Multidimensional material deprivation in Poland: a focus on changes in 2015–2017

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Abstract

The study applies the fuzzy approach to measuring material deprivation from a multidimensional perspective. By taking into account the intensity of deprivation this approach goes beyond the conventional research using the deprived/non-deprived dichotomy. The study is based on the European Union Statistics on Income and Living Conditions data including a set of nine-item material deprivation indicators adopted by all European Union countries. In order to examine the effects of social reforms introduced by the Polish government in 2016, it focuses on the situation of Polish households in 2015 and 2017. The study aims to identify correlates of material deprivation in Poland using the zero-inflated beta regression model. This model enables to understand the mechanisms behind the risk and the intensity of material deprivation. Moreover, the study provides evidence that households with at least three children experienced meaningful improvement during the studied period. This is probably due to the introduction of the ‘Family 500+’ programme supporting mainly large families.

Keywords Material deprivation · Household · Multidimensional measurement · Zero-inflated beta regression · Poland

1 Introduction

The concept of material deprivation is attracting an increasing amount of attention. It has recently gained relevance in the European Union (EU) in connection with the implementation and monitoring of the ‘Europe 2020 Strategy for smart, sustainable and inclusive growth’. In the EU, material deprivation (MD) refers to a state of economic strain and durables, defined as the enforced inability to pay for unexpected expenses, a 1-week annual holiday away from home, regular meals with meat, fish or a protein equivalent, the adequate heating of a dwelling, purchasing durable goods such as a washing machine, a colour TV,

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a telephone or a car, as well as dealing with payment arrears (Eurostat 2018). There are many reasons for interest in this issue. Firstly, an analysis of the above-mentioned deprivation items makes it possible to measure living standards by looking at the 'enforced lack of necessities'. This approach separates those who cannot afford a certain good or service from those who do not have it for another reason. In other words, the lack of items is not due to lifestyle preferences or choice. People would like to possess the items but cannot afford them (Fusco et al. 2013). Secondly, deprivation indicators are more useful than income in measuring the persistence of poverty and social exclusion because a lack of items is usually associated with a shortage of resources over a prolonged period (Caland-rino 1983). Thirdly, MD indicators enable, to some extent, to overcome the measurement problem of misreporting income, especially regarding the lower and upper tails of income distribution.¹

MD can be analysed in a multivariate framework by means of different approaches (Atkinson 2003; Nasri and Belhadj 2017; Pattanaik and Xu 2018). On the one hand, the union method identifies a household as materially deprived if the household experiences at least one of the considered symptoms. On the other hand, the intersection method requires the deprivation of all symptoms. In between these two extremes lie intermediate identification methods. The Alkire and Foster approach (2011) concentrates on counting the number of symptoms in which households suffer deprivation. In this approach, a cut-off value under which a household is considered to be deprived is established. EU indicators use the threshold of three out of nine items for MD measurement and the threshold of four out of nine items for severe MD measurement (Eurostat 2018; Guio et al. 2016). Thus, the established cut-offs divide households into sets of the deprived and non-deprived. The main advantage of such an approach is that the results can be easily interpreted, while the main drawback is a lack of distinction between items and the uncertainty about what level to set the cut-offs at. Another intermediate approach is the method based on fuzzy sets (Cerioli and Zani 1990; Cheli and Lemmi 1995; Betti et al. 2015; Neff 2013; Kim 2015) recognising various degrees of belonging to the poverty sphere rather than classifying households as deprived or non-deprived. Taking into account the weights assigned to each deprivation item, it provides a fuzzy measure of MD for each household. As this approach does not require thresholds to be set and it enables to attribute different weights to items, it overcomes the limitations of the counting approach. Moreover, addressing the intrinsic vagueness of 'being deprived', the fuzzy set method is in line with Sen's (1990) opinion that 'it is undoubtedly more important to be vaguely right than to be precisely wrong'.

In our study, we have analysed MD in Poland using the fuzzy measure approach with data-driven weights obtained by means of the 'prevalence-correlation' method. This method of weighting, proposed by Betti and Verma (2008), implies that forms of deprivation which affect only a small share of the population are assigned a larger weight than those which are more common in a given country. Moreover, it takes into account the problem of redundant information, limiting the influence of deprivation indicators which are highly correlated. The fuzzy approach yields to obtain a score being the value of 'a membership function' from the $[0, 1]$ interval, wherein the value 0 indicates that a household is unambiguously non-deprived, the value 1—definitely deprived, while all other values indicate partial belonging to the deprived group. In our study, we analysed the risk and the intensity of MD, wherein being at risk means experiencing at least one

¹ In particular, the data from surveys in Poland is burdened with the problem of the reluctance of the rich to reveal their income (Kośny 2019).

of the MD items. We examined how deep MD is for households at risk. In other words, a high membership function value indicates a high intensity of MD. In order to identify the correlates of the risk and the intensity of MD, we applied the zero-inflated beta regression model.

The study uses cross-sectional data of the European Union Statistics on Income and Living Conditions (EU-SILC). The analysis is based on a set of nine-item MD indicators adopted by all EU countries and the European Commission. It focuses on the households' situation in 2015 and in 2017. By comparing MD in these years, we wanted to examine the effects of the 'Family 500+' programme launched by the Polish government in April 2016. The aim of this programme was to boost the birth rate and reduce child poverty by improving the living conditions of large families. The programme entitles parents to receive a tax-free benefit of 500 PLN (about 120 EUR) per month for the second and each subsequent child until they reach the age of 18, regardless of how much the household earns. Moreover, if a family's income is lower than 800 PLN net per person (or 1200 PLN net per person for a disabled child), this benefit may also be received for the first or only child in the family. In 2015, before the programme was introduced, the overall expenditure on social protection for families and children in Poland was—as a percentage of the GDP—one of the lowest in the EU, whereas in 2017 it was above the EU average.

The causes of MD among Polish households are complex and there is a wide range of factors contributing to it. To better understand this issue, it is worth examining which households experience MD and investigating to what extent they are deprived. There is no reason to believe that the factors influencing the risk and the intensity of MD are the same. On the contrary, it should rather be expected that the vectors of variables describing individual households have significantly different distributions in the sub-population of MD-affected households and in the sub-population of households in which MD does not occur. Therefore, in our study we decided to verify the following hypothesis: (1) the set of significant correlates of MD risk is different from the set of significant correlates of MD intensity. Moreover, due to the fact that the 'Family 500+' programme was targeted mainly at large families, we verified the second hypothesis: (2) the risk and the intensity of MD among households with at least three children significantly decreased in 2017 compared to 2015. Thus, we aimed to examine the effects of 'Family 500+' by comparing the situation of households 1 year before and after the programme was launched.

This paper contributes to the research literature on households' vulnerability to MD in three main ways. Firstly, it provides the first analysis of MD in Poland from a multidimensional perspective. Secondly, it identifies the separate correlates of the risk and intensity of MD by applying the zero-inflated beta regression model. Thirdly, it provides empirical evidence of changes in MD in Poland due to social reforms introduced by the Polish government.

The paper is divided into six sections. The first section is the introduction. Section 2 features a review of literature regarding material deprivation research. Section 3 describes the used data and defines the key variables. It also contains a presentation of the step-by-step procedure for calculating fuzzy material deprivation measures and methods of their analysis. The empirical contribution of the paper is presented in Sect. 4. This section includes detailed results of the methodology applied to the data for Polish households. It presents the findings regarding correlates of fuzzy material deprivation measures, emphasizing the 2015–2017 comparative aspects. The discussion and conclusion of our research constitute the last sections of the paper.

2 Literature review

2.1 The origins of material deprivation research

MD has been a subject of research since the late 1970s, in particular the influential work of Townsend (1979), in which he stated that ‘individuals, families and groups can be said to be in poverty when they lack the resources to obtain the type of diet, participate in the activities and have the living conditions and the amenities which are customary, or at least widely encouraged or approved in the societies to which they belong’. Thus, according to Townsend, poverty is defined as a lack of resources and deprivation is its consequence. In 1985, Mack and Lansley developed Townsend’s approach by proposing the so-called ‘consensual’ or ‘perceived deprivation’ method defining poverty as an ‘enforced lack of socially perceived necessities’ due to a lack of income and to the fact that these ‘necessities’ could not be afforded. They considered as ‘necessities’ various consumption items, and they regarded as ‘poor’ those individuals who could not maintain a level of consumption perceived as necessary by the majority of society (Mack and Lansley 1985). From the mid-1980s, various deprivation indicators have been used in scientific literature, though with different applied methodologies. Important studies include (Mayer and Jencks 1989; Halleröd 1995; Nolan and Whelan 1996; Halleröd et al. 1997; Whelan et al. 2008; Whelan and Maître 2012; Fusco et al. 2013; Guio et al. 2016). Supported by the above-mentioned research, the measurement of MD has been commonly used to provide a deeper insight into the multidimensional phenomenon of poverty and social exclusion. Today, MD indicators are applied in various ways in countries around the world. For example, Saunders (2015) conducted an analysis for Australia, Nájera (2017) for Mexico, and Kim and Nandy (2018) for South Korea. Regardless of the methods used, researchers define MD as lacking items due to the inability to afford them. Thus, they separate people who can afford certain items but do not want them (i.e. due to lifestyle preferences and choice) from those who cannot afford them although they want to.

2.2 Material deprivation research in the EU

MD research in the EU has become much more relevant since 2010 as a result of adopting the ‘Europe 2020 Strategy on smart, sustainable and inclusive growth’ (Guio et al. 2016). Deprivation indicators combining nine material and social items are used as social indicators in the EU. They are used by all EU Member States and the European Commission to monitor national and EU progress in the fight against poverty and social exclusion (Fusco et al. 2013; Guio 2018). Research literature includes studies relating to MD in individual countries as well as the entire EU.

A number of authors use the dichotomy approach distinguishing between deprived and non-deprived households, wherein they use a threshold of three (or four) out of nine items. Applying logit or probit models in their studies, they examine the impact of various socio-economic factors on the probability of being deprived. Studies using such an approach include Nelson (2012), Rezanková and Želinský (2014), Bárcena-Martín et al. (2014), Šoltés and Ulman (2015), Israel (2016), Bruder and Unal (2017), Saltkjel (2018), and Israel and Spannagel (2019). Furthermore, basing on this dichotomy, some of the authors focus on the percentage of the population which cannot afford at least three (or four) of the nine items, and they analyse MD rates (or severe MD rates) at country or regional levels

(Nelson 2012; Wyduba and Kalinowski 2017; Dudek 2019; Notten and Guio 2019; Dudek and Sedefoğlu 2019).

Another approach to MD analysis is the use of composite multidimensional indicators which rely on the aggregation of binomial variables measuring the occurrence of different forms of deprivation. The aggregation can be done either by summing the binomial variables or by weighting them according to their importance. Such an approach enables to examine the intensity of material deprivation. Studies analysing the unweighted sum of the nine items include Bedük's research (2018) employing count models. The results obtained in this research prove that scoring zero on the material deprivation scale is a qualitatively different phenomenon to scoring at least one. Thus, using zero-inflated count models, Bedük (2018) shows that individuals with zero deprivation items have significantly distinct profiles to those who experience at least one deprivation item. Other relevant papers on the intensity of material deprivation are Bárcena-Martín et al. (2014) and Busetta et al. (2016). Although both these studies analyse composite indicators by assigning different weights to items, the modelling approaches are different. Bárcena-Martín et al. (2014) used the multilevel linear model and showed that differences in material deprivation across EU countries are explained from both individual and country-level perspectives, whereas Busetta et al. (2016) applied the zero-inflated beta model to examine MD among foreigners in Italy. Other important research analysing composite material deprivation indicators in the EU includes Figari (2012) and Betti et al. (2015). However, these papers use different sets than the standard EU set of nine items.

In our study, we used the weighting approach of Betti et al. (2015) for the aggregation of deprivation items. Next, in order to identify the drivers of material deprivation, we applied econometric methodology using the two-part zero-inflated beta model.

2.3 Correlates of material deprivation in the EU

Despite the fact that MD is measured by means of different applied methodologies, most studies point out the similar individual and household-level correlates used in different EU countries. First of all, many studies find an association between household income and MD (Bárcena-Martín et al. 2014; Bedük 2018; Israel 2016). However, monetary poverty and MD do not strictly coincide (Ayllón and Gábos 2017; Stávková et al. 2012; Szulc 2008). Ayllón and Gábos (2017) pointed out that these social indicators capture different aspects of economic hardship in the majority of analysed European countries.

The literature provides consistent findings in all countries that higher education reduces MD (Bárcena-Martín et al. 2019; Israel 2016; Nelson 2012; Šoltés and Ulman 2015). Unemployed persons, those living alone, and single parents are more vulnerable to MD (Bárcena-Martín et al. 2014; Israel and Spannagel 2019; Hicks 2016; Nelson 2012; Šoltés and Ulman 2015). Other socio-demographic factors such as gender, age, health status, and place of residence have also been examined by many authors. In particular, Bedük (2018) and Nelson (2012) found that women are generally more deprived than men. Moreover, Hicks (2016) and Bárcena-Martín et al. (2014) revealed that living in a female-headed household significantly increases the risk of MD. Additionally, because disabilities and illnesses require additional expenses, poor health is positively associated with MD (Bedük 2018; Israel 2016; Šoltés and Ulman 2015).

Regarding the age of the household head, the results are not entirely unambiguous across all countries. Nonetheless, most authors find young persons are more deprived compared to the middle-aged group. The elderly experience less deprivation

(Bárcena-Martín et al. 2014; Israel 2016; Šoltés and Ulman 2015). Likewise, results relating to the level of urbanisation depend on the country of residence (Bruder and Unal 2017). Apart from household-level drivers of MD, many studies point out the importance of country-level factors such as GDP (Bárcena-Martín et al. 2014; Israel 2016), social expenditures (Bárcena-Martín et al. 2014; Israel 2016; Nelson 2012) and income inequalities (Bárcena-Martín et al. 2014).

3 Research methodology

3.1 Data

In our study, we analysed nine material deprivation items used in the EU's Europe 2020 strategy. The list of items covers the inability to: (1) keep the home adequately warm, (2) eat a meal with meat, chicken or fish or a protein equivalent every second day, (3) go on a week-long holiday away from home once a year, (4) handle unexpected expenses, (5) pay the rent, mortgage, or utility bills, (6) afford a television set, (7) afford a washing machine, (8) afford a car, (9) afford a telephone. The first five items are labelled 'economic strain' and the next four are 'durable goods'.

The Survey on Income and Living Conditions (EU-SILC) is the source for MD information in the EU. Material deprivation questions in the EU-SILC usually have three potential responses: yes; no—because the household cannot afford it; no—for another reason. As in most analyses of MD in the EU, we focused on non-affordability only (Guio 2009; Nolan and Whelan 2010; Whelan and Maître 2012). Thus, in our study we included a set of nine binary variables. A value equal to one indicates that the household is deprived of a given item (attribute), and a value equal to zero is assigned otherwise.

We used cross-sectional data for the years 2015 and 2017 encompassing respectively 12,183 and 13,057 Polish households. In the analysed sample, 36% of households did not exhibit any considered deprivation symptoms in 2015, whereas in 2017 this percentage of households increased to 43%. In both years, the percentage of households with all nine deprivation symptoms was marginal.

The set of potential correlates of MD captures information on the whole household and attributes of the household head (HH). The first group of these correlates includes:

- yearly disposable equivalised income adjusted by the so-called 'modified OECD' scale (expressed in thousands of EUR);
- household type—characteristics referring to the number of adults and children in the household, wherein a child is considered a person under the age of 18;
- disability—characteristics referring to the presence of persons in households whose activities were strongly limited due to health reasons;
- degree of urbanisation;
- region—NUTS 1 level region;

The second group of correlates includes attributes of HH, such as age, education, employment, occupation and health status. A regression analysis was carried out to identify the effects of each of the considered characteristics on MD.

3.2 The fuzzy measure of material deprivation

In order to obtain a fuzzy measure, the deprivation items need to be weighted and aggregated. Thus, we define the deprivation score for the i th household as the weighted sum of nine deprivation items:

$$s_i = \sum_{k=1}^9 w_k d_{ik} \quad (1)$$

where d_{ik} ($k=1, 2, \dots, 9$) is a binary indicator variable taking the value 1 if i th household is deprived *with respect* to the k th item or taking the value 0 if there is a lack of deprivation *with respect* to the k th item, w_k is a weight reflecting the relative importance of the k th item, wherein $0 \leq w_k \leq 1$ and $\sum_{k=1}^9 w_k = 1$.

Thus, the value of the fuzzy measure of multidimensional MD is the deprivation score achieved by calculating the weighted average across all the deprivation items.

The measure (1) summarises the complex phenomenon of MD by reducing the size of a set of deprivation items without dropping the underlying information base. Its values belong to the unity interval, wherein a value of 0 means that a given household is not deprived of any items and a value of 1 means that the household is completely deprived, i.e. it is deprived of all the items. Thus, a fuzzy measure, being a membership function, is easy to interpret because a higher value of the index (1) indicates a higher intensity of MD.

The excess of zeros has substantive implications for defining and analysing MD (Bedük 2018). Therefore, apart from intensity, we examined the risk of MD, which in our study refers to being deprived of at least one of nine items. In other words, we treated zeros and positive values of the index (1) differently.

A number of different weighting procedures exist in poverty analysis (Cerioli and Zani 1990; Desai and Shah 1988; Betti and Verma 2008; Fusco et al. 2013). The simplest rule is equal weighting which treats each deprivation item as equally important. Such an approach causes that the fuzzy measure s_i is simply the average value of d_{ik} . In the context of multidimensional deprivation analysis, it is often argued that there should be an inverse relation between the frequency of the deprivation symptom and the weight of that item (Deutsch and Silber 2005). Thus, the other implemented rule is ‘frequency-based weighting’ which assigns weight proportionally to the prevalence of an item in the population. Such a rule attributes higher weights to relatively infrequent deprivation items to reflect the view that suffering from a ‘rare’ deprivation takes a greater toll on people’s standard of living (Cerioli and Zani 1990; Hildebrand et al. 2017). In such an approach, item weights are a function of their sample mean. For example, Desai and Shah (1988) propose to calculate

$$\omega_k = 1 - \bar{d}_k \quad (2)$$

and Cerioli and Zani (1990) suggest the formula

$$\omega_k = \ln \frac{1}{\bar{d}_k} \quad (3)$$

where $\bar{d}_k$ denotes the mean of item d_{ik} in the sample.

To sum to one, values (2) and (3) are normalised:

$$w_k = \frac{\omega_k}{\sum_{k=1}^K \omega_k} \quad (4)$$

where K is the number of items, i.e. $K=9$ in our study.

This kind of weighting can be interpreted as ‘objective measures of the subjective feelings of deprivation’ (Desai and Shah 1988). It is used in MD studies (Bárcena-Martín et al. 2014; Busetta et al. 2016) as well as in other research (Kapuria 2014).

Another important property that weights should satisfy is limiting the influence of those items which are highly correlated (Betti et al. 2006). Thus, the methodology developed by Betti and Verma (2008) comprises of two factors: the frequency of the deprivation item and its correlation with other deprivation items. According to this methodology, the weights can be computed as follows (Betti and Verma 2008):

$$\omega_k = \omega_k^a \cdot \omega_k^b \quad (5)$$

where the first factor is the coefficient of variation of the item and the second factor is a measure which gives less weight to items more correlated with others in order to reduce the effect of redundancy. In the case of binary indicators, the coefficient of variation can be expressed as:

$$\omega_k^a = \sqrt{\frac{1}{d_k} - 1} \quad (6)$$

Thus, this method assigns higher weights to relatively infrequent deprivation items. The second factor ω_k^b in formula (5) is defined by Betti and Verma (2008) in the following manner:

$$\omega_k^b = \left(\frac{1}{1 + \sum_{k'=1}^K r_{kk'} |r_{kk'} < r^*} \right) \cdot \left(\frac{1}{\sum_{k'=1}^K r_{kk'} |r_{kk'} \geq r^*} \right) \quad (7)$$

where $r_{kk'}$ is the correlation coefficient between two different indicators d_k and $d_{k'}$, r^* is a predetermined cut-off correlation level, K is the total number of indicators in the dimension.

Finally, ω_k are normalised to sum to one using formula (4).

In our study, we used the Betti and Verma method, because of its attractive properties:

- (1) the method ‘lets the data speak for itself’,
- (2) it assigns higher weights to relatively infrequent deprivation items,
- (3) the method takes into account the problem of the redundancy of information, limiting the influence of those deprivation indicators which are highly correlated.

In other words, the Betti and Verma approach enables to calculate data-driven weights using a sort of ‘prevalence-correlation’ method (Betti et al. 2015; Ciani et al. 2019).

In order to calculate weights to be assigned to each item, we applied the Stata procedure *mdepriv* (Pi Alperin and Van Kerm 2014). The weights are calculated separately for items within the ‘economic strain’ dimension and for items within the ‘durables’ dimension. We treated both dimensions in the same way, assigning them the weights of $\frac{1}{2}$. Therefore, the weights sum up to one. Because the purpose of the study is to compare the situation of households in 2015 and 2017, we calculated the weight on the basis of pooled data from both years,

i.e. weights are common for the items in both years. This enables assessing the change of MD intensity over time.

To sum up this sub-section, we focused in our study on 9 deprivation items, among which 5 belong to the ‘economic strain’ dimension and 4 belong to the ‘durables’ dimension. We aggregated deprivation items into the fuzzy multidimensional MD index using ‘prevalence-correlation’ weights.

In the next step of the study, to gain a deeper insight into the socio-economic and demographic correlates of fuzzy multidimensional MD scores, we carried out regression analysis. Because, as revealed in Sect. 2.1, we were dealing with data with excess zeros, in such case it is recommended to apply models adequately addressing the zero observations. Therefore, we used the zero-inflated beta regression model (ZIBRM).

3.3 Zero-inflated beta regression models

Zero-inflated beta regression models are applied because such models are well suited in the case of dependent variables between zero and one. More precisely, these models distinguish two separate processes (Öhler et al. 2019). The first estimates the probability of a value of zero. The second process determines, for households with at least one deprivation symptom, the intensity of MD. The idea here is that there is something qualitatively different about households which have at least one deprivation symptom compared to those which do not. Thus, accounting for the distinctiveness of zeros, the conceptual difference between the risk and the intensity of MD is revealed.

The zero-inflated beta regression model (ZIBRM) assumes the response variable has a mixed continuous-discrete distribution with the probability mass at zero. The appropriate mixture density is:

$$BI_0(s, \alpha, \mu, \psi) = \begin{cases} \alpha & \text{if } s = 0 \\ (1 - \alpha)f(s, \mu, \psi) & \text{if } s \in (0, 1) \end{cases} \quad (8)$$

where α is the probability of observing zero, $f(s, \mu, \psi)$ is the beta distribution density function defined as

$$f(s, \mu, \psi) = \frac{\Gamma(\psi)}{\Gamma(\mu\psi)\Gamma((1-\mu)\psi)} s^{\mu\psi-1} (1-s)^{(1-\mu)\psi-1} \quad (9)$$

Γ denotes the gamma function, μ is the mean of the outcome variable s for $s \in (0, 1)$, ψ is the parameter being scaling factor related to variance of s , $s \in (0, 1)$.

Beta distribution offers a very flexible two-parameter family of distributions for random variables taking values between 0 and 1. It can take a wide variety of shapes enabling incredible flexibility in the modelling of dependent variables.

Denoting by $s_1, s_2, \dots, s_n$ a random sample from zero-inflated beta distribution, where each s_i has a probability density function (8), the zero-inflated beta regression model can be defined by assuming the relationships for the mixture parameter α and the conditional mean μ (Ospina and Ferrari 2012):

$$h(\alpha_i) = \mathbf{z}_i' \boldsymbol{\gamma} \quad (10)$$

$$g(\mu_i) = \mathbf{x}_i' \boldsymbol{\beta} \quad (11)$$

Fig. 1 Rates of MD by number of deprivation items. *Source:* Eurostat database

where β are vectors of unknown parameters to be estimated, z_i and x_i are vectors of known covariates of household i ($i = 1, 2, \dots, n$), which may be identical or partly overlapping (Masserini et al. 2017), $h(\cdot): (0,1) \rightarrow R$, $g(\cdot): (0,1) \rightarrow R$, are strictly monotonic and twice differentiable functions.

Equations (10)–(11) define the sub-models of ZIBRM, wherein various link functions can be applied. In our study, we estimated ZIBRM using the Stata module *zoib* developed by Buis (2010), with a logit link for $h(\cdot)$ and $g(\cdot)$. The results of the estimated parameters and β are interpretable in terms of odds ratios (Masserini et al. 2017). Parameter estimation was carried out by maximum likelihood, wherein the log-likelihood function is given by:

$$\ln L = l_1(\gamma) + l_2(\beta, \lambda) = \sum_{i=1}^n l_{1i}(\alpha_{z_i}) + \sum_{i:s \in (0,1)}^n l_{2i}(\mu_{x_i}, \psi), \quad (12)$$

where

$$\begin{aligned} l_{1i}(\alpha_{z_i}) &= y_i \ln \alpha_{z_i} + (1 - s_i) \ln (1 - \alpha_{z_i}) \\ l_{2i}(\mu_{x_i}, \psi) &= \ln \Gamma(\psi) - \ln \Gamma(\mu_{x_i} \psi) - \ln \Gamma((1 - \mu_{x_i}) \psi) + (\mu_{x_i} \psi - 1) \ln s_i \\ &\quad + ((1 - \mu_{x_i}) \psi - 1) \ln (1 - s_i) \end{aligned}$$

For a detailed description of the estimation, inference and diagnostics of ZIBRM, see Ospina and Ferrari (2012).

4 Results and discussion

4.1 Introductory results

Firstly, we compared material deprivation rates in Poland and in the whole EU with 28 countries (EU28) (see Fig. 1). To get a better insight into the distribution of the number of items, we considered the percentage of the population that cannot afford one, two, three or at least four of the nine items. For example, as reflected in Fig. 1, in 2015, 22% of Poles exhibited one deprivation item, 20%—two items, 9%—three items and 8%—four or more items.

Figure 1 shows that, as compared to 2015, all rates decreased in 2017. This applies to Poland, as well as to the EU28. In both years, the percentage of the population unable to

Fig. 2 Material deprivation rates among the income poor. *Source:* Eurostat database)

afford one or two deprivation items in Poland was higher than in the EU28. However, taking into account at least three items, deprivation rates were slightly lower in Poland.

Income poverty does not perfectly overlap with a high intensity of MD. Thus, in Fig. 2, we considered the situation of persons living below the at-risk-of-poverty threshold, which is set at 60% of the national median equivalised disposable income.

As Fig. 2 shows, in Poland, as well as in the whole EU, the percentage of the income-poor population which did not exhibit any deprivation items in 2017 slightly exceeded 20%. Similar values can be observed among severely materially deprived income-poor citizens. In 2017, about 20% of the income-poor could not afford at least four of the nine items. Therefore, the risk and intensity of MD were not only affected by the availability of current monetary resources. On the one hand, some of the income-poor were not deprived. On the other hand, MD could also be experienced by households with equivalised income above the poverty threshold.

In the next stage of our study, we calculated the weights assigned to each of the nine deprivation symptoms. The results are shown in Table 7 in the “Appendix”. Using weights, we aggregated the households’ deprivation items into a fuzzy measure producing the households’ deprivation scores, wherein the score reached its maximum of 1 when the household was deprived in all component indicators. A household not deprived in any indicator received a score of 0. As mentioned in Sect. 2.1., 36% of households in 2015 and 43% in 2017 did not exhibit any of the nine deprivation symptoms. By contrast, we found that only 6 households in both years experienced each of the considered symptoms.

Because we aimed to evaluate the effects of the ‘Family 500+’ programme launched by the Polish government in 2016, we examined changes in MD between the years 2015 and 2017. Before carrying out regression analysis, we focused on the average risk and intensity of MD in various household types. For examining the average risk of deprivation, we considered the percentage of households deprived of at least one of the nine items, whereas for inspecting the average intensity of MD we analysed the mean values of the fuzzy measure (1) for those households. Survey weights were used to compute nationally representative estimates. The results in this regard are shown in Tables 1 and 2.

The results in Table 1 show that a statistically significant decrease of MD risk was observed in most types of households. Specifically, a meaningful decline was observed in households of at least two adults with at least three children. The position of such households improved in comparison to other types. The worst situation was recorded in one-person households and single-parent households. In these types, more than 60% of households

Table 1 The risk of MD in various household types

Household type	2015			2017		
	Estimate (%)	LCI (%)	UCI (%)	Estimate (%)	LCI (%)	UCI (%)
One-person	70.9	68.7	73.1	67.7	65.6	69.8
Single-parent	78.1	71.0	85.3	69.6	62.6	76.5
Without children	59.2	57.5	60.8	50.6	49.0	52.2
2+ adults with 1 child	55.9	53.1	58.8	48.0	45.2	50.7
2+ adults with 2 children	55.9	52.6	59.1	44.6	41.4	47.8
2+ adults with 3+ children	70.4	65.0	75.9	53.5	47.7	59.3
All households	61.7	60.6	62.8	53.9	52.9	55.0

LCI and UCI are the lower and upper bounds of 95% confidence intervals of estimates. The bold values denote not-overlapping intervals for 2015 and 2017

Table 2 The average intensity of MD in various household types

Household type	2015			2017		
	Estimate	LCI	UCI	Estimate	LCI	UCI
One-person	0.176	0.168	0.184	0.171	0.163	0.179
Single-parent	0.161	0.139	0.182	0.179	0.156	0.202
Without children	0.147	0.142	0.152	0.138	0.132	0.143
2+ adults with 1 child	0.141	0.132	0.150	0.146	0.137	0.156
2+ adults with 2 children	0.129	0.120	0.138	0.122	0.112	0.132
2+ adults with 3+ children	0.174	0.158	0.191	0.139	0.121	0.157
All households	0.154	0.150	0.157	0.148	0.145	0.152

LCI and UCI are the lower and upper bounds of 95% confidence intervals of estimates. The bold values denote not-overlapping intervals for 2015 and 2017

experienced at least one item of deprivation. Moreover, their MD risk did not change significantly in the analysed period.

Analogical analyses were conducted with regard to the intensity of MD. It was found that among households deprived of at least one of nine items, the average intensity of MD was about 0.15 in both years. Similarly to the risk, the worst situation was in one-person households and single-parent households. For most types, the intensity did not decrease significantly. A downturn was only observed in households of at least two adults with at least three children.

The results presented in Tables 1 and 2 support our second hypothesis. However, these findings refer to unconditional relationships between MD and household types. In order to examine changes in the risk and the intensity of MD conditional upon socio-economic factors, in Sects. 4.2 and 4.3 we have presented ZIBRM estimation results.

Our study also assesses the qualitative difference between risk and intensity. In the initial data analysis, we included simple relationships between 2 variables. The results are shown in Tables 3 and 4. Table 3 presents the results for Cramer's V measure of association between categorical variables, wherein the first variable is a binary variable indicating

Table 3 Cramer's V measure of association between binary variable relating to the risk of MD and other potential correlates

Variable	2015			2017		
	Cramer's V	Pearson chi	p value	Cramer's V	Pearson chi	p value
Household type	0.136	226	0.000	0.174	393	0.000
Disability	0.172	360	0.000	0.209	360	0.000
Degree of urbanisation	0.097	115	0.000	0.120	187	0.000
Region	0.035	15.1	0.010	0.057	42.4	0.000
Education of HH	0.312	1200	0.000	0.300	1200	0.000
Age group of HH	0.103	129	0.000	0.137	245	0.000
Health of HH	0.244	693	0.000	0.271	915	0.000
Economic activity of HH	0.213	553	0.000	0.247	794	0.000
Occupation of HH	0.298	1000	0.000	0.286	919	0.000

Table 4 Cramer's V measure for chosen potential correlates

Variable	Year	s = 0			s > 0		
		Estimate	LCI	UCI	Estimate	LCI	UCI
Household type							
Disability	2015	0.135	0.121	0.149	0.162	0.151	0.173
Disability	2017	0.128	0.115	0.141	0.163	0.152	0.174
Econ. activity of HH	2015	0.220	0.207	0.233	0.278	0.268	0.288
Econ. activity of HH	2017	0.238	0.226	0.249	0.272	0.261	0.282
Education of HH							
Age group of HH	2015	0.186	0.161	0.211	0.268	0.250	0.285
Age group of HH	2017	0.145	0.126	0.164	0.248	0.231	0.264
Econ. activity of HH	2015	0.162	0.142	0.182	0.199	0.184	0.213
Econ. activity of HH	2017	0.140	0.124	0.156	0.172	0.157	0.187
Income quartile groups							
Econ. activity of HH	2015	0.125	0.108	0.141	0.161	0.148	0.173
Econ. activity of HH	2017	0.129	0.114	0.143	0.169	0.157	0.182
Household type	2015	0.110	0.092	0.127	0.140	0.128	0.152
Household type	2017	0.092	0.077	0.107	0.132	0.121	0.144

LCI and UCI are the lower and upper bounds of 95% confidence intervals of estimates

whether or not the MD score equals 0 or not, and the second variable is a given potential correlate taken into account in our study.

The results in Table 3 indicate statistically significant associations between binary variables related to the risk of MD and other potential correlates. Moreover, we found that relationships between some potential correlates are different depending on whether the MD score equals zero or not (see Table 4).

The confidence intervals for Cramer's V measure in both considered cases (MD score equals zero or not) do not overlap. This means that relationships between independent variables in the group in which $s=0$ and in the group in which $s>0$ are distinct. These findings

suggest different distributions of household characteristics in the case of experiencing at least one deprivation and in the absence of any deprivation. Thus, we decided to analyse the risk and intensity of MD separately.

To examine the impact of various socio-economic and demographic factors on the risk and intensity of MD, in the next steps of our study we estimated the parameters of the zero-inflated beta regression model. Regression analysis allows to determine the impact of individual independent variables on a dependent variable and to measure the effects of changes at a level of one independent variable, with constant values of other variables. Moreover, the use of ZIBRM enables the identification of separate drivers of the risk and the intensity of MD, and the interpretation of results in odds ratio terms. As this model requires dependent variables to be defined over the interval $[0,1)$, we replaced 6 cases with the deprivation score equal to one (i.e. $s=1$) with a value of 0.999. Such cases correspond to households experiencing each of the nine deprivation items.

4.2 The results for the logistic regression sub-model

The applied ZIBRM separates zeros and positive values of the deprivation score explicitly by two sub-models: for the binary part and for the positive part, respectively. Table 5 presents the estimation results of the first sub-model—the logistic regression model for the probability of not experiencing any deprivation items.

In order to ensure the correct explanation of the obtained results, it necessary to underline that the estimates for the risk of deprivation should be interpreted in an opposite way to the estimates in Table 5. This is because, when examining the risk of deprivation, we considered the probability of being deprived of at least one of nine items, whereas the estimation of ZIBRM provides results for the probability of not being deprived of any items. As for odds, they are defined here as $P(s=0)/P(s>0)$, therefore to examine the odds ratio for the risk of deprivation we calculated and interpreted the reciprocals of OR reported in Table 5.

As expected, the risk of MD tends to decrease with higher equivalent income. The increase of a household's equivalised income by one thousand EUR led to the growth of the odds $P(s=0)/P(s>0)$ by about 20% in both years, under the *ceteris paribus* assumption. Furthermore, the results presented in Table 5 show that regardless of the equivalent income and the other factors considered in model, the impact of the household demographic type on the risk of MD is explicit. In comparison to the reference households—one-person households²—single-parent households experienced a greater risk of MD. However, while in 2015 the difference between these two types of households was statistically significant at a level of 0.05, it became insignificant in 2017. The other types of households exhibited a lower risk of MD than one-person households. Moreover, the situation of households of at least two adults with three or more children was better than of one-person households. The difference in the risk of MD between these two types of households was insignificant in 2015 (at a level of 0.05), but in 2017 it became significant, wherein the corresponding OR for MD risk was lower by almost twofold (as $P(s>0)/P(s=0)=1.849$, the odds for the risk of MD can be obtained by calculating: $1/1.849=0.541$).

The risk of MD is diverse due to different forms of long-standing limitations of household members related to health problems. Compared to households consisting of persons without any limitations in this regard, households with health-limited persons and

² We chose one-person households as a point of reference because in the analysed years, such households did not record a significant change in the risk and intensity of MD (see Tables 1 and 2).

Table 5 Estimates of the logistic regression model for $P(s=0)$

Variable	2015		2017		2015	2017
	b	S(b)	b	S(b)	OR	OR
Income	0.207	0.014	0.200	0.015	1.230	1.221
Household type (Ref.: One-person households)						
Single-parent	-0.685	0.283	-0.161	0.202	0.504	0.851
Without children	0.396	0.082	0.716	0.076	1.485	1.117
2 + adults with 1 child	0.443	0.106	0.690	0.105	1.558	1.994
2 + adults with 2 children	0.462	0.112	0.846	0.111	1.587	2.329
2 + adults with 3 + children	0.332	0.178	0.614	0.169	1.394	1.849
Disability (Ref.: households without disabled persons)						
Strongly disabled	-0.437	0.093	-0.545	0.092	0.646	0.580
Disabled	-0.160	0.065	-0.392	0.065	0.852	0.676
Degree of urbanisation (Ref.: Sparse)						
Dense	-0.102	0.070	0.129	0.027	0.903	1.138
Intermediate	-0.055	0.071	0.020	0.028	0.946	1.092
Region (Ref.: Southwest)						
Central	-0.179	0.105	-0.069	0.108	0.836	0.934
South	-0.315	0.106	-0.041	0.111	0.730	0.960
East	-0.057	0.101	-0.008	0.106	0.945	0.992
Northwest	-0.220	0.108	-0.021	0.110	0.802	0.979
North	-0.307	0.107	-0.167	0.111	0.735	0.847
Education of HH: (Ref.: Secondary)						
Primary	-0.597	0.092	-0.380	0.084	0.551	0.684
Tertiary	0.439	0.089	0.265	0.079	1.551	1.303
Age group of HH (Ref.: 70 or more)						
Below 34	-0.672	0.157	-0.468	0.145	0.511	0.626
34–54	-0.365	0.129	-0.164	0.120	0.694	0.849
55–69	-0.098	0.093	-0.154	0.084	0.907	0.857
Health of HH (Ref.: Fair)						
Very good	0.549	0.116	0.679	0.112	1.731	1.972
Good	0.370	0.070	0.238	0.069	1.448	1.269
Bad	-0.452	0.101	-0.328	0.098	0.636	0.720
Very bad	-0.852	0.246	-0.395	0.187	0.427	0.674
Economic activity of HH (Ref.: At work)						
Unemployed	-0.997	0.188	-0.878	0.193	0.369	0.415
Retired	-0.008	0.095	0.003	0.092	0.992	1.003
Inactive	-0.245	0.116	-0.267	0.109	0.783	0.765
Occupation of HH (Ref.: Intermediate)						
High	0.340	0.086	0.441	0.077	1.405	1.555
Unskilled	-0.187	0.070	-0.195	0.067	0.829	0.823
Constant	-1.739	0.177	-1.846	0.178	–	–

b are estimates, S(b): their standard errors. Bold values denote significance at a level of 0.05 (due to the shortage of space, we have reported only values of estimates and their standard errors, omitting the p value and the z -statistics. The bold values denote that a given estimated parameter is significantly different from zero at a level of 0.05). All standard errors are robust (with heteroscedasticity-robust asymptotic variance). OR are odds ratios

households with severely health-limited persons more often experienced deprivation. Thus, our findings show that the disability of household members has an effect on the risk of MD. However, according to the results, the level of urbanisation did not affect the analysed phenomenon. Furthermore, the results presented in Table 5 show that compared to 2015, the regional differentiation of MD risk decreased in 2017.

According to the results referring to the impact of the household head's attributes, a higher level of education, better general health and higher occupational positions are associated with a lower risk of MD. Furthermore, taking into account the age of the household head, we have observed that the risk of MD was higher among younger households than those headed by persons aged at least 70. Moreover, households headed by unemployed and inactive persons were significantly more likely to report MD than those who are working. Compared to households whose head was employed, in both years the odds for MD risk were more than twice as high for unemployed-headed households and 30% higher than inactive-headed households. However, there are no significant differences in this regard between households headed by retired persons and working persons.

The use of the regression model provides added value to this study. For example, when assessing the risk of MD by comparing the proportion of households experiencing at least one deprivation item, we noted higher risk in rural areas than in urban areas (see Table 8 in the "Appendix"). However, this high risk is the total effect produced not only by living in a rural area but also by other factors (e.g. a lower level of education and a lower level of income among rural households compared to urban households). Therefore, in order to determine the factors influencing MD, it is important to estimate the net influence of particular variables on generating MD. In effect, contrary to the above-mentioned finding obtained by means of a simple comparison of proportion, ZIBRM results indicate that the risk of MD did not differ significantly with respect to the degree of urbanisation. Thus, the estimation of the influence of particular factors on generating MD independently of other household characteristics may be misleading as it does not take into account the link between these variables and other variables.

4.3 The results for the beta regression sub-model

Table 6 shows the results of estimation for the second sub-model of ZIMBR—the beta regression model. This sub-model examines the impact of various correlates on the intensity of deprivation.

To establish the impact of the various socio-economic factors, we examined their statistical significance, and we analysed the odds ratios corresponding to them. The odds in the beta regression model with the logit link function are defined in terms of the mean of the outcome variable μ as $\mu/(1 - \mu)$. Thus, the OR informs us about the change in the $\mu/(1 - \mu)$ produced by a unit change in the given socio-economic factor when all other factors are held constant. In particular, the increase of the household's equivalised income by 1000 EUR was associated with a decline in $\mu/(1 - \mu)$ by about 5%, under the *ceteris paribus* assumption.

All types of households in terms of demographics experienced a lower intensity of MD than one-person households, which was the reference type. The differences between one-person households and single-parent households were statistically insignificant at a level of 0.05 in both years. The same applies to households of at least two adults with three or more children in 2015. However, the difference between this type and the reference type of households became significant in 2017.

Furthermore, there were no statistically significant differences in 2015 between households without disabled persons and households with health-limited persons. However, the

Table 6 Estimates of the beta regression model

Variable	2015		2017		2015	2017
	b	S(b)	b	S(b)	OR	OR
Income	-0.047	0.006	-0.052	0.006	0.955	0.949
Household type (Ref.: One-person households)						
Single-parent	-0.143	0.074	-0.052	0.083	0.867	0.949
Without children	-0.152	0.031	-0.162	0.031	0.859	0.850
2+adults with 1 child	-0.198	0.042	-0.135	0.043	0.820	0.874
2+adults with 2 children	-0.254	0.043	-0.290	0.046	0.776	0.748
2+adults with 3+children	-0.073	0.061	-0.224	0.071	0.929	0.800
Disability (Ref.: households without disabled persons)						
Strongly disabled	0.053	0.030	0.072	0.032	1.055	1.075
Disabled	-0.001	0.024	0.023	0.025	0.999	1.023
Degree of urbanisation (Ref.: Sparse)						
Dense	0.129	0.027	0.181	0.029	1.138	1.199
Intermediate	0.020	0.028	0.089	0.029	1.020	1.093
Region (Ref.: Southwest)						
Central	-0.172	0.039	-0.088	0.042	0.842	0.916
South	-0.133	0.042	-0.019	0.045	0.876	0.981
East	-0.078	0.041	-0.034	0.042	0.925	0.967
Northwest	-0.122	0.041	0.016	0.043	0.885	1.016
North	-0.167	0.040	-0.099	0.045	0.846	0.906
Education of HH (Ref.: Secondary)						
Primary	0.135	0.030	0.185	0.032	1.145	1.203
Tertiary	0.011	0.035	0.043	0.036	1.011	1.043
Age group of HH (Ref.: 70 or more)						
Below 34	0.109	0.055	0.235	0.058	1.115	1.265
34–54	0.217	0.047	0.350	0.050	1.242	1.419
55–69	0.191	0.033	0.229	0.032	1.211	1.257
Health of HH (Ref.: Fair)						
Very good	-0.134	0.045	0.135	0.030	0.874	0.877
Good	-0.082	0.027	-0.064	0.030	0.921	0.938
Bad	0.076	0.033	0.186	0.035	1.079	1.204
Very bad	0.216	0.064	0.213	0.063	1.241	1.238
Economic activity of HH (Ref.: At work)						
Unemployed	0.385	0.063	0.397	0.069	1.469	1.487
Retired	-0.067	0.036	-0.039	0.038	0.935	0.961
Inactive	0.109	0.039	0.143	0.042	1.115	1.154
Occupation of HH (Ref.: Intermediate)						
High	0.033	0.032	-0.003	0.033	1.033	0.997
Unskilled	0.145	0.025	0.088	0.026	1.156	1.092
Constant	-1.522	0.069	-1.763	0.067	–	–

b are estimates, S(b): their standard errors. The bold values denote statistical significance at a level of 0.05. All standard errors are robust (with heteroscedasticity-robust asymptotic variance). OR are odds ratios

intensity of MD in 2017 rose significantly for households with severely disabled persons. As for the degree of urbanisation, a higher level of MD was observed in urban than in rural areas. Thus, these findings for correlates of the intensity of MD differ from the results for the risk of MD. The results for regional differentiation are similar—the regional differentiation of the intensity of MD decreased in 2017 compared to 2015.

We found no statistically significant differences between households with household heads with secondary and tertiary education. However, the intensity of MD was significantly higher for households with poorly educated heads. The same applies to occupation—the differences between households, whose heads had high and intermediate occupational positions, were statistically insignificant at a level of 0.05 in both years. However, households headed by unskilled persons exhibited a higher intensity of MD than households headed by persons with intermediate occupational positions.

Our results indicate a negative relationship between the general health of the household head and the intensity of MD. Furthermore, considering economic activity, we noted a higher level in households headed by unemployed and inactive persons compared to households headed by working persons. Specifically, in both years, the odds for households headed by unemployed persons were almost 50% higher than in the reference households. Moreover, as in the analysis of MD risk, no significant differences were reported between households headed by retired and working persons.

Finally, we observed that the intensity of MD was higher among younger households than those headed by persons aged at least 70.

5 Discussion

This paper aims to shed light on the correlates of material deprivation in Poland. As MD is a multifaceted phenomenon, currently measured in the EU according to nine indicators, we decided to use the fuzzy composite indicator approach. The values of the composite indicator make up deprivation scores belonging to the unity interval, wherein a higher score indicates a deeper intensity of MD. Besides the intensity of MD, we analysed the risk of MD, which in our study means the probability of experiencing at least one symptom of MD. We applied a two-part zero-inflated beta regression model simultaneously estimating both issues.

Accounting for the distinctiveness of zeros reveals the difference between the risk and the intensity of MD. We recorded different impacts of various socio-demographic factors influencing them. In other words, we found that correlates of the risk and the intensity of MD do not fully coincide. Thus, this result supports the first research hypothesis of the study. In particular, the risk of MD did not differ significantly with respect to the degree of urbanisation. However, the intensity was higher in urban areas than in rural areas. This is in line with Bedük's (2018) results, proving that scoring zero on the material deprivation scale is a qualitatively different phenomenon to scoring at least one.

Moreover, our study provides evidence that households of at least two adults with at least three children experienced meaningful improvement during the studied years. The risk and the intensity of MD in such households declined in 2017 in comparison to 2015. This is probably due to the introduction of the 'Family 500+' programme in 2016 supporting mainly large families. Thus, this finding supports the second research hypothesis of the study.

The obtained results regarding factors influencing MD are consistent with other studies to a high degree. They confirm findings reported in (Israel 2016; Bárcena-Martín et al.

2019) that the demographic composition, current income situation, and health problems affect MD. In particular, our results support the conclusions of other authors showing that monetary poverty and MD do not strictly coincide (Ayllón and Gábos 2017; Stávková et al. 2012; Nolan and Whelan 2010; Szulc 2008). Furthermore, our findings confirm the importance of such attributes of the household head as age, educational attainment, economic activity, and occupational position. Specifically, as other studies have shown (Nelson 2012; Bárcena-Martín et al. 2014; Šoltés and Ulman 2015; Israel 2016; Bárcena-Martín et al. 2019), our results prove that MD varied substantially for different age groups. Households reported being more materially deprived when they were younger than when they were older. This finding may be related to the fact that older persons have accumulated on average more resources during their lifetime. Moreover, lower material needs and better budgeting skills among older persons may also be important factors.

Consistent with the results of Nelson (2012), Šoltés and Ulman (2015), and Israel (2016), our study found that poor education is positively associated with a greater risk of MD. Furthermore, in agreement with other studies (Bárcena-Martín et al. 2014; Hicks 2016; Nelson 2012; Šoltés and Ulman 2015; Israel and Spannagel 2019) we have provided evidence that households of unemployed persons are more vulnerable to MD than those headed by persons who are active on the labour market. Our results also confirm the findings of Israel (2016) and Bedük (2018) that low occupational positions are connected with a higher risk of MD.

Apart from typical correlates, we also examined the impact of urbanisation on the level on MD. This aspect has been often overlooked in econometric analyses of MD. Few studies have taken it into account (e.g. Šoltés and Ulman 2015). However, these authors have underlined that they could not draw clear conclusions about the influence of this factor on MD. Basing on the dichotomous approach (deprived/non-deprived), the results of Šoltés and Ulman (2015) in this respect depend on whether at least three or at least four of the nine items have been included in the logistic regression model. Our findings confirm these results to some extent because we show that the degree of urbanisation did not affect the risk of MD, but the intensity of MD was higher in densely urban areas than in rural areas.

The use of regression analysis provides added value to this study. We have pointed to the need of estimating the net influence of particular factors on generating MD. For example, we recorded different impacts of the degree of urbanisation on the risk of MD in the case of a simple comparison of proportions and in the case of applying ZIBRM.

We hope that the use of the fuzzy approach in our research helps to better understand the complex issue of MD from a multidimensional perspective. Moreover, through the application of the two-part ZIBRM model, our study helps to understand the mechanisms behind the risk and the intensity of MD. Thus, the results reported in this paper offer new insights into deprivation factors. Furthermore, we have given substance to the fact of changes which have taken place in recent years in Poland. As the current literature lacks any empirical examination of these issues, we have helped to fill the research gap by providing new empirical evidence.

6 Final remarks

Material deprivation is a multifaceted phenomenon currently measured in the EU according to nine indicators related to financial stress and the enforced lack of durables. Households threatened with deprivation in a multivariate framework can be identified using different

approaches. In our paper, we went beyond the conventional studies based on the deprived/non-deprived dichotomy, because such dichotomization of the population in two excluding groups hides some relevant aspects. We opted to use the fuzzy approach enabling to simultaneously capture the multidimensional character of deprivation and its vagueness. Thus, we constructed scores belonging to the unity interval, wherein a higher score indicates a higher intensity of MD. We also considered the risk of deprivation, which in our study means the probability of experiencing at least one symptom of MD. To model both issues, we applied the two-part zero-inflated beta regression approach. In order to examine the effects of social reforms introduced by the Polish government in 2016, the study focuses on the comparison of 2015 and 2017.

Our paper is a contribution to the literature on MD on the methodological and empirical levels. Specifically, it examines the issue from a multidimensional perspective using the fuzzy approach. To construct the composite indicator, we applied weights taking into account both the prevalence of deprivation items and the correlations among items. This approach is innovative in the analysis of MD. Moreover, to assess the impact of various socio-demographic factors on the risk and the intensity of material deprivation, we used the zero-inflated beta regression model. Furthermore, our study provides results on factors affecting the risk and the intensity of MD in Poland. As these issues have not been analysed yet, it yields empirical contributions. We found that correlates of the risk and the intensity of MD do not fully coincide. In addition, we have provided data showing that after the implementation of social reform by the Polish government, large households with children experienced a substantive reduction of MD. Thus, our study delivers empirical evidence that the 'Family 500+' programme introduced in 2016 provided meaningful help for households with at least three children and achieved important progress in reducing child deprivation. It is important to monitor these effects in the coming years. It would also be a valuable contribution to carry out an analysis of child poverty in Poland.

The results we obtained reveal that about 20% of the income-poor population did not exhibit any deprivation in 2017. This means that MD and income poverty did not fully overlap. However, the risk and the intensity of MD tended to decrease with higher equivalent income. Therefore, future research might examine correlates of MD separately among households below and above the poverty line. Such analysis might provide interesting conclusions about the deprivation profile in both groups of households.

Finally, we would like to emphasise that MD measurement has specific implications for policy analysis and evaluation. It is worth developing a strategy to reduce the risk of being affected by MD at the national level by appropriately measuring vulnerability to poverty. The fuzzy approach is crucial for public policy purposes because it helps to investigate the complex nature of MD. Such approach enables not only to identify those who are severely materially deprived, but also those who are vulnerable. This issue is important for anti-poverty policies, which aim at preventing MD and not solely on eradicating it.

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Appendix

See Tables 7 and 8.

Table 7 The weights of items. *Source:* own calculations based on EU-SILC data

The item	The weight
Inability to	
1) keep the home adequately warm	0.125
2) eat a meal with meat, chicken or fish or a protein equivalent every second day	0.114
3) go on a week's week annual holiday away from home	0.046
4) face unexpected expenses	0.043
5) pay the rent, mortgage, or utility bills	0.173
6) afford to have a television	0.180
7) afford to own a washing machine	0.146
8) afford to have a car	0.060
9) afford to own a telephone	0.113

Table 8 The proportions of households experiencing at least one deprivation item in rural and urban households. *Source:* own calculations based on EU-SILC data

Degree of urbanisation	2015			2017		
	Estimate	LCI	UCI	Estimate	LCI	UCI
Dense	0.557	0.537	0.577	0.464	0.446	0.482
Intermediate	0.616	0.594	0.637	0.540	0.518	0.562
Sparse (rural areas)	0.681	0.665	0.696	0.624	0.608	0.639

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