on the ISTAT webpage.

The main variable of interest for our analysis refers to monthly household expenditure for “Food and non-alcoholic beverages”, which constitutes division 01 (variable: d_01). This variable includes monthly expenditures on the following 11 classes: (i) Bread and cereals; (ii) Meat; (iii) Fish and seafood; (iv) Milk, cheese and eggs; (v) Oils and fats; (vi) Fruit; (vii) Vegetables; (viii) Sugar, jam, honey, chocolate and confectionery; (ix) Food products not elsewhere classified (n.e.c.); (x) Coffee, tea and cocoa; (xi) Mineral waters, soft drinks, fruit and vegetable juices.

In order to accurately account for variations in food poverty according to household size, we employed the Carbonaro equivalence scale [34], which is utilized by ISTAT for producing official estimates. This scale is particularly suited to the analysis of large households and the expenditure patterns of individuals who are likely to allocate a significant proportion of their total expenditure on food.

Another crucial aspect of our analysis is the examination of household composition and geographical analysis in order to accurately assess food poverty among vulnerable population groups.

In light of this, we developed and renamed certain socioeconomic and demographic variables. In particular, we created a novel variable for household composition by integrating multiple variables from the dataset. The total number of household members, their relationship with the reference person (spouse/partner/cohabitant with the reference person, child, or other), and their age (categorized as: 0–17, 18–34, 35–64, and over 64) were recorded. Consequently, the following family typologies have been created: individuals aged over 64 who live alone, individuals aged under 64 who live alone, and single parents with children. The following typologies have been created: elderly people living alone (individuals aged over 64 whose household consists of a single person), people under 65 years old living alone (individuals aged under 64 whose household consists of a single person), single parents with children (families with a single adult and at least one minor child), couples with children (households composed of two adults and at least one minor child), couples without children (households composed of two adults with no minor children), households without children (households with more than two adults but no minor children). Finally, the variable region has been taken into account to evaluate differences in food poverty across the Italian territory.

5. Results

5.1. Distribution of food expenditure and AROFP at regional level and for vulnerable households

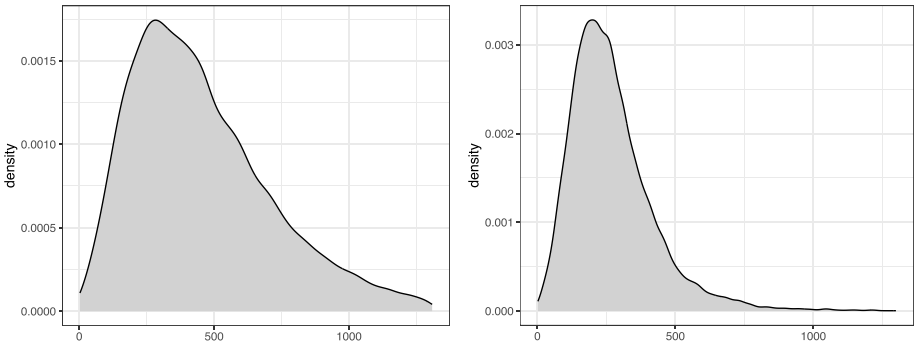
This section presents the estimated density of the monthly expenditure function at the national level, equivalised food expenditure and the estimated proportion of AROFP households for each region and for vulnerable households. The adopted approach is in line with the traditional poverty approach, based on the relative monetary poverty line defined as 60% of the median equivalised food expenditure. Fig. 1 illustrates the estimated density of the monthly expenditure function for Italian households. It should be noted that 276 households (approximately 1% of the sample) have zero food expenditure per month. The presence of households reporting zero food expenditure is a common issue in food expenditure surveys. In some cases, households may consume foods from their own production or gathered foods, receive foods in kind, or consume foods outside the home [43]. In these circumstances, the reported zero expenditure may be considered a potential source of bias. Consequently, we decided to not consider those households from the analysis and to investigate this issue in further analyses.

Moreover, to assess the presence of potential outliers on the tails of the distribution, we adopted the modified Z-Scores criteria, in which the median of the absolute deviation (MAD) is employed instead of the mean and standard deviation of the sample, respectively. Therefore, each household is assigned a value of $M_i = 0.6745 \times (y_i - \tilde{y})/MAD$, where $\tilde{y}$ denotes the median of the sample. According to Iglewicz and Hoaglin [44] observations are labeled as outliers when $|M_i| > 3.5$. This procedure detected 736 outliers leaving us with a total of 27,569 households.

At the national level, the estimated equivalized expenditure on food ranges from a minimum of 1.66 euros to a maximum of 1299.36 euros, with a median level of expenditure approximately equal to 243.63 euros (average 270.48 euros and standard deviation of 243.63 euros). Furthermore, the majority of households (75%) spend less than 340.31 euros, while the remaining 25% spend less than 166.43 euros. These figures vary considerably across Italian regions and household types, as illustrated in Tables 1 and 3, respectively.

Fig. 2 shows the estimated density functions for Italian regions (left panel) and household types (right panel), along with the estimated national food poverty line (141.83 euros). It is evident that the distribution of food expenditure in Sardegna exhibits a higher peak compared to other regions, whereas households from Molise display a flatter distribution with a heavier tail. A comparison of the estimated density functions for household types reveals that food expenditure distributions in single-parent households are more concentrated than in other household types. Conversely, individuals aged under 65 living alone exhibit a flatter density function in comparison to other household types.

A regional analysis of food expenditure is presented in Table 1, which



(a) Monthly household food expenditure *(b) Equivalent monthly household food expenditure*

Fig. 1. Food expenditure distribution.

Table 1
Equivalent food expenditure in Italian regions.

Region	N	Min.	Pctl.25	Mean	Median	Pctl.75	Max.	Std.Dev	CV (%)
Abruzzo	846	5.73	157.06	264.25	235.53	333.19	1202.91	159.07	60.20
Basilicata	610	19.31	169.66	268.75	241.68	332.73	1046.40	145.05	53.97
Calabria	912	2.60	155.81	287.61	239.01	351.59	1266.80	203.33	70.70
Campania	1854	7.57	167.40	275.67	242.67	348.83	1230.48	160.70	58.29
Emilia-Romagna	1924	5.32	176.14	268.92	246.16	335.33	1293.62	143.14	53.23
Friuli-Venezia Giulia	699	15.32	187.69	286.08	260.53	352.14	1211.62	152.88	53.44
Lazio	2370	1.66	164.19	274.01	241.55	346.99	1295.91	158.76	57.94
Liguria	800	5.45	175.39	289.11	253.25	362.69	1001.56	166.27	57.51
Lombardia	3768	2.47	172.08	277.95	249.51	353.99	1226.49	155.87	56.08
Marche	968	3.69	176.09	266.15	247.54	327.09	1063.68	133.13	50.02
Molise	632	8.68	137.39	253.57	214.62	315.08	1160.07	174.34	68.76
Piemonte	1753	12.49	176.76	283.58	259.72	361.13	1216.05	152.45	53.76
Puglia	1354	5.07	134.52	217.90	193.74	269.64	1084.05	124.47	57.12
Sardegna	623	11.87	138.35	229.96	210.06	293.93	994.50	132.34	57.55
Sicilia	1862	5.70	181.02	276.13	257.14	340.20	1145.42	140.50	50.88
Toscana	2167	3.02	166.34	273.24	245.88	342.83	1192.71	150.00	54.90
Trentino-Alto Adige	1188	5.32	169.22	268.73	248.78	345.95	1140.40	144.05	53.60
Umbria	827	7.06	163.91	272.37	253.58	347.44	985.69	149.35	54.83
Valle d'Aosta	501	17.54	178.48	293.23	264.30	369.68	1156.55	160.78	54.83
Veneto	1911	3.53	168.02	261.42	241.20	322.96	1299.36	135.68	51.90

Table 2
Estimated at-risk-of-food-poverty rate.

Region	AROFP	Std.Dev	CV (%)	Confidence Interval
Abruzzo	0.240	0.014	5.841	[0.216; 0.269]
Basilicata	0.184	0.021	11.162	[0.152; 0.229]
Calabria	0.228	0.016	7.073	[0.182; 0.26]
Campania	0.197	0.011	5.681	[0.176; 0.218]
Emilia-Romagna	0.164	0.012	7.054	[0.138; 0.197]
Friuli-Venezia Giulia	0.160	0.017	10.341	[0.132; 0.21]
Lazio	0.185	0.007	3.775	[0.167; 0.201]
Liguria	0.164	0.014	8.706	[0.135; 0.2]
Lombardia	0.184	0.007	3.803	[0.167; 0.198]
Marche	0.165	0.014	8.341	[0.134; 0.192]
Molise	0.274	0.018	6.437	[0.222; 0.306]
Piemonte	0.158	0.008	5.228	[0.142; 0.172]
Puglia	0.295	0.013	4.478	[0.267; 0.325]
Sardegna	0.280	0.019	6.653	[0.236; 0.314]
Sicilia	0.159	0.009	5.957	[0.138; 0.179]
Toscana	0.176	0.010	5.880	[0.159; 0.197]
Trentino-Alto Adige	0.175	0.011	6.366	[0.142; 0.194]
Umbria	0.188	0.015	8.106	[0.159; 0.219]
Valle d'Aosta	0.151	0.017	11.321	[0.119; 0.194]
Veneto	0.176	0.010	5.793	[0.154; 0.199]

displays summary statistics for equivalent expenditure among Italian regions. The estimated mean of monthly regional food expenditure ranges from approximately 200 Euros observed in Puglia up to 290 Euros for Valle d'Aosta. Calabria is the region for which we observed the highest level of variability (CV equal to 70.70%), followed by Molise (68.76%) and Sardegna (57.55%).

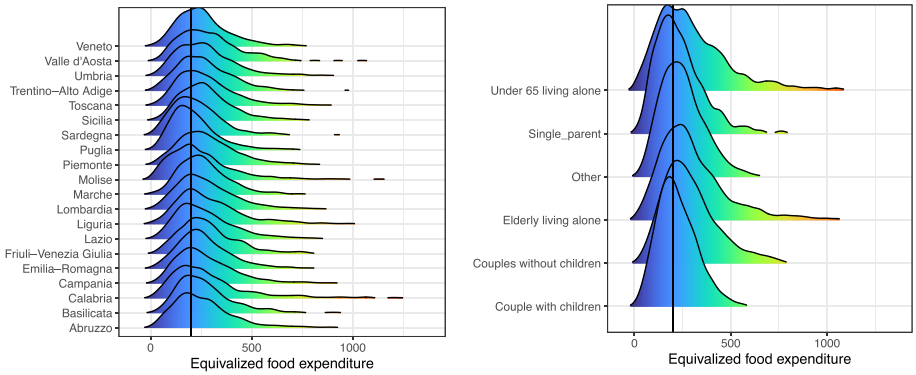
The estimated AROFP rate for each region is reported in Table 2. At the national level, the estimated AROFP rate amounts to 18.92% (standard error 0.28 euros), while it ranges between 0.151 (Valle d'Aosta) and 0.295 (Puglia) which is a very high regional value significantly different from the others. Valle d'Aosta is also the region for which we observe the highest level of variability (CV equal to 11.54%) followed by Liguria (11.13%). The traditional analysis of poverty approach confirms that the Italian North/South dichotomy in Italy plays a significant role in the AROFP, as previously highlighted by Marchetti and Secondi [14], albeit our study employs different data (Italian HBS for 2021) and a different equivalence scale.

Focusing on the analysis of vulnerable households, in our sample we have 5536 couples with children, 6928 couples without children, 4310 households consisting in elderly (over 65 years old) people living alone (4733 less than 65 years old), and 382 single-parent households. Table 3 and Table 4 report summary statistics of food expenditure and the estimated AROFP rate according to each household type, respectively.

The estimated mean of monthly food expenditure ranges from approximately 220 Euros observed for couples with children up to 300 Euros for under 65 living alone. The latter group exhibits the highest level of variability in food expenditure (CV equal to 66%). Furthermore, as shown in Table 4, the prevalence of food poverty seems to have a very strong impact on households with children. Couples with children not

Table 3
Food expenditure for Italian household types.

Type of household	n	Min.	Pctl.25	Mean	Median	Pctl.75	Max.	Std.Dev	CV (%)
Couple with children	5536	1.66	146.69	220.33	206.93	284.50	586.38	101.25	45.95
Couples without children	6928	7.44	184.86	287.34	263.53	362.01	783.39	142.13	49.46
Elderly living alone	4310	3.02	178.91	302.94	263.37	381.47	1299.36	184.95	61.05
Other	5680	7.00	165.39	249.22	235.68	314.87	780.54	115.19	46.22
Single parent	382	7.54	143.30	232.83	208.23	296.86	773.36	125.50	53.90
Under 65 living alone	4733	2.47	164.25	303.43	260.63	396.18	1295.91	198.76	65.51



(a) Italian regions *(b) Type of household*

Fig. 2. Food expenditure density functions.

Table 4
Estimated at-risk-of-food-poverty households.

Type of household	AROFP	Std.Dev	CV (%)	Confidence Interval
Couple with children	0.250	0.008	3.355	[0.235; 0.271]
Couples without children	0.141	0.005	3.489	[0.13; 0.15]
Elderly living alone	0.158	0.006	3.831	[0.142; 0.172]
Other	0.191	0.005	2.807	[0.182; 0.201]
Single parent	0.240	0.025	10.543	[0.178; 0.288]
Under 65 living alone	0.195	0.006	3.284	[0.184; 0.209]

only exhibit the lowest average food expenditure among various household types but also demonstrate the highest incidence of food poverty. In fact, the estimated AROFP rate reveals that 25% of couples with children fall below the food poverty threshold, followed by single-parent households (24%). The incidence of food poverty decreases significantly for households without children (14%). Therefore, it can be concluded that households with children and single-parent households are among the most vulnerable. Single-parent households are particularly susceptible to the risks of falling into conditions of deprivation as a result of economic crises, due to the fact that they are almost exclusively composed of women and children [45].

5.2. Results from the fuzzy set approach

This section presents the estimates of the fuzzy at-risk-of-food-poverty (FAROFP) rate, derived from regions and household types, as computed by the fuzzy approach. This innovative method is employed to compute food poverty.

Fig. 3 illustrates the estimated membership function of Equation 3, along with its associated factors. The membership function enables the circumvention of a strict dichotomy between poor and non-poor, thereby preserving the richness of data information. It can be observed that the function attains its maximum when the equivalent household food expenditure is equal to 0, and subsequently declines rapidly towards zero. For an expenditure of approximately 500 euros, the function is almost flat. Furthermore, 80% of households exhibit a membership degree that places them within the set of food-poor

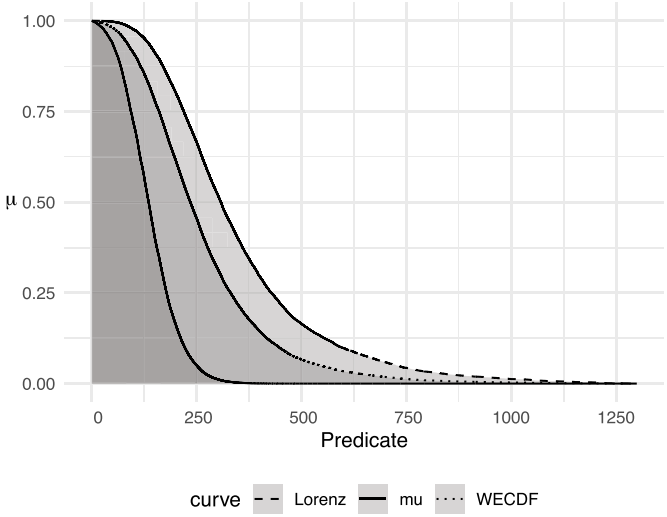


Fig. 3. Estimated membership function (Italy).

households with an equivalent household food expenditure below 0.423.

The fuzzy estimates for households living in food poverty conditions in the 20 Italian regions are shown in Table 5. These results are consistent with those previously seen in Table 2, which indicated that food poverty is more prevalent in southern regions than in northern regions. Indeed, Puglia and Sardegna are the regions with the highest rates of food poverty, with values of 0.305 and 0.293, respectively. The lowest values were observed in Valle d'Aosta, Piemonte and Friuli-Venezia Giulia (0.175, 0.188 and 0.172), while the highest values were observed in Calabria, Sicilia and Sardegna (0.305, 0.303 and 0.302). Fig. 4 presents the estimated FAROFP and confidence intervals for the Italian regions. It is evident that there are significant differences among the regions. Regarding the precision of these estimates, the average CV is approximately 4%. Puglia, Sardegna, and Molise have a

Table 5
Estimated fuzzy measures of food deprivation and their sampling errors for the Italian regions.

Domain	Estimate	Std. Dev.	CV (%)	Confidence Interval
Abruzzo	0.252	0.012	4.844	[0.228,0.276]
Basilicata	0.207	0.012	5.893	[0.183,0.231]
Calabria	0.237	0.011	4.644	[0.216,0.259]
Campania	0.223	0.007	3.242	[0.208,0.237]
Emilia-Romagna	0.198	0.007	3.285	[0.186,0.211]
Friuli-Venezia Giulia	0.172	0.011	6.400	[0.151,0.194]
Lazio	0.211	0.006	2.647	[0.2,0.222]
Liguria	0.196	0.010	5.299	[0.176,0.217]
Lombardy	0.206	0.005	2.247	[0.197,0.215]
Marche	0.190	0.009	4.552	[0.173,0.207]
Molise	0.283	0.014	4.990	[0.255,0.311]
Piemonte	0.188	0.007	3.510	[0.175,0.201]
Puglia	0.305	0.009	2.812	[0.288,0.321]
Sardegna	0.293	0.013	4.383	[0.268,0.318]
Sicilia	0.182	0.007	3.775	[0.168,0.195]
Toscana	0.205	0.006	2.982	[0.193,0.217]
Trentino-Alto Adige	0.209	0.009	4.243	[0.191,0.226]
Umbria	0.207	0.010	4.712	[0.188,0.226]
Valle d'Aosta	0.175	0.012	6.858	[0.152,0.199]
Veneto	0.204	0.007	3.485	[0.19,0.218]

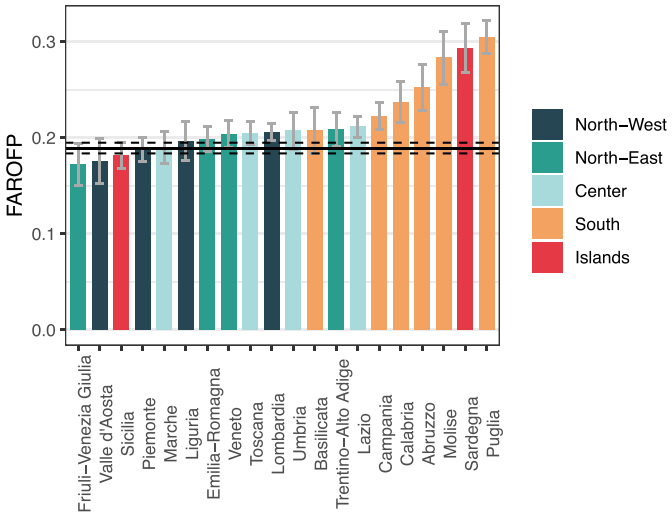


Fig. 4. Estimated FAROFP and their confidence intervals for the Italian Regions. The solid line: estimated national value, dashed lines: confidence interval.

FAROFP incidence that is significantly above the national value and is statistically different from the other regions.

Table 6 shows the situation of the most vulnerable households. We see that poverty affects mostly couples with children (estimate equal to 0.275) and single-parent households (estimate equal to 0.264), while on less extent households made of elderly (over 65 years old) living alone. Regarding the precision of these estimates, we observe that the CV ranges from 1.45% for couples with children to 6.22% for single-parent households. Regarding the statistical difference among these estimates, Fig. 5 shows the point estimates along with their confidence intervals. From this figure it is possible to note that couples with children and single-parent households have a FAROFP incidence significantly above the national value and are statistically different from the other household types.

Table 6
Estimated fuzzy measures of food deprivation and their sampling errors for the type of Household.

Domain	Estimate	Std. Dev.	CV (%)	Confidence Interval
Couple with children	0.275	0.004	1.455	[0.267,0.283]
Couples without children	0.172	0.003	1.925	[0.165,0.178]
Elderly living alone	0.178	0.004	2.232	[0.17,0.186]
Other	0.219	0.004	1.852	[0.211,0.226]
Single parent	0.264	0.016	6.076	[0.233,0.296]
Under 65 living alone	0.210	0.004	2.126	[0.201,0.219]

A key finding from the comparison of the standard errors and the coefficients of variation of the estimates for the Italian regions presented in Fig. 6 and 7 is that, when employing a fuzzy approach, the resulting estimates are more accurate for the majority of Italian regions. This result also holds when these sub-domains are considered collectively, as demonstrated in Tables 7 and 8. The point estimates are similar in magnitude (see Fig. 8), yet the coefficients of variation of the FAROFP are lower (Fig. 9). The estimates presented in Fig. 8, and more specifically the tables provided in the appendix, indicate that the incidence of food poverty, as determined through both traditional and fuzzy methods, is higher in couples with children and single-parent households in many Italian regions.

The highest incidence of food poverty for couples with children is observed in the Abruzzo and Molise regions, with AROFP estimates of 0.365 and 0.359, respectively, and FAROFP estimates of 0.363 and 0.324, respectively. In contrast, the highest incidence of food poverty is observed in single-parent households in Piemonte (AROFP estimates equal to 0.36 and FAROFP estimates equal to 0.34) and Toscana (AROFP estimates equal to 0.42 and FAROFP estimates equal to 0.36). These results may be linked to the geographical distribution of household types across Italian territories. Indeed, northern regions and, to a lesser extent, those of the centre, record a higher-than-average number of single-parent households. In contrast, in the south and islands the couple with at least one child continues to represent the most widespread type of household, despite the sharp decline recorded in the period considered [46]. However, the accuracy of these estimates cannot be always considered adequate, therefore, these domains may be considered as small areas [47].

6. Discussion and policy implications

This research provides a comprehensive analysis of food poverty at the sub-domain level with a particular emphasis on vulnerable individuals and under-represented groups, thus informing policy makers in the planning of appropriate evidence-based food policies for promoting more egalitarian and sustainable living conditions. The AROFP

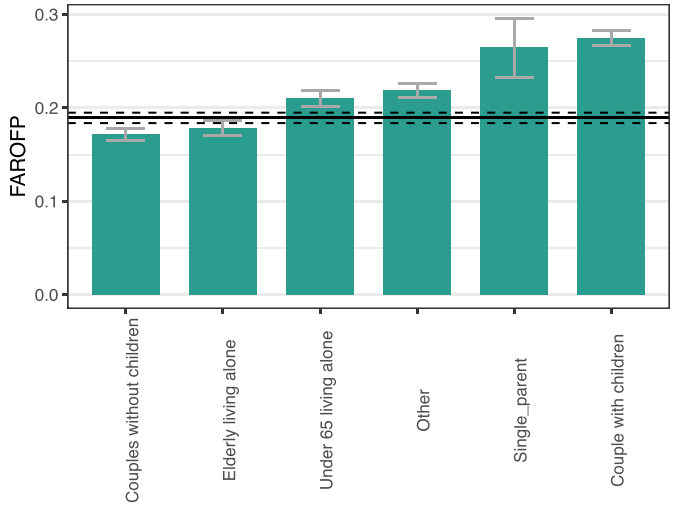
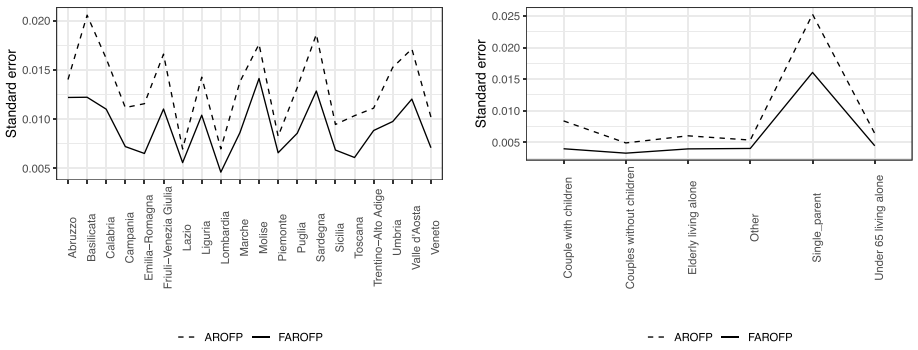
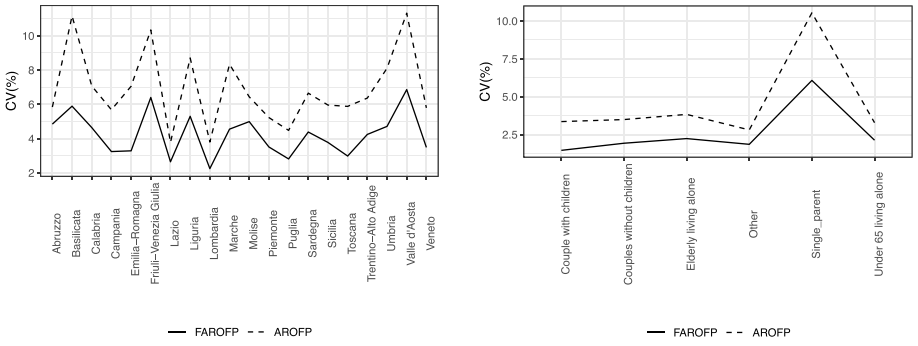


Fig. 5. Estimated FAROFP and their confidence intervals for the type of household. The solid line: estimated national value, dashed lines: confidence interval.



(a) Regions *(b) Type of household*

Fig. 6. Estimated standard errors for domain.



(a) Regions *(b) Type of household*

Fig. 7. Estimated CVs for Italian regions and type of household.

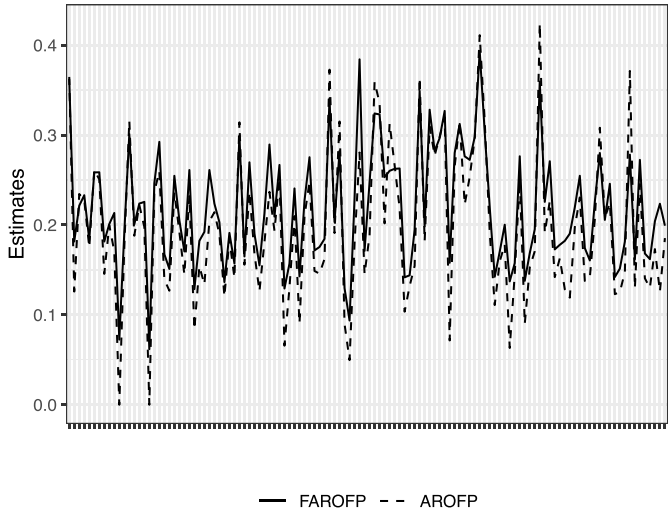


Fig. 8. Estimated AROFP and FAROFP for each Region-Type of household combination.

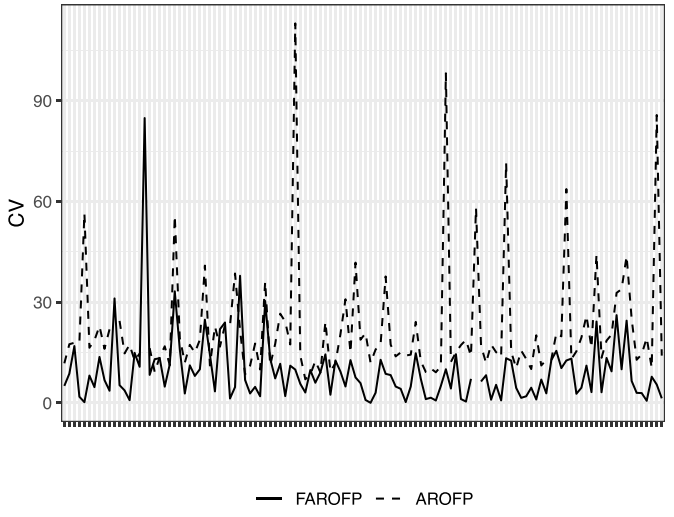


Fig. 9. Estimated CVs for AROFP and FAROFP and each combination of Region and Type of household.

and FAROFP estimates indicate that the most vulnerable demographic groups, including minors and young single parents with children under the age of 18, are disproportionately affected by food poverty. This is a significant issue, as vulnerable households may face greater challenges due to rising food prices, leading to increased food deprivation. The vulnerability of single-parent families, with a young or adult head of household, can be attributed to the fragility of this condition from a socio-assistance perspective. This is despite the continued prevalence of social support provided by the parental network. Furthermore, single-parent households are predominantly composed of women and children, which may indicate a reduced probability of having access to nutritionally adequate meals, and a higher risk of poverty and social exclusion [46]. In light of the aforementioned issues, it is crucial to have a proper and up-to-date measurement and monitoring of food poverty and insecurity.

Effective policymaking needs accurate estimates for the entire population derived from official survey data. This study presents empirical evidence indicating that a fuzzy approach yields more accurate

estimates at the detailed territorial level and for specific groups of vulnerable households than those obtained through the traditional crisp-set approach.

The potential of official data to inform territorial policy-making is contextualized within the challenges of obtaining economic and social indicators that are consistently available on an annual basis and relevant to the policy process. Moreover, the utilisation of data derived from European harmonised official HBS surveys allows to replicate the methodology beyond the Italian case study. Consequently, the methodology proposed may facilitate the transfer of knowledge.

In order to eradicate food poverty and to reduce inequalities across all segments of the population, it is necessary to implement appropriate food policies and interventions at the household and individual levels. In this context, food policies, and specifically urban food policies, which may be defined as "comprehensive plans providing a roadmap for the future growth of a community including access to healthful and affordable foods for all residents" [48], have the potential to leverage food security, thereby allowing for the improvement of individual dietary patterns across a broader spectrum of interdisciplinary research (health, environment, and social sustainability).

In addition to other strategies for influencing food consumption behaviour, the EAT-Lancet Commission proposes a behavioural public policy based on enhancing the desirability and accessibility of food [49].

However, the cost of food plays an important role in determining decisions related to the purchase and food consumption [50]. Therefore, food cost is a barrier to the adoption of an appropriate nutritionally adequate diet, particularly among people with lower socio-economic status [51]. This socioeconomic gradient in the diet quality is thus likely to contribute to the health disparity among different socioeconomic groups [52] which in turn leads to a rise in overall societal costs [51].

From the perspective of public policy, our findings highlight the importance of initiatives that improve diet quality, with a particular focus on the most vulnerable groups. In order to achieve the desired outcomes, it is essential to pursue the aforementioned initiatives through two distinct, yet complementary approaches. Firstly, consumer education programmes should focus on imparting knowledge about the nutritional value and affordability of food. Among the various nutritional patterns, the traditional Mediterranean Diet (MD) appears to be the healthiest and most well-balanced diet due to healthy foods which should be frequently consumed - such as seasonal fruits, vegetables, cereals and legumes [53]. In this perspective, previous studies found a significant correlation between food insecurity and poor adherence to the MD [54]. Secondly, communication strategies should be developed to educate consumers on how to select and purchase healthy foods within varying economic constraints.

7. Conclusions

The issue of food insecurity is a challenge both at national and sub-national level. It is, therefore, of great importance to gain a comprehensive understanding of the spatial patterns of food poverty if the implementation of targeted policies and programs aimed at addressing this increasingly prevalent issue in developed countries is to be effective [55].

This paper provides a detailed exploration of food poverty in Italy by considering the fuzzy approach, which offers a nuanced understanding of food poverty and incorporates fuzzy logic and relative measures, providing a more holistic assessment that overcomes traditional binary classifications. This study demonstrates the effectiveness of the fuzzy approach in capturing the complexities of food poverty dynamics and informing evidence-based policy interventions based on empirical analysis of the 2021 Italian HBS microdata. Both traditional and fuzzy AROFP results confirm the well-known North–South economic divide in Italy. The findings indicate that food poverty is less prevalent in the Northern regions of Italy. The analysis also confirms the vulnerability of couples with children and single-parent households. Indeed, the latter family typology has been included by ISTAT among the families monitored to measure social and material vulnerability in Italy.

Adopting a fuzzy approach allows us to obtain results that are consistent with those derived using the traditional approach, while also providing estimates with a significantly greater degree of accuracy. Moreover, the estimation of the membership function is an important tool that contributes to a richer understanding of poverty in the whole domain of the equivalent food expenditure, as it gives a degree of poverty for each value of the expenditure.

Our approach differs from the approach adopted by Marchetti and Secondi [14] since our methodology employs a single poverty line, as opposed to multiple (e.g., regional) poverty lines. Additionally, our approach computes the fuzzy measures at the sub-national domain level by averaging the entire estimated membership function over the statistical units within that domain. This approach aligns with the existing literature in this field (see Refs. [17,56,57]), yet it represents a notable departure.

By addressing food poverty at detailed territorial level and implementing targeted interventions for specific household types, policymakers and communities can work towards achieving food security and well-being for all individuals. The results of this paper provide key information to support research in the field of food poverty and insecurity as well as evidence-based results to support policymakers in planning appropriate urban food policies to define effective socio-economic interventions. Furthermore, the findings of this study will have a significant impact on the scientific community, reinforcing the importance of reducing social exclusion and achieving more equitable and sustainable living conditions for the entire population, with particular emphasis on vulnerable individuals and underrepresented groups.

Future research could involve adjusting poverty thresholds for price level differences to assure that the poverty line represents the same standard of living across the different areas.To this aim consumer spatial price indices, produced by ISTAT (2023) be used [58]. Furthermore, it would be interesting to introduce the small area estimation methods for investigating the presence of food poverty heterogeneity within each combination of region and household type. Indeed, in those circumstances, sample size of each domain is small, and the direct estimators are usually unreliable, due to their unacceptably large variance. Therefore, by applying small area estimation methods we would be able to aim to obtain reliable estimates by using indirect or model-based estimators.

Finally, this study has not considered food poverty in terms of the nutritional aspects of the diet, but only in terms of an economic quantification of the food expenditure. Consequently, we did not assess the composition of the basket of food items purchased by households. A possible improvement over this paper would be developing a novel analytical approach to assess food poverty also in terms of adherence to a 'healthy and sustainable' dietary pattern. This will entail determining the economic value of associated nutrient profiles using official and open-access statistical data.

CRediT authorship contribution statement

Ilaria Benedetti: Writing – review & editing, Writing – original draft, Project administration, Funding acquisition, Data curation. **Federico Crescenzi:** Writing – review & editing, Writing – original draft, Software, Methodology, Formal analysis, Data curation. **Tiziana Laureti:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Data curation, Conceptualization. **Luca Secondi:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Investigation, Data curation, Conceptualization.

Declaration of competing interest

The authors have no competing interests or conflict of interests to

disclose.

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Data availability

Data are public from ISTAT database

Appendix

Region	Type of household	Estimate	Std. Dev.	CV (%)
Abruzzo	Couple with children	0.365	0.043	11.814
Abruzzo	Couples without children	0.126	0.022	17.494
Abruzzo	Elderly living alone	0.234	0.042	17.930
Abruzzo	Other	0.228	0.041	17.951
Abruzzo	Single-parent	0.175	0.099	56.444
Abruzzo	Under 65 living alone	0.261	0.043	16.458
Basilicata	Couple with children	0.251	0.047	18.667
Basilicata	Couples without children	0.146	0.033	22.907
Basilicata	Elderly living alone	0.200	0.032	16.136
Basilicata	Other	0.170	0.037	21.922
Basilicata	Single-parent	0.000	0.000	NaN
Basilicata	Under 65 living alone	0.175	0.043	24.426
Calabria	Couple with children	0.316	0.047	14.773
Calabria	Couples without children	0.188	0.033	17.352
Calabria	Elderly living alone	0.222	0.028	12.646
Calabria	Other	0.198	0.029	14.715
Calabria	Single-parent	0.000	0.000	NaN
Calabria	Under 65 living alone	0.237	0.039	16.325
Campania	Couple with children	0.260	0.024	9.221
Campania	Couples without children	0.139	0.019	13.691
Campania	Elderly living alone	0.127	0.021	16.870
Campania	Other	0.236	0.027	11.241
Campania	Single-parent	0.193	0.107	55.766
Campania	Under 65 living alone	0.145	0.028	19.328
Emilia-Romagna	Couple with children	0.232	0.028	12.005
Emilia-Romagna	Couples without children	0.084	0.014	17.296
Emilia-Romagna	Elderly living alone	0.154	0.023	14.974
Emilia-Romagna	Other	0.134	0.025	18.853
Emilia-Romagna	Single-parent	0.204	0.083	40.892
Emilia-Romagna	Under 65 living alone	0.214	0.024	11.174
Friuli-Venezia Giulia	Couple with children	0.190	0.043	22.785
Friuli-Venezia Giulia	Couples without children	0.120	0.020	16.784
Friuli-Venezia Giulia	Elderly living alone	0.184	0.043	23.227
Friuli-Venezia Giulia	Other	0.141	0.033	23.102
Friuli-Venezia Giulia	Single-parent	0.314	0.121	38.545
Friuli-Venezia Giulia	Under 65 living alone	0.156	0.034	21.793
Lazio	Couple with children	0.237	0.020	8.513
Lazio	Couples without children	0.168	0.019	11.110
Lazio	Elderly living alone	0.126	0.022	17.686
Lazio	Other	0.181	0.018	9.984
Lazio	Single-parent	0.237	0.086	36.135
Lazio	Under 65 living alone	0.194	0.022	11.174
Liguria	Couple with children	0.252	0.044	17.610
Liguria	Couples without children	0.066	0.017	26.571
Liguria	Elderly living alone	0.130	0.032	24.215
Liguria	Other	0.210	0.037	17.436
Liguria	Single-parent	0.090	0.102	113.011
Liguria	Under 65 living alone	0.210	0.030	14.171
Lombardia	Couple with children	0.248	0.018	7.060
Lombardia	Couples without children	0.149	0.013	8.442
Lombardia	Elderly living alone	0.146	0.018	12.534
Lombardia	Other	0.162	0.015	9.094
Lombardia	Single-parent	0.373	0.090	24.180
Lombardia	Under 65 living alone	0.191	0.018	9.361
Marche	Couple with children	0.315	0.037	11.892
Marche	Couples without children	0.090	0.018	20.535
Marche	Elderly living alone	0.050	0.015	30.862
Marche	Other	0.179	0.027	14.956
Marche	Single-parent	0.280	0.117	41.778
Marche	Under 65 living alone	0.145	0.027	18.855
Molise	Couple with children	0.188	0.039	20.773
Molise	Couples without children	0.359	0.043	11.978
Molise	Elderly living alone	0.335	0.053	15.913

(*continued on next page*)

(*continued*)

Region	Type of household	Estimate	Std. Dev.	CV (%)
Molise	Other	0.202	0.036	17.622
Molise	Single-parent	0.313	0.118	37.659
Molise	Under 65 living alone	0.266	0.046	17.371
Piemonte	Couple with children	0.219	0.030	13.882
Piemonte	Couples without children	0.104	0.016	15.040
Piemonte	Elderly living alone	0.132	0.019	14.103
Piemonte	Other	0.155	0.022	14.397
Piemonte	Single-parent	0.364	0.088	24.134
Piemonte	Under 65 living alone	0.182	0.023	12.441
Puglia	Couple with children	0.309	0.029	9.224
Puglia	Couples without children	0.277	0.028	10.262
Puglia	Elderly living alone	0.298	0.027	9.148
Puglia	Other	0.320	0.035	10.920
Puglia	Single-parent	0.072	0.070	98.157
Puglia	Under 65 living alone	0.265	0.032	12.237
Sardegna	Couple with children	0.315	0.047	15.076
Sardegna	Couples without children	0.223	0.038	17.235
Sardegna	Elderly living alone	0.253	0.048	18.794
Sardegna	Other	0.296	0.041	13.945
Sardegna	Single-parent	0.411	0.239	58.043
Sardegna	Under 65 living alone	0.315	0.054	17.062
Sicilia	Couple with children	0.192	0.023	11.883
Sicilia	Couples without children	0.111	0.019	17.401
Sicilia	Elderly living alone	0.160	0.024	15.137
Sicilia	Other	0.178	0.025	13.768
Sicilia	Single-parent	0.063	0.045	71.559
Sicilia	Under 65 living alone	0.146	0.022	15.325
Toscana	Couple with children	0.252	0.026	10.361
Toscana	Couples without children	0.090	0.014	15.589
Toscana	Elderly living alone	0.153	0.020	13.121
Toscana	Other	0.171	0.017	10.112
Toscana	Single-parent	0.424	0.085	20.139
Toscana	Under 65 living alone	0.191	0.021	11.171
Trentino-Alto Adige	Couple with children	0.227	0.029	12.831
Trentino-Alto Adige	Couples without children	0.142	0.018	12.953
Trentino-Alto Adige	Elderly living alone	0.163	0.034	20.789
Trentino-Alto Adige	Other	0.128	0.026	19.862
Trentino-Alto Adige	Single-parent	0.119	0.076	63.674
Trentino-Alto Adige	Under 65 living alone	0.198	0.026	13.067
Umbria	Couple with children	0.231	0.035	15.387
Umbria	Couples without children	0.138	0.027	19.491
Umbria	Elderly living alone	0.141	0.037	25.996
Umbria	Other	0.207	0.034	16.431
Umbria	Single-parent	0.308	0.136	44.173
Umbria	Under 65 living alone	0.208	0.028	13.478
Valle d'Aosta	Couple with children	0.224	0.042	18.562
Valle d'Aosta	Couples without children	0.123	0.025	20.355
Valle d'Aosta	Elderly living alone	0.125	0.041	32.777
Valle d'Aosta	Other	0.148	0.050	33.907
Valle d'Aosta	Single-parent	0.371	0.162	43.759
Valle d'Aosta	Under 65 living alone	0.130	0.033	25.066
Veneto	Couple with children	0.245	0.032	12.872
Veneto	Couples without children	0.141	0.020	14.452
Veneto	Elderly living alone	0.130	0.025	19.397
Veneto	Other	0.173	0.018	10.427
Veneto	Single-parent	0.126	0.108	85.726
Veneto	Under 65 living alone	0.185	0.026	14.103

Table 8
Estimated fuzzy measures (FAROFP) of food deprivation and their sampling errors for each combination of region and type of household

Region	Type of household	Estimate	Std. Dev.	CV (%)
Abruzzo	Couple with children	0.363	0.018	5.096
Abruzzo	Couples without children	0.182	0.016	8.740
Abruzzo	Elderly living alone	0.221	0.037	16.935
Abruzzo	Other	0.233	0.004	1.863
Abruzzo	Single-parent	0.183	0.000	0.237
Abruzzo	Under 65 living alone	0.258	0.021	8.149
Basilicata	Couple with children	0.259	0.012	4.728
Basilicata	Couples without children	0.182	0.025	13.694
Basilicata	Elderly living alone	0.201	0.014	6.818
Basilicata	Other	0.213	0.008	3.656

(*continued on next page*)

Table 8 (*continued*)

Region	Type of household	Estimate	Std. Dev.	CV (%)
Basilicata	Single-parent	0.072	0.023	31.121
Basilicata	Under 65 living alone	0.191	0.010	5.300
Calabria	Couple with children	0.301	0.011	3.746
Calabria	Couples without children	0.201	0.002	0.848
Calabria	Elderly living alone	0.224	0.033	14.916
Calabria	Other	0.226	0.024	10.792
Calabria	Single-parent	0.062	0.052	84.826
Calabria	Under 65 living alone	0.246	0.021	8.381
Campania	Couple with children	0.292	0.038	13.039
Campania	Couples without children	0.167	0.022	13.331
Campania	Elderly living alone	0.151	0.007	4.876
Campania	Other	0.255	0.029	11.477
Campania	Single-parent	0.205	0.068	33.234
Campania	Under 65 living alone	0.171	0.027	15.993
Emilia-Romagna	Couple with children	0.261	0.007	2.826
Emilia-Romagna	Couples without children	0.129	0.014	11.194
Emilia-Romagna	Elderly living alone	0.182	0.015	8.060
Emilia-Romagna	Other	0.192	0.019	10.049
Emilia-Romagna	Single-parent	0.261	0.065	24.795
Emilia-Romagna	Under 65 living alone	0.224	0.032	14.396
Friuli-Venezia Giulia	Couple with children	0.203	0.007	3.459
Friuli-Venezia Giulia	Couples without children	0.137	0.030	21.976
Friuli-Venezia Giulia	Elderly living alone	0.191	0.046	23.951
Friuli-Venezia Giulia	Other	0.157	0.002	1.346
Friuli-Venezia Giulia	Single-parent	0.300	0.014	4.723
Friuli-Venezia Giulia	Under 65 living alone	0.165	0.062	37.864
Lazio	Couple with children	0.270	0.019	6.877
Lazio	Couples without children	0.190	0.005	2.846
Lazio	Elderly living alone	0.155	0.007	4.788
Lazio	Other	0.213	0.004	2.011
Lazio	Single-parent	0.289	0.088	30.362
Lazio	Under 65 living alone	0.209	0.028	13.225
Liguria	Couple with children	0.267	0.020	7.328
Liguria	Couples without children	0.129	0.015	11.659
Liguria	Elderly living alone	0.157	0.003	2.061
Liguria	Other	0.241	0.027	11.096
Liguria	Single-parent	0.143	0.014	9.947
Liguria	Under 65 living alone	0.227	0.013	5.712
Lombardia	Couple with children	0.275	0.009	3.132
Lombardia	Couples without children	0.172	0.017	9.789
Lombardia	Elderly living alone	0.175	0.011	6.041
Lombardia	Other	0.185	0.017	9.091
Lombardia	Single-parent	0.341	0.049	14.460
Lombardia	Under 65 living alone	0.203	0.005	2.461
Marche	Couple with children	0.282	0.036	12.657
Marche	Couples without children	0.130	0.012	9.333
Marche	Elderly living alone	0.094	0.005	4.919
Marche	Other	0.229	0.029	12.748
Marche	Single-parent	0.384	0.029	7.613
Marche	Under 65 living alone	0.171	0.010	5.893
Molise	Couple with children	0.247	0.002	0.900
Molise	Couples without children	0.324	0.000	0.051
Molise	Elderly living alone	0.323	0.010	3.051
Molise	Other	0.253	0.033	12.853
Molise	Single-parent	0.260	0.023	8.680
Molise	Under 65 living alone	0.262	0.022	8.302
Piemonte	Couple with children	0.263	0.013	4.900
Piemonte	Couples without children	0.142	0.006	4.207
Piemonte	Elderly living alone	0.144	0.000	0.274
Piemonte	Other	0.195	0.010	4.900
Piemonte	Single-parent	0.349	0.052	14.795
Piemonte	Under 65 living alone	0.198	0.014	7.230
Puglia	Couple with children	0.328	0.004	1.159
Puglia	Couples without children	0.282	0.004	1.561
Puglia	Elderly living alone	0.297	0.002	0.738
Puglia	Other	0.327	0.017	5.088
Puglia	Single-parent	0.158	0.016	10.035
Puglia	Under 65 living alone	0.280	0.012	4.311
Sardegna	Couple with children	0.312	0.045	14.505
Sardegna	Couples without children	0.276	0.003	1.175
Sardegna	Elderly living alone	0.272	0.001	0.424
Sardegna	Other	0.298	0.021	7.183
Sardegna	Single-parent	0.394	NA	NA
Sardegna	Under 65 living alone	0.303	0.019	6.402
Sicilia	Couple with children	0.220	0.018	8.257
Sicilia	Couples without children	0.142	0.001	0.993

(*continued on next page*)

Table 8 (*continued*)

Region	Type of household	Estimate	Std. Dev.	CV (%)
Sicilia	Elderly living alone	0.170	0.009	5.392
Sicilia	Other	0.200	0.002	0.778
Sicilia	Single-parent	0.137	0.018	13.321
Sicilia	Under 65 living alone	0.157	0.020	12.615
Toscana	Couple with children	0.276	0.012	4.502
Toscana	Couples without children	0.138	0.002	1.528
Toscana	Elderly living alone	0.169	0.003	2.001
Toscana	Other	0.195	0.009	4.541
Toscana	Single-parent	0.359	0.004	1.059
Toscana	Under 65 living alone	0.226	0.016	6.964
Trentino-Alto Adige	Couple with children	0.271	0.008	2.879
Trentino-Alto Adige	Couples without children	0.173	0.022	12.750
Trentino-Alto Adige	Elderly living alone	0.178	0.028	15.522
Trentino-Alto Adige	Other	0.182	0.019	10.394
Trentino-Alto Adige	Single-parent	0.190	0.024	12.657
Trentino-Alto Adige	Under 65 living alone	0.220	0.029	13.209
Umbria	Couple with children	0.255	0.007	2.752
Umbria	Couples without children	0.174	0.008	4.541
Umbria	Elderly living alone	0.161	0.018	11.111
Umbria	Other	0.226	0.007	3.241
Umbria	Single-parent	0.280	0.068	24.234
Umbria	Under 65 living alone	0.206	0.007	3.202
Valle d'Aosta	Couple with children	0.246	0.033	13.394
Valle d'Aosta	Couples without children	0.142	0.013	9.429
Valle d'Aosta	Elderly living alone	0.151	0.040	26.142
Valle d'Aosta	Other	0.181	0.018	10.042
Valle d'Aosta	Single-parent	0.278	0.068	24.498
Valle d'Aosta	Under 65 living alone	0.162	0.011	6.572
Veneto	Couple with children	0.272	0.008	3.018
Veneto	Couples without children	0.168	0.005	2.951
Veneto	Elderly living alone	0.162	0.001	0.660
Veneto	Other	0.204	0.016	7.808
Veneto	Single-parent	0.224	0.012	5.480
Veneto	Under 65 living alone	0.199	0.003	1.390

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Ilaria Benedetti is (senior) Assistant Professor in Economic Statistics at University of Tuscia. She achieved her PhD at the University of Napoli Parthenope in 2018. She teaches various Statistics course at the University of Tuscia and at Sapienza University. She participates to several international research projects, including ERASMUS+ and Comunikos project coordinated by GOPA Luxembourg S.à.r.l. She is the principal investigator of the PRIN 2022 project "Food MeaSure: Poverty, Vulnerable individuals and Sustainable Diets - New perspectives on Official Statistical data". Her research interests cover various fields of economic statistics related to the estimation of spatial and temporal price indexes, income and living conditions, poverty and well-being, consumer behavior, environmental statistics, digitalization and economic growth.

Federico Crescenzi is a research fellow in Economic Statistics at the department of Economics, Engineering, Society and Business Organization at the University of Tuscia, Italy. He obtained his Ph.D. in Statistical Sciences at the Department of Statistics at the University of Bologna. He is author of several publications on computational aspects of poverty estimation and other topics in the field of economic statistics.

Tiziana Laureti is Full Professor of Economic Statistics at University of Tuscia. She achieved her PhD in Applied Statistics at the University of Florence. She was a member of the Italian National Scientific Qualification Commission for full and associate professors in Economic Statistics. She participates to various international research projects, e.g. MAKSWELL and INNOVAFRICA. She is an elected member of the International Statistical Institute and the Italian Statistical Society. Her research interests cover various fields of statistics from applied works in consumer behavior, environmental statistics, subjective well-being and education inequality to more methodological aspects of consumer price indexes and purchasing power parities.

Luca Secondi is Associate Professor of Economic Statistics. He obtained the PhD in Applied Statistics at the University of Florence. He currently holds the role of task leader and support for the coordination of the H2020 LOWINFOOD project (November 2020–February 2025 - Multi-actor design of low-waste food value chains through the demonstration of innovative solutions to reduce food loss and waste) and he is responsible for the University of Tuscia unit of the project DONO ERGO SUM (reDistributiON Of supply chain wastagE duRinG and after the pandemic in favor Of the moSt vUlnerable categories of people in alignMent with the Sustainable Development Goals).