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Application of Expanded Alkire and Foster Multidimensional Poverty Index to Nigeria

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Abstract

An improved Alkire and Foster Multidimensional Poverty Index (MDPI) with 20 indicators clustered into seven dimensions, namely, Social Security, Water and Sanitation, Living Standard, Employment and Income, Health, Nutrition, and Education was developed and implemented with '*mdpi function*' deployed in R Programming Language. The function computes MDPI along with useful associated measures at sub-national or context-specific levels. It was applied to data collected from 1614 respondents from 13 selected Nigerian states and the results compare favourably with existing studies. From the results obtained, the national MDPI is 0.418 but computing MDPI at National, sub-national or context-specific levels does not always give the same trend. Also, the results further reveal that states in Northern Nigeria (0.420) are more multidimensionally deprived in most of the dimensions although there are instances where states in the South (0.415) also show severe deprivation despite their level of development. In line with the findings, it is recommended that UNDP should implement this new MDPI strategy to ensure that every sector of the society is covered by development interventions. The interventions should be region and context-specific, addressing the North's educational and employment deprivation and the South's urban living and social protection deficiencies as well as sex, gender and religious disparities in deprivation.

Key words: Expanded poverty indicators; Poverty measurements; Poverty dimensions; National data sample; Social security

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AUTHORS CONTRIBUTION

Conceptualization: HS, JNN
Project administration and Supervision: HS, JNN
Methodology: All
Software and coding: HS, JNN
Validation: All
Formal analysis: HS, JNN
Investigation: All
Data Curation: All
Writing - Original draft, review and editing: HS, JNN

1. INTRODUCTION

Poverty is a multidimensional issue that transcends income deprivation, affecting various dimensions of human well-being such as education, health, living conditions, and income security. It remains a significant challenge despite various targeted government and policy interventions as well as resource optimization aimed at improving income, enhancing welfare as well as poverty alleviation and reduction. Traditional income-based poverty measures have proven inadequate for capturing the complex and interlinked dimensions of deprivation faced by the low-income members of society, especially in developing countries, leading to the adoption of multidimensional approaches. Recognizing this limitation, the Alkire and Foster Multidimensional Poverty Index (AF-MDPI) developed by Alkire and Foster (2011) has

emerged as a more holistic measure beyond income-based measures. The AF-MDPI evaluates poverty by considering multiple indicators across dimensions such as health, education, and living standards. However, the standard set of indicators used in the AF-MDPI may not fully reflect the context-specific nature of poverty, which is influenced by unique socio-economic conditions and such other factors like national and regional disparities, cultural practices, and infrastructural deficits.

The AF-MDPI is widely utilized to assess poverty beyond monetary dimensions and offers a robust approach for measuring multidimensional poverty by evaluating poverty through multiple dimensions. Although the AF-MDPI may be the appropriate tool for the evaluation, it might have overlooked certain critical dimensions relevant to the determination of the actual sources of multidimensional poverty. Thus AF-MDPI can be a more comprehensive poverty assessment tool for guiding targeted policy interventions by expanding the methodology to encapsulate a broader spectrum of additional sources of deprivations experienced in developing countries. The expansion will also reflect the complex nature of poverty, as experienced by the low-income earners more accurately. The extended MDPI framework incorporating an additional number of indicators will provide a comprehensive understanding of deprivation beyond income-based measures and engender informed policies targeted at poverty alleviation. It is in view of this limitations that this study aims to expand the AF-MDPI by incorporating additional indicators that are particularly relevant and critical in determination of the real situation of MDPI especially in developing countries like Nigeria. The indicators may include access to clean energy, quality of housing, security, and financial inclusion, which are crucial for understanding poverty dynamics.

By enhancing the existing MDPI framework, this research seeks to provide policymakers with a more robust and accurate understanding of multidimensional poverty as a tool for designing informed and targeted poverty alleviation interventions thereby promoting sustainable development. Expanding this framework to incorporate regional and cultural contexts can lead to more effective poverty measurement and intervention strategies. These interventions and strategies will ensure a faster march towards the achievement of at least 8 SDGs i.e. 1-4, 6-8 & 10. In addition, the expansion is expected to reveal deeper insights of the multifaceted nature of poverty and its various dynamics and further suggest more effective strategies for poverty alleviation by outlining actionable options for policymakers to optimize scarce resources. The large number of SDGs that are aligned to multidimensional poverty shows that dealing with it adequately will bring about sustainable development and enduring prosperity.

1.1 Research Questions

Based on the foregoing views on the need to expand AF-MDPI, pertinent questions that can address the shortcomings needs to be raised, which are:

i. How can AF-MDPI methodology be expanded to better reflect multidimensional poverty measures?

ii. What are the additional indicators and dimensions that could provide a more accurate representation of multidimensional poverty and reflect socio-economic realities?

iii. How does the expanded MDPI compare with AF-MDPI metrics in assessing multidimensional poverty levels?

1.2 Aims and Objectives of the Study

The aim of the study is to show that an expanded AF-MDPI is consistent with the prevailing method and the results of such expansion can be validly utilized to address strategic policies and interventions on multidimensional poverty reduction. The specific objectives are to:

i. Enumerate the various methods for expanding the AF-MDPI methodology to better reflect multidimensional poverty measures,

ii. Enumerate various indicators that could provide a more accurate representation of multidimensional poverty and reflect socio-economic realities and their dimensions, and

iii. Compute the expanded MDPI measure and compare them with the AF-MDPI metrics in assessing multidimensional poverty levels.

2. LITERATURE REVIEW

2.1 Conceptual Framework on Multidimensional Poverty

Traditional poverty assessments have predominantly relied on monetary metrics, such as income or consumption levels, to determine poverty status. However, this unidimensional approach often fails to capture the complex and multifaceted nature of poverty. Recognizing these limitations, scholars and policymakers have advocated for a multidimensional perspective that encompasses various deprivations individuals or households may experience.

The concept of multidimensional poverty (AF-MDPI methodology), which was developed by the Oxford Poverty and Human Development Initiative (OPHI) in collaboration with the United Nations Development Program (UNDP) in 2010, recognizes that poverty is not merely a lack of income or monetary poverty, but deprivation extending beyond income and cutting across three core dimensions: health, education, and standard of living of human well-being and social security. The methodology utilizes a dual-cutoff approach to measure multiple deprivations simultaneously. The dual-cutoff

method involves setting thresholds for each dimension and identifying individuals or households as poor if they fall below a certain aggregate deprivation level. It is widely recognized for its capability to capture these multiple dimensions comprehensively through a set of carefully selected indicators and a weighted approach. Each dimension comprises specific indicators, such as child mortality and nutrition (health), years of schooling and school attendance (education), and access to electricity, drinking water, sanitation, cooking fuel, housing, and asset ownership (standard of living). Each indicator is weighted to reflect its importance, and a deprivation score is assigned to households. A household is considered multidimensionally poor if its deprivation score exceeds a specified threshold and more specifically, if it is deprived in at least one-third of these weighted indicators (Alkire & Foster, 2011).

The MDPI framework integrates both the incidence (headcount ratio) and intensity (average deprivation score) of poverty, offering a comprehensive understanding of poverty dynamics. Its adaptability allows policymakers to customize dimensions and indicators based on regional and national contexts, making it a versatile tool for targeting poverty alleviation strategies (Alkire *et al*., 2015, 2022). The index has been applied by international bodies such as the United Nations Development Program (UNDP) to assess poverty in over 100 countries, highlighting its global relevance and applicability (UNDP, 2020). By considering multiple deprivations, the MDPI offers a more holistic understanding of poverty, capturing aspects that monetary measures might overlook.

Building upon the AF-MDPI, scholars have proposed alternative multidimensional poverty indices that incorporate sensitivity to inequality among the poor. For instance, Chakravarty and D'Ambrosio (2006) and Rippin (2010) developed measures that account for the distribution of deprivations, highlighting the importance of considering inequality within multidimensional poverty assessments. In addition, scholars continue to argue that the standard MDPI indicators may overlook context-specific factors critical to understanding poverty in certain regions (Bourguignon & Chakravarty, 2019). For instance, factors such as access to electricity, quality of housing, and security are pivotal to well-being yet remain unaccounted for in the conventional MDPI. Thus, an expanded framework incorporating these dimensions could offer a more hair-splitting understanding of poverty. Another argument put up by Wang *et al*. (2023) is that **t**here is no universally agreed set of dimensions and indicators of MDPI to be utilized in the computations only that most studies chose the dimensions of education, health, and living standards as originally proposed (Alkire & Foster, 2011, Alkire and Santos, 2014; Alkire and Seth, 2015). Furthermore, the Foster-Greer-Thorbecke (FGT) indices (Foster *et al.*, 1981, 1984), originally formulated for unidimensional poverty measurement, have been extended to multidimensional contexts. These indices allow for varying degrees of sensitivity to the depth and severity of poverty, providing a flexible framework for poverty analysis.

2.2 Theoretical Review of Studies on Multidimensional Poverty

The Capability Approach, pioneered by Sen (1999), serves as the theoretical foundation for multidimensional poverty measurement. This approach emphasizes the importance of assessing individuals' capabilities and freedoms rather than merely focusing on income. This approach is closely followed by the Human Development Framework for multidimensional poverty measurement. These theories advocate for assessing poverty through multiple dimensions beyond financial metrics to capture human well-being comprehensively. Sen (1999) argues that poverty should not only be seen as a lack of income but as a deprivation of capabilities, which the MDPI aims to capture by incorporating multiple dimensions.

The multidimensional poverty approach builds on the capability theory, which emphasizes the importance of individuals' capabilities and opportunities in achieving well-being. The AF-MDPI method operationalizes this theory by providing a flexible and adaptable framework for poverty measurement, allowing for the inclusion of context-specific indicators. The theoretical underpinnings of the AF-MDPI are grounded in the capability approach, emphasizing the importance of evaluating individuals' ability to achieve valuable states of being and doing. AF-MDPI quantifies multiple deprivations that impact an individual's ability to live a fulfilling life. This methodology aligns with the broader theoretical perspectives of human development and social inclusion, advocating for a multi-faceted analysis of poverty that can inform more effective policy interventions (Alkire *et al.*, 2015).

Other theoretical perspectives, such as the Basic Needs Approach (Streeten, 1981) and the Social Exclusion Theory (Silver, 1994), also contribute to the understanding of multidimensional poverty. The Basic Needs Approach focuses on the fulfillment of minimum requirements for a decent life, while the Social Exclusion Theory emphasizes the processes by which individuals or groups are systematically marginalized from economic, social, and political opportunities.

Critics of AF-MDPI have highlighted its rigidity in indicator selection and weighting, suggesting that a more flexible framework that accommodates regional contexts could enhance its applicability (Laderchi *et al.*, 2003). In the same vein, scholars such as Ajakaiye and Adeyeye (2018) have advocated for the inclusion of indicators like energy access, financial services, and social security to capture the true extent of deprivation.

2.3 Empirical Review of Studies on Multidimensional Poverty

Previous studies have applied the AF-MDPI across different contexts and demonstrated that incorporating additional indicators such as unemployment, health insurance, and security significantly alters poverty profiles and enhances policy relevance (Batana, 2013; Adeoti & Akinwande, 2020). For example, Alkire and Santos (2010, 2010a, 2014) utilized the MDPI to assess poverty trends in developing countries, revealing significant heterogeneity in poverty levels and dimensions across regions and that approximately 1.7 billion people lived in multidimensional poverty. Their study highlighted significant disparities in poverty levels and compositions across regions, underscoring the necessity of context-specific policy interventions. Similarly, Batana (2013) and Berenger (2019) applied the MDPI in Sub-Saharan Africa, revealing that education and living standards were the most significant contributors to multidimensional poverty. Berenger (2019) examined multidimensional poverty in Malawi, Mozambique, Tanzania, and Zimbabwe and compared the MDPI with alternative poverty measures sensitive to inequality, providing meticulous insights into the breadth and inequality components of poverty in these countries.

In Nigeria, studies by Ogwumike and Ozughalu (2018) used the MDPI to evaluate poverty reduction strategies, highlighting the need for targeted interventions in health and education sectors. Further research by Oyekale (2019) applied the MDPI to rural communities, demonstrating how access to clean water and improved sanitation significantly reduced multidimensional poverty levels. However, the current MDPI indicators have been criticized for not fully capturing the poverty realities in rural and urban areas alike.

Internationally, the World Bank integrated multidimensional poverty measures into its poverty assessments. Its Multidimensional Poverty Measure (MPM) includes monetary poverty, education, and basic infrastructure services, capturing a more comprehensive picture of poverty. The MPM has been applied to over 100 countries, facilitating global poverty monitoring and policy design. In addition, empirical analyses by the UNDP (2020) demonstrated that countries with tailored poverty alleviation programs, aligned with the MDPI findings, achieved more substantial poverty reductions. The flexibility of the MDPI allows for dynamic monitoring and evaluation of poverty-related programs, contributing to more transcendent policymaking and resource allocation.

Empirical studies have demonstrated the efficacy of the AF-MDPI in assessing poverty globally. For instance, studies in South Asia and Sub-Saharan Africa have shown how multidimensional poverty metrics reveal disparities hidden by traditional income-based measures (Santos & Ura, 2008). In Nigeria, existing research has applied the MDPI at the national level, but there is limited exploration of its application with expanded indicators at the state level (Adewuyi & Ogunleye, 2020). Also, significant regional disparities in multidimensional poverty have been observed by Ogunniyi and Olagunju (2020) who applied MDPI in rural South Western Nigeria and found that education and living standards were the most significant contributors to poverty. In contrast, studies in the northern regions revealed that health and security are more pressing concerns (Adetoro *et al.*, 2019).

The inclusion of additional indicators has proven effective in capturing poverty dynamics more accurately. For example, a study by Edeh and Sulyman (2021) integrated access to clean energy and financial services into the MDPI framework for states in Northern Nigeria, resulting in a more comprehensive poverty profile. These findings suggest that an expanded MDPI could provide a deeper understanding of poverty and inform more effective policy responses.

In high-income countries, discussions have emerged regarding the adoption of multidimensional poverty measures. For example, in Australia, experts have advocated for an official MDPI to capture the complex nature of poverty beyond income metrics. Such a measure could inform more effective policymaking and resource allocation, addressing various factors like housing, education, health, and social connections. These empirical studies demonstrate the versatility and applicability of the MDPI and related methodologies in diverse contexts, highlighting their potential to inform targeted and effective poverty alleviation strategies.

3. METHODOLOGY

Enumerate the various methods for expanding the AF-MDPI methodology to better reflect multidimensional poverty measures:

To achieve this objective, a survey of previous attempts to expand AF-MDPI was undertaken to outline available methods that could be used. In the search, it was discovered that attempts have been made to modify the procedure, but all the studies have not directly modified the methodology but merely proposed something a bit new (Table 1). For example, Berenger (2019) modified the methodology by using nine of the 10 indicators while excluding “Access to health care”. In the same vein, NBS (2022) used eight indicators from the methodology by omitting “Child mortality and Electricity” but added four additional indicators, i.e., “School lag, Security shock, Unemployment, Underemployment”. On their own part, Wang *et al.* (2023), added “Chronic diseases, Activities of daily living, Depression, Health insurance, Pension insurance, and Employment and Income” but omitted

"Child mortality, Access to health care, Nutrition, School attendance and Electricity". Based on the foregoing, it might be inappropriate to compare the MDPI results from these studies but the general trend of the MDPI among the sampled population with differential indicators and dimensions is similar. On the number of dimensions, Berenger (2019) used the same dimensions with AF-MDPI while NBS (2022) used four dimensions by adding "Work and Shock". Wang *et al.* (2023) introduced two additional dimensions, i.e., "Social Security, and Employment and Income" to the existing three used in the original methodology thus computing MDPI on five dimensions. In all, a total of 22 indicators have been variously used to calculate MDPI on differential dimensions. It is remarkable to note that NBS (2022) also computed child MDPI with separate additional indicators and "Child Survival and Development" dimension (Table 1). Although there are indicators that spatial and time-dependent MDPI could be computed, the general procedure is to compute static MDPI at each given time. Also, due to limitations placed by data availability, in most cases, only sample-based (national) MDPI are computed although recent trends suggest that sub-national and context-based MDPI are possible (Arancibia & Girela, 2024).

Enumerate various indicators that could provide a more accurate representation of multidimensional poverty and reflect socio-economic realities and their dimensions

In this study, it is proposed that all variant indicators to the original AF-MDPI except two that have narrow application, i.e., Activities of daily living and Depression, be integrated into a comprehensive MDPI infrastructure, i.e., 20 indicators under four additional dimensions, i.e., Nutrition, Water and Sanitation, Social security, and Employment and Income, as presented in Table 2. The new attempt would also involve computing sample-based (national) MDPI as well as sub-national and various context-based measures.

Compute the expanded MDPI measure and compare them with the AF-MDPI metrics in assessing multidimensional poverty levels.

a. Sampling and Data collection

To achieve this objective, a cross-section of data was utilized. The data were collected from 13 selected states of Nigeria. Table 3 shows the spatial and socio-economic characteristics as well as the Local Governments Areas (LGAs) of the states involved in the study. The states are in the North Central, North West and South West. North East, South East and South South states were excluded mainly because of security concerns of the data enumerators. The location of the study area is presented in Fig. 1. Six of the states, namely, Lagos, Ogun, Oyo, Kwara, Niger, Kebbi and Benue share international boundaries with Benin Republic in the West and Cameroon in the East. The data was collected from randomly selected 1614 respondents in the farming communities of the selected LGAs as shown in Table 4.

The instrument for the data collection was a structured questionnaire mounted on Kobo toolbox (www.kobotoolbox.org, 2024) app and the administered by trained enumerators via interview schedules in a cordial atmosphere. The respondents provided all the information requested from them without any compulsion. The data covered a wide-ranging issues like socio-economic characteristics, five-year recall of diseases infection and deaths, housing characteristics, employment and income, children schooling and lags, etc. The data collection exercise was between May and October 2024.

b. Computation

The computation of MDPI based on the AF-MDPI procedures is straightforward, relying on counting and averages. But the data preparation is tedious. First the various items that make up each indicator must be assembled and prepared for the computation. This goes to structuring the questions that elicit such responses so as not to create any ambiguity in the responses. A comprehensive review of the step-by-step procedures for computing AF-MDPI are provided by

Table 1
Indicators and domains adopted in various studies for computation of MDPI

Indicators (Proposed)	Alkire and Foster (2011)	Berenger (2019)	NBS (2022)	Wang et al. (2023)	Dimension
Child mortality	Child mortality	Mortality			
Chronic diseases				Chronic diseases	
				Activities of daily living	
				Depression	Health
Access to health care	Access to health care		Time to healthcare		
Nutrition		Nutrition	Nutrition		
Food insecurity			Food insecurity		
Years of schooling	Years of education	Years of schooling	Years of schooling	Schooling	
School attendance	School attendance	Child enrolment	School attendance		Education
School lag	School lag		School lag		

Indicators (Proposed)	Alkire and Foster (2011)	Berenger (2019)	NBS (2022)	Wang et al. (2023)	Dimension
Access to an improved sanitation	Access to an improve sanitation	Sanitation	Sanitation	Flushable toilets, Bathing facilities	
Access to drinking water	Access to clean source of water	Water	Water, Water reliability	Running water	
Cooking fuel	Cooking Fuel	Cooking fuel	Cooking fuel	Cooking fuel	Living standard
Access to electricity	Electricity	Electricity			
Type of housing materials	Housing Materials	Floor	Housing materials	Housing structure	
Ownership of household assets	Asset ownership	Assets	Assets	Household assets	
Health insurance				Health insurance	Social security
Pension insurance				Pension insurance	
Level of income				Income	Employment and Income
				Employment	
Unemployment			Unemployment		Work and shocks
Security shock			Security shock		
Underemployment			Underemployment		
			Birth attendance		Child Survival and Development
			Child engagement		
			Child care		
			Playground		
			Breastfeeding		
			Supplement		
			Immunisation		
			Severe undernutrition		

Table 2
Dimension, cutoff and weight of the indicators included in the MDPI for Nigerian states[1]

Dimensions	Indicator	Deprivation cutoff	Weight
Health	Child mortality (Chm)	A household is deprived if any child died in the past five years	1/21
	Chronic diseases (Chd)	A household is deprived if any individual had at least one chronic disease and did not receive any treatment	1/21
	Access to health care (Athc)	A household is deprived if it takes them 30 minutes or more to reach the nearest functional health facility or primary healthcare centre on foot.	1/21
Nutrition	Nutrition (Ntr)	A household is deprived if any child under the age of 5 is undernourished (i.e. stunted or underweight) or if there is any adult household member with a body mass index lower than 18.5	1/14
	Food insecurity (Fdi)	A household is deprived if the household is severely food insecure according to the Food Insecurity Experience Scale (FIES) >=7 answers affirmatively1	1/14
Education	Years of schooling (Yos)	A household is deprived if no member aged 15 years and above has completed primary school	1/21
	School attendance (Sca)	A household is deprived if any child between the ages of 6 and 15 years is not attending school	1/21
	School lag (Scl)	A household is deprived if any child who is school age + 2 years (8–17 years of age) is educationally lagging at least two years behind.	1/21
Water and Sanitation	Access to an improved sanitation (Atais)	A household is deprived if the household's sanitation facility is not improved (according to SDG guidelines),3 or it is improved but shared with other households	1/14
	Access to drinking water (Atdw)	A household is deprived if the household does not have access to safe drinking water (according to SDG guidelines)2	1/14
Living standard	Cooking fuel (Ckf)	A household is deprived if the household cooks with dung, wood or charcoal	1/28
	Access to electricity (Ate)	A household is deprived if the household lacks access to electricity	1/28
	Type of housing materials (Tohm)	A household is deprived if the household has a natural/rudimentary floor, roof or wall4	1/28
	Ownership of household assets (Ooha)	A household is deprived if the household has fewer than two assets5 and does not own a car	1/28

[1] See Appendix 1 for more details on the indicators marked

Dimensions	Indicator	Deprivation cutoff	Weight
Social security	Health insurance (Hli)	A household is deprived if no member is participating in any health insurance	1/21
	Pension insurance (Pni)	A household is deprived if no member is participating in any pension insurance	1/21
	Security shock (Scs)	A household is deprived if it experienced at least one shock over the past 12 months6	1/21
Employment and Income	Unemployment (Unm)	A household is deprived if any member aged 15 years and above is unemployed not in employment, but looking for work and available for work	1/21
	Underemployment (Und)	A household is deprived if at least one household member aged 15 years and above is working fewer than 40 hours per week but is available and willing to do extra hours of work	1/21
	Level of income (Loi)	A household is deprived if the daily per capita net income of the household is less than USD1.25/day or USD456.23/annum	1/21

Table 3
Spatial and socio-economic characteristics of the states included in the study

State	Location	Number of LGAs	Major tribes	Major Economic activities	Population	LGAs in the study	Communities in the Study	Annual Rainfall	Annual temperature	Major crops produced
Benue	6.5º - 8.5º N 7.47º - 10 E.	23	Tiv, Idoma, and Igede	Farming and fishing	4,253,641	Gboko, Tarka	Abugu, Yandav, Abgbide, Abulu	1200-1500mm	23-37°C	oranges, mangoes, sweet potatoes, cassava, soy bean, guinea corn, flax, yams, sesame, rice, groundnut and palm trees
FCT	8°30′-9°30′N 6°30′-7°30′E	6	Gbagyi, Koro	Administration, Tourism, Farming	3,278,779	Kuje, Kwali	Chibiri, Chukuku, Ijah, Yangoji	1100-1600 mm	25-28°C	Maize, Rice, Cassava, Yam, Potatoes, Sweet potatoes, Tomatoes, Peppers, Cucumbers, Vegetables
Kaduna	9°30′-11°00′N 7°30′-8°30′E	23	Adara, Bajju, Atyap, Kamantan, Ham, Gbagyi, Gwong, Berom	Farming, Mining	9,032,200	Igabi, Zaria	Birnin Yero, Rigachukun, Amaru, Kaura	1000-1300 mm	23-26°C	maize, rice, cowpea, groundnut
Kebbi	12.4376°N, 4.2078° E	21	Hausa, Fulani	Fishing and farming	6,260,592	Argungu, Zuru	Rafin Zuru, Zodi, Galadima, Gulma	787.53-1200	18.3-40°C	sorghum, groundnuts, millet, onions, and rice
Kogi	7°20′-8°10′N 6°20′-7°10′E	21	Igala, Ebira, Okun	Farming, Mining	5,685,864	Adavi, Okehi	Kuroko, Abobo, Eganyi	1016-1524 mm	24-27°C	yam, cassava, maize, cowpea, melon, bambara nut, beniseed, oil palm, castor, cashew, citrus
Kwara	8.9669°N, 4.3874° E	16	Yoruba, Nupe, Fulani, and Bariba	Farming	3,660,000	Ifelodun, Irepodun	Odofian, Omupo, Ajase, Oro	800-1500mm	28.28-44.47°C	maize, sorghum, rice, millet, beans, yam, cassava, and vegetables
Lagos	6.5244°N, 3.3792° E	20	Yoruba	Commerce and finance, manufacturing (automobiles, food & beverages, textiles, etc.), agriculture, and fishing	15,946,000	Badagry, Ikorodu	Agbara, Ibereko, Imota, Isawo	1627-1747mm	21-34°C	cassava, maize, plantain, rice, palm oil, and coconut

State	Location	Number of LGAs	Major tribes	Major Economic activities	Population	LGAs in the study	Communities in the Study	Annual Rainfall	Annual temperature	Major crops produced
Nasarawa	8.4998°N, 8.1997° E	13	Eggon and Alago	Farming	2,886,000	Keffi, New Karu	Fagidi, Ganta, Aso District, Mararaba	1123-1500mm	27.6-39.3°C	rice, yam, maize, beans, and cassava
Niger	9°00′-10°30′N 5°30′-7°10′E	25	Nupe, Gbagyi, Hausa	Farming, Fishing	6,783,300	Bosso, Chanchaga	Garatu, Gidan Kwanu, Kasuwan Gwari, Tunga	1219 mm	26.10-30.30°C	rice, guinea corn, maize, yam, beans, groundnut, sugarcane
Ogun	6.9980°N, 3.4737° E	20	Yoruba	Farming	6,379500	Ijebu North, Ijebu Ode	Eben Alafin, Igbeba, Itanrin, Ososa	1400-1500mm	23.3-33.9°C	cassava, rice, maize, yams, plantains, and bananas
Osun	7°30′-8°00′N 4°00′-4°45′E	30	Yoruba	Farming	4,350,800	Ife Central, Osogbo	Ile Ife, Modakeke, Oke Bale	1100-800 mm	21.10C - 31.10°C	Cocoa, kola, citrus, oil palm, maize, yam, rice, cassava, tomato, pepper
Oyo	8.1574°N, 3.6147° E	33	Yoruba	Farming, cattle rearing, mining and commercial activities	7,976,100	Iseyin, Itesiwaju	Ado Adaye, Odo Ogun, Ipapo, Oke Amu	1050-1350mm	21-35°C	cassava, cocoa, maize, rice, palm oil, yams, and beans
Plateau	9.2182°N, 9.5179° E	17	Berom and the Tarok	Farming	4,717,300	Jos South, Riyom	Chugwi, Vom, Ganawuri, Kwakwi	814-1634.4mm	11.4-28.3°C	Rice, maize, millet, yams, potatoes, cassava, cocoa yam plus carrots, cabbage, peas

Figure 1
Location of the states in which data collection took place

Table 4
Sampling distribution of the respondents

State	LGA	Sample	%
Benue	Gboko	56	3.47
	Tarka	64	3.97
FCT	Kuje	58	3.59
	Kwali	63	3.90
Kaduna	Igabi	60	3.72
	Zaria	61	3.78
Kebbi	Argungu	66	4.09
	Zuru	59	3.66
Kogi	Adavi	49	3.04
	Okehi	71	4.40
Kwara	Ifelodun	66	4.09
	Irepodun	58	3.59
Lagos	Badagry	77	4.77
	Ikorodu	61	3.78
Nasarawa	Keffi	59	3.66
	NewKaru	61	3.78
Niger	Bosso	77	4.77
	Chanchaga	48	2.97
Ogun	IjebuNorth	57	3.53
	IjebuOde	68	4.21
Osun	IfeCentral	83	5.14
	Osogbo	40	2.48
Oyo	Iseyin	71	4.40
	Itesiwaju	53	3.28
Plateau	JosSouth	62	3.84
	Riyom	66	4.09
Total		1614	100

Alkire and Foster (2011), Alkire & Santos (2014), Arancibia & Girela (2024) and Wang *et al.* (2023) as summarized below:

i.Define a set of dimensions (D) considered relevant for context-specific and human development strategies. Each dimension is represented by several indicators.

Define the set of indicators (q) that adequately capture the full measure of each D and which is to be included in the computation of MDPI. It is advised that the data source should be the same for all indicators.

ii. Establish the level of achievement (deprivation cutoff, z_j) considered sufficient in order not to be considered deprived in the *j*-th indicator ($j = 1,\ldots,q$) for each indicator.

The first three steps depend on the priorities of the community or state or country, and the development plan necessitating the computation, among other normative reasons and these are key decisions that the AF-MDPI method leaves to the users.

iii. Apply each cutoff z_j to determine whether the *i*-th observation ($i = 1,\ldots,n$) is deprived or not in each indicator and build a deprivation matrix, each cutoff defines a vector of binary random variables.

iv. Set a vector of indicator relative weights $w=w_1,\ldots,w_q$ such that .

v. Determine a unique poverty cutoff *k* as the proportion of weighted deprivations an individual or household acquire to be considered multidimensionally poor. Both the relative weights and the poverty cut-off *k* are also based on value-judgments.

vi. Calculate the deprivation score for each observation, and compare it with *k* to identify the poor. If $c_i \geq k$, the *i*-th unit of analysis is multidimensionally poor.

vii. The proportion of people deprived or the uncensored headcount ratio in the *j*-th indicator can be obtained from the deprivation matrix columns:

$$h_j = \frac{1}{n}\sum_{i=1}^{n} d_{ij} \quad (1)$$

The censored indicators' headcount ratio is as follows:

$$h_j(k) = \frac{1}{n}\sum_{i=1}^{n} d_{ij}(k) \quad (2)$$

which is the proportion of people who are deprived in indicator j and multidimensionally poor.

i. Compute the Adjusted Headcount Ratios (MPI or M_0):

$$M_o = \frac{1}{n}\sum_{i=1}^{n}\sum_{j=1}^{q} w_j d_{ij}(k) = \frac{n_d}{n} x \frac{1}{n_d}\sum_{i=1}^{n}\sum_{j=1}^{q} w_j d_{ij}(k) = HxA \quad (3)$$

where n_d is the number of individuals or households identified as poor; H and A are the *incidence* (proportion of individuals or households who are multidimensionally poor) and the *intensity* (average deprivation share across the poor) of multidimensional poverty, respectively. It is easy to see that the MPI can also be computed using the censored indicators headcount ratios $h_j(k)$:

$$M_o = \sum_{j=1}^{q} w_j \frac{1}{n}\sum_{i=1}^{n} d_{ij}(k) = \sum_{j=1}^{q} w_j h_j(k) \quad (4)$$

Once the data collection and pre-processing are completed, the next major task is to get the appropriate algorithm for the computations. A few algorithms have been developed and are available in R programming language (vers. 4.4.2, R Core Team, 2024). For example, Kukiattikun & Chainarong (2022); Abdulsamad (2024)

and Girela (2025). They all share common procedure and are well-adapted to the three-domain computation popularized by the AF-MDPI. In addition, they are all well adapted to computing the sample-based MDPI. Their main shortcoming is their inability to efficiently accommodate additional domains which is the main goal of this study. In addition, the AF-MDPI also developed some algorithm for the computation in Stata (Alkire *et al.*, 2021) while Arancibia & Girela (2024) developed some MATLAB procedures for the computations. Given the constraints of the above procedures, there was an overwhelming need to develop a fresh algorithm that is suited to the following changes:

i. The need to efficiently and effortlessly include higher numbers of domains in the computation,

ii. The need for the modules to have the capability to simultaneously compute associated measures that tend to strengthen the MDPI, and

iii. The need for the modules to be able to compute sub-national and other context-specific measures.

Given the need to develop another robust algorithm, *mdpi function*' which computes the indices and all associated measures of multidimensional poverty sequentially in a dynamic way, was developed and deployed in R Programming ((vers. 4.4.2, R Core Team, 2024, Nmadu, 2025). Dynamically, it computes various indices for between three and nine dimensions (D). The computations are carried out either for the national sample data or can be dis-aggregated based on *context-specific* or *grouping factors*, like region, sex, gender, marital status or any suitable one. The computations are in line with various procedures already outlined in literature starting with the work of Alkire et. al, (2015) but has been expanded from three dimensions to nine. Each dimension is given equal weight in the computation, but all indicators are weighed in line with existing guidelines in Alkire & Foster (2011) and Alkire & Santos (2010). See also Alkire & Santos (2014) and Chan & Wong (2024).

c. Comparison

The results obtained from the computation using the new function is now presented in the next section and compared to existing ratios.

4. RESULTS AND DISCUSSION

This section is devoted to the analysis obtained from data collection, the trial of the new algorithm and the various computational results obtained. The algorithm was successfully implemented and computations of various MDPI under the extended seven domains were obtained as found in Fig. 2-11 as follows. Fig. 2 presents the inter-relationship between the various indicators included in the MDPI computation while Fig. 3 is the National MDPI results along with other measures. The presentation in Fig. 4 is the regional MDPI while Fig. 5 shows the MDPI based on the zone and Fig. 6 shows state-level MDPI. The results in Fig. 7 are MDPI based on the level of development and Fig. 8 MDPI based on the nature of access road to the communities included in the study. The presentation on Fig. 9-Fig. 13 are the sex, gender and other family-related MDPI. The full presentations of the results and their comparison with existing finding follow in the subsequent sections[2].

4.1 Inter-relationship between the indicators included in the MDPI computation

Fig. 2 provides a visual representation of the complex and intertwined nature of poverty indicators, reinforcing the rationale behind the multidimensional approach to poverty measurement and highlighting the need for holistic and comprehensive development strategies to address poverty sustainably. The results illustrate the inter-relationship among the various indicators utilized in computing the MDPI, reflecting how different dimensions of deprivation are interconnected and jointly contribute to overall poverty outcomes. Typically, the conceptual framework or diagram that groups indicators under key dimensions such as education, health, and living standards, and shows how these indicators interact or overlap in contributing to multidimensional poverty. The results clearly demonstrate that poverty is not merely a result of low income but a multifaceted phenomenon that manifests through simultaneous deprivations across several aspects of life. For example, a lack of education, like no school attendance or low years of schooling, may influence employment opportunities and income-generating potential, thereby reinforcing deprivation in living standards such as poor housing, inadequate sanitation, or lack of access to clean water. Similarly, poor health outcomes, such as malnutrition or lack of access to healthcare services, may limit an individual's ability to work, attend school, or participate in productive economic activities. The inter-relationships also suggest that indicators are not mutually exclusive, they often co-exist and reinforce one another, creating a cycle of poverty. For instance, poor nutrition (a health indicator) may negatively affect educational performance, while lack of electricity (a living standards indicator) can limit children's ability to study at home, thereby affecting education outcomes. Moreover, the interdependence of dimensions, implying that addressing one indicator (for example providing education) in isolation may not be sufficient to lift individuals out of poverty unless parallel improvements are made in other interconnected areas like health and living conditions. Therefore, multidimensional poverty alleviation requires integrated and cross-sectoral policy interventions that target multiple deprivations simultaneously.

4.2 National MDPI and other measures under the various domains in the study

Fig. 3 presents a comprehensive breakdown of MDPI and

[2] See Appendix 2 for the raw estimates

its associated components namely: Incidence of poverty, Adjusted incidence of poverty, Average deprivation among the deprived, Contribution of each domain to poverty, Deprivation score, Intensity of poverty, and the overall MDPI (0.418), disaggregated across the extended domains: Social Security, Water and Sanitation, Living Standard, Employment and Income, Health, Nutrition, and Education.

The Adjusted incidence of poverty shows the proportion of the population experiencing multiple deprivations, adjusted for the number of indicators each individual is deprived in. The results highlights Social Security as the domain with the highest adjusted incidence of poverty, followed by Water and Sanitation, and Living Standard. This implies a larger share of the population is simultaneously deprived in these domains, reflecting weak social protection mechanisms and inadequate access to basic services. This is consistent with the findings of Alkire and Santos (2014) who argue that deprivations in social services often compound other forms of poverty, making them critical domains for intervention.

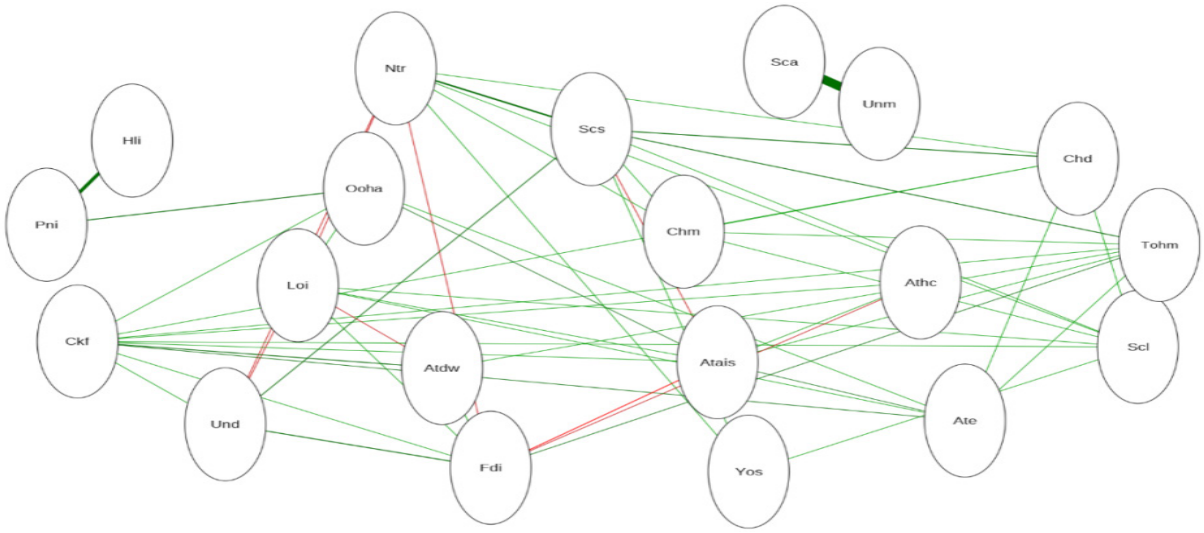

Figure 2
Inter-relationship between the indicators included in the MDPI computation

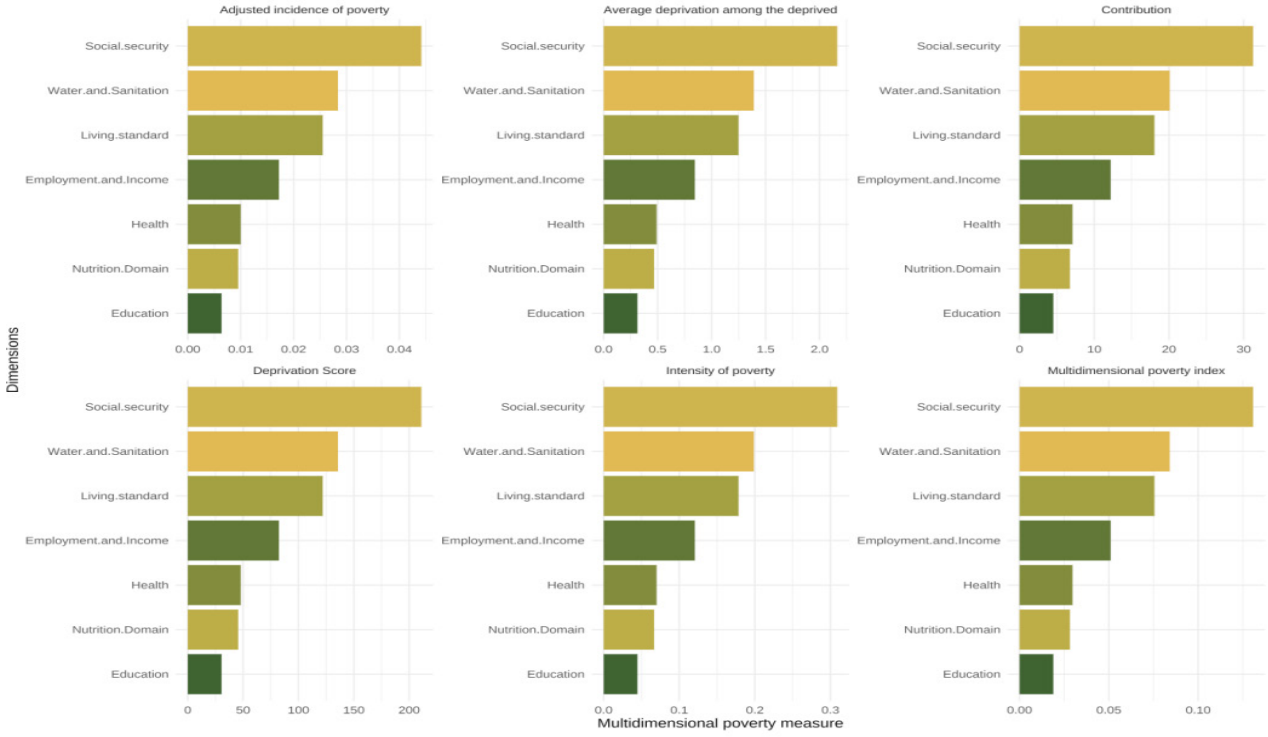

Figure 3
National MDPI and other measures under the various domains in the study

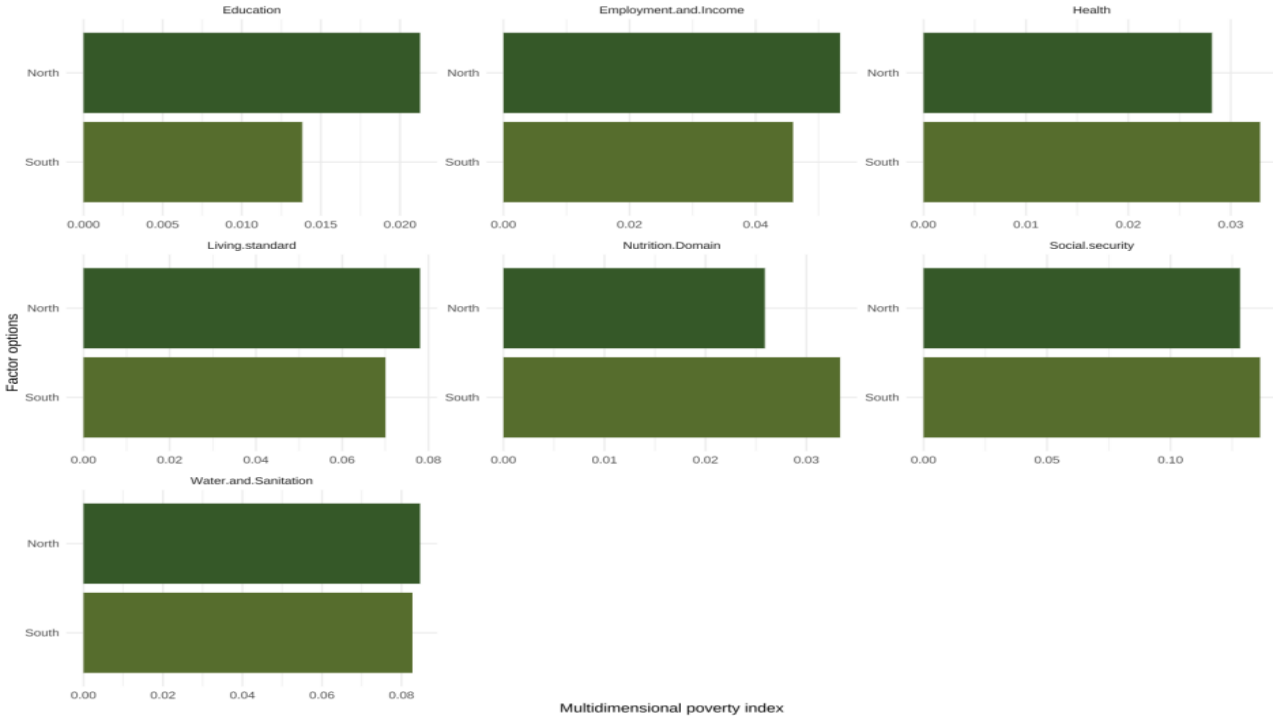

Figure 4
MDPI based on the region of the states included in the study

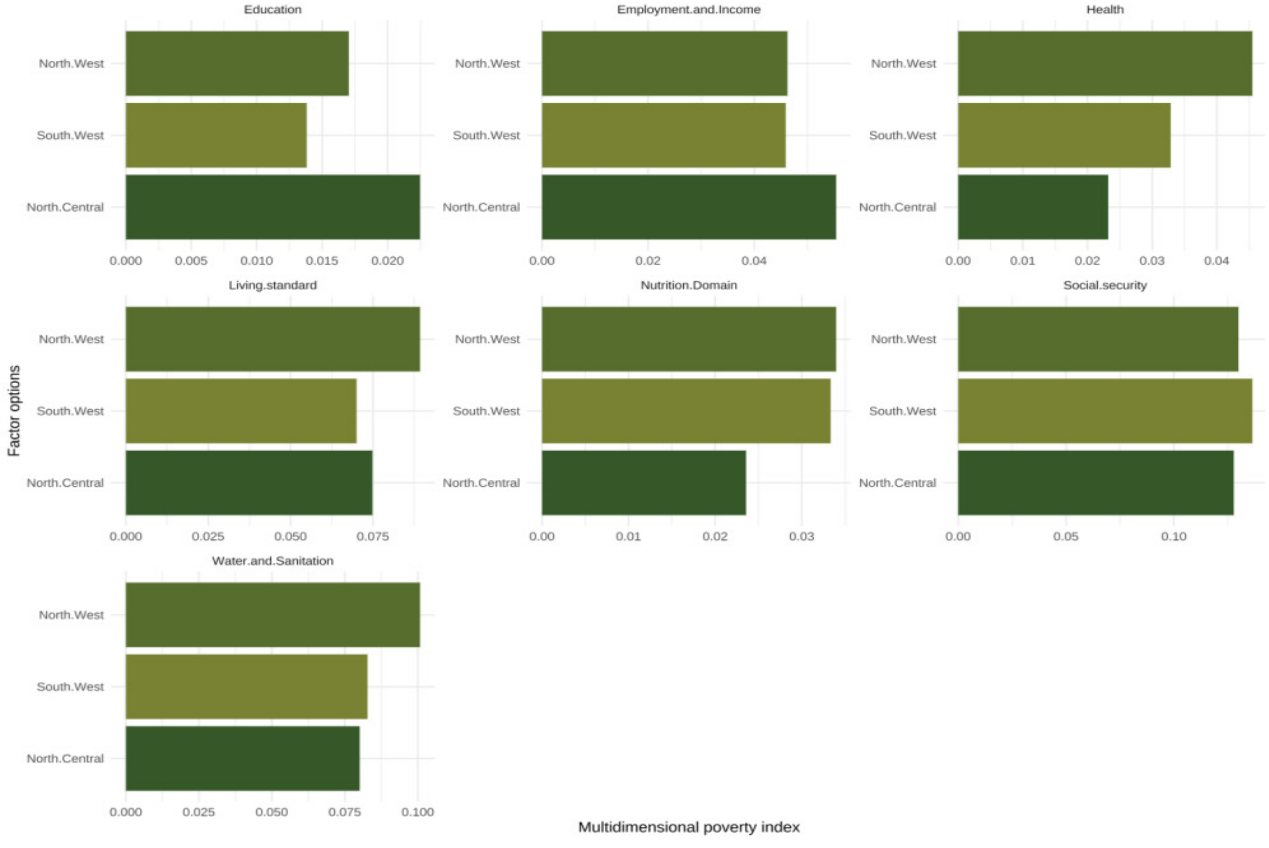

Figure 5
MDPI based on the zone of the states included in the study

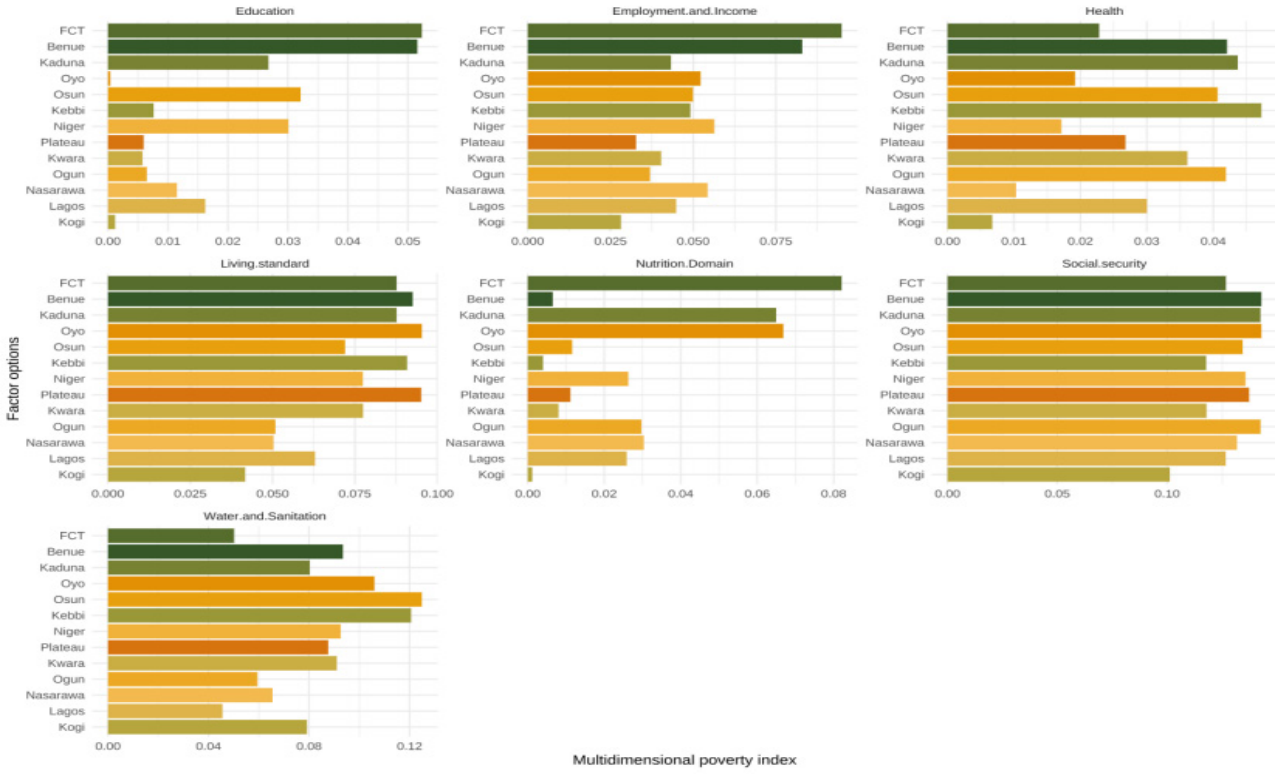

Figure 6
MDPI based the states included in the study

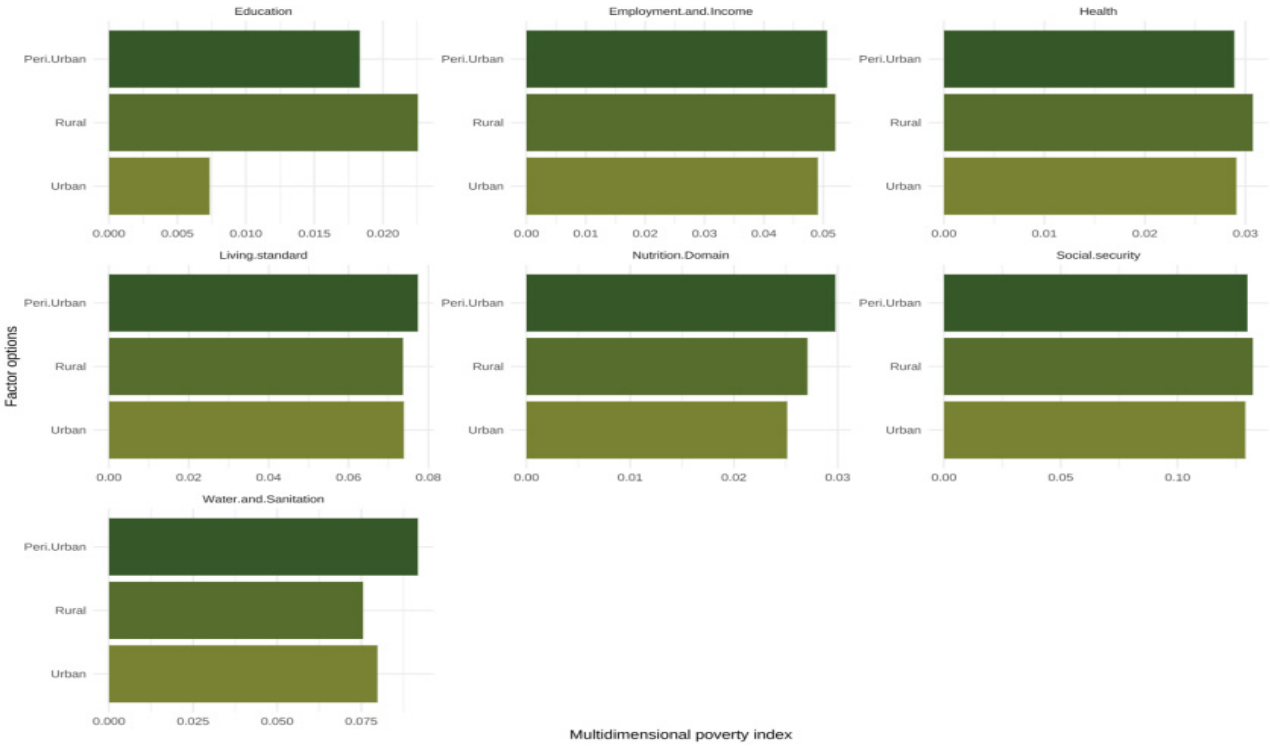

Figure 7
MDPI based on the level of development of the communities included in the study

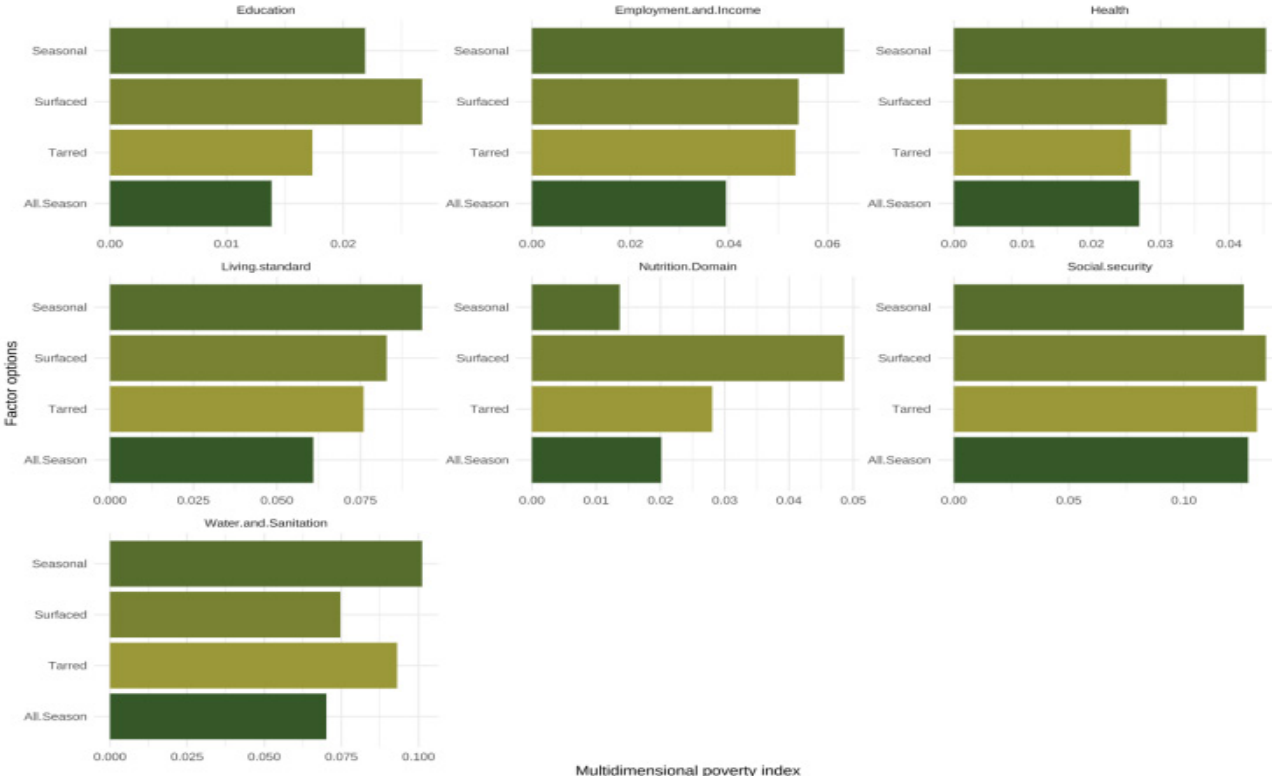

Figure 8
MDPI based on the nature of access road to the communities included in the study

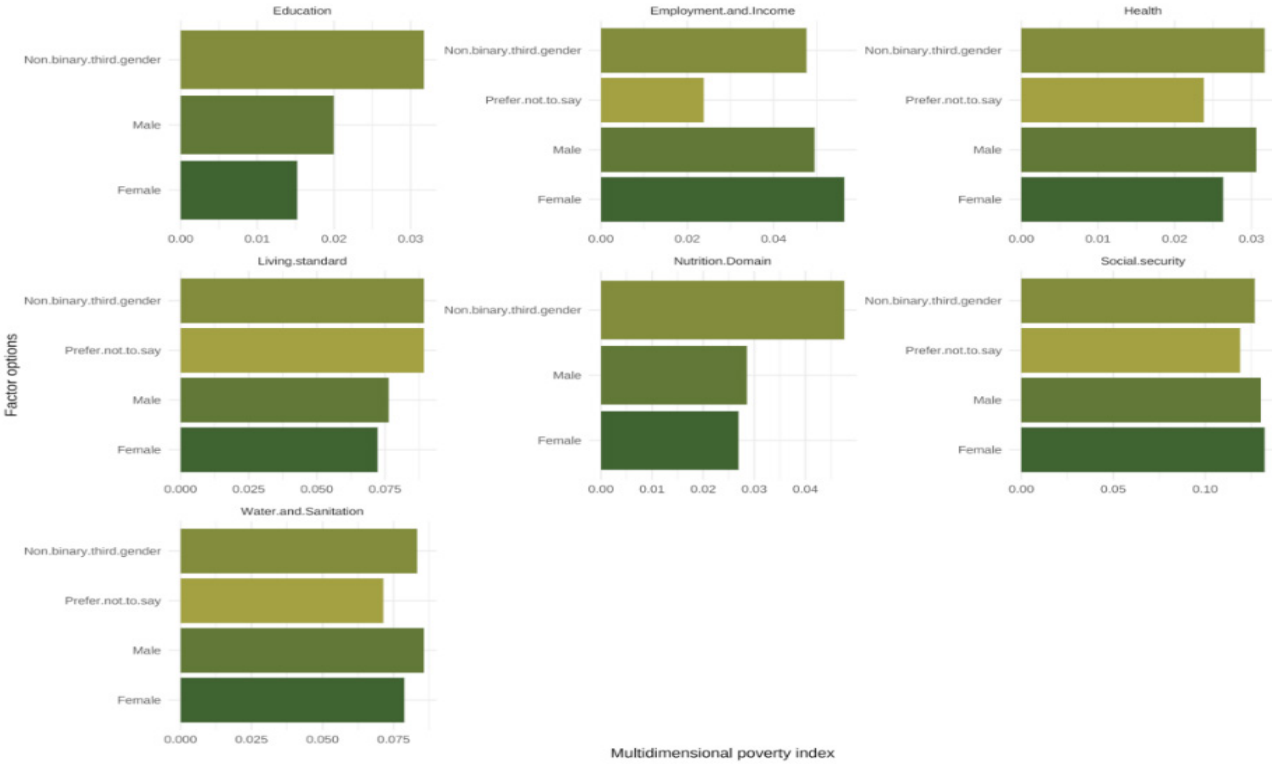

Figure 9
MDPI based on sex of the respondentts

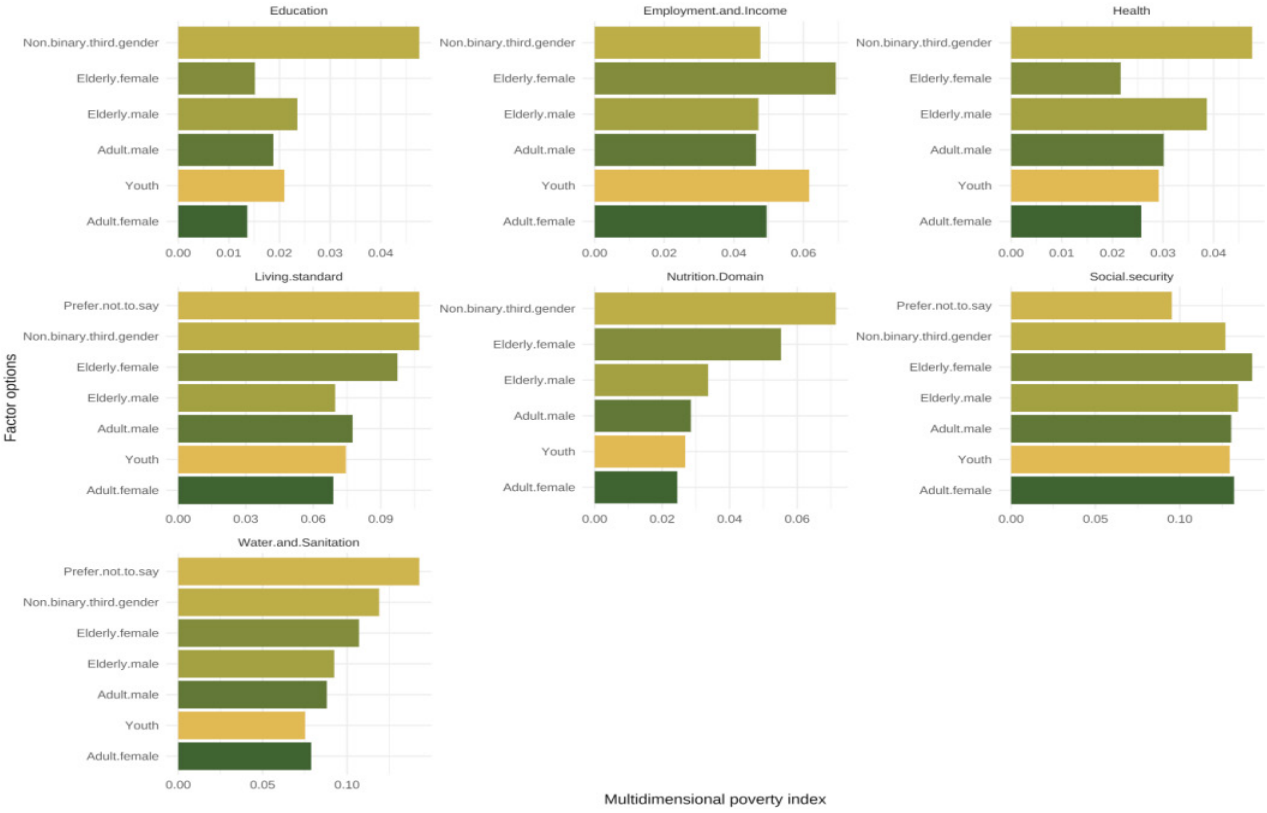

Figure 10
MDPI based on gender of the respondentts

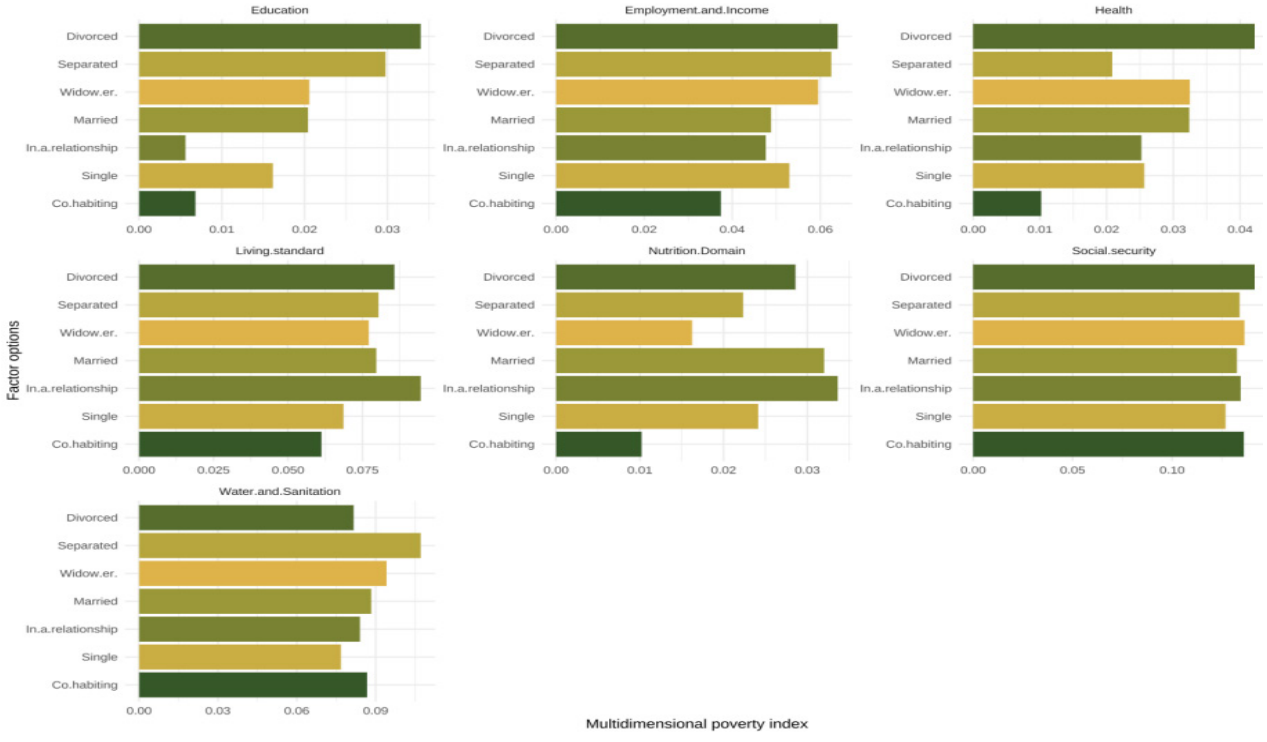

Figure 11
MDPI based on the marital status of the respondents

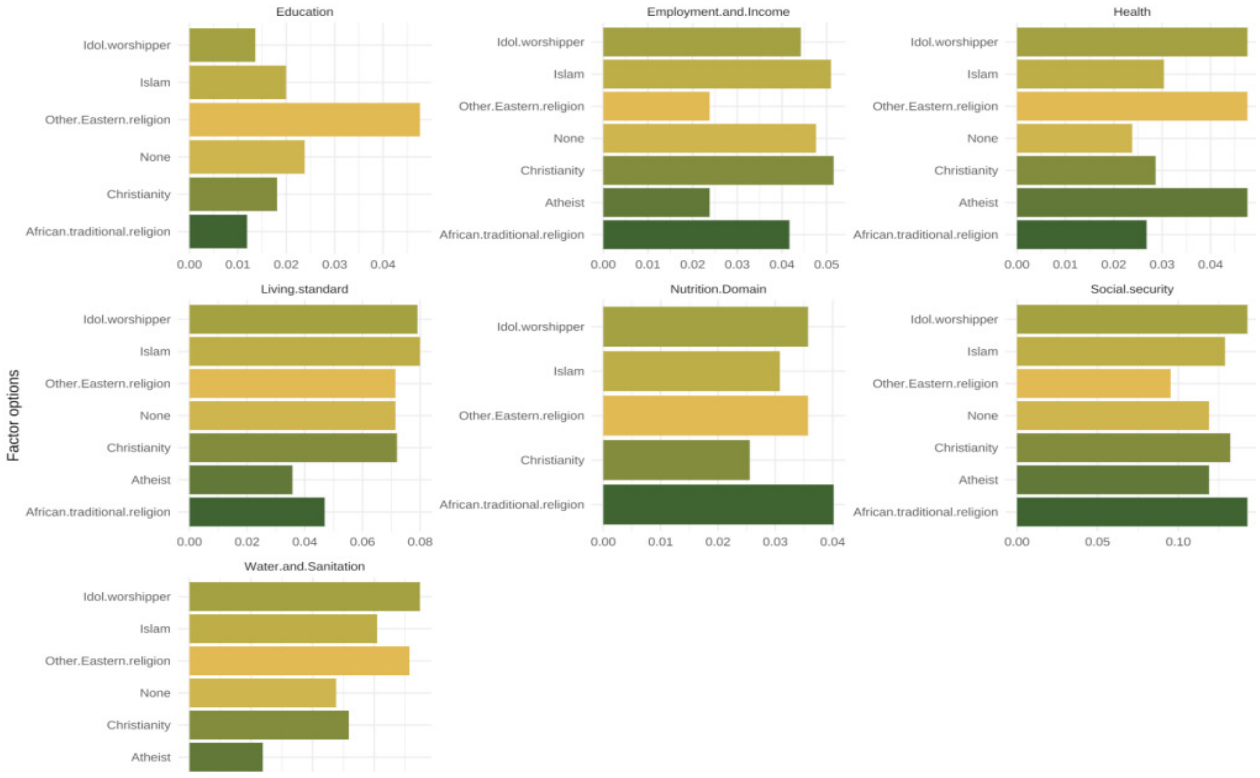

Figure 12
MDPI based on the religious persuation of the respondents

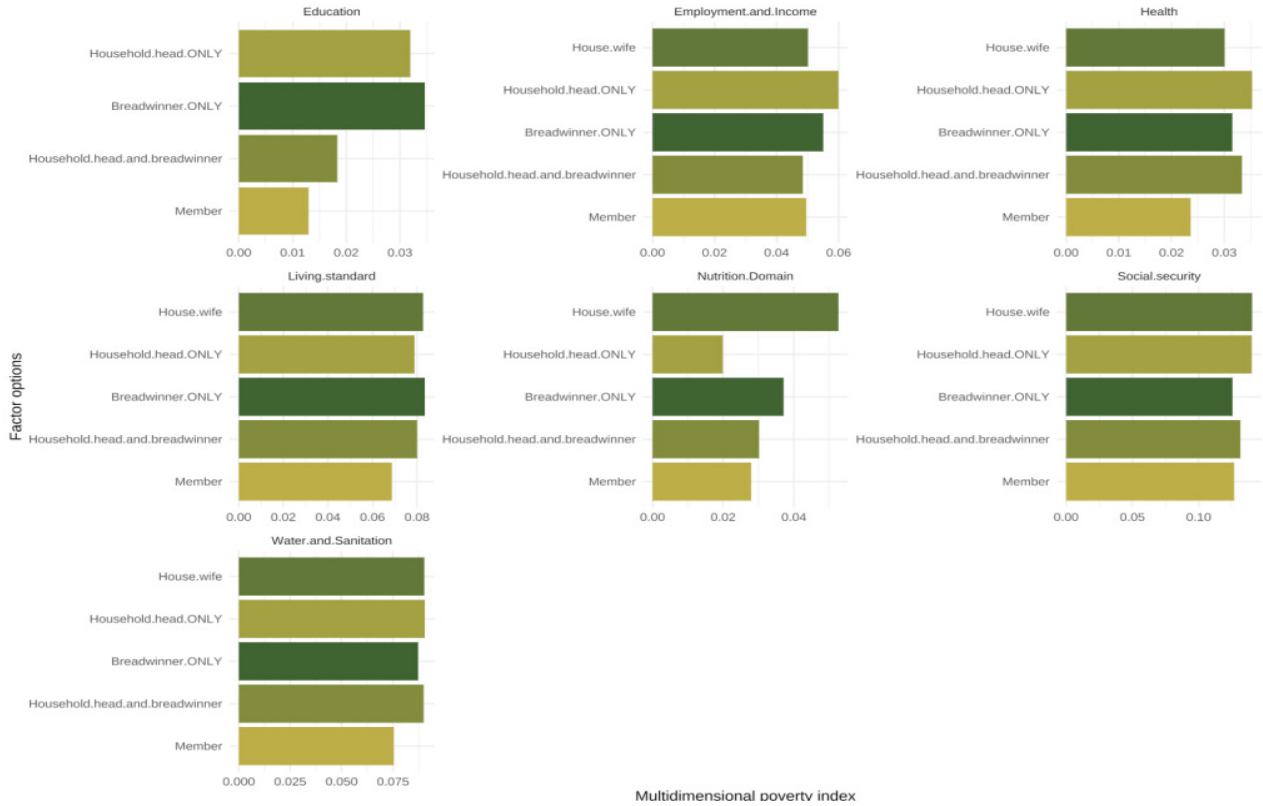

Figure 13
MDPI based on the status of the respondents in the family

The average deprivation among the deprived component reflects the intensity of deprivation experienced by those identified as multidimensionally poor. Again, social security stands out as the most severe domain, indicating not only more people are affected, but those affected suffer from deeper levels of deprivation. Water and sanitation, and living standards follow closely. This supports earlier empirical evidence by UNDP (2020) which emphasized that social protection inadequacies and poor infrastructure significantly aggravate multidimensional poverty severity.

The percentage contribution of each domain to the overall MDPI revealed that social security alone contributes nearly 30%, making it the largest contributor to multidimensional poverty, followed by water and sanitation (~25%) and living standard (~20%). Conversely, education, nutrition, and health contribute less, suggesting either lower intensity or fewer people affected in those areas. This reinforces the notion that improving social protection schemes (pensions, health insurance, unemployment benefits) could significantly reduce poverty burdens (World Bank, 2018).

The aggregate deprivation score which is the extent of deprivation across all domains shows that social security dominates, with water and sanitation and living standards closely following. These patterns demonstrate that deprivations are both widespread and overlapping, especially in areas connected to infrastructure and welfare policies. In line with this, Sabates-Wheeler and Devereux (2008) argue that social protection deficits are often structural and institutional, hence requiring long-term policy reforms to alleviate.

The intensity of poverty as depicted in Fig. 3 displays the average proportion of deprivations faced by poor individuals. Social Security, Water and Sanitation, and Living Standard again emerge as the domains with the highest intensity values, suggesting that interventions in these areas would yield substantial impact on reducing overall poverty depth. These findings align with Alkire *et al*. (2020), who emphasized the importance of addressing high-intensity domains for effective poverty alleviation.

A composite view of the MDPI across domains confirms social security (highest MDPI) as the most pressing area of concern, followed by water and sanitation, living standards, and then employment and income. These results strongly suggest that tackling poverty requires multi-sectoral, integrated interventions, focusing primarily on strengthening social protection systems, improving access to clean water, sanitation facilities, and enhancing employment opportunities. This is in line with Nigeria's National Social Protection Policy (2017) which underscores these same areas as strategic pillars for reducing vulnerability and enhancing livelihoods.

The policy implications of these results underscores that sectoral interventions must be prioritized based on domain-specific deprivation contributions. Policies that aim to expand social safety nets, improve infrastructure and basic services, and stimulate employment through agribusiness engagement can significantly reduce multidimensional poverty. This provides empirical grounding for designing agricultural interventions and social welfare programs that are contextually tailored to high-contributing dimensions of poverty.

4.2 Regional and sectoral MDPI and other measures under the various domains

The results in Fig. 4 – Fig. 13 provide critical insights and highlights how state-level and other sectoral disparities in deprivation levels vary significantly by offering granular insights into the heterogeneity of poverty profiles across Nigeria. For instance, the Northern region (0.420) exhibits higher MDPI (Fig. 4) in Education, Employment and Income, and Water and Sanitation, indicating structural poverty driven by weak human capital development and infrastructural deficits. Conversely, the Southern region (0.415) shows higher MDPI in Health, Nutrition, Social Security, and Living Standard, reflecting emerging urban and systemic deprivations. In the same way, the North Central (Fig. 5) exhibits the highest level of deprivation in education, while the North West shows the highest deprivation in health. The South West has the lowest MDPI values in education and employment and income domains. Regarding the level of development and the nature of access roads in the study area, peri-urban communities (Fig. 7) exhibit the highest deprivation levels in education, employment and income, and living standards while communities with all-season roads (Fig. 8) correspond with lower MDPI, suggesting improved access to schools, better teacher attendance, and resource delivery.

The FCT, Benue, and Kaduna States (Fig. 6) show the highest deprivations in the education, and employment and income, while Kwara, Ogun, Nasarawa, Lagos, and Kogi exhibit the lowest levels of deprivation. Similar trends were observed for health, living standards, social security, and water and sanitation. However, a further look at the results presented in Table 5 revealed that deprivations across divisions were not uniform. For example, the states with highest deprivations in health and nutrition differ with the regions respectively. This therefore suggests that aggregation and disaggregation of MDPI computations are not likely to always give the same results. States with higher deprivation are economically vulnerable in labor and income generation resulting in weaker education infrastructure and lower school attendance, fewer qualified teachers, and low literacy/enrollment and literacy rates (NBS, 2022; UNICEF, 2021). Abuja, being a bustling and fast-growing affluent urban environment, is exhibiting high deprivations, most likely due to informal labor dominance, limited formal employment and weak rural-urban linkages in satellite towns and rural hinterlands (World Bank, 2022). Inadequate healthcare infrastructure

and low access to essential services in rural communities as well as high maternal/child health burdens are the attendant consequence of high deprivations in health (WHO, 2021; NBS/UNDP, 2021).

Table 5
Highest and lowest MDPI of states, zones and regions in the Nigeria MDPI

Domain	Highest			Lowest		
	State	Zone	Region	State	Zone	Region
Health	Kebbi	North West	South	Kogi	North Central	North
Education	FCT	North Central	North	Oyo	South West	South
Living standard	Oyo/Plateau	North West	North	Kogi	South West	South
Social security	Oyo	South West	South	Kogi	North Central	North
Employment and Income	FCT	North Central	North	Kogi	North West/South West	South
Nutrition	FCT	North West	South	Kogi	North Central	North
Water and Sanitation	Osun	North West	North	Lagos	North Central	South

In terms of sex (Fig. 9) of respondents and marital status (Fig. 11), non-binary individuals as well as Divorced and Widowed individuals exhibit the highest deprivation in education, employment and income, and living standards. However, based on gender (Fig. 10), youths and adults generally exhibit lower deprivations than the elderly, although the elderly female exhibited higher deprivations in social security, nutrition, health, living standard, Employment and income as well as education. Also, respondents practicing African Traditional Religion and Christianity (Fig. 12) exhibit lower MDPI values across most poverty dimensions. But Breadwinner Only (Fig. 13) respondents show the highest deprivation in education, while Household Head and Breadwinner status exhibits the lowest deprivation.

The implications of the above findings are far-reaching. High nutritional deprivation in agrarian states like Benue and Kaduna could be attributed to paradoxical food insecurity amid abundant food production due to poor food access or nutrition as well as affordability. Child feeding practices may have also accentuated stunting and wasting rates (FAO, 2020). Persistent open defecation, unimproved water sources, and sanitation challenges in many states, especially where urban-rural inequality is high, give rise to poor health and nutrition outcomes (WHO/UNICEF JMP, 2021). Therefore, food availability does not necessarily translate into adequate nutrition as it must be complemented with other appropriate policy framework. States with weaker institutional coverage and social protection systems might experience higher income instability and absence of safety nets as noted by World Bank (2020) because of low coverage of social safety net programs, particularly in less urbanized and politically decentralized states.

The educational challenges in the Northern region driven by low school enrollment, poor access to quality education and lower access to quality healthcare with attendant poor educational outcomes, high disease burden, poor maternal and child health outcomes amidst infrastructural inadequacies, poor housing conditions, open defecation, lack of pipe-born water, access to electricity and cooking energy, asset ownership and poor waste disposal systems. In addition, income and employment-related deprivations across zones are widespread, reflecting the national reality of underemployment, informal labor dominance, and low wage structures. Job access and income stability are major challenges in the North's informal labor sector with limited industrial diversification underpining the World Bank (2020) findings that employment-related poverty is more entrenched in agrarian and less diversified economies. The above results are collaborated by a few findings including but not limited to World Bank (2020), UN-Habitat (2020), UNICEF (2021), WHO (2021), NBS/UNDP (2021) and WHO/UNICEF Joint Monitoring Program (2021) and NBS (2022). They found that there was high incidence of out-of-school children as well as poor sanitation and lower health service coverage and higher rates of maternal mortality in Northern Nigeria. They also opined that labor market conditions in Nigeria reflect a structural shift, with low-income informal jobs prevalent across both rural and urban settings, especially in agricultural zones. Their findings also highlight poor urban housing infrastructure and lack of basic amenities in the Northwest and some parts of South West urban slums as well as higher rates of unimproved water sources in the North West.

Notwithstanding the economic vibrancy of the South West and their proximity with Lagos, they struggle with infrastructure gaps hence the nutritional deprivation which might stem from urban dietary insufficiency, food insecurity in slums, or poor dietary diversity. The South West also experienced high social security deprivation owing to limited reach of social protection programs, job insecurity, and high urban informal employment. In line with that, FAO (2019) and UNICEF (2020) indicated that increased malnutrition in poor southern urban communities is not due to food unavailability but poor nutritional quality and affordability. World Bank (2022) notes that despite relatively higher economic activity in South West, social safety net programs often fail to reach marginalized urban dwellers, limiting their protection against economic shocks.

The high deprivation by non-binary individuals in educational access and possibly gender-based privilege for females points to the likelihood of underrepresentation or marginalization. UNDP (2022) and Alkire and Santos (2010) emphasized that gender identity disparities often correlate with unequal educational outcomes and severe employment and income-related deprivation, especially in conservative socio-cultural settings. The deprivation by elderly female which confirms global patterns (ILO, 2017) might be due to few context-specific empowerment programs for women or male-dominated unemployment in rural economies (FAO, 2020). Health and nutrition deprivation among non-binary/ third gender respondents as well as "Prefer not to say" individuals may reflect social invisibility and exclusion from social safety nets and healthcare discrimination (WHO, 2018; FAO, 2021; WFP, 2019) highlighting inadequate gender-inclusive healthcare services in many rural and low-income settings or lack of gender-targeted infrastructure and housing schemes (UN-Habitat, 2016). The findings may also reflect general systemic deficiency in social protection regardless of gender, but again marginalized genders suffer more severely as found in a similar study by ILO (2021) in which they opined that informal workers and marginalized groups are often excluded from national social protection mechanisms. The various possibilities of exclusion might in fact result in compounded challenges in accessing shared or community resources (UNICEF, 2020; WHO, 2019).

CONCLUSION

The possibility of expanding AF-MDPI to reflect the dynamic nature of multidimensional poverty by incorporating additional indicators and providing a flexible means of dimensioning them was explored in this research. The expansion led to successfully testing 20 indicators clustered into seven dimensions, namely, Social Security, Water and Sanitation, Living Standard, Employment and Income, Health, Nutrition, and Education; using '*mdpi function*' deployed in R Programming Language. The function computes MDPI along with useful associated measures, i.e., Incidence of poverty, Adjusted incidence of poverty, Average deprivation among the deprived, Contribution of each domain to poverty, Deprivation score, Intensity of poverty. The function is also capable of computing the measures either at national scale of the data or at sub-national or context-specific levels. The funcion was applied to data collected from 1614 respondents from 13 selected Nigerian states which compres favourably with existing results from similar studies.

From the results obtained, it has been shown that computing MDPI at National, sub-national or context-specific levels does not always give the same trend. Also, the results further reveal that states in Northern Nigeria are more multidimensionally deprived in most of the dimensions although there are instances where states in the South also show severe deprivation despite their level of development. Furthermore, peri-urban areas show the highest level of multidimensional poverty across nearly all indicators while non-binary/ third gender respondents consistently experience the highest multidimensional poverty across nearly all domains. In the same way, Divorced, Widowed, and Separated individuals consistently exhibit the highest multidimensional poverty levels and African Traditional Religion adherents consistently exhibit the lowest MDPI across all dimensions. Islamic adherents faced slightly higher deprivations than Christians but are much better than traditional adherents pointing to the influence of faith-based networks and support institutions. Those whose status is Household heads and Breadwinner role consistently shows lowest MDPI across all dimensions. Although females display the lower MDPI than males in most dimensions, in their gender role, they face severe deprivations underscoring the intersectional nature of poverty and gender identity. Household Members, despite their non-leadership roles, benefit from relatively lower deprivation in education and some other dimensions, perhaps due to spillover effects of household welfare.

The overall impact of these findings was adequately analysed but suggests that peri-urban areas face a unique mix of urban and rural deprivation, often overlooked in development planning. These findings also reinforce the argument that marital status is a critical socio-economic determinant in multidimensional poverty assessments.

In line with the findings, it is recommended that UNDP should implement this new MDPI strategy to ensure that every sector of the society is covered by development interventions. The interventions should be region-specific, addressing the North's educational and employment deprivation and the South's urban living and social protection deficiencies. Also, efforts to reduce MDPI must improve governance capacity, monitoring mechanisms, and implementation of pro-poor programs, especially in the South where program impact seems diluted. There is need to address discrimination, unequal access to services, and lack of representation in social policy frameworks which are critical in reducing MDPI disparities by integrating inclusive education, gender-responsive social protection and equitable health services which can significantly lower multidimensional poverty. Lastly, social protection programs must prioritize widowed, separated, and divorced individuals, particularly in rural communities where dependency on spousal resources is higher with targeted interventions such as skills training, access to credit, nutrition support, and healthcare coverage to address their unique vulnerabilities.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

DATA AVAILABILITY

The data is available upon reasonable request, however only the main MDPI data can be shared.

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Appendix 1: Details regarding the cut-off details of some indicators

1. In line with the Food Insecurity Experience Scale (FIES) of the Food and Agricultural Organization (FAO), households are identified as being severely food insecure if they answer yes to at least seven of the following eight questions: during the last 30 days, was there a time when you or any other adult member of your household:

a. Were worried about not having enough food to eat because of money or other resources?
b. Were unable to eat healthy and nutritious/preferred food because of lack of money or other resources?
c. Ate only a few kinds of food because of lack of money or other resources?
d. Skipped a meal because of lack of money or other resources?
e. Ate less than you thought you should because of lack of money or other resources?
f. Ran out of food because of money or other resources?
g. Were hungry but did not eat because of lack of money or other resources?
h. Went without eating for a whole day because of money or other resources?

2. Water sources considered to be not improved are unprotected wells; unprotected springs; rainwater collection; tanker trucks; carts with small tanks; surface water (rivers, lakes); sachet water; and other non-improved sources.

3. Unimproved sanitation facilities include flushing somewhere else or an unknown place (not sewer system, septic tank, or pit (latrine)); pit latrine without slab; bucket; hanging toilet or latrine; and no improved bathing facilities.

4. Natural or rudimentary housing materials are:

a) Floors: natural floor: earth/sand; dung. Rudimental floor: wood planks; palm/bamboo.

b) Roofs: no roofs; natural roofing: thatch/palm leaf. Rudimentary roofing: rustic mat; palm/bamboo; wood planks; cardboard/plastic sheeting. Walls: natural walls: no walls; cane/palm/trunks/thatch; dirt/earth. Rudimentary walls: bamboo with mud; stone with mud; uncovered adobe/mud brick; plywood; cardboard; reused wood.

5. These assets include radio, TV, refrigerator; bicycle; motorbike; landline phone; mobile phone; Personal Computer; and animal cart.

6. A household is deprived if it has experienced at least one of the following over the past 12 months:

Someone got into your home without permission and stole or tried to steal something.
Someone deliberately damaged or destroyed your home, shop, or any other property that you or your household owns.
Something was stolen from a member of your household outside your home.
Someone was physically assaulted (injured, slapped, punched, or kicked).

- Someone was raped or experienced attempted rape.
- Someone was killed in an attack by another person.
- Household was displaced because of herdsmen, banditry, flood, violence between communities, etc.
- Someone died because of conflict in the household.

APPENDIX 2 BRIEF GUIDE ON RUNNING THE MDPI FUNCTION IN R

1. Install the package from GitHub
```
# install.packages("devtools")
devtools::install_github("JobNmadu/Dyn4cast")
```
2. Load the library
```
library(Dyn4cast)
```
3. load the data
```
3.1 From excel
data <- read_excel("path/to/file.xlsx")
```
3.2 From CSV file
```
Library(readr)
data <- read_csv("path/to/file.csv")
```
4. Define parameters and options
```
dm <- list(d1 = c("Child mortality", "Chronic diseases",
            "Access to health care"),
d2 = c("Years of schooling", "School attendance", "School lag"),
d3 = c("Cooking fuel", "Access to electricity",
     "Type of housing materials", "Ownership of household assets"),
d4 = c("Health insurance", "Pension insurance", "Security schock"),
d5 = c("Unemployment", "Underemployment", "Level of income"),
d6 = c("Nutrition", "Food insecurity"),
d7 = c("Access to drinking water", "Access to an improved sanatation"))
```

5. Define dimension names
```
# The first three are given, three is the minimum
id = c("Health", "Education", "Living standard")

# additional dimension names
id_add = "Social security", must be given
id_add1 = "Employment and Income", must be given
id_addn = additional names up to 4, can be NULL
all the dimension names must match with the list of indicators/variables names in the data
```

6. Compute the MDPI
```
mdpi(data, dm, id_addn, plots = "t", Factor = "road")
# computation can be carried out with or without Factor.
```

APPENDIX 2 MDPI ESTIMATES

Dimension	Combined	Health	Education	Living standard	Social security	Employment and Income	Nutrition	Water and Sanitation
National	0.418	0.030	0.019	0.076	0.131	0.051	0.028	0.084
Region								
North	0.420	0.028	0.021	0.078	0.128	0.053	0.026	0.085
South	0.415	0.033	0.014	0.070	0.136	0.046	0.033	0.083
Zone								
North Central	0.407	0.023	0.022	0.075	0.128	0.055	0.024	0.080
North West	0.463	0.045	0.017	0.089	0.130	0.046	0.034	0.101
South West	0.415	0.033	0.014	0.070	0.136	0.046	0.033	0.083
States								
Benue	0.512	0.042	0.052	0.093	0.143	0.083	0.007	0.093
FCT	0.517	0.023	0.052	0.088	0.127	0.095	0.082	0.050
Kaduna	0.489	0.044	0.027	0.088	0.142	0.043	0.065	0.080
Kebbi	0.437	0.047	0.008	0.091	0.118	0.049	0.004	0.121
Kogi	0.259	0.007	0.001	0.042	0.101	0.028	0.001	0.079
Kwara	0.377	0.036	0.006	0.077	0.118	0.040	0.008	0.091
Lagos	0.352	0.030	0.016	0.063	0.127	0.045	0.026	0.046
Nasarawa	0.354	0.010	0.012	0.050	0.132	0.054	0.030	0.065
Niger	0.436	0.017	0.030	0.077	0.136	0.056	0.026	0.093
Ogun	0.368	0.042	0.006	0.051	0.142	0.037	0.030	0.059
Osun	0.466	0.041	0.032	0.072	0.134	0.050	0.012	0.125
Oyo	0.483	0.019	0.000	0.095	0.143	0.052	0.067	0.106
Plateau	0.397	0.027	0.006	0.095	0.137	0.033	0.011	0.088
Level of development								
Peri Urban	0.427	0.029	0.018	0.077	0.130	0.051	0.030	0.092
Rural	0.414	0.031	0.023	0.074	0.132	0.052	0.027	0.076
Urban	0.393	0.029	0.007	0.074	0.129	0.049	0.025	0.080
Access road								
All Season	0.359	0.027	0.014	0.061	0.128	0.039	0.020	0.070
Seasonal	0.465	0.045	0.022	0.093	0.126	0.063	0.014	0.101
Surfaced	0.454	0.031	0.027	0.083	0.136	0.054	0.049	0.075
Tarred	0.425	0.026	0.017	0.076	0.132	0.053	0.028	0.093
Sex								
Female	0.408	0.026	0.015	0.072	0.132	0.056	0.027	0.079
Male	0.421	0.031	0.020	0.076	0.130	0.050	0.029	0.086
Non-binary/third gender	0.458	0.032	0.032	0.089	0.127	0.048	0.048	0.083
Prefer not to say	0.327	0.024	0.000	0.089	0.119	0.024	0.000	0.071
Gender								
Adult female	0.393	0.026	0.014	0.069	0.132	0.049	0.024	0.079
Adult male	0.420	0.030	0.019	0.077	0.130	0.046	0.029	0.088
Elderly female	0.509	0.022	0.015	0.097	0.143	0.069	0.055	0.107
Elderly male	0.439	0.039	0.024	0.070	0.134	0.047	0.034	0.092
Non-binary/third gender	0.567	0.048	0.048	0.107	0.127	0.048	0.071	0.119
Prefer not to say	0.345	0.000	0.000	0.107	0.095	0.000	0.000	0.143
Youth	0.418	0.029	0.021	0.075	0.130	0.062	0.027	0.075
Marital Status								
Co-habiting	0.349	0.010	0.007	0.061	0.136	0.037	0.010	0.087
Divorced	0.478	0.042	0.034	0.086	0.141	0.064	0.029	0.082
In a relationship	0.425	0.025	0.006	0.095	0.134	0.048	0.034	0.084

Dimension	Combined	Health	Education	Living standard	Social security	Employment and Income	Nutrition	Water and Sanitation
Married	0.434	0.032	0.020	0.080	0.133	0.049	0.032	0.088
Separated	0.457	0.021	0.030	0.080	0.134	0.063	0.022	0.107
Single	0.391	0.026	0.016	0.069	0.127	0.053	0.024	0.077
Widow(er)	0.436	0.032	0.021	0.077	0.136	0.060	0.016	0.094
Religion								
African traditional religion	0.350	0.027	0.012	0.047	0.143	0.042	0.040	0.040
Atheist	0.262	0.048	0.000	0.036	0.119	0.024	0.000	0.036
Christianity	0.406	0.029	0.018	0.072	0.132	0.052	0.026	0.078
Idol worshipper	0.475	0.048	0.014	0.079	0.143	0.044	0.036	0.112
Islam	0.432	0.030	0.020	0.080	0.129	0.051	0.031	0.091
None	0.357	0.024	0.024	0.071	0.119	0.048	0.000	0.071
Other Eastern religion	0.429	0.048	0.048	0.071	0.095	0.024	0.036	0.107
Status in the family								
Breadwinner ONLY	0.455	0.032	0.035	0.083	0.126	0.055	0.037	0.087
Housewife	0.446	0.030	0.000	0.083	0.140	0.050	0.053	0.090
Household head and breadwinner	0.432	0.033	0.018	0.080	0.131	0.048	0.030	0.090
Household head ONLY	0.456	0.035	0.032	0.079	0.140	0.060	0.020	0.090
Member	0.385	0.024	0.013	0.069	0.127	0.050	0.028	0.075