A fuzzy hybrid MCDM approach to the evaluation of subjective household poverty

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Abstract

Poverty is one of the most important global socio-economic problems. Despite a strong interest in this phenomenon, there is no unified concept for measuring it. It is difficult to quantify due to the diversity of the dimensions of perceived poverty, particularly subjective ones. Thus, the aim of the research described in the article is to propose a comprehensive procedure for constructing a synthetic measure of subjective poverty in households. This involves aggregating factors describing the present, future, and past, which make it easier to grasp the feeling of deprivation. Methods such as fuzzy TOPSIS and fuzzy hierarchical analysis (FHA) based on the fuzzy sets theory were used for this purpose, which is not standardly used for this type of research. This innovative procedure was applied to assess the level of subjective household poverty in Poland. The analyses are based on data from primary research carried out in three stages in 2020 using the CAWI method. The results show that the assessment of households' current socio-economic situation is also influenced by past events as well as projections of future developments. Changes in the values of the synthetic index illustrate the trajectory of switching from panic to negation, and attempting to cope with the situation or, alternatively, switching to a state of irritation. The research results can form the basis for formulating policies and strategies to combat poverty.

Key words: fuzzy TOPSIS, fuzzy hierarchical analysis (FHA), MCDM, subjective poverty, household, CAWI

1. Introduction

Due to its interdisciplinary nature, poverty is a specific research category. Understanding its specificity requires various scientific disciplines – economics (including behavioral), sociology, social policy, or psychology. The considerations of poverty highlight that it is the result of many overlapping social and economic difficulties, including the lack of work, low income, dysfunctions, limited opportunities or low human capital. Schiller (1989) points to three causes: flawed character, restricted

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opportunities and inefficient state policy, which Schiller describes as Big Brother. Bradshaw (2007) suggests that it is the "effect of individual deficiencies, cultural belief systems that support subcultures in poverty, political-economic distortions, geographic disparities, or cumulative and circumstantial origins". Given the wide range of causes of poverty, it can be assumed that it is an anomic feature of the contemporary world. Although there are many causes (Brandt, 1908; Thurow, 1967; Shaw, 1996; Jennings, 1999; Dudek, 2008; Dudek & Szczesny, 2021; Brady, 2019; Kalinowski, 2020), the problem of the COVID-19 pandemic and its negative effects on the functioning of households seems to have been the most important in recent years (Kalinowski & Wyduba 2020; Gupta et al., 2021; Asfaw, 2021).

Although 120 years have passed since Rowntree's first poverty research (1901), there is still no unified definition. The concept of poverty is unclear, which makes it difficult to define it (Blank, 1997; van Praag at al., 2008), as a result of which there is also no generally accepted method of measuring it (Kalinowski, 2015). In most research into poverty, a person is classified as poor if he or she lacks sufficient resources to achieve an acceptable standard of living. Usually the analysis is limited to economic deprivation and distress. However, as Shaw (1996) and Blank (2003) (among others) point out, poverty is a very complex social problem with many variants and roots, all of which are important depending on the situation. The very attempt to define poverty itself is a consequence of research traditions resulting from the overlapping of behavioral, social and economic factors, reinforced by political considerations.

The essence of poverty is inequality (Valentine, 1968). It can be reflected both in unequal income and consumer spending, as well as in the level of perceived needs and the way in which they are perceived. Thus it can be assumed that inequality in terms of perceived needs may favor various levels of satisfaction, regardless of the objective dimension of satisfying the needs. The amount of funds held cannot reflect satisfaction. It can be assumed after Ahuvia (2008) that the chances of determining an individual's situation are greater when knowing the evaluation of satisfaction with life as a whole rather than by knowing the level of income. Thus the objective dimension expressed in income or expenditure will not be reflected in the subjective satisfaction with the various dimensions of life (cf. Easterlin, 1974; Nettle, 2005; Rayo & Becker, 2007; Michoń, 2010).

Since the objective dimension is not sufficient to describe multidimensional poverty, we have chosen to redefine subjective poverty. "We assumed that this is an awareness of the lack of sufficient resources to meet one's needs in terms of socio-economic status (income and current financial situation, level of education and occupation, residence, lifestyle and leisure) and one's own aspirations to achieve and maintain the desired standard of living" (Łuczak & Kalinowski, 2022). We recognized that to some extent subjective poverty is a consequence of the emphasis on relative deprivation of needs discussed by Townsend (1979) and Runciman (1966). We assumed after Townsend that poverty is an inability to meet the standards of a given

society. Although Townsend's definition refers to a relative dimension, it is simply reflected in individuals' subjective expectations, especially given their aspirations.

It is worth noting that the definition of subjective poverty that we adopted limits the fraction of poor people only to those who have a feeling of unmet needs, while leaving out those who do not have this feeling. In conceptualizing subjective poverty, we thus found that behavioral factors are extremely important. This emphasis allows us to assume that subjective poverty is influenced by the respondents' circumstances. We assumed that the sense of poverty is influenced by the feeling of deprivation in relation to the environment, i.e., the situation of the surveyed individual and how he or she perceives his or her own well-being. To quote John Stuart Mill (1907), "Men do not desire merely to be rich, but to be richer than other men." This relativism of thinking at the same time encourages the formation of subjective assessments of one's own position in relation to the environment. A question arises – what is this environment? Who is this benchmark for respondents' assessments? Without much error, it can be assumed that they are people closely related to the respondents (family, friends) or other people they know (neighbors, co-workers). However, without being sure of who constitutes the comparison group, one should be cautious in this regard.

According to Haveman (2015), "the process of measuring poverty and analyzing its causes and consequences has advanced social science research in several areas, including identifying the underlying causes of poverty, understanding social mobility, attainment, and income dynamics, and measuring the behavioral effects of antipoverty policy interventions." A problematic issue in all the measures indicated is the feeling of deprivation of needs in relation to expectations and, consequently, the estimation of one's own line of prosperity. This leads to measurement errors. In deciding to create a synthetic measure, we therefore wanted it to be the result of the evaluation of financial situation and material conditions of one's own household, as well as the perception of one's own income compared to the income of other households. We also wanted the proposed measure to be based on a subjective sense of the standard of living of household members and a sense of helplessness against the risk of poverty. We believe that it is not only the moment of the pandemic that is important, but also the past situation and the anticipation of future changes. It should be emphasized that our innovation in research consists in the use of the time dimension in research, including the past, present, and future. We propose a procedure for constructing a synthetic measure based on repeated surveys (in this case from three periods) conducted using the CAWI method. The comprehensive procedure we propose is a hybrid MCDM approach based on fuzzy methods that extend the approach proposed by Łuczak and Kalinowski (2022). The key elements of the methodology, i.e. determination of the indicator-weighting system and calculation of synthetic measures, are based on the fuzzy hierarchical analysis (FHA) and the fuzzy technique for order of preference by similarity to ideal solution (FTOPSIS), respectively. In addition, we propose our own compactness measure to examine the homogeneity of the created groups of objects.

As the main objective of the research, we adopted a presentation of a unconventional procedure for the construction of a synthetic measure of subjective household poverty in the context of poverty types and household types based on a hybrid multi-criteria decision-making approach in a fuzzy environment. The proposed approach was used to study the perception of subjective poverty by households in Poland during the COVID-19 pandemic. The research was carried out on the basis of three-stage primary research in April, June and September 2020. This paper consists of five parts. In addition to the introduction, section 2 provides a detailed description of the proposed multiple-criteria decision-making method. Section 3 describes the results of empirical research on the evaluation of subjective household poverty in Poland during the COVID-19 pandemic. Chapter 4 discusses the proposed research procedure and the results obtained. The conclusions are presented in Chapter 5.

2. Literature review

Poverty is a multidimensional phenomenon, the definition and measurement of which raises a lot of controversy and discussion. In research on poverty, the lines of poverty separating relatively well off (non-poor) people from poor people are most often used (Golinowska 1997, Broda-Wysocki 2012). They are criticized in many studies because they cause a dichotomous division of society. Generally, there are two approaches to determining the poverty line – economic and multidimensional (Figure 1). The objective approach is determined both on the basis of normative and parametric lines. The first are absolute, while the second are relative. Determining the normative lines consists in determining the value of income necessary to satisfy a certain group of needs (Booth 1889, Rowntree 1901, Orshansky 1969). They are based on various types of standards (expert or political) regarding the fulfillment of needs (Kalinowski, 2015).

Relatively the least important in the measurements is the poverty threshold based on official lines. Its minor importance results, on the one hand, from a certain underestimation, and on the other from overestimation. This is due to several factors (Kalinowski, 2015):

1) lowering the statistics contributes to the apparent reduction of the poverty threshold without its actual elimination, which may lead to a lack of valorization of the number entitled to receive benefits,
2) for fear of being stigmatized some people consciously do not want receive social welfare benefits, thus they are not included in the assistance systems, and as a result they are not treated as poor, even though they cannot meet their needs,
3) some people receive benefits, although they are not formally entitled to them (e.g. working illegally),
4) lack of international comparability.

The subjective measures of poverty are also important (cf. Hagenaars, van Praag 1985, Kapteyn, van Praag, van Herwaarden 1978, Goedhart et al. 1977). These are

considered the most democratic methods of defining poverty, which results from the individual setting of the limit of deprivation.

Measurement of poverty is often limited to objective, one-dimensional indicators (e.g. income or expenses). However, when assessing poverty, its subjective dimension is also important, as it shows the perceptions of the poor. The growing contrast between the rich and the poor only increases the level of feeling poverty. There are many levels of poverty, from no poverty to extreme poverty. It should be noted that poverty is not always immediately noticeable, and those that are visible are not always felt by the respondents. Hence the problem of subjective poverty measurement is important, as it identifies various degrees of poverty perception among respondents and often depends on the point of reference (on the people to whom the respondents compare themselves, e.g. family, friends, neighbors). For these reasons, research on the measurement of subjective poverty was undertaken. The study of subjective poverty allows for the identification of the diversity of the respondents' perceptions of poverty.
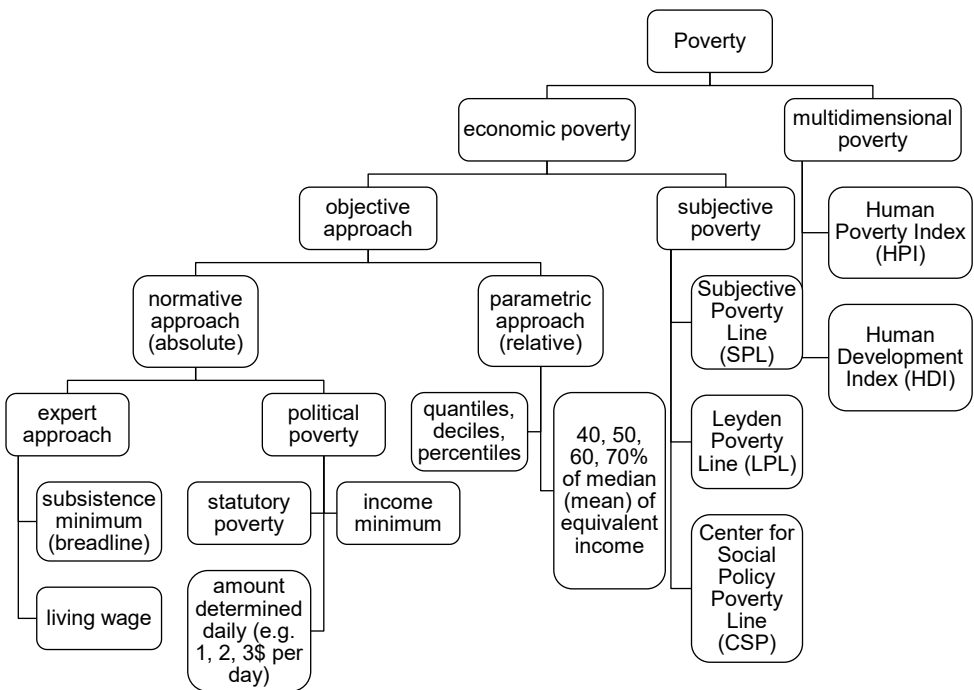

Figure 1: Methods of determining the poverty.
Source: Kalinowski (2015).

Existing definitions of poverty are characterized by a high degree of subjectivity and individual interpretation by individual researchers. This is why some of them have a broad scope, others are narrower. Due to this, in many cases, it is difficult to make comparisons because adopting a different understanding of the definition often means that the researcher had a research sample that was different in terms of quality.

Nevertheless, in many cases, one can note that despite the differences in the approach to particular definitions, the core is similar and many elements remain common (Kalinowski, 2015). Thus we defined subjective poverty as a conscious sense of the lack of sufficient resources to meet one's needs in relation to the "socioeconomic status (income and current financial situation, level of education and profession, place of residence, lifestyle and leisure activities) and one's own aspirations to achieve and maintain the desired standard of living" (Łuczak & Kalinowski, 2022).

To complete the picture of measurement of poverty, it is necessary to add an observation of problems that need to be taken into account when assessing subjective poverty. They are related to the selection of variables, survey design, measurement errors, frames of reference, idiosyncratic characteristics of respondents, and differences in their personality and tastes (Ravallion & Lokshin, 2002; Ravallion, 2012; Ravallion et al., 2016). Some of these can be solved by conducting research which is well grounded in theory and practice. However, some of them are unmeasurable and elusive in nature, regardless of the research procedure adopted.

We would like to emphasize the fact that objective and subjective dimensions of poverty are equally important, just as in well-being analyses (cf. Stiglitz et al., 2009). Instead of treating them as substitutes, they should be regarded as complementary. The picture of reality should be created by juxtaposing various approaches. Only then will it be possible to draw the correct conclusions.

3. Methodological approach

There are different approaches to assessing poverty based on fuzzy sets theory (Cerioli & Zani, 1990; Chiappero-Martinetti, 1994; Betti et al., 2008; Montrone et al., 2010; Belhadj, 2011; Neff, 2013; Betti et al., 2017; Belhadj & Limam, 2012; Aristondo & Ciommi, 2017; Ciani et al., 2019). However, our proposed composite-index approach goes far beyond what has been proposed so far, describing the subjective evaluation of household poverty as a multi-dimensional self-evaluation of respondents using multiple-criteria decision-making methods i.e. the fuzzy hierarchical analysis (FHA) and the fuzzy technique for order of preference by similarity to ideal solution (FTOPSIS). In this paper we introduce the time dimension to the poverty measure and propose a triple reference-point approach. This is based on the respondents' past, present and future feelings. Each step of the proposed procedure is described in detail below.

Step 1: Preparation of and conducting a survey on subjective poverty. In this step, we assume that households are characterized by three criteria: perceptions of the present situation, perception of the past, and future projections. In typical measures of subjective poverty, participants are asked to assess their financial situation or standard of living in relation to other families. Individual prosperity lines are constructed on this basis. Without going into the details of the creation of these lines, they can be reduced

to a number of commonly used ways of measuring poverty on the basis of subjective perceptions. They are related to:

a) an evaluation of one's own income situation (Hagenaars, van Praag, 1985),

b) a feeling of being poor – a minimum income (Kepteyn et al. 1988),

c) evaluation of one's life in verbal terms, e.g.: "very bad", "bad", "sufficient" and "good", "very good" (Van Praag, 1971, Van Praag et al. 1980). Such questions treat poverty as a more general concept than just income poverty and often approach terms such as subjective well-being, satisfaction with life and happiness,

d) assessment of the possibility of "making ends meet" (often referred to as the Deleeck question) or difficulties in making the necessary payments (Deleeck & Van Den Bosch, 1990; Ghiatis, 1990).

On one hand, households' perception of their own poverty may affect self-evaluation in the future, even if objective poverty decreases. On the other hand, previous experience of poverty may also result in a household currently having a sensation of a higher level of income than it actually does and vice versa (Ravallion & Lokshin, 2002). Thus the hysteresis in the perception of subjective poverty by households occurs. It should be added that the perceived condition of the household is also influenced by the actual dynamics of poverty (Alem et al., 2014).

Each of these criteria is described by k_i (i= 1, 2, 3) indicators, $k = k_1 + k_2 + k_3$. Households are subject to self-evaluation within each indicator using an ordinal measurement scale and verbal descriptions. The measurement scales used in the study have m_j categories ($j = 1, 2, ..., k$), where 1 is the most optimistic response in relation to the criterion of subjective poverty, and m_j is the most pessimistic. In other words, the higher the evaluation, the worse the perception with regard to the level of subjective poverty. So there are $(m_j - 1)/2$ positive and negative responses. In the case of an ordinal scale with inverted categories, these should be re-coded to the form described above.

Step 2: The selection of indicators of subjective poverty. A set of indicators[3] (attributes) is used to describe subjective poverty, characterizing it in terms of: an assessment of the financial situation and material conditions of the household, the perception of one's own income against the income of other households, the household's standard of living, feeling helpless in the face of poverty.

The collected indicator values are summarized in the data matrix:

$$\mathbf{X} = \left[x_{ij} \right] \tag{1}$$

where: x_{ij} – is the value of j-th indicator in i-th household, $i = 1, ..., n$; n – the number of households; $j = 1, ..., k$, k – the number of indicators.

Step 3: Determination of the nature of the indicators in relation to the main criterion. The direction of indicator preferences in relation to the criterion in question

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[3] An indicator (variable) is a quantitative or a qualitative measure that can show value of characteristics or their level for an objects. On the other hand, aggregated indicators are an index.

is determined, i.e. their division into benefit and cost indicators. A benefit indicator contributes to increasing the level of a phenomenon, whereas a cost indicator is a variable that reduces the level of that phenomenon. We assumed that all indicators were benefit indicators, because when measuring complex phenomena (i.e. the level of subjective poverty) using surveys, the criteria are usually selected so that they are positively correlated with the phenomenon (the higher the evaluation of an indicator, the higher the level of subjective poverty)

Table 1: Formulas for determining the parameters of triangular fuzzy numbers.

Categories	Triangular fuzzy number parameters		
	a_{ij}	b_{ij}	c_{ij}
1	0	0	$1/[2(m_j-1)]$
2	$1/[2(m_j-1)]$	$1/(m_j-1)$	$3/[2(m_j-1)]$
…	…	…	…
m_j-1	$(2m_j-5)/[2(m_j-1)]$	$(m_j-2)/(m_j-1)$	$(2m_j-3)/[2(m_j-1)]$
m_j	$(2m_j-3)/[2(m_j-1)]$	1	1

Step 4: Conversion of ordinal categories of indicators to triangular fuzzy numbers. Indicator variants are transformed into triangular numbers (a, b, c) in the form of three evaluations (parameters). Table 1 shows the formulas for determining the parameters of triangular fuzzy numbers. The parameters of triangular fuzzy numbers can be scaled by a selected fixed value freely determined by the researcher. The triangular fuzzy numbers obtained are presented in the form of fuzzy data matrix:

$$\widetilde{\mathbf{X}} = \left[\tilde{x}_{ij}\right] \tag{2}$$

where: $\tilde{x}_{ij} = \left(a_{ij}, b_{ij}, c_{ij}\right)$, $i = 1, \dots, n$; $n = n_1 + n_2 + n_3$; n_1, n_2, n_3 – number of households in stages I, II and III respectively; $j = 1, \dots, k$, k – number of indicators.

Step 5: Determination of the indicator-weighting system. One of the most commonly used methods of determining the weighting system is equal treatment of all indicators (Aaberge & Brandolini, 2015). This is the case, for example, with the Human Development Index. However, it should be noted that indicators under each criterion have different impacts on the level of subjective poverty, so a differentiated indicator-weighting system should be introduced. In our research, we used one version of the fuzzy analytical hierarchical process – the Fuzzy Hierarchical Analysis (FHA) – to determine the weighting system. This is an extension of the analytical hierarchical process (AHP) and also applies when there are difficulties in presenting the evaluations of comparisons of pairs of elements in the hierarchy in the form of real numbers. In our paper, we calculated the weighting system $\widetilde{w}_j = \left(w_j^L, w_j^M, w_j^U\right), j = 1, \dots, k; k = k_1 + k_2 + k_3$ using fuzzy hierarchical analysis (see Csutora & Buckley 2001, Buckley et al. 2001, Łuczak & Wysocki 2008).

Step 6: Normalization of indicator values. Normalization of indicators with a nature of stimulants:

$$\tilde{z}_{ij} = \left(a_{ij}^{(z)}, b_{ij}^{(z)}, c_{ij}^{(z)}\right) = \left(\frac{a_{ij}}{c_j^+}, \frac{b_{ij}}{c_j^+}, \frac{c_{ij}}{c_j^+}\right) \qquad (i = 1, 2, \ldots, n; \; j \in P_s) \quad (3)$$

where $c_j^+ = \max_i(c_{ij})$, $c_j^+ \neq 0$; P_s – a set of stimulant indices.

for the destimulants:

$$\tilde{z}_{ij} = \left(a_{ij}^{(z)}, b_{ij}^{(z)}, c_{ij}^{(z)}\right) = \begin{cases} \left(\frac{a_j^-}{c_{ij}}, \frac{a_j^-}{b_{ij}}, \frac{a_j^-}{a_{ij}}\right) \text{ for } a_{ij}, b_{ij}, c_{ij} \neq 0 \\ (0,0,0) \qquad \text{ for } a_{ij}, b_{ij} = 0 \end{cases} \quad (4)$$

$$(i = 1, 2, \ldots, n; \; j \in P_D)$$

where $a_j^- = \min_i(a_{ij})$; P_D – a set of destimulant indices.

Structure of the weighted normalized fuzzy data matrix:

$$\tilde{\mathbf{R}} = [\tilde{r}_{ij}] \quad (5)$$

where $\tilde{r}_{ik} = \tilde{z}_{ij}(\cdot)\tilde{w}_j = \left(a_{ij}^{(z)}, b_{ij}^{(z)}, c_{ij}^{(z)}\right)(\cdot)\left(w_j^L, w_j^M, w_j^U\right) =$
$= \left(a_{ij}^{(z)} w_j^L, b_{ij}^{(z)} w_j^M, c_{ij}^{(z)} w_j^U\right) = \left(a_{ij}^{(r)}, b_{ij}^{(r)}, c_{ij}^{(r)}\right)$, $(\cdot)$ is the fuzzy numbers multiplication.

Step 7: Calculating the pattern and antipattern. Determination of a fuzzy pattern $\tilde{A}^+$ (cf. Hwang & Yoon 1981, Chen 2000):

$$\tilde{A}^+ = \left(\max_i(\tilde{r}_{i1}), \max_i(\tilde{r}_{i2}), \ldots, \max_i(\tilde{r}_{ik})\right) = (\tilde{r}_1^+, \tilde{r}_2^+, \ldots, \tilde{r}_k^+) \quad (6)$$

where $\tilde{r}_j^+ = \left(a_{ij}^{(r)+}, b_{ij}^{(r)+}, c_{ij}^{(r)+}\right)$, $j = 1, \ldots, k$.

and fuzzy antipattern $\tilde{A}^-$:

$$\tilde{A}^- = \left(\min_i(\tilde{r}_{i1}), \min_i(\tilde{r}_{i2}), \ldots, \min_i(\tilde{r}_{ik})\right) = (\tilde{r}_1^-, \tilde{r}_2^-, \ldots, \tilde{r}_k^-) \quad (7)$$

where $\tilde{r}_j^- = \left(a_{ij}^{(r)-}, b_{ij}^{(r)-}, c_{ij}^{(r)-}\right)$, $j = 1, \ldots, k$.

Step 8: Calculation of the distance of each object from the pattern and antipattern. Calculation of the distance between fuzzy indicator values for the evaluated objects and the pattern is performed using the following formula (Chen 2000):

$$d_i^+ = \sum_{i=1}^k \sqrt{\frac{1}{3}\left[\left(a_{ij}^{(r)} - a_{ij}^{(r)+}\right)^2 + \left(b_{ij}^{(r)} - b_{ij}^{(r)+}\right)^2 + \left(c_{ij}^{(r)} - c_{ij}^{(r)+}\right)^2\right]} \quad (8)$$

and from the antipattern:

$$d_i^- = \sum_{i=1}^k \sqrt{\frac{1}{3}\left[\left(a_{ij}^{(r)} - a_{ij}^{(r)-}\right)^2 + \left(b_{ij}^{(r)} - b_{ij}^{(r)-}\right)^2 + \left(c_{ij}^{(r)} - c_{ij}^{(r)-}\right)^2\right]} \quad (9)$$

Step 9: Calculation of synthetic measures of the level of subjective poverty for households at different research stages.

Calculation of the value of the synthetic measure (index) for each household $i = 1, 2, \ldots, n$ using the following formula of TOPSIS (Hwang and Yoon 1982):

$$S_i = d_i^- / (d_i^+ + d_i^-) \quad (10)$$

The higher the value S_i, the higher the level of subjective poverty of the household. The measure S_i is normalized to the range $[0,1]$ and S_i becomes 0 for the antipattern object and 1 for the pattern object.

Step 10: Identification of subjective poverty types for households according to selected criteria and research stages.

Averaging of the standard values within the researched criteria:

$$S_i^{csv} = \underset{i \in P_{csv}}{\mathrm{med}}(S_i) \tag{11}$$

where P_{csv} – a set of household indices within the s-th category of the c-th criterion at the v-th stage of survey ($v = 1, 2, 3$). Three categories were adopted: for the whole country, divided into village and city, or village, small town with less than 20,000 residents, urban area with 20,000-99,000 residents, urban area with 100,000-499,000 residents, urban area with 500,000 or more residents.

Table 2: Subjective poverty index values and theoretical types of poverty – poverty profiles

S_i^{csv}	Level of index	Type of household poverty	Type of household
[0.00; 0.10)	very extreme low	no poverty	prosperous
[0.10; 0.20)	extremely low	very mild poverty	
[0.20; 0.30)	very low	at risk of poverty	relatively prosperous/ coping/ resourceful
[0.30; 0.40)	low	indistinct poverty	
[0.40; 0.50)	medium-low	moderate low poverty	endangered by poverty
[0.50; 0.60)	medium-high	moderate high poverty	
[0.60; 0.70)	high	strong advancing poverty	poor
[0.70; 0.80)	very high	severe poverty	
[0.80; 0.90)	extremely high	very severe poverty	extremely poor
[0.80; 1.00]	very extreme low	utter poverty	

Source: own elaboration.

The identification of subjective poverty level types can be carried out arbitrarily. Theoretical (hypothetical) poverty types – poverty profiles (Table 2) were also proposed on the basis of synthetic measure S_i^{csv}. Poverty is not dichotomous; households cannot be divided into poor or non-poor. There are many shades within the limits of the lack of poverty up to extreme poverty. Households may therefore be characterized by various levels of poverty (cf. Cerioli & Zani, 1990; Betti et al., 2008; Montrone et al., 2010; Belhadj & Limam, 2012; Ciani et al., 2019).

The authors' indicators of LK_{csv} compactness were also calculated as part of the s-th category of the c-th criterion at the v-th stage of survey:

$$LK_{csv} = \frac{\sum_{i=1}^{n_{csv}}\left(S_i^{csv} - \underset{i \in P_{csv}}{\mathrm{med}}(S_i)\right)}{n_{csv} \cdot \underset{i}{\max}\left(1 - \underset{i \in P_{csv}}{\mathrm{med}}(S_i); \underset{i \in P_{csv}}{\mathrm{med}}(S_i)\right)} \tag{12}$$

where n_{csv} – the number of households within the s- th category of the ($s = 1, 2, 3$) c-th criterion ($c = 1,.., n_s$) at the stage v ($v = 1, 2, 3$). The indicators are normalized within the range [0, 1]. The lower the measure of the compactness index, the more homogeneous is the group. The degrees of compactness according to the gradation given in Table 3 can be assumed.

Table 3: Degrees of compactness

LK_{csv}	[0.00; 0.20)	[0.20; 0.40)	[0.40; 0.60)	[0.60; 0.80)	[0.80; 1.00]
Degree of compactness	very high	high	medium	low	very low

Source: own elaboration.

4. Conducting research and results

The analyses used data from primary household research in Poland, during which the CAWI (Computer-Assisted Web Interview) method was used. The research was conducted in three stages: April, 2020 (1st research stage), June, 2020 (2nd research stage), September, 2020 (3rd research stage). In each of the three stages, the sample is a quota sample according to the key size category of the place of usual residence and covers 458 households.

The research included variables describing the subjective situation of households according to three criteria:

- perceptions of the present situation: feeling of being satisfied with life (x_1), degree of present satisfaction of household needs through income earned (x_2), evaluation of household income compared to other households, evaluation of the change in food needs during the pandemic period compared to previous years (x_3), evaluation of own household situation (x_4), whether it is possible to "make ends meet" with current income (x_5),
- future projections: perception of the degree of possibility of deterioration of one's own household's situation in the near future (x_6), feeling concerning the degree of potential for loss of income (x_7), perception of the degree of potential loss of financial stability (x_8), perception of the degree of possibility of losing work (x_9), evaluation of the possibility of change in one's own household's financial situation within the next 12 months (x_{10}),
- perceptions of past situations: degree of satisfaction of one's own household's needs through income (before the epidemic) (x_{11}), past feelings of being poor (x_{12}).

The variables adopted for the research define three unique time dimensions, not taken into account in research on poverty, in which it manifests itself, i.e.: the past (past fillings), the present (current subjective state) and the future (perceptions of future projections). We assumed that all indicators were stimulants. We assumed this because when measuring complex phenomena (i.e. the level of subjective poverty) by surveys,

usually the criteria are selected in such a way that they are positively correlated with this phenomenon. The higher the partial assessment, the higher is the level of subjective poverty. We adopted a system of differentiated fuzzy weights for indicators (Table 4).

Table 4: Fuzzy weights system for indicators

Indicator category	Indicators	Triangular fuzzy number		
		a	*b*	*c*
Perceptions of the present situation	$x_1 - x_5$	0.079	0.155	0.269
Future projections	$x_6 - x_{10}$	0.014	0.027	0.054
Perception of the past situation	x_{11}, x_{12}	0.043	0.045	0.097

As shown in Figure 2, the levels of perceived poverty at the different stages of the research suggest that there has been a shift from panic to adaptation. Figure 3 shows box-plots for levels of subjective household poverty, in which even greater disparities can be observed in the evaluation of subjective poverty between the 1st and 2nd and 3rd stages of the research; a relatively large increase in optimism can be observed in Poland between the 1st and 2nd stages of the research (the decrease in the index value from 0.387 to 0.354). At the third stage, despite the increase in disease incidence, the subjective evaluation of poverty remained almost unchanged (0.348). This may indicate that constant fear stimulation has become a factor of coronavirus becoming more common. Effective metaphors, war comparisons or post-apocalyptic language have become an adaptive factor to a "new normality" (Kalinowski, 2020a). This weakened the negative perception of one's own socio-economic situation.
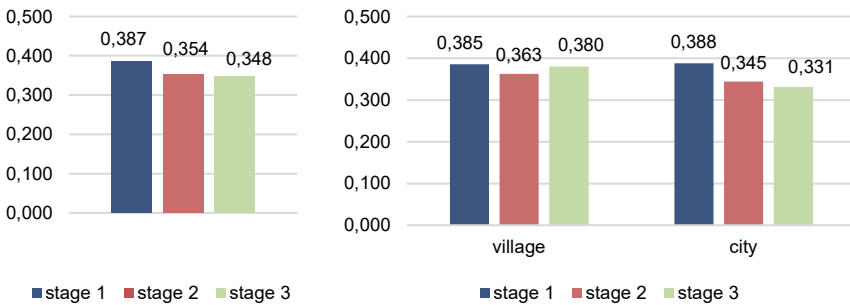

Figure 2: Levels of subjective household poverty by research stages and division into the village and the city.

Although, as indicated in public discourse, COVID-19 is treated more as an urban disease, studies indicate that it is a reason for rural residents' unfavorable assessment of their own situation to a greater extent. Although in the first stage, poverty perceived among rural residents (0.385) was almost at the same level as among urban residents (0.388), in subsequent stages, stratification to the disadvantage of rural areas occurred (Figure 2). As many studies show, it is rural areas that suffer greater economic and social consequences of poverty.
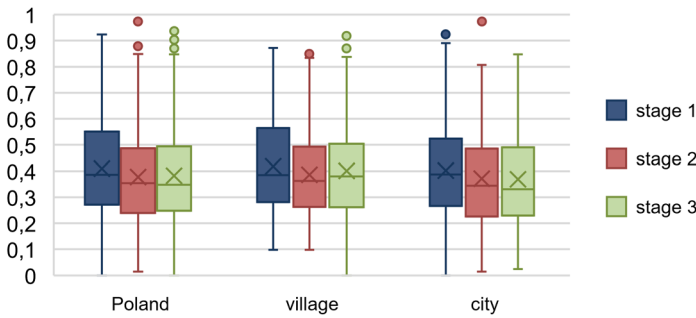
Figure 3: The box-plot for levels of subjective household poverty by research stages and division into village and city

Note: A box based on: median, and the first and third quartiles. Above the third quartile, a distance of 1.5 times the interquartile range (IQR) is measured and a whisker is drawn to the largest observed point from the set of data that falls within this distance. Similarly, a distance of 1.5 times the IQR is measured below the lower quartile, and the whisker is drawn to the bottom observed point from the set of data that falls within this distance. All other observed points are plotted as outliers.
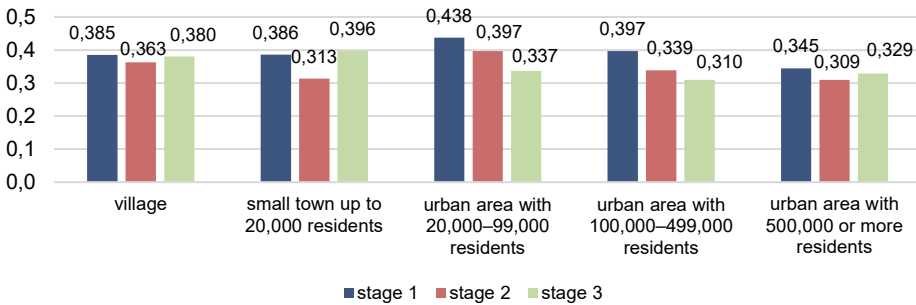
Figure 4: Levels of subjective household poverty by research stages and the class of the locality of the household head
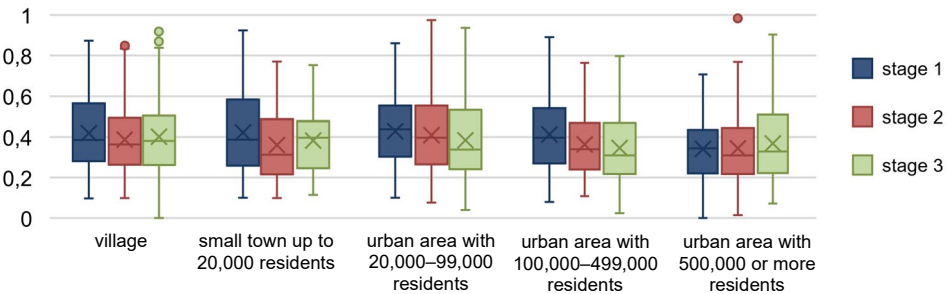

Figure 5: Box plot for levels of subjective household poverty by research stages and class of the locality of the household head

It is worth noting that the village and city categories are a certain mental construct. Just as there is no one village (Stanny et al., 2018), it is difficult to speak of a unified city.

It is worth noting that residents of small towns (up to 20,000 residents) and urban areas with 20,000-100,000 residents evaluate the level of poverty much below residents of medium or large cities (over 100,000 residents). The level of subjective poverty of small towns and villages was similar at all stages of the research (Figure 4). Interestingly, in the largest cities, the poverty-perception level increased again at the third stage. On the one hand, this may result from the ongoing lockdown, but also from rising expectations and discouragement, which fostered negative evaluations during surveys. However, despite a fairly significant increase in negative evaluation, the largest cities – next to the medium-sized ones – were still at the lowest risk of subjective poverty (Figures 4 and 5).
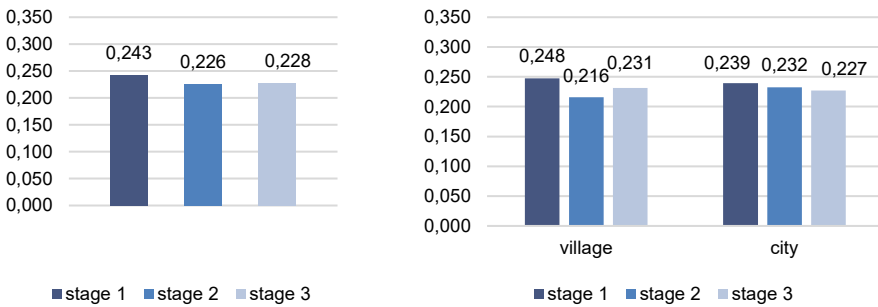

Figure 6: Compactness indices (*LK*) of the synthetic measure of subjective household poverty in Poland by research stages and rural-urban division
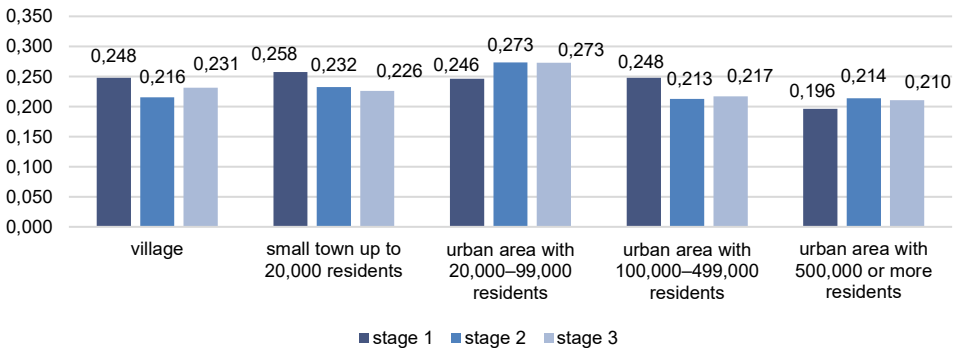

Figure 7: Compactness indices (*LK*) of locality classes in terms of a measure of the subjective household poverty level by stages

It is also worth mentioning that the groups of areas studied were characterized by high compactness of synthetic measures (Figures 6 and 7), as evidenced by the values of the LK index, which ranged from 0.193 (for large cities with more than 500,000 residents at stage I of the research) to 0.277 (for cities with 20,000 to 99,000 residents at stages II and III of the research) (Figure 7). This confirms that large cities with more than 500,000 residents are more homogeneous in their perception of poverty than smaller cities.

5. Conclusion

The multiplicity of subjective poverty indicators raises the following question – what is the purpose of establishing an additional synthetic measure of it? In our view, decomposing poverty using self-assessments of unidimensional indicators and then constructing new synthetic measure is justified for several reasons. First, this makes it possible to show the impact of many factors on the changes in the socioeconomic situation of the population, especially during epidemics. Changes of the synthetic index illustrate the trajectory of switching from panic to negation or trying to cope with the situation or alternatively switching to the state of irritation. Second, the proposed synthetic measure takes account of several overlapping factors related to both income security, deprivation, job security and the expectation of changes in them in the future, all of which are extremely important for assessing subjective poverty. Third, in the analysis of this index we took into account the fact that the assessment of one's own situation is influenced by expectations and aspirations. The index is therefore designed to take these aspects into account as well. Fourth, realizing that the current assessment of one's own socioeconomic situation is also influenced by past events, as well as predictions of changes in that situation in the future, we also took these into account.

Given the above aspects of perceived subjective poverty, our proposed synthetic measure allows us to easily compare various aspects of subjective poverty during the periods studied. The number of variables offsets the risk that a change in one factor will significantly alter the entire index. At the same time, the total level of perceived subjective poverty is affected by a number of variables that amplify or offset its magnitude.

By constructing the synthetic index, we would like to show that the measurement of poverty is a complex issue. Our contribution to research into poverty is to show that the synthetic measure capturing factors combining the future, present and past makes it easier to grasp the feeling of deprivation. It is useful for studying changes in the level of poverty perception over time under the influence of unpredictable phenomena, in this case, during the coronavirus period, without going into detail about the factors causing it. The proposed procedure could be used for conducting official statistics with regularly repeated surveys.

The indicators used are static. Both the LPL (Leyden Poverty Line) and the SPL (Subjective Poverty Line) or the CSP (The Center for Social Policy Poverty Line) are based on individual welfare lines, defining the situation at a given point in time. Such estimates ignore projections both of the future situations and take limited account of events from the distant past. It should be emphasized here that our innovative methodology for constructing a subjective measure of poverty takes into account indicators describing the past, present, and future. In addition, the previously mentioned indicators existing in the literature also have the disadvantage that a significant segment of the population cannot estimate the income that separates the

poor from the wealthy or the income that allows them to live at a certain acceptable level. Individual prosperity lines also have the disadvantage of focusing solely on income while ignoring behavioral aspects, or those related to the socioeconomic environment.

Knowledge of subjective poverty makes it possible to define the elements that influence the sense of poverty. It helps to bridge the gap between its objective and subjective dimensions. In the subjective dimension, the research also makes it possible to pay attention to the nature of inequality. Our study is in line with Aristondo and Ciommi's (2017) observation that "the recent literature on poverty measurement stresses the importance of an index to take into account intensity, incidence and inequality." By emphasizing subjective poverty, we wanted to highlight the importance of maximizing individual wealth, because, as Pouw (2020) argues, it translates into an increase in the prosperity of society as a whole. It is also worth adding, quoting Mowafi (2004), that "studies can only be justified if their conclusions are conscientiously used to inform the development of an adequate and accurate definition of poverty – a definition that not only withstands the rigors of science, but also reflects the realities of the poor."

To summarize our discussion of the construction of a measure of subjective household poverty, several facts should be noted. First, using a fuzzy approach to assessing subjective poverty allows us to identify individual indicators more precisely than with a standard poverty measurement. To the best of our knowledge, nearly all existing approaches to studying household poverty self-assessment are based on a dichotomous division of respondents into poor or non-poor. The advantage of our method is to determine the degree of poverty of the households studied. For these reasons, our work goes beyond a conventional poverty study. We confirm the opinion of Betti et al. (2017) that "the conventional approach presents a serious limitation: poverty is not an attribute that characterises an individual in terms of its presence or absence, but is rather a predicate that manifests itself in different shades and degrees."

Second, the subjective poverty index that we constructed is an attempt to explain poverty from the perspective of the poor. By estimating the level of subjective poverty for each household studied, the index we propose can be used to create a truly individual measure of poverty, taking account of a multi-faceted perceptions of feelings regarding the household's current situation, but also its past situation and predictions for the future.

Third, the subjective picture of the economic stratification of the population is reflected in the aggregate subjective poverty index for each class of locality. A comparison of the dynamics of population indicators revealed their multidirectional dynamics. This may indicate that either people are gradually getting used to the pandemic and are no longer bothered by it that much, or that they are adapting to the new circumstances.

In conclusion, our methodological proposal opens the door to new opportunities for research and applications of multidimensional subjective poverty. Quantitative measurement of subjective poverty at the micro (household) level is an important tool for evaluating anti-poverty policies. At the same time, research over time helps to explain changes occurring in households. In addition, the subjective poverty index can also be viewed as a measure of vulnerability to poverty and can provide a basis for formulating poverty-alleviation policies and strategies.

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