



Evaluating the Role of Households' Food Security Status and Socioeconomic Determinants on Child Mortality in Nigeria

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Abstract

When addressing global development, it is imperative to recognize the relationship between food security and child mortality. Despite the targeted goals of SDGs 2 (zero hunger) and 3 (good health and well-being), Nigeria continues to grapple with relatively high rates of child malnutrition, alongside persistent challenges in child mortality and food insecurity that affect its population significantly. This study employed the Nigeria Living Standard Survey (NLSS) dataset with 11,655 households to estimate the impact of food (in)security on child mortality using the Propensity Score Matching (PSM). The study shows that food insecurity is predominant in the rural northern and urban southern part of Nigeria. Child mortality rates were found to be influenced by various factors such as maternal education, maternal age, geopolitical zones, place of residence, and access to healthcare facilities, showcasing a complex interplay of positive and negative impacts. The empirical estimates revealed that households' food insecurity had a significant impact on child mortality in Nigeria. Hence, in order to achieve the SDG's 2 and 3 in Nigeria, a more concerted effort should be geared towards food security and child mortality among the Nigerian rural and urban communities. The insights from this study underscore the importance of prioritizing interventions that drives food security, enhancing nutritional access, and tackling underlying social determinants to substantially reduce child mortality rates. It is imperative for policymakers, healthcare professionals, and communities to integrate complementarity approaches in developing sustainable solutions that safeguard the well-being and prospects of Nigeria's children.

Keywords Child well-being · Food-nutrition behaviors · Health economics · Social welfare · Sustainability

1 Introduction

In the context of global development, food security and child mortality are closely intertwined, representing two crucial aspects that deeply impact each other. Ensuring access to sufficient, safe, and nutritious food plays a pivotal role in promoting child health and survival (Pérez-Escamilla, 2017; Wertheim-Heck et al., 2019). Despite the efforts of international and local institutions towards the eradication of food insecurity and hunger, the number of malnourished and hungry individuals around the world remain on the rise. Insufficient food is a problem for more than 821 million people worldwide (Kakaei et al., 2022). This figure indicates that almost one in nine individuals worldwide are undernourished (Behera et al., 2019; Kilic, 2022; Moseley & Battersby, 2020). The majority of the world's hungry people reside in developing nations (McGuire, 2015; Mota et al., 2019) with 12.9% of the global population suffering from malnutrition (Kilic, 2022).

According to Wudil et al. (2022), the region with the highest incidence of hunger is the Sub-Saharan Africa, where one in four individuals suffer from malnutrition. Every year, one in five newborn children dies from malnutrition (Adeyeye et al., 2017, 2023; Kilic, 2022). One in six children in underdeveloped nations die from malnutrition while one-fourth of the children around the world do not exhibit adequate physical development (Kilic, 2022). Many developing nations, including Nigeria, are still at risk as a result of this issue. Nigeria sometimes depends on imports because it cannot grow enough or store enough food to satisfy its population (Eme et al., 2014; Garrity et al., 2010; Sanchez, 2019). This condition, known as food insecurity, is not encouraging and describes a circumstance in which there is a limited or unclear supply of foods that are safe and nutritionally appropriate, or a restricted or uncertain capacity to obtain acceptable healthy foods (Ivers, 2015; Richterman et al., 2019; Tarasuk & Beaton, 1999; UNICEF, 2015). Children and the elderly are especially impacted by the issue of food (in)security (Barrett, 2010; Black et al., 2013; Boserup et al., 2013).

Children suffer from malnutrition when their diet lacks the necessary amounts of protein and calories for growth and maintenance, or when they are unable to fully utilize the food they consume owing to conditions such as illness and disease. Nigeria presently ranks second in the world in terms of infant mortality, and a UNICEF assessment on children and women found that 50% of infant fatalities there were caused by malnutrition (Liu et al., 2012; Olusegun et al., 2012). Additionally, according to the research by UNICEF (2011), the three primary factors contributing to child malnutrition in the nation are food instability, subpar child care policies, and subpar health services. Current estimates show that 65% of Nigerians experience food insecurity based on the findings by Osagie (2013). The correlations between children's health/development and food security have been previously examined (Cordeiro et al., 2012; Dean & Sharkey, 2011; Herba et al., 2016). Furthermore, several findings (Cook & Frank, 2008; Hadley & Patil, 2006; Pakravan-Charvadeh et al., 2021) indicated that food insecurity is linked to increased rates of negative health outcomes for children at household level.

Children in Nigeria face a significant risk of negative health outcomes and mortality due to the nation's high level of food insecurity. This issue has been documented by various studies (Anema et al., 2009; Black et al., 2013; Olusegun et al.,

2012). Moreover, the limited access to essential resources is further exacerbated by the disparity in infrastructure development between rural and urban areas, such as inadequate roads and power supply. Nigeria's economy is burdened by significant challenges, including food security and child mortality. While there is an established association between household food insecurity and child stunting (Baig-Ansari et al., 2006) as well as underweight, the connection with child mortality lacks thorough characterization in literature.

This study differentiates itself from previous studies (Bjornlund et al., 2022; Denard et al., 2022) on linking food insecurity to child mortality by looking at the study, first, in the lens of public health significance. This implies that understanding the major drivers of child mortality in Nigeria is crucial for public health interventions and policymaking which are scarce in previous studies. If there is a significant association between identified factors and child mortality, targeted interventions can be designed to address these factors and reduce child mortality rates. Secondly, contribution to global knowledge— considering that child mortality is a global concern, and insights gained from studying the Nigerian context can contribute to the broader understanding of factors influencing child health due to high incidence of deprivations in the country. This study may offer valuable insights applicable to other regions facing similar challenges.

In addition, unlike other studies (e.g., Cassidy-Vu et al., 2022) that investigated the interrelationships among food security, child mortality, and socioeconomic factors, this study relies on a nationally representative dataset. The study tends to answer two major research questions and hypotheses: (i) What are the main major drivers of child mortality in Nigeria? $H_0 = \text{There is no significant association between the identified major drivers and child mortality in Nigeria.}$ (ii) Does household food security status influence child mortality in Nigeria? $H_0 = \text{There is no significant relationship between household food security status and child mortality in Nigeria.}$ Additionally, we assess the distribution of household food security across different regions of Nigeria. Based on the aforementioned, the objectives of this study are to identify factors influencing child mortality in Nigeria and examine the impact of food insecurity on child mortality. It is expected that these findings will enhance our understanding of how food security influences child health outcomes and inform the development of appropriate policies to improve child nutrition and reduce child mortality rates in Nigeria.

2 Literature Review

This section presents the conceptual issues for food security, defined as the consistent availability of food to ensure a healthy life for all individuals (Almadini, 2024; Berry et al., 2015; Capone et al., 2014). The study embraces a theoretical framework that aligns with this food security definition (Kanter et al., 2015; Nicholson et al., 2020). In this context, the aspect of *food availability* evaluates how easily households can access food, primarily influenced by crop production and livestock ownership. The concept of food availability pertains to the "supply side" of food security and is influenced by factors such as the quantity of food production, stock levels, and net trade. Another closely related concept is *food access*, indicating the ability to obtain an

adequate amount of food. Merely having a sufficient amount of food at the national or global scale does not automatically ensure food security at the household level. The emphasis on addressing concerns related to inadequate access to food has led to an increased policy attention on factors such as incomes, expenditures, markets, and prices as essential components in attaining food security goals.

Food utilization mainly focuses on the quality of the diet. Utilization is generally recognized as the manner in which the body optimally utilizes different nutrients present in food. Adequate energy and nutrient intake by individuals are outcomes of effective care and feeding practices, food preparation methods, dietary diversity, and the equitable distribution of food within households. The last concept of food security is *stability*. Stability in the other three dimensions over time is crucial. Even with sufficient food intake today, you may be deemed food insecure if you face periodic challenges in accessing food, risking a decline in your nutritional well-being. Factors such as adverse weather conditions, political instability, or economic challenges such as unemployment and escalating food prices can influence your food security status. This study will be assessing food security with the lens of food accessibility in the context of expenditures.

The interrelationship between food security and child mortality is a complex and critical issue that draws policymaker's attention (Cassidy-Vu et al., 2022; Pérez-Escamilla, 2017; Wudil et al., 2022). The existence of disparities in food security has significant implications for child mortality rates. When certain populations or regions experience limited access to sufficient and nutritious food, children within those communities are more vulnerable to health complications and higher mortality rates (Cassidy-Vu et al., 2022). These disparities in food security can manifest in various ways. For instance, socioeconomic factors such as poverty, unemployment, and income inequality can contribute to inadequate food availability and affordability for certain households. Inadequate access to quality healthcare services and sanitation facilities further exacerbate the impact of food insecurity on child health (Pérez-Escamilla, 2017; Wudil et al., 2022).

Meanwhile, it is important to understand the pathways through which food insecurity affects child health outcomes which is crucial for developing effective strategies to mitigate the negative impact. Several key pathways contribute to this relationship: in the context of *malnutrition*, food insecurity often leads to inadequate access to a diverse and nutritious diet, resulting in malnutrition among children (Gulati, 2010; Narayan et al., 2019). Insufficient intake of essential nutrients, such as proteins, vitamins, and minerals, can impair growth and development, weaken the immune system, and increase the risk of diseases (Cassidy-Vu et al., 2022).

Another important pathway of food insecurity-nutrition relationship is through the impaired cognitive development. The inadequate nutrition due to food insecurity can impair cognitive development in children. The malnourished children may experience difficulties in learning, memory, attention, and problem-solving abilities, which can have long-term consequences on their educational attainment and overall well-being (Gallegos et al., 2021; Shankar et al., 2017). The *increased susceptibility to infections* is critical pathway of association between food insecurity and child mortality. Usually, malnutrition weakens the immune system, making children more susceptible to infectious diseases (Palar et al., 2017; Pryor & Dietz, 2022). Under-

nourished children are more likely to experience severe illness and have a higher mortality risk when exposed to common infections such as diarrhea, respiratory infections, and malaria (Palar et al., 2017; Pryor & Dietz, 2022).

Families facing food insecurity may struggle to *access adequate healthcare services*, including preventive care, immunizations, and timely treatment for illnesses. Limited financial resources may lead to delayed or inadequate healthcare seeking behaviors, thereby further exacerbating child health issues. *Social and economic factors* is a critical pathway of interconnection between the two variables. Food insecurity is often associated with poverty and limited resources (Matemilola, 2017; Omotayo, 2016; Omotayo et al., 2022; Omotoso et al., 2018). The stress and strain caused by food insecurity can disrupt family dynamics, impact parental mental health, and reduce the capacity to provide a nurturing and supportive environment for children (Lambi et al., 2012; Mugambiwa & Tirivangasi, 2017). Addressing these pathways requires a comprehensive approach that includes interventions aimed at improving household food security, promoting nutrition education and behavior change, enhancing healthcare access, and addressing underlying socioeconomic determinants such as poverty and inequality. By targeting these pathways, efforts can be directed towards improving child health outcomes and breaking the cycle of food insecurity and its detrimental effects on the well-being of children.

Empirically, there are studies (Banerjee et al., 2021; Cassidy-Vu et al., 2022; Kind et al., 2006; Lee et al., 2016), that have examined the relationship between food (in) security and child health outcomes including child mortality. For instance, Lee et al. (2016) investigated 95 lower-income countries, the study found that reduced access to food correlated with an upsurge in both undernourishment and overall infant mortality rates. Additionally, in rural Gambia, Kind et al. (2006) found that enhancing the consumption of protein, calcium, and iron resulted in higher birth weights and a decrease in perinatal mortality. In North Carolina (USA), Cassidy-Vu et al. (2022) found that food insecurity is positively correlated with infant mortality. Banerjee et al. (2021) found that food insecurity leads to higher mortality and cardiovascular mortality.

3 Methodology

3.1 Study Area

As shown in Fig. 1, Nigeria is divided into six geopolitical regions (Olatomiwa et al., 2015). The geopolitical zones in Nigeria comprises of the north central, north east, north west, south east, south west and south south. Generally, studies have suggested that the food and nutrition security issues differ along the geopolitical. For instance, the household survey of 2018/19 conducted by FAO (2022), shows that the North-East and North-West regions exhibit the most severe levels of food insecurity in Nigeria compare to the southern regions, a trend substantiated by the Cadre Harmonise surveys (FAO, 2022). The survey further reveals substantial variations in food insecurity rates between urban (18%) and rural areas (52%), a perspective corroborated by other findings (Mekonen et al., 2023; Mekonnen et al., 2021).

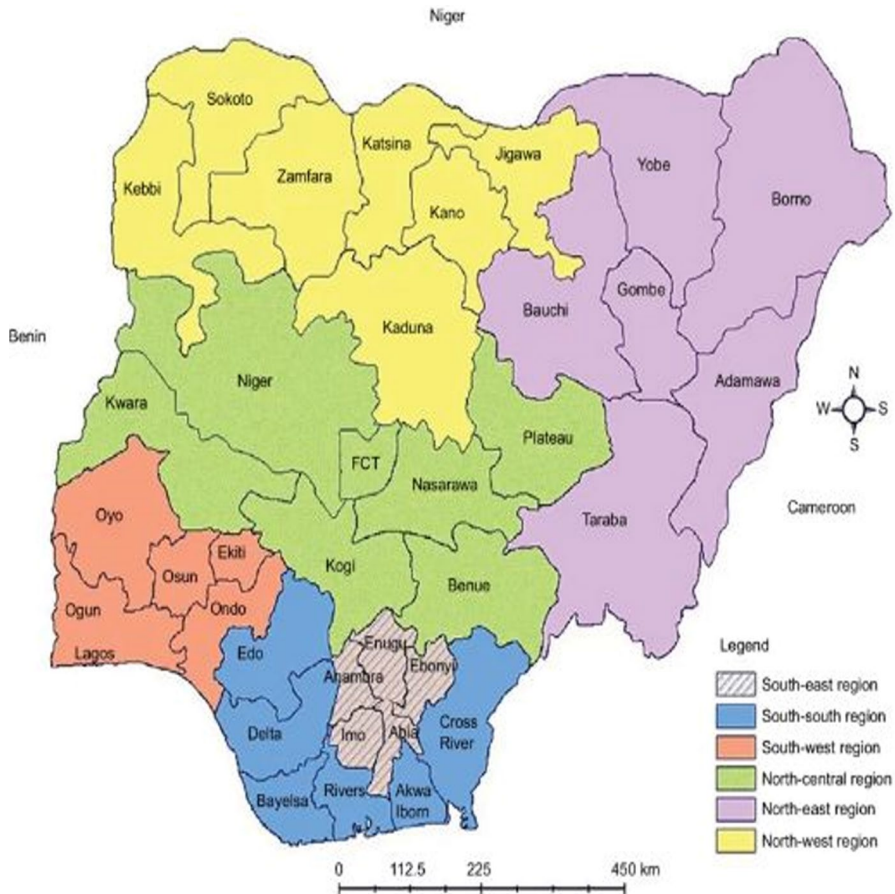


Fig. 1 Geopolitical location of the six geographical zones of Nigeria

With a population of over 200 million, Nigeria is the most populated black country in the world (Kalu, 2020; Olarewaju, 2021) with 102,407,327 (or around 50% of the population) people living in deep poverty. The significance of Nigeria being the world's largest black country is multifaceted and carries cultural, historical, and socio-political implications. For instance, *Cultural and Ethnic Diversity*: Nigeria is home to a rich tapestry of ethnicities, languages, and cultures. Being the largest black country underscores the incredible diversity within the Black community, showcasing the multitude of traditions, customs, and languages that exist within Nigeria. *Economic Influence*: Nigeria is one of the largest economies in Africa, and its economic strength contributes to the overall well-being and development of the continent. As the world's most populous Black nation, Nigeria's economic successes and challenges have reverberations on a global scale, influencing discussions on trade, development, and investment in Africa.

In Nigeria, the Yoruba, Hausa-Fulani, and Igbo ethnic groups make up the majority of the population. Nigeria is a nation with an increased number of individuals

experiencing food insecurity (Owoo, 2018; Poulsen et al., 2015). Despite reducing its population's undernourishment by more than half, from 19.3% in 1990 to 8.5% between 2010 and 2012, Nigeria had an increase in undernourished residence between 2010 and 2012, going from about 10 million to almost 13 million (Owoo, 2021). In addition, food security varies across the nation depending on area, rurality, urbanity, and culture. The degree of food insecurity varies within households and is directly correlated with intra-household traits including family structure and decision-making procedures (Zingwe et al., 2023).

The complex and diverse family structures in Nigeria may have an impact on the resource and wealth distribution, which are key factors in determining both household and individual's food security (Owoo, 2018). Indeed, Nigeria is characterized by complex and diverse family structures. The nation's demographic diversity is reflected in a variety of familial arrangements, shaped by cultural, ethnic, religious, and regional factors (Gururani et al., 2021; Mai-Bornu & Mai-Bornu, 2020; Salawu, 2010). In Nigeria, family structures can encompass extended families, nuclear families, and variations in between, all influenced by the specific traditions and customs of the various ethnic groups across the country (George et al., 2014; Idogo, 2015). This diversity in family structures plays a crucial role in shaping social dynamics, relationships, and community bonds within Nigerian society (Falade & Eseadi, 2022).

3.2 Data Source and Description

Data from the Nigeria Living Standard Survey (NLSS) was utilized, it provides details on 11,655 Nigerian homes. The children sampled in the study is around 37,780 children. The NLSS provides thorough information on the self-produced food and household spending on different food types. The sampling design used a stratified random sampling technique with two stages, the first of which involved identifying housing unit clusters known as Enumeration Areas and the second of which involved selecting housing units at random. In a cycle of 30 days, seven interviewers paid the chosen home visits at minimum four-day intervals. A diary of daily food intake and expenditures was included in the questionnaire to track households' non-food spending as well as the food that they produced and bought. The following six food groups' expenditure profiles for each family were also included: 1) Basic foods, 2) meat and fish, 3) dairy items, 4) fruits and vegetables, 5) fats and oils, and 6) sugars. The dataset also provided in-depth details on non-food expenditure items, as well as communication. Additionally, it listed the socioeconomic characteristics of the household, and principal engagement of the household head. Information about the mother and the child was also available.

3.3 Measurement of Food Security

Using per capita food expenditure as a measure of food security has become a common practice (Ogundari, 2017; Regmi et al., 2019; Russell et al., 2018; Usman & Haile, 2022), often employed to evaluate how easily people can access food. While Hendriks and Msaki (2009) argue that spending on food reflects both the accessibility of food and, to some extent, how vulnerable a household is to food insecurity, Faridi

and Wadood (2010) suggest that higher spending proportions mainly indicate vulnerability to food insecurity over time. In essence, food expenditure acts as a stand-in for the aspect of food security related to accessibility since it is influenced by food prices and household resources. It is worth noting that food expenditure does not reveal details about the nutritional content consumed by households but rather demonstrates how household resources affect the quantity of food consumed. This study, following previous approaches (Ogundari, 2017; Usman & Haile, 2022), uses a threshold set at two-thirds of the mean of per capita expenditure, categorizing a household as food secure (or food insecure) based on whether the observed per capita food expenditure is greater (or less) than the specified threshold.

3.4 Analytical Framework: Impact Assessment using Propensity Score Matching

In this study, we assessed the impact of food (in)security on child mortality using the propensity score matching (PSM) approach. The choice of this method is to estimate the impact of a household being food secure, which will serve as treatment (with a value of 1), as against household that are food insecure serving as a counterfactual (with a value of 0). The counterfactual, or what would have happened if the household is not food secure, must be estimated in an impact assessment. By comparing a control group to the treatment group (food secure), the influence of the food security on the child mortality can be assessed to determine the counterfactual. The two groups are similar except from food security of the households. When it is not practical to randomly assign people to receive the intervention, propensity scores are another approach of measuring the impact of getting an intervention. Propensity score matching (PSM) is the process of matching the propensity scores of the intervention and control units, as well as possibly other covariates, and eliminating all unmatched units. Although it can be utilized to analyze more than two groups of subjects, its primary function is to compare two groups of subjects. According to Diaz and Handa (2004), PSM is effective as long as the survey instrument used to measure the outcomes is the same for both sets of participants. The effectiveness of PSM is also based on the data that is available and the variables that are utilized for matching.

Rosenbaum & Rubin, (1983) established the propensity score matching (PSM) concept first, while Heckman et al., (1997) also contributed to the development of PSM by concentrating on selection bias and emphasizing the use of casual inferences in the presence of non-random participant assignment. PSM is a technique for evaluating programs that is based on the notion of comparing the outcomes of program participants with 'equivalent' non-participants. Except for program participation, all observed features between the two groups are comparable, hence it is presumed that the program is to blame for any disparities in the outcomes. The conditional likelihood of being assigned to a specific treatment, given a vector of observable covariates x_i , is known as the estimated propensity score for subject $e(x_i)$, ($i = 1, \dots, N$) (Rosenbaum & Rubin, 1983):

$$e(x_i) = \Pr(z_i = 1 | x_i) \quad (1)$$

and

$$\Pr(Z_i, \dots, X_1, \dots, X_n) = \sum_{i=1}^N e\{X_i\}^{Z_i} \{1 - e\{X\}\}^{1-Z_i} \quad (2)$$

Where

z_i 1 for treatment

z_i 0 for control

x_i the vector of observed covariates for the i^{th} subject.

An ideal propensity score for each participant in a randomized experiment contrasting two groups would be 0.50. The propensity score is a probability with values ranging from 0 to 1. This is so that each participant would have a 50% chance of being randomly allocated to either the treatment group or the control group. It is necessary to estimate the propensity score in study designs without randomization, such as in a quasi-experimental design. Values for propensity scores are based on a vector of observed factors that are connected to receiving an intervention. The propensity score matching (PSM) method was employed in this study to assess the effect of food security on infant mortality in Nigeria. This method enables assessors to determine the mean effect of the program on the participants. If Y_1 represents the prospective outcome contingent upon participation (food secure) and Y_0 represents the potential outcome contingent upon non-participation (food insecurity), the influence of the program is indicated by:

$$\Delta = Y_1 - Y_0 \quad (3)$$

3.5 Estimating the Impact (Average Treatment Effect on the Treated)

The matched sample was used to compute the Average Treatment Effect for the treated (impact). It is estimated as follows:

$$ATT = E(\Delta|D = 1, X) = E(Y_1 - Y_0|D = 1, X) \quad (4)$$

$$= E(Y_1|D = 1, X) - E(Y_0|D = 1, X) \quad (5)$$

where $D = 1$ stands for a home that has access to food (treatment) and is a group of conditioning variables that were used to match the individuals. If equation $E(Y_0|D = 1, X)$ had not been present, equation 5 would have been simple to estimate. This is the average of the counterfactual, which represents what the results would have been for all participants if they had not undergone the treatment. PSM offers a method for calculating this equation. PSM has the distinct advantage that individuals only need to match on a single item, the propensity score, which calculates the likelihood that they would participate in the program, as opposed to a vector of characteristics. The mean effect of the treatment is calculated as the mean difference in the outcomes of the matched pairs under the condition that the conditional independence assumption and the common support assumption is true:

$$ATT = E[Y_1|D = 1, P(X)] = E[Y_0|D = 0, P(X)] \quad (6)$$

Although the equation is easily adapted to many programs, it is appropriate to single programs if the treatment variable is categorical and has just two mutually exclusive categories (Imbens, 2004; Lechner, 1999, 2001). The ATE, or average treatment effect, is the following for a person chosen at random from the entire population:

$$ATE = \frac{N_1}{N} \times ATT + \frac{N_0}{N} \times ATU \quad (7)$$

where N_0 represents the number in the control group and N_1 represents the number in the treatment group. The relationship between ATT (average treatment on treated), ATE (average treatment effect on an individual), and ATU (average treatment on untreated) may be seen in the equation above.

3.6 Logistic Regression Model

The variables that will have a substantial impact on under-five child mortality in families were found using a logistic regression model. The logistic regression model is employed when the dependent variable is dichotomous, and the independent factors can be of any type. It expresses a qualitative dependent variable as a function of many independent variables. The dependent variable in this analysis, child mortality (Z), has a value of 1 if any children in the family under the age of five die, and 0 otherwise. In other words, $Z=1$ if any children in the home between the ages of 1 and 5 die, and 0 otherwise. The logistic model assumes (P_i) that child mortality is a function of an index (Z_i) where: (Z_i) is an inverse of the standard logistic cumulative function of P_i i.e. $P_i(y) = f(Z_i)$ (Z_i) is also an inverse of the standard logistic cumulative function of P_i i.e. $P_i(y=1) = f(Z_i)$. The probability of child mortality is given by:

$$P_i(y=1) = \left(\frac{1}{1+e} \right)^{-Z_i} \quad (8)$$

e represents the base of natural logarithms (2.718). The probability of no child mortality is given by

$$Q_i(y=0) = 1 - P_i(y=1)$$

Since,

$$1 - P_i(y=1) = 1 - \frac{1}{1+e^{-Z_i}} 1 - P_i(y=1) = \frac{1+e^{-Z_i}-1}{1+e^{-Z_i}} 1 - P_i(y=1) = \frac{e^{-Z_i}}{1+e^{-Z_i}}$$

But

$$\frac{1}{P_i(y=1)} = 1 + e^{-Z_i} \quad (9)$$

Thus;

$$\frac{P_i(y=1)}{1 - P_i(y=1)} = \frac{1}{e^{-Z_i}} \text{ And } \frac{P_i(y=1)}{1 - P_i(y=1)} = e^{Z_i} \quad (10)$$

The probability that child mortality occurs is calculated from Z_i value

$$Z_i = b_0 + b_1x_1 + b_2x_2 + b_3x_3 + \dots + b_nx_n \quad (11)$$

X_1 - X_n are the independent variables described in Table 1

Z_i under-five child mortality in household (1 if yes, 0 otherwise)

b_0 constant

b_1 is the coefficient of the X 's variables.

Z_i child mortality (1 if yes, 0 otherwise)

4 Results and Discussions

4.1 Distribution of Household Food Insecurity Across Geopolitical Zones in Nigeria

Food security is the ability of a household to consistently obtain food in quantities and of a quality that allows all of its members to live healthy, active lives (Gillespie & Haddad, 2001). However, poverty and a lack of financial means are directly responsible for early childhood malnutrition and food insecurity (Begin et al., 1999). The data shows that a sizable part of Nigerian homes with children under the age of five experienced food insecurity, with this percentage being determined to be at 42.03%. When the distribution of food insecurity among the geopolitical zones was examined, the North-east had the largest proportion (63.71%) of households with this status. According to the United Nations International Children's Emergency Fund (UNICEF & WHO., 2003), over 50% of under-five deaths in Nigeria, primarily in the Northern region of the country, were attributed to malnutrition.

This is in line with the findings of Adebayo et al., (2016), which discovered that the majority of households in northern Nigeria are food insecure, with a high proportion of male and rural residents. These findings may be related to the incidence of insurgencies and societal crises in the area. The South-South and South-East had the lowest levels of food insecurity, respectively (Table 1) (NBS, 2004). In the United States, the prevalence of food insecurity was higher in rural than in urban areas as indicated by, the United States Department of Agriculture report on household food security (Mueller, 2010). In the sectorial review, the rural population often had the highest levels of food insecurity (Table 2).

Table 1 Determinants of child mortality and their description in Nigeria

Variables	X_i	Variable
Geopolitical Zone(GPZ) dummy variables		
North Central (NC)	X_1	Dummy (1 = NC, 0 = otherwise)
North East (NE)	X_2	Dummy (1 = NE, 0 = otherwise)
North West (NW)	X_3	Dummy (1 = NW, 0 = otherwise)
South West (SW)	X_4	Dummy (1 = SW, 0 = otherwise)
South East (SE)	X_5	Dummy (1 = SE, 0 = otherwise)
South South (SS)	X_6	Dummy (1 = SS, 0 = otherwise)
Place of residence		
Rural	X_6	Dummy (1 =, 0 = otherwise)
Urban	X_7	Dummy (1 =, 0 = otherwise)
Demographic characteristics		
Female headed households	X_8	Dummy (1 = female, 0 = male)
Maternal age	X_9	Continuous (years)
Maternal literacy level	X_{10}	Continuous (years)
Household size	X_{11}	Continuous (Number)
Welfare indicators		
Improved flooring material	X_{12}	Dummy (1 = yes, 0 = no)
Wealth index	X_{13}	Continuous (Index)
Access to Infrastructural facilities		
Electricity	X_{14}	Dummy (1 = yes, 0 = no)
Safe sanitation/waste management	X_{15}	Dummy (1 = yes, 0 = no)
Safe water source	X_{16}	Dummy (1 = yes, 0 = no)
Primary health care services	X_{17}	Dummy (1 = yes, 0 = no)
Immunization	X_{18}	Dummy (1 = yes, 0 = no)
Sociopolitical and economic profile		
Membership of association	X_{19}	Dummy (1 = yes, 0 = no)
Access to credit facilities	X_{20}	Dummy (1 = yes, 0 = no)
Household income	X_{21}	Continuous (naira)
Self & wage employed in agriculture	X_{22}	Dummy (1 = yes, 0 = no)
Agro-ecological and environmental characteristics		
Proximity to dump site	X_{23}	Dummy (1 = yes, 0 = no)
High polluting fuel use	X_{24}	Dummy (1 = yes, 0 = no)

4.2 Determinants of Child Mortality in Nigeria

Using logistic regression analysis, we estimate the factors determining child mortality in Nigeria (Table 6). The results, demonstrated that the combined dependent variables account for 76.9% of the variance in child mortality. Among the total explanatory factors included in the model, 22 were identified as statistically significant at different levels of significance. Additionally, several other explanatory variables exhibited the expected direction of influence, despite varying levels of statistical significance.

Table 2 Distribution across geopolitical zones in Nigeria

	Food secure (%)	Food insecure (%)
National Zones	57.97	42.03
North Central	41.50	58.50
North West	38.06	61.94
North East	36.29	63.71
South South	66.97	33.03
South East	60.66	39.34
South West	57.04	42.96
Sector		
Rural	38.61	61.39
Urban	59.13	40.87

Geopolitical Zones In 2015, UNICEF reported that child health indices in Nigeria show significant geographical differences, with the North East and North West geopolitical zones having the lowest rates of child survival. This evidence is supported by our findings, which show that three of the six zones—North Central, North East, and North West—in the northern area of Nigeria significantly influenced under-five child mortality, increasing the likelihood that this would happen. Due to a variety of factors, including social unrest, terrorism, extreme poverty, low educational attainment, and subpar healthcare facilities, the North region experiences a high level of food insecurity (Table 2). Specifically, the likelihood of child mortality increases by 44.5, 34.5 and 23.0 percentage-points if the child's household is located in the North Central, North East and North West region respectively. There is a likelihood of a decreased incidence of child mortality in the Southern area. The results shows a negative and significant relationship with child mortality. Compared to the northern region, where social and cultural constraints limit the adoption of innovations that can benefit society, the southern region is tranquil and known for having higher levels of education and openness.

Place of Residence Infrastructure is the fundamental element that makes it easier for people to engage in activities such as production, distribution, and consumption, which has an impact on their quality of life. In terms of the most fundamental aspects of development, rural communities in Nigeria are severely underdeveloped and frequently have limited options. Potable water, electricity, health care, educational, recreational, and adequate roads are typically lacking in rural places. They have high rates of population increase, which are correlated with short life expectancy, high newborn and maternal mortality, and a lack of contemporary tools to exploit the natural resources they depend on to survive (Chinsman, 1998; Galadima & Muraza, 2014). The findings show that these difficulties raise the likelihood of under-five child mortality incidence in rural Nigerian homes. The result suggest that the likelihood of child mortality increase by 34.4% if the child residence in the rural households.

Demographic Characteristics Mothers are the main care giver in most households, particularly for the under-five child. The findings indicated that female headed homes had a higher likelihood of reducing child mortality, with a probability of 98.7%

Table 3 Factors influencing child mortality in Nigeria

Variables	Coefficient	Standard Error	P-values	Marginal effect
Geopolitical Zone(GPZ) dummy variables				
North Central	0.169***	0.022	0.000	0.445
North East	0.090***	0.025	0.000	0.345
North West	0.109***	0.009	0.000	0.230
South West	-0.593***	0.023	0.000	-0.456
South East	-0.299***	0.012	0.000	-0.345
Place of residence				
Rural	0.339**	0.154	0.050	0.344
Demographic characteristics				
Female headed households	-0.808***	0.089	0.000	-0.987
Maternal age	-0.199***	0.016	0.000	-0.789
Maternal literacy level	-0.987***	0.108	0.000	-0.865
Household size	0.899***	0.086	0.000	0.897
Improved flooring material	-0.987	0.340	0.000	-0.378
Wealth index	-0.590***	0.079	0.000	-0.345
Access to infrastructure				
Electricity	0.569	0.800	0.700	0.987
Safe sanitation/waste management	-0.017**	0.077	0.023	-0.334
Safe water source	-0.200***	0.050	0.000	-0.234
Primary health care services	-0.956*	0.301	0.000	-0.765
Immunization	-0.338	0.101	0.002	-0.567
Socio-economic profile				
Society membership of the head	-0.032***	0.001	0.002	-0.789
Credit facilities	-0.969***	0.230	0.000	-0.678
Household income	-0.990***	0.090	0.000	-0.689
Self & wage employed in agriculture	0.090**	0.342	0.023	0.897
Environmental characteristics				
Proximity to dump site	0.837***	0.307	0.001	0.456
High polluting fuel use	0.095*	0.051	0.067	0.768
Constant	0.860***	0.031	0.000	

Pseudo $R^2=0.129$

Log likelihood = -289.790

***Significant at 1% level, ** Significant at 5%level, *Significant at 10%

(Table 3) than those headed by males. However, experience as a caregiver is essential when determining chances of child survival. A young mother might lack the necessary experience to overcome possible challenges that arise during child care. Therefore, an increase in mothers age reduces the likelihood of child mortality (Bryce et al., 2005) with higher education significantly reducing the probability of infant and child mortality (Mondal et al., 2009; Pamuk et al., 2011).

Parental education plays a dual role in shaping a child's health and nutritional status. First, more productive livelihood engagements should result from improved education, raising earnings and improving food security. Parents that are more educated are likely to be better equipped to use the information that is available on child nutrition and health. They may also opt to have fewer children, which may also reflect

the increasing opportunity cost of the mother's time. Depending on the caliber of the education received, successful completion of basic school or functional literacy may be adequate. Furthermore, even if education does not have any benefit, it can be contributing to a positive coefficient. We discovered that a mother who has higher education has a better chance of lowering the infant death rate. The dependency ratio—the proportion of non-working to working (or total) household members—can be influenced by the size and makeup of the household. If a large home has a lot of able-bodied individuals of working age, its welfare should be higher and the child's health and nutritional condition should be better due in part to economies of scale in consumption. However, individuals of a higher birth order are particularly susceptible to infant mortality if there are many young children vying for resources.

Infrastructural Characteristics Basic amenities need to be available to raise the chances of survival of a child, safe sanitation/waste management, potable water, primary health care and immunization services, have a negative and significant relationship with child mortality. By implication, access to all the listed infrastructural facilities leads to a reduction in the probability of child mortality in Nigeria. Exposure to undesirable microorganism through poor waste management practices can result in a child being vulnerable to diseases. Better health care services are essential to eradicating child mortality incidence, particularly in the rural households. Access to immunization to prevent and reduce the severity of childhood diseases reduces the likelihood of child mortality in Nigeria.

Sociopolitical and Economic Characteristics Household income is a significance player in food security and combating malnutrition. Household income had the probability of reducing child mortality, as it has a negative and significant relationship with child mortality. Specifically, a unit increase in income is associated with a 68.9 percentage-point decrease in the probability of experiencing child mortality. Credit facilities help to cushion the effects of low income as it is being used to augment the loop hole left behind by low income by engaging in productive activities which generate income. Access to credit facilities by the household head had the likelihood of reducing child mortality. The result implies that if the household receive credit, there is likelihood of reducing child mortality by 67.8 percentage-point.

Membership of a social group is a form of social capital is known to have a strong linkage in reducing poverty. Hence, being a membership of a social group reduces the probability of child mortality as the parent has access to information on health related issues for themselves and their children. This can as also be due to various programs that may be available to them to attend that creates awareness about how improve family hygiene and reduce or prevent common illnesses. Agricultural production in Nigeria is unable to sustain its rural families, many of whom rely on subsistence agriculture to feed themselves, with farmers being classified as the poor of the poorest. In addition, there is insufficient employment in agriculture to accommodate all rural dwellers, some of which is seasonal, with parents who rely solely on such wages being more likely to experience child mortality due to hunger and malnutrition.

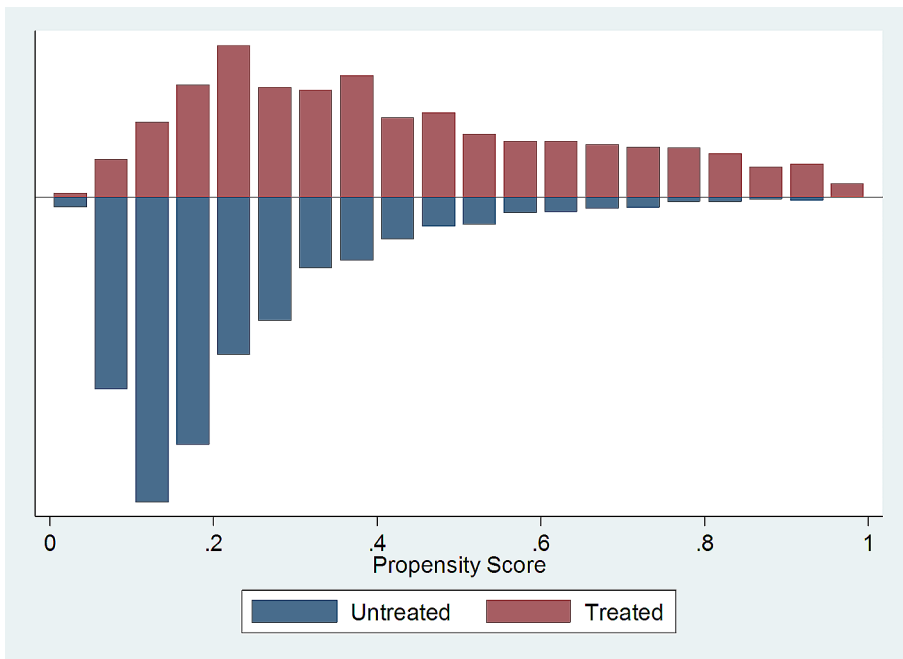


Fig. 2 Test of region of common support: child mortality

Environmental Characteristics The result shows household near dumping site have a positive relationship with child mortality. Hence the result suggests households located near dumping site are more likely to experience child mortality. The probable reason may be due to the increased presence of disease carrying organisms. In rural areas, firewood is the major sources of energy, which generates smoke and potentially pollutes the environment. Environmental pollution remains dangerous to the health of the child in any environment. The result from our study suggest that the likelihood of child survival is reduced in areas of high pollution. Specifically, the result indicates that the likelihood of child mortality increases by 76.8 percentage point.

4.3 Common Support: Propensity Scoring

Common support graphs were created to provide a visual grasp of the caliber of the matching procedures in order to construct the test for balancing, or the quality of matching two opposing situations. The propensity score overlap between the intervention and control cases is demonstrated by this test. According to Dehejia & Wahba, (2002), a higher percentage of overlap denotes a good match between them. As shown in Figs. 2, 3, 4, and 5, there is a significant amount of overlap between the propensity scores of the intervention and control participants, indicating that they are well-matched and balanced.

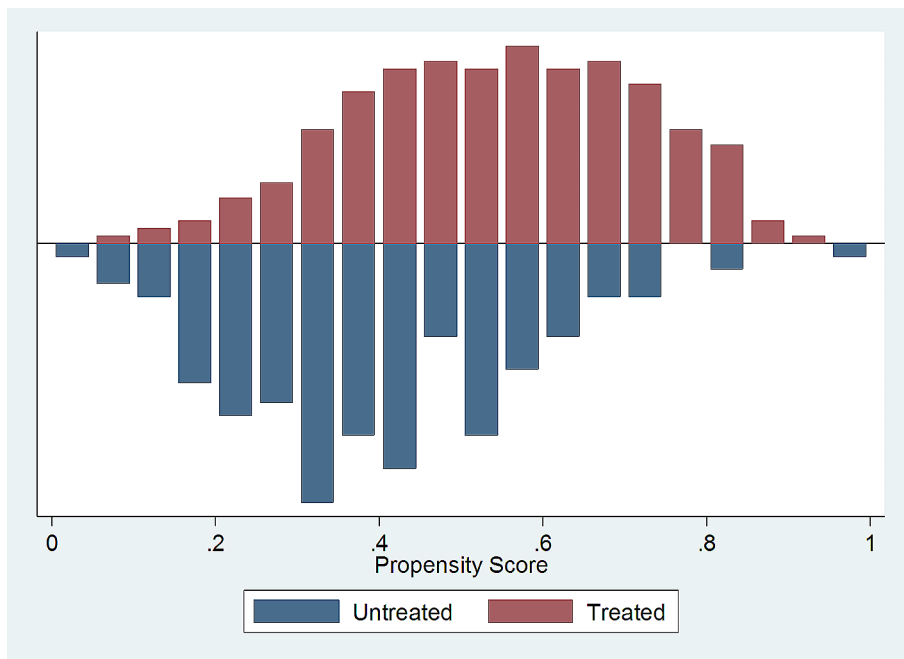


Fig. 3 Test of region of common support: Rural–urban child mortality

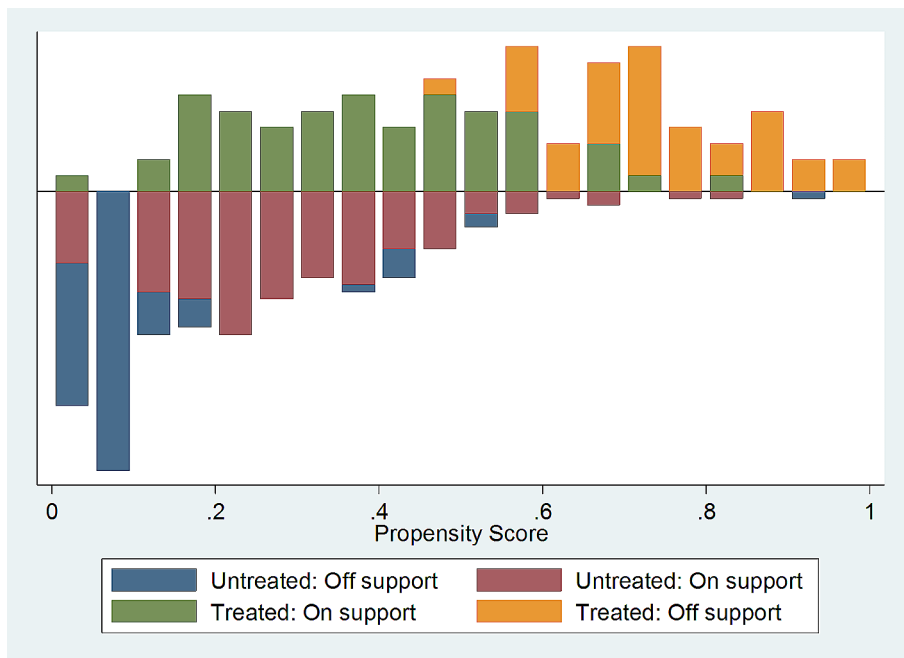


Fig. 4 Test of region of common support: Northern child mortality

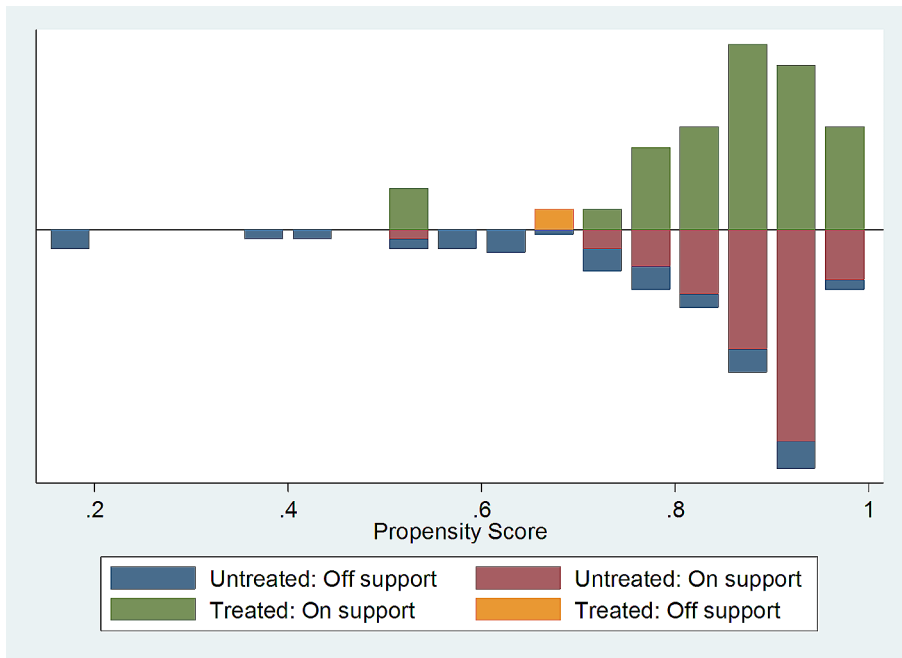


Fig. 5 Test of region of common support: Southern child mortality

4.4 Average Impact Estimates of Propensity Score Matching of Food Security on Child Mortality

To obtain a clearer understanding of the impact of the household food security status (HFSS) on child mortality, we estimated its impact using households with child mortality records with the three most commonly adopted matching methods; Nearest-Neighbor Matching (NNM), Radius-Based Matching (RBM) and the Kernel-Based Matching (KBM) in the literature. We reported kernel matching following the necessary selection conditions, such as smallest pseudo- R^2 , quality of match, significance level, reduction bias and smallest variance. The impact of introducing a spatial dimension approach was estimated by considering national data, geopolitical zones and sectoral (rural and urban).

A significant and negative result implied a potentially significant reduction in child mortality rate if the household is food secured, with a probability of reducing child mortality. As noted by UNICEF & WHO, (2013), Nigeria is the second highest contributor to the world's under-five and maternal mortality rates, with almost 2,300 deaths for children under five and 145 for women who are childbearing age every day. Globally, at least 6.3 million children under the age of five died in 2013—nearly 17,000 every day. Malnutrition and food insecurity are major contributors to the high child mortality rate, particularly in sub-Saharan Africa (2015). Based on the KBM results (Table 4), the data from the national statistics demonstrate that HFSS has a negative and significant impact on child mortality.

Table 4 Average impact estimates of propensity score matching of food security on child mortality in Nigeria

Child Mortality	Sample	Treated	Control	Difference	t-stat
National	Unmatched	0.0146	0.0213	-0.0067	-0.99
	ATT	0.0146	0.0500	-0.0355	-5.76*
	ATU	0.0190	0.0109	-0.0080	
	ATE			-0.0348	

*Significant at 1% level- ATT=***; ATU=***, ATE=***

Table 5 Average impact estimates of propensity score matching of food security on child mortality sector

Child Mortality	Sample	Treated	Control	Difference	t-stat
Rural	Unmatched	0.0554	0.1023	-0.0468	-8.78*
	ATT	0.0438	0.1022	-0.0584	-11.36*
	ATU	0.0543	0.0984	-0.0440	
	ATE			-0.0525	
Urban	Unmatched	0.1031	0.1132	-0.0100	-0.41
	ATT	0.0312	0.1132	-0.0820	-2.51**
	ATU	0.1031	0.0614	-0.0417	
	ATE			169.89	

*** Significant at 10% level, ** Significant at 5% level, * Significant at 1% level

The data indicates the average difference between the child mortality of similar pairs of households, with each belonging to a different food security group. Herewith, the Average Treatment Effect on the Treated (Attah), which gives the average effect of the HFSS on child mortality for food secure households was of interest. Specifically, the KBM causal effect of HFSS on child mortality suggests that child mortality was potentially reduced by about 0.03 in food secure households than food insecure household. In terms of the percentage decrease in child mortality generated by the food security status of the households, the results of KBM show that the food had an approximately 24.0% decrease in child mortality (Table 4). The result suggests that ensuring food security of the household perhaps in the context of increase food expenditure to enhance household dietary diversity, consumption to nutrient-rich foods will decrease vulnerability of the child to susceptible diseases emerging due to poor nutrition. This result supports the findings of Kind et al., (2006) that found that enhancing the consumption of protein, calcium, and iron resulted in a decrease in perinatal mortality (Table 5).

4.5 Average Impact Estimates of Household Food Security on Child Mortality: Rural and Urban

According to Adepoju, (2015), more children die in rural parts of Nigeria than in urban areas, with a rural infant mortality rate of 95 per 1,000 live births in 2008 compared to 67 per 1,000 in urban areas. Furthermore, Rutstein, (2008) explained that there were 121 fatalities per 1,000 live births in urban areas compared to 191 deaths per 1,000 live births in rural regions. Estimates of the impact of HFSS on child mortality within the six areas in Nigeria indicate that food security has had a negative and significant influence on both rural and urban child mortalities. The estimated

average impact of HFSS on child mortality of a sample rural and urban households was denoted by ATT, with the impact parameter suggesting that it is likely to decrease the probability of child mortality by 0.05 and 0.08 for rural and urban households respectively. Levels of 11.4% and 26.3% reduction in child mortality were recorded as a result of food security for rural and urban households respectively. This result is congruence with the findings of (Rezende et al., 2014), which suggested a strong linkage between household food security and alleviation of under-five child and pregnant women mortality. However, a higher impact was observed at the urban than rural areas, (Adebayo et al., 2016; Schiller et al., 2012), with more than 75% of rural dwellers living on agriculture as their means of livelihood (Attah, 2012).

4.6 Average Impact Estimates of Household Food Security on Child Mortality: Northern Nigeria

Based on the study by Adepoju, (2015), the Northern region of Nigeria had the highest child mortality rate of 200.90 deaths per 1000 births. In addition, WFP, (2012) reported that due to violence, the food security in the Northern part of the nation continues to be a challenge and under-five mortality is on the increase. The impact shows that there were significant differences in the child mortality between the food secure and counterfactual households for the Northern region of Nigeria (North central, North West and North East) at 1% significance level for all the considered zones. Among the Northern states, the North eastern zone experienced a higher frequency of insurgency more than other zones, resulting in food insecurity being very high (see Table 2). The North West had the highest probability of a reduction in child mortality, followed by North East and North Central respectively (see Table 6). Food secure households in the Northern region of Nigeria will reduce the probability of child mortality by 8.88%, 7.25% and 8.19% for North Central, North East and North West respectively.

Table 6 Average impact estimates of propensity score matching of food security on child mortality Northern Nigeria

Child Mortality	Sample	Treated	Control	Difference	t-stat
North Central	Unmatched	0.0105	0.0980	-0.0874	-6.99**
	ATT	0.0109	0.0985	-0.0875	-6.09*
	ATU	0.0981	0.0106	-0.0874	
	ATE			-0.0875	
North East	Unmatched	0.0189	0.1111	-0.0921	-7.14*
	ATT	0.0189	0.0918	-0.0728	-3.78*
	ATU	0.1048	0.0133	-0.0914	
	ATE			-0.0791	
North West	Unmatched	0.0182	0.1370	-0.1187	-10.59*
	ATT	0.0175	0.1371	-0.1197	-8.82*
	ATU	0.1356	0.0184	-0.1172	
	ATE			-0.1182	

*** Significant at 10% level, ** Significant at 5% level, * Significant at 1% level

4.7 Average Impact Estimates of Household Food Security on Child Mortality: Southern Nigeria

Contrary to the Northern region, the Southern region had the lowest child mortality rate of 92.4 deaths per 1000 births (Fayehun & Omololu, 2009). Otaha (2013) reported that excessive rainfall and floods in the Southern region is a contributor to food insecurity in the region. We found that food insecurity is less in the Southern than the Northern region (see Table 2). Using the ATT that measures the average difference between child mortality rate of food secure and the food insecure household of the corresponding match, with a statistically significant difference of changes in the probability of reduction in child mortality between the two. Thus, our findings confirmed that there were substantial decreases in the probability of child mortality in households as a result of being food secure in the Southern region of Nigeria. This confirmed that food and nutritional security is essential for reducing the high child mortality rates in SSA (Table 7).

5 Conclusion and Policy Implications

Child mortality remains a global area of public health concern, with its clear link to a hunger, food insecurity, poverty and lack of health facilities. The study examined the impact of household food security on under-five child mortality in Nigeria and found that a large proportion of those were food insecure. A significant percentage of the households did not have the purchasing capacity to access the less available food in Nigeria due to low food production and recession facing the nation. The results indicated that the drivers of child mortality in Nigeria include maternal education and age, geopolitical zones, place of dwelling (rural or urban) and access to health care facilities. The estimates in this national level study across the Northern and Southern regions and rural and urban households revealed that food security had an impact on child mortality. Food security had a probability of reducing the child mortality rate in

Table 7 Average impact estimates of propensity score matching of food security on child mortality Southern Nigeria

Child Mortality	Sample	Treated	Control	Difference	t-stat
South East	Unmatched	0.1324	0.3354	-0.2030	-8.72*
	ATT	0.1331	0.2464	-0.1133	-4.18*
	ATU	0.3396	0.1425	-0.1971	
	ATE			-0.1461	
South South	Unmatched	0.0271	0.1021	-0.0750	-9.54*
	ATT	0.0263	0.1020	-0.0757	-11.58*
	ATU	0.0996	0.0266	-0.0730	
	ATE			-0.0748	
South West	Unmatched	0.0130	0.1421	0.1291	-7.64*
	ATT	0.0075	0.1407	0.1332	-8.91*
	ATU	0.1379	0.0110	0.1269	
	ATE			0.1305	

*** Significant at 10% level, ** Significant at 5% level, * Significant at 1% level

Nigeria, with the most populous Northern region having the highest food insecurity level and with its associated impact compared to their Southern region. The current findings suggest that by prioritizing food security, improving access to nutrition, and addressing underlying social determinants, we can significantly reduce child mortality rates. It is imperative for policymakers, healthcare providers, and communities to work collaboratively towards creating sustainable solutions that safeguard the well-being and future of children in Nigeria.

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Declarations

Ethical Approval This article does not include any studies involving experimentation on human participants or animals.

Research Involving Human Participants and/or Animals Not Applicable.

Informed Consent Not applicable.

Competing Interests The authors declare that they have no competing interests.

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