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ORIGINAL RESEARCH

Leaving No One Behind: An Individual-Level Approach to Measuring Multidimensional Poverty in Botswana

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Abstract
The Leave No One Behind principle is at the core of the 2030 Agenda for sustainable development and acknowledges that poverty is multidimensional and should be examined at individual level. Notwithstanding this, most empirical studies use the household as the unit of analysis for multidimensional poverty measurement. However, estimation of poverty levels at household-level underestimates poverty levels of the society and does not capture intra-household inequalities. The objective of this study is two-fold: (1) developing a country-specific individual-level multidimensional poverty measure; and (2) providing estimates of multidimensional poverty for Botswana. This study contributes to the limited literature on individual-level multidimensional poverty measurement. Empirically, this study offers the first attempt to estimate a nationally relevant and context-specific multidimensional poverty index for Botswana using the individual as a unit of analysis. The results reveal that an estimated 46.2% of individuals are considered multidimensionally poor based on individual-level analysis. This figure is higher than the household-level estimate of 36.5%, which indicates that using the household as a unit of analysis leads to underestimating poverty levels in the society. The results show that on average, the multidimensionally poor are deprived in 47.4% of all indicators under consideration. This finding indicates that multidimensional poverty intensity is also a considerable concern in Botswana. These findings warrant policy interventions.

Keywords Multidimensional poverty · Inequality · 2030 Agenda · Leave no one behind · Sustainable development · Botswana

1 Introduction

The worldwide adoption of the United Nation's Sustainable Development Goals (SDGs) in 2015, also known as the 2030 Agenda for Sustainable Development, has reinforced interest in multidimensional poverty measures (UN, 2016). The SDGs are framed around ending absolute poverty (Alkire et al., 2015a), recognising that poverty has many dimensions (UN,

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2015). Specifically, SDG 1, calls to 'end poverty in all its forms everywhere' (UN, 2015: 14). Furthermore, target 1.2 of SDG 1 states that: 'by 2030, reduce at least half the proportion of men, women and children of all ages living in poverty in all its dimensions according to national definitions' (UN, 2015: 15).

The leave no one behind (LNOB) principle has emerged as a central theme of the 2030 Agenda of Sustainable Development (Fukuda-Parr & Hegstad, 2018; UN, 2015) and relates closely to three important dimensions of the 2030 Agenda: poverty, inclusiveness, and inequality (UN, 2016). LNOB aims to address two related concerns: ending absolute poverty in all its forms and reducing inequalities among both individuals and groups (Klasen & Fleurbaey, 2018; Stuart & Samman, 2017; UN, 2015). The LNOB principle acknowledges that poverty is multidimensional (Klasen & Fleurbaey, 2018; UN, 2015) and it should be examined at individual level (Klasen & Fleurbaey, 2018). It also recognises the importance of data disaggregation (UN, 2015).

Notwithstanding this, most empirical studies on multidimensional poverty measurement have used the household as a unit of analysis (Espinoza-Delgado & Klasen, 2018; Franco-Correa, 2014; Klasen & Lahoti, 2020). Using the household as a unit of analysis means that if the household is multidimensionally poor, all members of the same household are considered poor (Ervin et al., 2018; Espinoza-Delgado & Klasen, 2018). However, even though most empirical studies used the household as a unit of analysis, it has not escaped criticism.

First, the 'household' means different things to different people in different countries, and defining it can be tricky and complex (Bolt & Bird, 2003). The most widely used definition of a household is by the UN, which defines a household as 'a group of people who live and eat together' (Bolt & Bird, 2003: 10). However, this definition may be problematic since individuals residing in the same household may have different living arrangements making it difficult to differentiate traditional households from other ones (Franco-Correa, 2014).[1]

Second, household measures are unable to capture possible intrahousehold inequalities in resource allocation (Alkire & Fang, 2019; Vijaya et al., 2014), and to distinguish individual poverty within the household (Alkire & Fang, 2019). Children and women are more likely to receive an unequal share of the resources or opportunities (Klasen & Lahoti, 2020; Rodríguez, 2016). Individuals' needs and preferences vary across age (Osberg & Sharp, 2014) and gender (Vijaya et al., 2014).

Third, and in addition to the stated above, using the household as a unit of analysis leads to underestimating poverty levels in the society (Haddad & Kanbur, 1990). This is because intrahousehold inequalities conceal deprived individuals within non-poor households (Brown et al., 2017), and this may, in turn, lead to biased assessments of social policies and targeting (Rodríguez, 2016). Poverty is an individual characteristic (Deaton, 1997), and therefore, deprivations that affect one household member do not necessarily affect all other household members.

Considering these limitations, the analysis performed in this study adopts the individual as the unit of analysis. The individual-level analysis allows for data disaggregation by demographic characteristics as required by the LNOB principle. Furthermore, the individual centred approach eases policy-making exercises because it takes into account individual deprivations (Franco-Correa, 2014), which will help highlight priorities for particular

[1] For example, in cases where one household member lives temporarily in two different households.

groups in specific places to ensure no one is left behind. However, studies that assessed individual-based multidimensional poverty across the entire population using the individual as a unit of analysis are scarce (Espinoza-Delgado & Klasen, 2018; Franco-Correa, 2014; Klasen & Lahoti, 2020). The scarcity of such studies could be a result of the unavailability of individual-level data. Another reason could be associated with the conceptual and empirical challenges in constructing individual deprivations (Klasen & Lahoti, 2020; Vijaya et al., 2014).

To the best of our knowledge so far, only three studies have attempted to estimate individual-level multidimensional poverty for the whole population using the Alkire and Foster methodology. The first study was done by Franco-Correa (2014) for the case of Chile, Columbia, Ecuador, and Peru. Following this study, Klasen and Lahoti (2020) examined the case of India, and Espinoza-Delgado and Klasen (2018) did the case of Nicaragua. However, these studies did not provide an in-depth analysis of poverty levels by different socio-demographic characteristics of the population. For example, Espinoza-Delgado and Klasen (2018) considered analysis by gender and age only, while Franco-Correa (2014) examined multidimensional poverty across age groups.

The main objective of this study is to develop an individual-level and country-specific multidimensional poverty measure. Also, the study aims to provide a multidimensional poverty estimate for Botswana. The study employs the Alkire and Foster (2011a) methodology for aggregation and the absolute measure of inequality proposed by Alkire and Seth (2014a) to examine inequality among the multidimensionally poor. Botswana presents a salient case study. The country has made significant progress in reducing monetary poverty. However, Botswana has not had an equally impressive record in terms of other key social indicators such as unemployment, rising inequalities, among others, an indication that the country has not been successful in transforming national wealth into improvements in human development. The country has also committed to the SDGs and the LNOB principle. To the best of our knowledge, this study constitutes the first attempt in Botswana and the African region to estimate the individual-level multidimensional poverty index and inequality for the whole population.

This study contributes to the conceptual and methodological aspects of the study of multidimensional poverty. The study also provides an attempt to operationalising the LNOB principle. Also, it adds to the literature on multidimensional poverty in Botswana. Empirically, this study offers the first attempt to estimate nationally relevant and context-specific individual-level multidimensional poverty for Botswana. The study is structured as follows: Sect. 2 presents theoretical framework. Section 3 presents data sources and methodology. Section 4 presents and discusses empirical results, and Sect. 5 presents robustness analysis. Last, Sect. 6 presents conclusions and policy implications.

2 Theoretical Framework

2.1 Capability Approach

There has been a growing consensus regarding the insufficiency and limitation of monetary poverty measures (Alkire & Santos, 2014; Sen, 1992; Tsui, 2002). Having an income above the poverty line does not guarantee that other needs like education or health have been met. For example, a person's health status cannot be reduced to money (Kim, 2016). Therefore, this study employs the theoretical premise of the capability approach developed

by Sen (1985, 1992, 1999). The capability approach considers the multidimensionality of poverty. It consists of two core concepts: *functionings* and *capabilities*. While functionings refer to the various things a person succeeds in 'doing or being' (e.g., being healthy or participating in the social life), capabilities represent the set of all functionings an individual can choose from (Hick, 2016; Suppa, 2018). The capability approach advocates for an evaluation at the capability space and emphasises the capabilities a person has, irrespective of whether they choose to exercise these or not (Hick, 2016). However, considering the constraints in terms of available data and the limitations for the direct measurement of capabilities, obtaining appropriate information on the capability set is challenging.

On the other hand, the information on the functionings set is widely available in the existing data (Hick, 2016). Therefore, deprivation indicators are located in the functioning space and account for the functioning's infeasibility (Suppa, 2018). Poverty, then, is understood as capability deprivation, implying both a shortfall in one or several of the functionings deemed relevant and their infeasibility for the individual in question (Sen, 1992). In operationalising the capability approach, we made several decisions, including the unit of analysis, the selection of function dimensions and indicators, the weighting scheme, the poverty cutoff, and the aggregation method. Motivated by normative theories and expert studies, we developed our list of functioning dimensions and indicators. We also reviewed the literature of some empirical studies employing the capability approach using nationally representative data (e.g. Alkire et al., 2015b; Klasen, 2000; Qizilbash & Clark, 2005; Wagle, 2008). In addition, the functioning dimensions are included for their intrinsic and instrumental significance (Klasen, 2000). Also, the study relied on Botswana's policy commitments and development priorities such as Vision 2036, NDP 11, Botswana Poverty Eradication Policy and Strategy (BPEPS) and the SDGs to ensure that the measure is contextually relevant. Finally, data availability is considered. Thus, the selection is reasoned, transparent, open to modification, and subjected to public debate (see Sen, 2004).

2.2 Measuring Poverty in Botswana

Botswana, a landlocked country with about 2 million inhabitants, has pursued poverty reduction since 1966. As a result, the country has witnessed rapid GDP growth for most of its post-independence period (Lekobane & Seleka, 2017). The country has transitioned from the poorest country at independence to the current "upper middle income" status in four decades. Botswana's economy has proliferated during 1966–2008, with a real GDP average growth rate of 8.7% per annum, making Botswana one of the fastest-growing economies (MFDP, 2010). Such impressive economic growth performance was primarily propelled by the mining sector, which has accounted for the largest shares of GDP, exports and government revenue. However, the real GDP growth rate has declined, estimated at 3 per cent in 2019 (SB, 2020).

In Botswana, poverty is and has been almost exclusively measured using the traditional monetary approach. Statistics Botswana computes monetary poverty measure based on consumption expenditure (SB, 2018).[2] According to official monetary measure, poverty levels have declined over time, from 59% in 1985/86 to 47%, 30.6%, 19.3% and 16.3% in

[2] Statistics Botswana provides a clear account of the method used to estimate the poverty datum line (PDL). Individuals from household whose consumption expenditure falls below its PDL are categorised as poor.

Table 1 Sample and population distributions 2015/16 *Source*: Author's estimates based on the 2015/16 BMTHS data

Age group	Sample		Population	
	Frequency	Percent	Frequency	Percent
0–17 (Children)	9,718	39.3	817,843	39.4
18–35 (Youth)	7,582	30.7	643,726	31.0
36–64 (Adults)	6,023	24.4	501,326	24.2
65 + (Older persons)	1,397	5.7	110,781	5.3
Total	24,720	100.0	2,073,675	100.0

1993/94, 2002/03, 2009/10 and 2015/16, respectively. Similarly, the proportion of people living in extreme poverty (below one dollar a day) (currently $1.90) has also been declining over time, from 23.4%, 6.4% and 5.8% in 2002/3, 2009/10 and 2015/16 (respectively) (SB, 2018). However, impressive as they are, these figures do not tell the entire story of the country's poverty situation.

Despite the significant progress in monetary poverty, Botswana has not had an equally impressive record on other key indicators such as unemployment, especially amongst the youth, rising inequalities, increasing HIV/AIDS prevalence rates, and child malnutrition. This indicates that Botswana has not successfully transformed national wealth into improvements in wellbeing for its citizens. Inequality, measured by the Gini coefficient, has increased from 0.495 in 2009/10 to 0.522 in 2015/16 (SB, 2018). Unemployment rates, especially amongst the youth, continue to pose a severe challenge. The youth (aged 15–35 years) unemployment rate stood at 25.2% in 2015/16, much higher than the average national rate of 17.7% in the same period (SB, 2018). The unemployment rate rose steadily from 10.2 in 1981 to 17.7% in 2015, and it has been consistently higher for females (SB, 2016), partially explaining higher incidences of poverty among females than males.

3 Data Source and Methodology

3.1 Data Sources

The analysis of this study utilises the 2015/16 Botswana multi-topic household survey (2015/16 BMTHS hereafter) collected by Statistics Botswana (SB). This survey is a cross-sectional and nationally representative survey, allowing disaggregation by demographic characteristics, economic variables, and administrative district. The 2015/16 BMTHS collected socio-economic information, among others, on demographic characteristics, household expenditure and consumption, labour force, health, education, self-assessed well-being and food insecurity, housing, utilities, durable goods and anthropometric measurements (see SB, 2018). The dataset contains information from 24,720 individuals from 7,060 households surveyed in 2015/16. After applying sample weights, this resulted in an estimated 589,909 households and an estimated national population of 2,073,675 individuals (SB, 2018). The survey employed a two-stage stratified probability sample design (see SB, 2018).

In this study, the individual is adopted as a unit of identification. In terms of analytical strategy, this study classified the population of Botswana into four age groups: below 18 years (children), 18 to 35 years (youth), 36 to 64 years (adults) and 65 years and above

(older persons). This classification is in line with the different policies for different age cohorts of the population. For example, the Botswana Children's Act, 2009 (Republic of Botswana, 2009) was used to set an age threshold for children (0–17 years). Table 1 presents the sample and population distribution by age groups.

3.2 The AF methodology

This study employs the axiomatic counting methodology developed by Alkire and Foster (2011a) (henceforth AF) to estimate individual-level multidimensional poverty.[3] The AF methodology was chosen over other methods for several technical and practical reasons (Alkire et al., 2015b). First, this method can identify all poverty measures: incidence, intensity, MPI (adjusted headcount ratio) and inequality (Alkire & Foster, 2011a). Second, being an axiomatic family of measures, this method satisfies several desirable properties, including the axioms of population subgroup decomposability and dimension breakdown (Chen et al., 2019), which is useful for policymakers when developing interventions and targeted policies (Alkire & Apablaza, 2016). Third, from a practical perspective, the AF method uses the intuitive counting approach to identify the poor and explicitly assess the simultaneous or joint distribution of deprivations experienced by the poor people in a set of indicators (Alkire & Foster, 2011a). Fourth, it allows for the examining of the composition of poverty in different subgroups (socio-demographic and location), indicators and dimensions required by the LNOB principle. Fifth, this method is chosen for its methodological robustness, intuitive characteristics, and growing popularity in the field (Alkire et al., 2015b). Fifth, the AF method is simple, flexible and clear (Silber, 2011; Thorbecke, 2011), making it an attractive option to inform policy.

Before describing the identification and the aggregation steps of the AF methodology, the achievements of all n persons within a society in all d indicators, summarised by an $n \times d$-dimensional matrix $\boldsymbol{X} = \left[x_{ij}\right]$, where x_{ij} refer to an indicator's achievement matrix for each individual under consideration, where i ($i = 1, \cdots, n$) represent individuals and j ($j = 1, \cdots, d$) are indicators within the selected dimensions. Thus, row i of $\mathbf{X}$ represents the achievement vector of person i, summarising the person's achievements in all d indicators, and its jth column contains the achievements of all n persons in indicator j. The AF methodology uses a two-step 'dual cut-off' process to identify the poor (Alkire & Foster, 2011b).

The first cut-off process is linked to deprivation cut-offs for each indicator, x_i and is denoted by z_j represented by a vector $z = \left(z_1, z_2 \cdots, z_d\right)$, where d represents the number of indicators. Any person i is deprived in any indicator j if her achievement falls below the deprivation cut-off z_j for indicator j and deprivation is given the value 1 when $x_{ij} < z_j$ and 0 otherwise. From the $\boldsymbol{X}$ matrix and z vector, a matrix of deprivation $g^0\left[g_{ij}^0\right]$ is obtained such that $g_{ij}^0 = 1$ if $x_{ij} < z_j$ and $g_{ij}^0 = 0$ if $x_{ij} > z_j$ for all $j = 1, \cdots, d$ and $i = 1, \cdots, n$. Next, let $w = (w_1, w_2 \cdots, w_d)$ be the vector of indicators' weights. The weight attached to indicator j is denoted by w_j such that $\left(w_j > 0\right)$. These weights sum to 1, that is, $\sum_{j=1}^{d} w_j = 1$ and $w_j \in [0, 1]$. Then, the deprivation score c_i is computed for each person i, such that $c_i = \sum_{j=1}^{d} w_j g_{ij}^0$. If an individual is not deprived in any indicator $c_i = 0$ and if an individual

[3] For a detailed outline of the methodology and discussion in aggregation approaches see Alkire et al. (2015b). Chapter 5 of the book discusses the methodology in detail.

is deprived in all indicators $c_i = 1$. The vector of deprivations for all individuals is given by $c = (c_1, c_2 \cdots, c_n)$.

The second step involves choosing poverty cut-off point, k, using the deprivation profiles in all indicators to identify the multidimensionally poor.[4] The choice of k is such that $1 \leq k \leq d$.[5] The poverty cut-off is implemented by using the method of identification ρ_k. A person i is identified as multidimensionally poor using a poverty cut-off k, such that $c_i \geq k$. Algebraically, $\rho_k(x_i;z) = 1$ if $c_i \geq k$, and $\rho_k(x_i;z) = 0$ otherwise. Following Alkire and Santos (2014), this study uses a cut-off of 33.33% ($k = 0.3333$). From the deprivation matrix $g^0\left[g_{ij}^0\right]$, a censored deprivation matrix $g^0(k)$ is constructed by multiplying each element in g^0 by the identification function $\rho_k(x_i;z) : g_{ij}^0(k) = \rho_k(x_i;z) : g_{ij}^0 \times \rho_k(x_i;z)$ for all i and all j. A censored deprivation score vector for all individuals is then obtained from the original deprivation score vector: $c(k) = c \times \rho_k(x_i;z)$. Let $c(k) = \sum_{j=1}^{d} w_j g_{ij}^0(k)$ be the censored deprivation score of individual i; by definition $c_i(k) = c_i$, if $c_i \geq k$ and $c_i(k) = 0$, if $c_i < k$ (Alkire & Santos, 2014).[6] Then, $c(k) = \left[c_1(k), c_2(k) \cdots, c_n(k)\right]$.

The AF methodology proposes a family of multidimensional poverty measures M_α that is based on the Foster, Greer, and Thorbecke (FGT) class of poverty measures (Foster et al., 1984) to solve the problem of aggregation. This study uses the first measure of this family; the adjusted headcount ratio denoted by M_0 and contains both multidimensional headcount ratio (multidimensional poverty incidence), H and the average deprivation scores, capturing the intensity of poverty, A (Alkire et al., 2015b). Algebraically, M_0 is computed as:

$$M_0 = H \times A = \frac{q}{n} \times \frac{1}{q} \sum_{i=1}^{q} c_i(k) = \frac{1}{n} \sum_{i=1}^{n} c_i(k) \tag{1}$$

This study uses M_0 to estimate individual-level multidimensional poverty in Botswana. The advantages of this measure are based on its two key properties: the 'population subgroup decomposability' which allows for examining subgroup contributions to all poverty, and the breakdown property by indicator which makes it possible to find out the contribution of each indicator to the overall poverty.

3.3 The Inequality Methodology

Inequality is one of the key priorities of the SDG agenda (UN, 2015). However, inequality has been neglected in the study of multidimensional poverty as evidenced by few studies assessing inequality in the empirical literature (e.g. Espinoza-Delgado & Klasen, 2018; Hanandita & Tampubolon, 2016). Therefore, in line with LNOB, this study examines inequality among the multidimensionally poor and adds to the limited literature. Using inequality measure provides value addition to the information provided by the adjusted headcount ratio (M_0). The study employs a separate decomposable inequality measure (I_q)

[4] The choice of k can be made normatively, either based on previous studies or what the society would consider reasonable. It can also be chosen to reflect the country's policy goal (Mushongera et al., 2017).

[5] k represents the share of weighted deprivations that a person must experience to be considered multidimensionally poor. That is, in order to be identified as multidimensionally poor, a person's deprivation score must be equal to or larger than the poverty cut-off ($c_i \geq k$).

[6] The censoring step retains the deprivation scores of those who are identified as poor and replaces the deprivation scores of those who are not identified as poor ($c_i < k$) by 0 (Alkire et al., 2015b).

proposed by Alkire and Seth (2014a).[7] The inequality measure is based on the adjusted headcount ratio which is a part of the AF method. This proposed measure is based on a positive-multiple variance to overcome the obstacles stemming mainly from the use of non-cardinal indicator variables in the construction of M_0 (Alkire & Seth, 2014a; Hanandita & Tampubolon, 2016).

To assess inequality among the multidimensionally poor, and following Alkire and Seth (2014a), we suppose that the deprivation scores are ordered in descending order, and the first q persons are identified as poor. The elements are taken from the censored deprivation score vector $y = \left[c_1(k), c_2(k) \cdots, c_q(k)\right]$. Vector y is chosen such that it contains only the deprivation scores of the poor ($t = q$). The average of all elements in y then is the intensity of poverty which for q persons is $\mu(y) = A$. We then denote the inequality measure that reflects inequality in multiple deprivations only among the multidimensionally poor by I_q, which can be expressed as:

$$I_q = \frac{\tilde{\beta}}{q} \sum_{i=1}^{q} \left[c_i(k) - A\right]^2 \tag{2}$$

where q denotes the number of the multidimensionally poor, $c_i(k)$ is the deprivation score among the poor, A is the intensity of poverty, and $\tilde{\beta}$ is the normalisation factor that must be chosen such that $I_q = [0, 1]$ (Alkire & Seth, 2014a), representing the properties of any standard inequality (Hanandita & Tampubolon, 2016). Following Alkire and Seth (2014a), $\tilde{\beta}$ equals the inverse of $\frac{1}{4}\left\{max\left[c_i(k)\right] - min\left[c_i(k)\right]\right\}^2$.[8] Therefore, $\beta = 4$ in Eq. 2. This measure (I_q) helps to reveal pockets of high intensities that might otherwise be missed by poverty measures, thereby helping to ensure that no one is left behind (Alkire & Seth, 2014b). In the SDGs, this is captured by SDG 10, which aims to reduce inequality within and among countries (UN, 2015). Inequality is a problem of inclusion, and LNOB can be viewed as a tool for addressing inequality (Fukuda-Parr & Hegstad, 2018).

3.4 Proposed Dimensions, Deprivation Indicators and Cut-Offs

Following other studies dealing with multidimensional poverty measures (Alkire & Foster, 2011a, 2011b; Alkire et al., 2015b; Kuklys, 2005), this study employs the capability approach (Sen, 1985, 1999), in conjunction with the normative approach in selecting dimensions and indicators (Alkire, 2002). The study also relied on Botswana's policy commitments and development priorities such as Vision 2036, NDP 11, BPEPS and the SDGs, to ensure that the measure is contextually relevant. Finally, data availability is considered. As a result, the following seven dimensions are included in the multidimensional poverty measure: (1) *Assets*, (2) *Housing and living condition*, (3) *Water and sanitation*, (4) *Food security*, (5) *Health*, (6) *Education*, and (7) *Security*. The selected dimensions cover most of the indicators and dimensions of the global MPI (Alkire & Santos, 2014), and the dimensions proposed in MODA child poverty study for Botswana (de Neubourg et al., 2015).

[7] This is referred to as 'triple I' of poverty (Incidence, intensity and inequality) (Espinoza-Delgado & Klasen, 2018; Hanandita & Tampubolon, 2016; Sen, 1976).

[8] That is, 'the maximum possible value that variance takes is one fourth of the range of the deprivation score vector, which is attained when half of the population have the lowest scores and the other half have the highest deprivation scores' (Alkire & Seth, 2014a: 16).

It should be noted that there are some conceptual and empirical challenges in the construction of individual indicators from those indicators defined and identified at the household level (for example, housing and living conditions, water and sanitation and asset indicators) (Espinoza-Delgado & Klasen, 2018). Most of these are public in nature within households (Klasen & Lahoti, 2020). This study follows other studies that attempted the individual level multidimensional poverty measure in conceptualising these indicators (see Espinoza-Delgado & Klasen, 2018; Franco-Correa, 2014; Klasen & Lahoti, 2020). The indicators are assumed to be true public goods, equally accessible to all individuals within the household (Espinoza-Delgado & Klasen, 2018; Klasen & Lahoti, 2020). The selected household-level indicators are included for their intrinsic and instrumental significance (Klasen, 2000). Table 2 discusses the proposed dimensions, deprivations indicators, as well as the deprivation cut-offs, identification level and groups for which the indicators are applicable.[9]

3.4.1 Asset Dimension

This dimension measures deprivations related to possession of household assets, and it provides insights into the household economic activity and reflects both past and future income-generating opportunities (Deere et al., 2012; McKay, 2009). Household durable assets are integral to the functioning and attainment of well-being. In reference to the capability approach, assets are closely connected with ends (functionings) they facilitate (Alkire & Santos, 2014). For example, homeownership is essential because it indicates a crucial functioning of 'security or protection' (Blank, 2008). Four deprivation indicators are considered for this dimension: *information*, *durable goods*, *transport* and *homeownership* (*tenure*).

3.4.2 Housing and Living Condition Dimension

This dimension relates to material capabilities (Sen, 1984) and directly captures capabilities of 'bodily health' and 'affiliation' (Nussbaum, 2003). It captures deprivations relating to housing and living conditions (quality and overcrowding) and access to basic amenities, to capture the functioning of 'being well-sheltered'. The BPEPS emphasised shelter poverty (Republic of Botswana, 2018). Housing is also reflected in the SDG agenda (SDG 11.2) (UN, 2015). This dimension is also related to health. For example, individuals living in overcrowded households often suffer from poor health conditions (Wanyeki et al., 2006) and educational outcomes (Leventhal & Newman, 2010). Similarly, the use of dirty fuel may cause high air pollution levels and may be harmful to their health (Duflo et al., 2008; Kaplan, 2010). Housing quality is also associated with morbidity from infectious diseases, chronic illnesses, injuries, poor nutrition, and mental disorders (see Krieger & Higgins, 2002; Vaughan & Platts-Mills, 2000). In line with the capability approach, six deprivation indicators are considered for this dimension: *overcrowding*, *cooking fuel*, *electricity*, *floor material*, *roof material* and *wall material*.

[9] Age groups 0–4 and 5–17 have 20 indicators each while age groups 5–14 and 18 years and above have 19 indicators each. In total there are 24 indicators considered for the construction of the index.

Table 2 List of proposed dimensions and deprivation indicators† *Source*: Developed by the author. †HH stands for household, IND stands for the individual, Y indicates data availability for the indicator, and N indicates data unavailability. Level means the identification level

Dimension	Indicator	Indicator Definition	Deprivation cut-off (an individual is deprived if …)	Level	Group
1. Asset	Information	Captures lack of access to information and communication by household members	He/she resides in a household which does not own at least one of the following: TV, radio, PC/laptop, telephone (land-line), mobile	HH	All
	Durable goods	Captures the lack of durable assets used within the house	He/she resides in a household which does not own at least two of the following: refrigerator, washing machine, electric/gas stove, microwave, air conditioner, wheelbarrow, sewing machine, grinding machine	HH	All
	Transport	Captures lack of ownership of automobiles (van/bakkie/truck or car)	He/she resides in a household which does not own any automobile including van/bakkie/truck, car, tractor, donkey cart, motorcycle, bicycle	HH	All
	Land tenure	Captures land ownership or possession of land and housing in which the housing unit is built	He/she resides in a household that does not own the land where the housing unit is built	HH	All
2. Housing and living condition	Overcrowding	Captures the shortage of living space based on the number of rooms and persons in the household	He/she resides in a household with more than three people per sleeping room (excluding the kitchen, bathroom, and garage)	HH	All
	Cooking fuel	Captures the source of fuel for cooking used by households	He/she resides in a household which uses the following source of fuel: Biogas, wood, paraffin, cow-dung, coal, charcoal, and crop waste OR has no source of cooking fuel at all	HH	All

Table 2 (continued)

Dimension	Indicator	Indicator Definition	Deprivation cut-off (an individual is deprived if …)	Level	Group
	Floor material	Assesses the quality of the main material of the floor	He/she resides in a housing unit with the main material of floor made of the following: mud, mud dung, brick/stones, none, or any other material apart from cement, floor tiles, or wood	HH	All
	Roof material	Assesses the quality of the main material of the roof	He/she resides in a housing unit with the main material of the roof is made of the following: thatch/straw, asbestos, or any other material apart from slate, roof tiles, corrugated iron/zinc/tin, concrete	HH	All
	Wall material	Assesses the quality of the main material of the outside wall	He/she resides in a housing unit with the main material of the outside wall is made of the following: mud bricks/blocks, mud and poles/cow dung/thatch/reeds, poles and reeds, corrugated iron/zinc/tin, asbestos, wood, stone, other/mixed materials	HH	All
	Electricity	Assess household connectivity to the national grid	He/she resides in a household which is not connected to the BPC grid	HH	All

Table 2 (continued)

Dimension	Indicator	Indicator Definition	Deprivation cut-off (an individual is deprived if …)	Level	Group
3. Water and sanitation	Water supply	Assesses lack of access to safe drinking water source	He/she resides in a household which uses unimproved water source: bowser/tanker, well, borehole, river/stream, dam/pan, rainwater, spring water, OR if it takes at least 30 min to fetch water from a communal tap	HH	All
	Toilet facility	Measures lack of access to basic and safe sanitation facility in the household	He/she resides in a household which uses an unimproved toilet facility: pit latrine, communal flush toilet, communal VIP, communal pit latrine, communal neighbours' toilet OR has no toilet facility at all	HH	All
4. Food security	Food insecurity access (HFIAP)	Assesses household's lack of access to sufficient quantity and quality food	He/she resides in a household categorised as moderately food insecure or severely food insecure based on HFIAP measure	HH	All
	Weight-for-age (WAZ)	Assesses children's nutrition status	He/she is a child who is malnourished. That is if his/her z-score of weight-for-age is below minus two standard deviation from the median of the reference population	IND	0–4 years
	Height-for-height (HAZ)	Assesses children's chronic nutrition status (stunting)	He/she is a child who is stunted. That is if his/her z-score of height-for-age is below minus two standard deviation from the median of the reference population	IND	0–4 years
	Weight-for-height (WHZ)	Assesses children's nutrition status in terms of wasting	He/she is a child who is wasted. That is if his/her z-score of weight-for-height is below minus two standard deviation from the median of the reference population	IND	0–4 years

Table 2 (continued)

Dimension	Indicator	Indicator Definition	Deprivation cut-off (an individual is deprived if …)	Level	Group
	Body Mass Index (BMI)	Assesses children's nutrition status based on BMI	He/she is a child aged between 5 and 17 with a BMI z-score below minus two standard deviation from the median of the reference population	IND	5–17 years
5. Health	Health facility	Assesses the perceived quality of the nearest health facility	The perceived quality of nearest health facility he/she uses is poor and has the following problems: the facility is too far, the facility is not clean or in poor condition, few trained professional staff, staff frequently absent, lack of drugs, does not offer all services, limited opening hours	IND	All
	Chronic illness	Assess individuals' health status	He/she has a long-term chronic illness that prevents them from working, being active or going to school	IND	All
6. Education	Child school attendance	Quantifies the enrolment of individuals in the education system	He/she is a child aged 6–17 and is currently not enrolled in school	IND	5–17 years
	Schooling achievement	Measures the number of years schooling	He/she is an adult aged 18 and above and has less than 9 years of education	IND	Above 18 years
	Literacy	Measures the ability of an individual to read and write	He/she is an adult aged 15 years and above, and he/she cannot read and write	IND	Above 15 years
7. Security	Safety	Assess the perceived safety of household from crime and violence	He/she feels not safe from crime and violence	HH	All
	Crime	Ascertains whether the member of the household has been a victim of violence or crime in the past 12 months	He/she resides in a household which has at least one member who has been a victim of violence or crime in the past 12 months	HH	All

3.4.3 Water and Sanitation Dimension

Like household and living condition, water and sanitation are also of considerable instrumental and intrinsic significance (Klasen, 2000). The water and sanitation dimension is reflected in SDG 6 that calls to ensure availability and sustainable management of water and sanitation for all (UN, 2015). This dimension is linked to higher morbidity and infant and child mortality (Trani & Cannings, 2013). The United Nations General Assembly and the Human Rights Council recognise both access to water and sanitation as human right issues (UN, 2010). Water and sanitation are publicly provided (public goods) and accessible equally within the household (Klasen & Lahoti, 2020). Two indicators are used to capture this dimension: *water supply* and *toilet facility*.

3.4.4 Food Security Dimension

Deprivation in food is a good proxy for lacking the capability to avoid hunger or undernourishment (Sen, 1992). The issue of hunger and food insecurity features prominently in the 2030 Agenda and is reflected in SDG 2 (target 2.1) (UN, 2015). According to FAO (1996), there are four major food security dimensions: food availability, food access, food stability and food utilisation (FAO, 1996). Food insecurity is measured based on two indicators: *food access* and *food utilisation* (*nutrition*). These two are chosen based on data availability.[10] This study adopts the Household Food Insecurity Access Scale (HFIAS) methodology in developing the household food insecurity access indicator (see Coates et al., 2007). Two main indicators are created to derive the *food access* indicator: The Household Food Insecurity Access Scale Score (HFIASS) and the Household Food Insecurity Access Prevalence (HFIAP).[11] The second indicator (*nutrition*) goes beyond the '*access*' indicator and captures food utilisation. This indicator captures the functioning of 'being well-nourished'. It is derived using anthropometric measure; child undernourishment based on WHO methodology (Alkire & Santos, 2014; WHO, 2006).[12]

3.4.5 Health Dimension

Health is considered a central capability (Nussbaum, 2003; Sen, 2000). It has intrinsic as well as instrumental value (Alkire & Santos, 2014; Klasen, 2000). Being unhealthy can limit an individual's ability to participate in social activities, negatively influences his/her emotions, and may prevent him/her from participating in active employment (Rippin, 2016). For example, prolonged chronic illness can utterly impoverish people (Chambers, 1983) and can lead to loss of income (due to inability to work) (Beatty & Fothergill, 2005) and asset depletion (Kyegombi, 2003). The health dimension is reflected in SDG 3 (target 3.8) of the SDGs (UN, 2015). Vision 2036 and NDP 11 both reiterates the importance of health (MFED, 2017; Republic of Botswana, 2016). The health dimension captures deprivations related to access and quality of the nearest health facility and chronic illness. Due

[10] The 2015/16 BMTHS do not have variables to capture food availability and food stability, hence their exclusion in deriving the food insecurity dimension.

[11] The HFIASS is a continuous measure of the degree of food (access) insecurity, ranging from 0 to 27. The HFIAP categorises households into four levels of household food insecurity: food secure, and mildly, moderately and severely food insecure (Coates et al., 2007). The algorithm used to compute household food insecurity access prevalence categories is based on Coates et al. (2007).

[12] The algorithm provided by WHO Child Growth Standards was used to estimate the z-scores of weight-for-age. BMI is computed as: $\text{BMI} = \text{weight}/(\text{height}/100)^2$.

to data constraints, this dimension is captured using two indicators: *the condition of the nearest health facility* and *chronic illness*.

3.4.6 Education Dimension

Education, like health, has intrinsic and instrumental value (Klasen, 2000). It captures human capital and is vital for enhancing capabilities (Sen, 2000), and to be educated is a valuable achievement (Espinoza-Delgado & Klasen, 2018). Education enhances one's well-being, such as the likelihood of employment, future income, self-confidence, and the ability to social interaction (Rippin, 2016). Nussbaum (2003) captured the education dimension in her list of capabilities (senses, imagination, and thoughts). The education dimension is also included in the global MPI (Alkire & Santos, 2014). Education plays a vital role in achieving Botswana's national development aspirations and priorities (MFED, 2017; Republic of Botswana, 2016). In the SDGs, education has a stand-alone goal reflected by SDG 4 (UN, 2015). The education dimension is captured using three deprivation indicators: *child enrolment*, *school attainment* and *literacy*.[13]

3.4.7 Security Dimension

This dimension captures the capability of 'being able to move freely from place to place' (Nussbaum, 2005). That is, to live a safe life free from crime and violence. Feeling unsafe diminishes numerous valuable capabilities (Nussbaum, 2005). This dimension is directly linked to the capability of 'bodily integrity' (Nussbaum, 2000, 2003). In the SDGs, this dimension is reflected in SDG 16, target 16.1, which aims to significantly reduce all forms of violence and related deaths rates everywhere (UN, 2015). This dimension is measured using two indicators (*safety* and *crime*) identified at household-level, due to unavailability of information at individual-level.

3.5 Weighting of Dimensions

The choice of weights for dimensions and indicators is another crucial step in constructing a multidimensional measure (Alkire et al., 2015b). Different weighting approaches exist in the literature (Alkire & Santos, 2014; Decancq & Lugo, 2013).[14] The most widely used is the *equal weighting scheme* across dimensions (see Alkire & Foster, 2011a, 2011b; Alkire & Santos, 2014; Alkire et al., 2015b; Ervin et al., 2018). Advantages of this weighting scheme are that its use eases the interpretation of the index for policy, it is more transparent, and it allows comparisons over time (Alkire & Santos, 2014). The LNOB principle is also premised on the human rights approach, and rights are deemed to be equally important. Therefore, based on a normative approach, this study adopts an equally weighting scheme across dimensions and equal nested weights within dimensions for each indicator (Alkire & Santos, 2014; Ervin et al., 2018). However, actual weights per indicator will

[13] The four deprivation indicators are captured by targets 4.1, 4.2 and 4.6 in the 2030 SDG agenda document.

[14] Decancq and Lugo (2013) classified these different weighting schemes into three main categories: *normative, data-driven* and *hybrid*. For a detailed discussion of these three approaches see Decancq and Lugo (2013).

differ across age groups as the total number of indicators differs across age groups (as a result of using the individual as a unit of analysis). Table S8 (supplementary tables) presents the weighting structure across the age groups. However, for robustness analysis, the weighting structure across indicators are varied across the dimensions and indicators to test our results to different weights.

3.6 Association Between Deprivation Indicators

Before computing the aggregate MPI, it is important to check for associations between indicators. The Spearman rank correlation matrix is employed. Overall, the results show that most deprivation indicators are weakly correlated (Supplementary Table S1). For example, the correlation between education indicators and other indicators is comparatively very low (exhibiting correlations below 0.30). Similarly, health deprivation indicators are weakly related to other indicators (less than 0.20). The same is observed for security deprivation indicators and nutrition deprivation indicators. Except for a moderate correlation between electricity and durable goods, all assets indicators are weakly related to other deprivation indicators. Housing and living condition indicators show mixed results with most indicators exhibiting weak correlations, except for electricity showing moderate correlation with durable goods and cooking fuel. Quality of housing condition indicators (roof, floor, and wall) are related, showing moderate to a strong association (exhibiting correlations between 0.655 and 0.75). Electricity shows a significant moderate and positive association with durable goods and cooking fuel. The generally weak correlation between deprivation indicators justifies a more holistic approach to measuring multidimensional poverty (Espinoza-Delgado & Klasen, 2018).

4 Results and Discussions

The High-Level Panel of Eminent Persons on the Post-2015 Development Agenda proposed that to leave no one behind there is need to ensure that, 'no person – regardless of ethnicity, gender, geography, disability, race or another status – is denied basic economic opportunities and human rights' (UN, 2013: 29). Individuals at the intersection of these factors are at the risk of being left behind.[15] Therefore, this study disaggregates the analysis by individual characteristics, household-level variables, economic variables and geographical variables. Individual characteristics include gender, age, citizenship, disability status and household level variables include gender, age, marital status, educational attainment and employment status of the household head household size. Household per capita consumption quintiles are used to capture the economic status of the household. For geographical variable, administrative districts are used.[16] These selected variables are commonly used in the literature as key determinants of poverty (e.g., Grootaert, 1997; Lekobane & Seleka, 2017; Qi & Wu, 2016).

[15] In LNOB personal factors captures what is known as discrimination. For example, people are left behind when they experience exclusion or mistreatment or access to public services based on their gender, disability, age nationality and other personal characteristics.

[16] The final list of variables is also dependent on data availability. For example, the 2015/16 BMTHS data does not capture information on ethnicity or race which are key variables in the LNOB principle.

Table 3 Proportion of deprived population by indicator† *Source*: Author's estimates based on the 2015/16 BMTHS data

Dimension	Indicator	Sample	% Deprived	SD	Age group
1. Asset	Information	24,720	22.4	0.4167	All
	Durable goods	24,720	56.2	0.4962	All
	Transport	24,720	71.4	0.4521	All
	Land tenure	24,720	37.5	0.4840	All
2. Housing and living conditions	Overcrowding	24,720	40.2	0.4903	All
	Cooking fuel	24,720	47.5	0.4994	All
	Floor material	24,720	12.5	0.3311	All
	Roof material	24,720	10.6	0.3073	All
	Wall material	24,720	17.6	0.3804	All
	Electricity	24,720	36.2	0.4807	All
3. Water and sanitation	Water supply	24,720	9.7	0.2959	All
	Toilet facility	24,720	64.7	0.4780	All
4. Food security	HFIAP	24,720	49.2	0.4999	All
	WAZ	3,104	7.6	0.2653	0–4
	HAZ	3,104	17.4	0.3789	0–4
	WHZ	3,104	5.2	0.2226	0–4
	BMI	6,614	10.7	0.3093	5–17
5. Health	Health facility	24,720	33.8	0.4730	All
	Chronic illness	24,720	17.0	0.3758	All
6. Education	School enrolment	6,614	10.5	0.3051	5–17
	Literacy	16,227	8.9	0.2853	15 and above
	School attainment	15,002	41.7	0.4931	18 and above
7. Security	Safety	24,720	39.7	0.4893	All
	Crime	24,720	10.4	0.3051	All

†All percentages are estimated at population-level using sample weights. SD, standard deviation. HFIAP, household food insecurity access prevalence; WAZ, weight-for-age; HAZ: height-for-age; WHZ, weight-for-height; BMI, body mass index. Sample size: 24,720

4.1 Deprivation Levels by Indicator

Before aggregating the results into a single index, the unidimensional results for each deprivation indicators across the whole population is examined. Table 3 presents 'the uncensored headcount ratio' (see Alkire & Santos, 2014), that is the estimated proportion of individuals deprived in each of the twenty-four indicators used. Even though Botswana has done well to reduce monetary poverty, this study finds a rather gloomy picture with respect to non-monetary deprivation indicators.

Generally, the results show that most Batswana are deprived in indicators relating to asset and housing and living conditions dimensions. Concerning asset, the majority of the population are deprived in transport (71.4%) followed by durable goods (56.2%). In terms of housing and living conditions, cooking fuel (47.5%) and overcrowding (40.2%) exhibited higher levels (respectively) compared to other housing and living conditions indicators. Most of the population is deprived in sanitation (64.7%). Concerning food security, access to food recorded higher rates (49.2%). Concerning education, adults exhibited

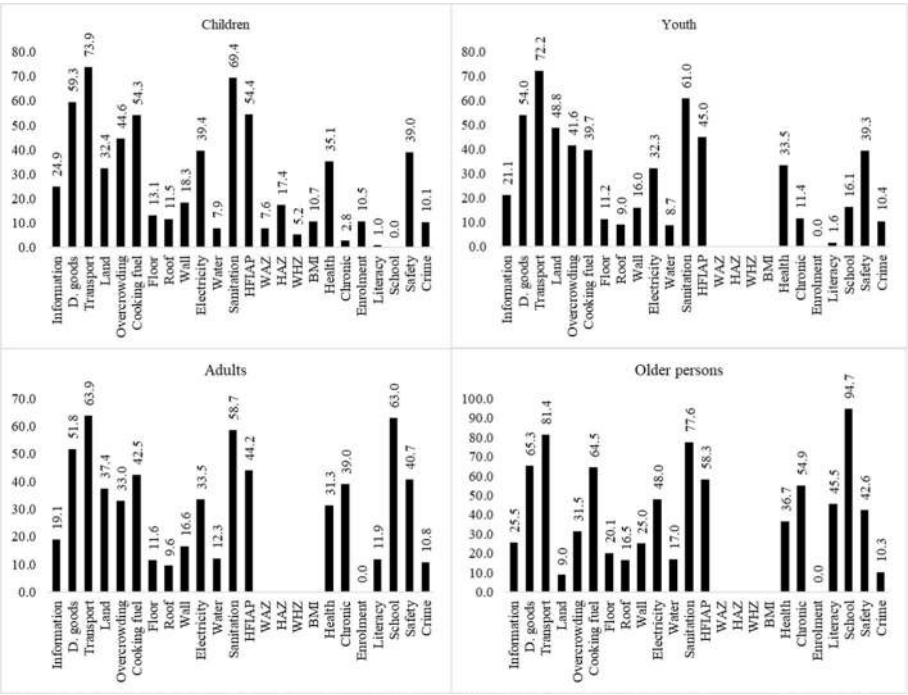

Fig. 1 Proportion of deprived population by age and indicator[†] *Source*: Author's estimates based on the 2015/16 BMTHS data. [†]All percentages are estimated at population-level using sample weights. HFIAP: household food insecurity access prevalence; WAZ: weight-for-age; HAZ: height-for-age; WHZ: weight-for-height; BMI: body mass index. Sample size: 24,720

higher deprivations (41.7%) in educational attainment. Despite free access to basic education, a section of children aged 5–17 is not enrolled in school (10.7%). Regarding health, access to a health facility exhibited higher deprivation levels (33.8%) despite free health services. In terms of security, a significant proportion of the population indicated they feel unsafe (39.7%). Overall, these findings confirm the need to shift from monetary measure to multidimensional measure of poverty.

In line with LNOB principle and SDG 1 (target 1.2), the deprivation incidences across all the indicators in all selected dimensions by different population groups are discussed. Figure 1 depicts deprivation levels across age groups. In general, the results reveal substantial differences in deprivation levels across age groups, with older persons exhibiting higher deprivation rates than other age groups in most of the deprivation indicators. Overall, varying deprivation levels exist across sub-groups of the populations (see Supplementary Tables S2–S4 for detailed results).

4.2 Multidimensional Poverty Incidences and Intensity

Table 4 presents the results of the estimates of multidimensional headcount ratio (H), the average deprivation share across the multidimensional poor (A), and the adjusted headcount ratio (M_0). The results reveal that 46.2% of the population in Botswana can be considered to be multidimensionally poor. The results show that the incidence of multidimensional

Table 4 Multidimensional poverty measures by demographic and economic variables 2015/16[†] *Source*: Author's estimates based on the 2015/16 BMTHS data

Subgroup	Population	(%)	H (%)	A (%)	M_0
Gender					
Female (ref)	1,097,366	52.9	46.8	47.6	0.223
Male	976,309	47.1	45.6***	47.1***	0.215***
Age					
0 to 17 years (children) (ref)	817,843	39.4	41.7	43.4	0.181
18 to 35 years (youth)	643,725	31.0	42.5***	46.7***	0.198***
36 to 64 years (adults)	501,325	24.2	51.8***	51.1***	0.264***
65 + (older persons)	110,781	5.3	76.6 ***	53.9***	0.413***
Disability status					
Persons with disability (PWD)	58,028	2.8	73.3***	53.8***	0.395***
No disability (ref)	2,015,647	97.2	45.5	47.1	0.214
Citizenship					
Citizen (ref)	2,005,908	96.7	47.2	47.4	0.224
Non-citizen	67,767	3.3	18.2***	46.4***	0.085***
Gender of HH					
Female-headed (ref)	1,070,945	51.6	49.7	46.7	0.232
Male-headed	1,002,730	48.4	42.6***	48.2***	0.205***
Age of HH					
12–17 (children)	4,109	0.20	58.1***	41.5***	0.241***
18–35 (youth)	462,535	22.3	40.9***	46.2***	0.189***
36–64 (adults) (ref)	1,202,243	58.0	43.3	47.1	0.204
65 + (older persons)	404,788	19.5	61.0***	48.8***	0.298***
Marital status of HH					
Married (ref)	643,176	31.0	32.6	46.5	0.151
Living together	513,572	24.8	53.8***	48.1	0.259***
Separated	41,454	2.0	52.5***	46.5	0.244***
Divorced	40,579	2.0	38.1***	47.4***	0.181***
Widowed/Widower	273,647	13.2	54.1***	47.8***	0.259***
Never married	561,248	27.1	51.2***	47.2***	0.242***
Household size					
1 to 3 members	630,661	30.4	41.8***	49.1***	0.205***
4 to 6 members (ref)	798,554	38.5	40.8	46.9	0.192
More than 7 members	644,460	31.1	57.3***	46.5***	0.267***
Educational attainment of HH					
None (ref)	573,172	27.6	67.9	49.9	0.339
Primary	530,910	25.6	54.8***	46.9***	0.257***
Secondary	594,822	28.7	39.6***	44.5***	0.176***
Vocational	70,540	3.4	22.2***	42.4	0.094***
University	304,231	14.7	9.1***	44.3***	0.040***
Total	2,073,675	100	46.2	47.4	0.219

H, headcount ratio; A, intensity; M_0, adjusted headcount ratio; HH, household head

[†]All percentages are estimated at population-level using sample weights. Sample size: 24,720

Significance levels: *$p < 0.1$; **$p < 0.05$; ***$p < 0.01$

Table 5 Multidimensional poverty measures by economic variables 2015/16[†] *Source*: Author's estimates based on the 2015/16 BMTHS data

Economic variables	Population	(%)	H (%)	A (%)	M_0
Employment status of HH					
Unemployed (ref)	910,301	43.9	59.6	47.7	0.284
Paid employment	667,766	32.2	26.1***	44.6***	0.116***
Self-employment	225,456	10.9	29.7***	44.6***	0.132***
Own farm	141,822	6.8	59.8***	50.6***	0.303***
Family helper	128,329	6.2	70.1***	49.8***	0.350***
Quintiles					
Q1 (ref)	726,785	35.1	68.3	48.1	0.329
Q2	461,592	22.3	51.3***	46.9***	0.241***
Q3	351,832	17.0	36.2***	46.3***	0.168***
Q4	281,835	13.6	23.8***	46.3***	0.110***
Q5	249,105	12.0	11.6***	44.8***	0.052***
Total	2,073,675	100	46.2	47.4	0.219

[†]All percentages are estimated at population-level using sample weights. Sample size: 24,720

Per capita quintiles were calculated at household-level. H, headcount ratio; A, intensity; M_0, adjusted headcount ratio; HH, household head

Significance levels: *$p<0.1$; **$p<0.05$; ***$p<0.01$

poverty in Botswana remains a substantial problem. Multidimensional poverty intensity is estimated at 47.4%, meaning, on average, individuals are simultaneously deprived in at least eleven (11) out of the twenty-four (24) indicators considered. The adjusted headcount ratio is estimated at 0.219.

4.2.1 Estimates by Demographic Characteristics

The analysis is disaggregated by different demographic characteristics to identify those left behind. The results reveal that poverty levels are almost equal for males and females, with females slightly worse off than males. With respect to age, poverty levels vary significantly and increase with an increase in age. Older persons exhibit higher levels of multidimensional poverty compared to other age groups. This finding is consistent with other researchers who found that multidimensional poverty is higher for older persons than children (Espinoza-Delgado & Klasen, 2018; Franco-Correa, 2014). It is essential to note the substantially wider gap in poverty levels between persons with disabilities and those with no disability, with persons with disability exhibiting highest poverty levels. This finding is consistent with the recent literature that found multidimensional poverty to be higher for persons with disabilities (Trani & Cannings, 2013; Trani et al., 2016).

Individuals residing in households headed by men are slightly better off than those in households headed by women. Similar studies in developing countries confirm this finding (Fransman & Yu, 2019; Trani et al., 2016). Individuals residing in households headed by older persons and children experience higher incidences of poverty than those living in other households. However, the intensity of poverty declines with an increase in age of household head. Poverty levels exhibit a U-shaped relationship with household size. With respect to marital status, individuals from households headed by married couples

experience lower poverty levels than those from households headed by unmarried persons. As expected, poverty levels decline with higher levels of educational achievements.

4.2.2 Estimates by Economic Variables

It is interesting to examine how multidimensional poverty levels vary across income groups (Table 5). Per capita consumption is used as a proxy for income. The results reveal a wide disparity in poverty levels. Individuals from the poorest households (bottom quintile) exhibited the highest multidimensional poverty levels. For example, the incidence of poverty for individuals from the poorest quintile are almost six times higher than that of individuals from the wealthiest quintile. This finding is consistent with other studies (Fransman & Yu, 2019; Mushongera et al., 2017; Roelen, 2017).

With respect to the employment status of the household head, the results reveal mixed and surprising findings. Poverty levels are more pronounced among individuals from households headed by family helpers (domestic workers) or engaged in subsistence agriculture than those from households headed by unemployed persons. The majority have lower educational attainments, resulting in low wages. As expected, individuals from households whose heads are engaged in formal paid employment exhibited lower poverty levels.

4.2.3 Estimates by Geographic Variables

To identify where those who are multidimensionally poor live, the results are analysed by geographical location. Table 6 presents poverty levels by geographic variables. The results reveal that multidimensional poverty levels are more pronounced in rural areas than in urban villages and cities/towns. This finding has been confirmed in developing countries (Fransman & Yu, 2019) and elsewhere (Alkire & Santos, 2014; Trani et al., 2016) in the empirical literature. With respect to administrative districts, the results reveal varying levels of poverty. For example, individuals from Ngamiland West and Kweneng West experienced the highest incidence of poverty (88.1% and 78.8% respectively), while in contrast, those from Sowa Town recorded lower levels (4.6%).

4.3 Individual-level and Household-level comparison

To compare individual-level and household-level estimates, the same index is calculated using indicators identified at household-level. The same indicators explained in Sect. 3.4 and presented in Table 2 are considered. Equal weighting across the seven dimensions and equal nested weighting for indicators within each dimension used is employed. In household-based multidimensional poverty measurements, thresholds are not defined based on the achievements of each individual but collectively for the household. Based on indicators identified at household level, all members of the household are assumed to have the identical deprivation vector. However, when dealing with indicators identified at the individual level, we classify the thresholds of using individual-level data to assess household-level deprivation into two types, restrictive and expansive (Klasen & Lahoti, 2020). The deprivation threshold is defined as *restrictive* when the entire household members are categorised as deprived in an indicator if at least one individual is deprived of that particular indicator (Klasen & Lahoti, 2020). For example, a household deprived of nutrition if at least one household member is undernourished is such a *restrictive* one. The deprivation threshold is *expansive* when

Table 6 Multidimensional poverty measures by geographical variables 2015/16† *Source*: Author's estimates based on the 2015/16 BMTHS data

Geographical location	Population	(%)	*H* (%)	*A* (%)	M_0
Strata					
Cities/towns	438,262	21.1	22.6***	44.1***	0.100***
Urban villages (ref)	911,022	43.9	40.2	45.2	0.182
Rural areas	724,391	34.9	68.1***	49.6***	0.338***
Districts					
Gaborone	238,643	11.5	20.6***	44.0***	0.090***
Francistown	90,992	4.4	28.4***	45.3***	0.129***
Lobatse	23,825	1.1	31.7***	41.7***	0.132***
Selibe Phikwe	53,427	2.6	23.2***	44.4***	0.103***
Orapa	9,532	0.5	12.9***	48.1***	0.062***
Jwaneng	18,856	0.9	13.8***	39.6***	0.055***
Sowa Town	2,987	0.1	4.6***	39.5***	0.018***
Southern	119,739	5.8	56.7***	48.0***	0.272***
Barolong	53,818	2.6	57.6***	46.7***	0.269***
Ngwaketse West	13,517	0.7	61.0***	46.7***	0.285***
South East	90,130	4.3	29.2***	44.8***	0.131***
Kweneng East (ref)	297,420	14.3	44.5	46.1	0.205
Kweneng West	52,441	2.5	78.8***	53.0***	0.418***
Kgatleng	94,258	4.5	35.7***	44.8***	0.160***
Central Serowe/Palapye	184,216	8.9	53.2***	48.5***	0.258***
Central Mahalapye	135,225	6.5	62.8***	47.1***	0.296***
Central Bobonong	64,719	3.1	54.8***	46.0***	0.252***
Central Boteti	57,868	2.8	55.1***	50.2***	0.277***
Central Tutume	143,497	6.9	57.8***	47.9***	0.277***
North East	48,293	2.3	42.6***	44.7***	0.190***
Ngamiland East	105,845	5.1	48.7***	49.2***	0.240***
Ngamiland West	63,381	3.1	88.1***	51.7***	0.456***
Chobe	24,418	1.2	34.7***	41.8***	0.145***
Ghanzi	45,082	2.2	57.1***	47.3***	0.270***
Kgalagadi South	24,950	1.2	60.2***	46.0***	0.277***
Kgalagadi North	16,594	0.8	53.1***	47.1***	0.250***
Total	2,073,675	100	46.2	47.4	0.219

H, headcount ratio; *A*, Household-level intensity; M_0, adjusted headcount ratio; HH, household head

†All percentages are estimated at population-level using sample weights. Sample size: 24,720

Significance levels: *$p < 0.1$; **$p < 0.05$; ***$p < 0.01$

the entire household members are categorised as non-deprived in an indicator if at least one individual is non-deprived of that particular indicator. For example, the entire household is deemed non-deprived in educational achievement if at least one household adult member has 9 years of education. Except for educational achievement, all individual-level indicators are defined in a restrictive way. Tables S9 and S10 in the

Table 7 Individual- and household-level multidimensional poverty estimates by age 2015/16[†] *Source*: Author's estimates based on the 2015/16 BMTHS data

Subgroup	Individual-level			Household-level			
Subgroup	$H(\%)$	$A(\%)$	M_0	$H(\%)$	$A(\%)$	M_0	Δ Incidence
0 to 17 years (children)	41.7	43.4	0.181	40.3	43.0	0.173	1.40
18 to 35 years (youth)	42.5	46.7	0.198	30.7	42.9	0.132	11.8
36 to 64 years (adults)	51.8	51.1	0.264	34.2	44.0	0.151	17.5
65 + (older persons)	76.6	53.9	0.413	53.0	44.9	0.238	23.6
Total	46.2	47.4	0.219	36.5	43.4	0.158	9.70

H, headcount ratio; A, intensity; M_0, adjusted headcount ratio

Δ Incidence is the difference between individual- and household-level poverty incidences (H)

[†]All percentages are estimated at the population-level using sample weights. Sample size: 24,720

Table 8 Inequality across demographic and economic variables 2015/16[†] *Source*: Author's estimates based on the 2015/16 BMTHS data

Age group	H (%)	A (%)	M_0	I_q
0 to 17 years (children)	41.7	43.4	0.181	0.032
18 to 35 years (youth)	42.5	46.7	0.198	0.036
36 to 64 years (adults)	51.8	51.1	0.264	0.057
65 + (older persons)	76.6	53.9	0.413	0.076
Total	46.2	47.4	0.219	0.044

H, headcount ratio; A, intensity; M_0, adjusted headcount ratio; I_q, inequality level

[†]All percentages are estimated at population-level using sample weights. Sample size: 24,720

supplementary tables presents an illustration based on three households comprising twelve individuals.

Table 7 presents the results. Based on poverty incidence (H), 36.5% of the population is considered multidimensionally poor when using the household as a unit of analysis compared to 46.2% when using individual as a unit of analysis. This result in 9.7 percentage points between the two measures. The results confirm that household-level measure underestimate poverty levels of the population. The results point towards a U-shaped relationship between age and multidimensional poverty, while the results based on individual measure reveal a positive linear relationship. The results support the use individual as a unit of analysis to identify those left behind in line with LNOB principle.

4.4 Inequalities among the multidimensionally poor

Inequality across society is a growing and highly prominent issue (Alkire & Seth, 2014a). In the SDGs, this is captured by SDG 10, which aims to reduce inequality within and among countries (UN, 2015). Inequality is a problem of inclusion, and LNOB is a tool for addressing inequality (Fukuda-Parr & Hegstad, 2018). This measure summarises empirical information that enables policymakers to assess whether the poorest of the poor share

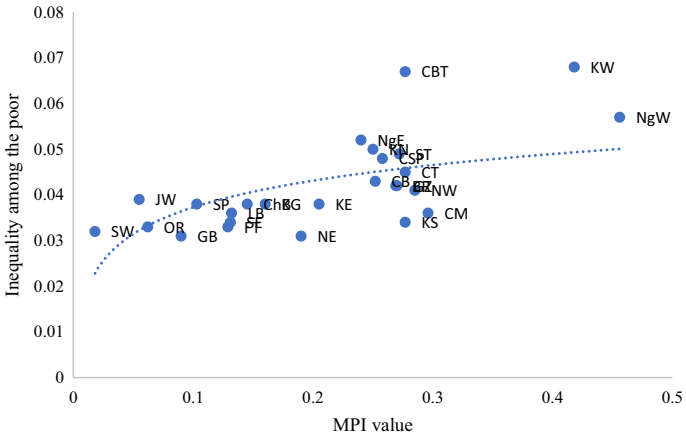

Fig. 2 Inequality and MPI among the multidimensionally poor across districts *Source*: Author derived from 2015/16 BMTHS. GB: Gaborone; FT: Francistown; LB: Lobatse; SP: Selibe Phikwe; OR: Orapa; JW: Jwaneng; SW: Sowa Town; BR: Barolong; NW: Ngwaketse West; SE: South East; KE: Kweneng East; KW: Kweneng West; KG: Kgatleng; CSP: Central Serowe Palapye; CM: Central Mahalapye; CB: Central Bobonong; CBT: Central Boteti; CT: Central Tutume; NE: North East; NgE: Ngamiland East; NgW: Ngamiland West; ChB: Chobe; GZ: Ghanzi; KS: Kgalagadi South; KN: Kgalagadi North

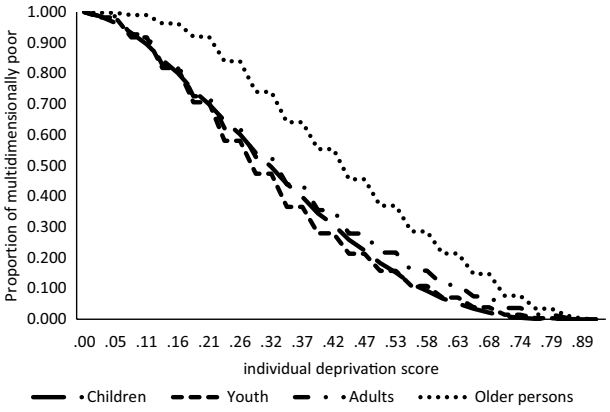

Fig. 3 Complementary cumulative distribution function (CCDF) by age group *Source*: Author's estimates based on the 2015/16 BMTHS data

the benefits of poverty alleviation (Alkire & Seth, 2014b). This index lies between zero and one, with zero indicating complete equality (no inequality) and one showing absolute inequality (Hanandita & Tampubolon, 2016).

Table 8 presents the results of inequality estimates among the multidimensionally poor across different subgroups of the population. Inequality among the multidimensionally poor is estimated at 0.044. The results reveal a positive relationship between inequality levels and the individual's age, with older persons exhibiting higher inequality levels. These results are consistent with those based on the multidimensional poverty index. This finding is an indication that multidimensional poverty index and the inequality among the poor are positively related (Alkire & Seth, 2014b; Espinoza-Delgado & Klasen, 2018).

Figure 2 depicts inequality and MPI among the multidimensionally poor across administrative districts. The figure depicts a wide variation across administrative districts in

inequality among the multidimensionally poor; Kweneng West (KW) exhibited the highest inequality level followed by Central Boteti (CBT) and Ngamiland West (NgW). Although we find that the level of inequality among the multidimensionally poor and the levels of poverty in terms of MPI are positively related, there are several exceptions across administrative districts. For example, an interesting observation is that CBT, CT and KS have the same MPI value of 0.277 but varying inequality levels. For example, the inequality among the poor in CBT is almost double (0.067) the inequality level of KS (0.034), suggesting that the poor in CBT experience higher levels of intensities of poverty.

5 Robustness Analysis

Following Alkire et al. (2015b), this study assesses if the main conclusions are robust to the different choices of parameters: (1) different poverty cut-offs (k values) and (2) changes in weighting structure (w). First, the complementary cumulative distribution function (CCDF) is employed to investigate whether the results are robust to the choice of a multidimensional poverty line (k). Figure 3 depicts the CCDFs for children, youth, adults, and older persons for various values of k, and the results do not find strict first-order stochastic dominance between the CCDFs for different k values. In general, the results show that older persons' distribution dominates those of other age groups. That is, no matter what value of k we choose, the proportion of multidimensionally poor individuals (H) will always be larger for older persons than for children, youth, and adults. The main conclusions also remain robust when using alternative weighting schemes (Supplementary Tables S5–S7). This robustness analysis proves that even though normative decisions were employed when constructing the index, the public policy conclusions drawn from the index are robust to a choice of diverse parameters.

6 Conclusions and Policy Implications

The LNOB principle is at the core of the 2030 Agenda for sustainable development. The call to end poverty in all its forms and for everyone, as emphasised by SDG 1.2, acknowledges the multidimensional nature of poverty and that poverty should be examined at the individual level. Notwithstanding this, most empirical studies use the household as the unit of analysis for multidimensional poverty measurement. However, household-based measures lead to biases in multidimensional poverty assessment and are not sensitive to demographic characteristics such as gender and age. Also, household based MPIs considerably underestimate the poverty levels of society. When using household-level measure, the incidence of female-headship as a sign of gendered poverty would be deeply misleading (Klasen & Lahoti, 2020). Therefore, the main objective of this study is to develop an individual-level and country-specific multidimensional poverty measure. Also, the study aims to provide estimates of multidimensional poverty for Botswana. This study contributes to the limited literature on individual-level multidimensional poverty measurement. Empirically, this study deepened the understanding of poverty in Botswana by providing a detailed analysis and data disaggregation in line with the LNOB principle.

The results reveal that an estimated 46.2% of individuals are considered multidimensionally poor based on individual-level analysis. This figure is higher than the household-level

estimate of 36.5%, which indicates that using the household as a unit of analysis leads to underestimating poverty levels in Botswana. The results show that, on average, the multidimensionally poor are deprived in 47.4% of all indicators under consideration. This finding indicates that multidimensional poverty intensity is also a considerable concern in Botswana. The extent and nature of multidimensional poverty vary significantly across different subgroups of the population. In Botswana, those left behind are mostly older persons and persons with disabilities. Significant disparities are observed across geography, with some districts such as Ngamiland West and Kweneng West West recording the highest poverty levels. In sum, the analysis in this study highlights the heterogeneity of different groups of the population. It suggests that more in-depth analyses of poverty at specific individual groups levels are needed to reveal the poverty situation of the society to inform policy better and improve the effectiveness of evidence-based planning. This way, interventions can be customised, taking into account these heterogeneities and improve the targeting of policy interventions.

The findings of this study have policy implications that might help the government, policymakers and researchers. The findings of this study are also expected to inform the poverty eradication initiatives as stipulated in the BPEPS, Vision 2036 and track the progress of the 2030 Agenda for Sustainable Development, especially SDG 1. The AF methodology used to construct the individual-level multidimensional poverty measure helps to explore the joint deprivation of the poor, thus helping policymakers to implement nationally appropriate social protection systems and to be able to cover those left behind as emphasised by SDG 1.3 of the SDGs. The analysis across different subgroups provides vital information that policymakers need since it shows the specific areas of *who* the poor are, *where* they live and *how* poor they are. Since different indicators are related to services whose provision falls under the mandate of different ministries/departments, an integrated approach to service delivery is key to reducing multidimensional poverty in Botswana. Also, disaggregating data analysis by different subgroups of the population allows for monitoring the SDG commitment of halving the proportion of men, women, and children experiencing poverty in all its dimensions and the LNOB commitment.

The finding that PWDs have higher multidimensional poverty levels warrants policy intervention. For example, there is a need to develop platforms for PWDs to have their voice heard regarding their specific lived experiences and priorities. Also, PWDs should be included in the broader decision-making processes as stipulated by the Convention on the Rights of Persons with Disabilities (CRPD). Notwithstanding this, Botswana is among the only five African countries that have not yet ratified the CRPD. Therefore, Botswana needs to sign the CRDP, which is intended as a human rights instrument for persons with disabilities. Also, there is a need to have specific interventions and policies aimed at older persons to prevent them from experiencing multiple deprivations.

The study concludes that mining plays a vital role in socio-economic development, as evidenced by lower multidimensional poverty levels in mining towns. However, whether mining contributes to socio-economic development for all is not clear-cut. Concerning tourism, the study concludes that it is not clear-cut that tourism plays an essential role in the socio-economic development of ordinary citizens. For example, Ngamiland West recorded the highest poverty levels, despite being rich in natural resources and providing some of the best tourist attraction places in the country. Therefore, the government of Botswana should put in place more inclusive tourism policies that will benefit communities living in areas with rich natural resources to leave no one behind.

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