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COVID-19, food insecurity and dietary diversity of households: Survey evidence from Nigeria

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Abstract
The policy measures of the government of Nigeria to restrain the spread of COVID-19, particularly in the initial three months (April – June 2020) led to significant disruptions to household livelihoods and food security. We investigate the effects of COVID-19 on food security and dietary diversity of households; focusing on the pathways through which income loss, endowments of wealth, social capital, and safety net programs moderate the severity of households' food security and dietary diversity. Primary data obtained from a telephone survey of 1,031 Nigerian households were analyzed using ordered logit and negative binomial models. Our results show that income losses due to the COVID-19 restrictive measures had pushed households into a more severe food insecurity and less diverse nutritional outcomes. Regarding wealth effects, livestock ownership significantly cushioned households from falling into a more severe food insecurity amid the pandemic. We found that because of the pandemic's indiscriminate effect across communities, the potential of social capital as an informal support mechanism might have been eroded to enable households to cope with shocks. Furthermore, safety net programs by the government and NGOs did not provide significant protection to households from falling into severe food insecurity and malnutrition amid the pandemic. We suggest three policy propositions – prioritize investment in local job creation to curb income loss; build the wealth base of households (e.g., land tenure security or livestock) to enhance resilience to shocks; and target safety nets and other social support programs spatially, temporally, and across social groups to enhance the effectiveness of such programs amid shocks.

Keywords COVID-19 · Food insecurity · Dietary diversity · Households · Income loss · Livelihoods

1 Introduction

Following the outbreak of the coronavirus (COVID-19) pandemic,[1] interruptions of general economic activities and within food supply chains have severely threatened the livelihoods and food security of households in developing nations like Nigeria, particularly the most vulnerable working in informal sectors, including in agriculture and agri-food systems (Laborde et al., 2020; Mahmud & Riley, 2021). Studies published amid the pandemic have documented many of the dire effects of COVID-19 in developing countries – income losses (Dang & Nguyen, 2021; Mahmud & Riley, 2021); increases in food prices (Laborde et al., 2020; Yu et al., 2020) increased food insecurity (Chenarides et al., 2021) and sharply hindering progress towards meeting the Sustainable

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[1] The presence of coronavirus in Nigeria was first reported on 27 February 2020.

Development Goal 2 of 'Zero Hunger' (Otekunrin et al., 2020; Saccone, 2021).

Nigeria faced significant food insecurity and malnutrition problems prior to the onset of COVID-19. Recent studies showed that spending on food comprises 58 percent of household expenditures nationally. However, households in the lowest wealth quintile spend more than 75 percent of their resources on food (Balana et al., 2020; Obayelu et al., 2021). Nigeria experiences significant seasonal and geographical food price fluctuations due to the seasonal nature of rainfed crop production that dominates the farming sector; limited access to markets and transport infrastructure; inadequate processing, storage, and preservation facilities; and the impact of global food price volatility on the cost of imported foods.[2] As more than 50 percent of foods consumed in Nigerian households, including in agricultural households, comes from purchases, food price volatility has led to substantial instability in household food consumption and food security. Households in countries like Nigeria with significant food insecurity and malnutrition problems prior to the onset of COVID-19 have seen those difficulties worsened under the pandemic.

The adverse food security situation many Nigerian households face is situated within a context of serious socio-economic challenges that includes high rates of poverty, unemployment, and acute malnutrition, especially among vulnerable groups (Andam et al., 2020; Matthew et al., 2020; Okeke-Ihejirika et al., 2020). COVID-19 induced economic and social shocks have exacerbated the vulnerability and food insecurity of Nigerian households (Amare et al., 2020; Andam et al., 2020; Balana et al., 2020). Nonetheless, the severity of both the direct and the indirect effects of COVID-19 on livelihoods and food insecurity have been found to be heterogeneous both spatially and across the population in diverse countries like Nigeria (Ayebare et al., 2020; Caggiano et al., 2020). Moreover, beyond increasing economic volatility, the pandemic has heightened prevailing security threats, including increased insecurity in urban centers and greater inter-community conflicts in rural areas, such as between farmers and herders (Balana et al., 2021).

In times of shocks and economic crises, households ordinarily adopt various strategies to smooth and cope with shocks, such as informal social support mechanisms, using own savings, borrowing from others, selling household assets and livestock, increasing their supply of labour, reducing consumption of both food and non-food items, and seeking support from both formal and informal social safety net programs (Asare et al., 2020; Chiappori et al., 2014; Dercon & Porter, 2014). However, unlike most other shocks

with limited temporal or spatial coverage, the COVID-19 pandemic simultaneously affects almost all sectors of the economy and the wider society.[3] Consequently, many of these coping strategies were insufficient for all the affected households (Balana et al., 2020). Households, thus, have faced a two-fold calamity – depletion of their means of livelihoods (losses of jobs or other sources of income) and increased vulnerability to food insecurity and malnutrition.

The main objective of this paper is to investigate the effects of the COVID-19 pandemic on the food security and diets of Nigerian households. As the government's initial responses to contain the virus were imposed between April and June 2020, i.e., shortly after its emergence in Nigeria, the effects of these policy measures on employment, incomes, and the food security and diets of Nigerian households were heightened over this period. Using household survey and econometric models, we rigorously analyzed the pathways through which income and job losses, initial household wealth endowments, social capital, and externally provided safety net programs are associated with the severity of food insecurity and malnutrition among Nigerian households. To the best of our knowledge, no previous studies have undertaken quantitative analysis of the associations between income losses, initial endowments, social capital, and safety net programs and how these factors moderate the severity of food insecurity and dietary problems amid the COVID-19 pandemic in Nigeria. However, we would like to highlight the limitations and draw reader's attention that we do not overclaim the present work as an impact assessment study, because of the nature of our data (recall-based cross-section survey data) and the empirical strategy implemented. Nevertheless, the study comprises of policy relevant descriptive and econometric results that illuminate light on the empirical associations of COVID-19 induced disruptions in livelihood activities and the food security of households. The study contributes to our understanding and the growing body of literature on the pathways through which COVID-19 induced shocks affect the severity of food insecurity of households. The findings provide decision support evidence to address the challenges of household food insecurity and adverse dietary effects in the context of Nigeria and other developing countries with similar socio-economic settings. Additionally, the study demonstrates the need for targeted approaches and the inappropriateness of 'one-size-fits-all' policy approach to cushion the impacts of COVID-19.

To address the objectives of the study, we collected household level data on demographics, income, assets and

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[2] Nigeria imported 2.4 million MT of rice in 2019/20. According to the National Bureau of Statistics, Nigeria spent USD 4.1 billion on food imports over this period.

[3] A simulation-based economy-wide analysis on the economic costs of COVID-19 in Nigeria using a Social Accounting Matrix (SAM) model estimated that during the lockdown periods Nigeria's GDP suffered a 23 percent loss due to COVID-19, amounting to USD 11 billion (Andam et al., 2020).

wealth, employment, food insecurity, dietary quality indicators, and household coping strategies from sample households using computer assisted telephone interviews (CATI) in July 2020. We adapted the FAO's Food Insecurity Experience Scale (FIES) measurement approach (FAO, 2016; Cafiero et al., 2018) to generate indicators of the level of household food insecurity. To capture the pandemic's effect on dietary diversity, we used Household Dietary Diversity Scores (HDDS) (Maxwell et al., 2014). An ordered logit model and a negative binomial (count data) model were used to estimate the effects of COVID-19 on the severity food insecurity and household's dietary diversity, respectively.

The remainder of the paper is structured as follows. Section 2 presents the conceptual framework and hypotheses that underpin the empirical analysis. Data, description of model variables, and analytical models are presented in Sect. 3. Sections 4 and 5 respectively present descriptive findings and econometric model results. The last section concludes the paper with some policy recommendations.

2 Conceptual framework and hypotheses

Here we present the conceptual basis and hypotheses that underpin our empirical analysis of the effects on the food insecurity and dietary diversity of income losses, wealth endowment, social capital, and safety net programs of government and NGOs amid the COVID-19 pandemic among Nigerian households. The conceptual basis to the understanding of household food insecurity and dietary diversity can be connected to the widely accepted four dimensions of food security – *availability (*physical availability of food), *accessibility (*economic and physical access to food), *utilization (*dietary quality which ensures suitable selection and preparation of food), and *stability* (stability of food availability, food access, and food utilization over time) (FAO, 2008). The COVID-19 pandemic likely affected one or more of these dimensions of food security via direct disruptions to food systems or indirectly through the policy measures introduced to curb the pandemic. Devereux et al. (2020) noted that COVID-19 and related responses could unintentionally destabilize food production, processing, and marketing. Hence, food availability will be strongly reduced. Access to food can be adversely affected through increased food prices or reduced household income. Several studies suggest that job and income losses and rising food costs are making access to food difficult, especially for vulnerable households (Jafri et al., 2021). Without availability and effective access to food, efforts to efficiently utilize food could be undermined. Obayelu et al. (2021) found that the COVID-19 pandemic destabilized Nigerian food systems through weakening food availability, access, and utilization.

However, differences among households, for instance initial endowments to livelihood capitals and social networks, largely determine the degree of vulnerability to shocks and the effects shocks exert on food security of households. In this study, we focused on four key factors – income and employment, wealth endowment, social capital, and safety net programs of the government/NGOs– that could play important roles in moderating household food security and dietary diversity under the COVID-19 pandemic. Studies have shown that economic shocks in the context of *income decline or job loss* can adversely affect household food security (Akter & Basher, 2014; Smith & Frankenberger, 2018; Rufai et al., 2021). Particularly, the poor and vulnerable households are the most affected (Andam et al., 2020; Obayelu et al., 2021; Ogunmodede et al., 2020). In contrast, increases in household incomes play a significant role in access to food, promoting both adequate consumption and dietary diversity (Deaton & Deaton, 2020; Manda et al., 2020). *Wealth endowments*, such as natural capital (land) and physical capital (livestock), can play an important role in determining the household's food security and diet quality. Mulwa and Visser (2020) and Wodajo et al. (2020), for instance, found that livestock ownership plays an important role in ensuring household food security, either through own consumption or through sales of livestock for cash during periods when the household has limited income.

While food security in developing countries often depends on the household's ability to produce its own food combined with its capacity to purchase foods, it is also observed that the strength of a household's *social capital* – its bonds with the rest of the community (e.g., family, relatives, and friends) – significantly helps it minimize the severity of food insecurity, especially in times of shocks (Mbugua & Nzuma, 2020; Nosratabadi et al., 2020). However, considering the nature of the indiscriminate shocks imposed by COVID-19, which is likely to affect every household in a community, the potential of social capital to serve as a buffer for other households may be undermined. Supports offered to vulnerable households by government and NGOs through *social safety nets* programs[4] may also play an important role in minimizing the negative consequence of COVID-19 on a household's food security. Studies have shown that interventions from both the government and NGOs in the times of shocks, have reduced the severity of food insecurity (Devereux et al., 2020; Headey et al., 2020; Laborde et al., 2020; Obayelu et al., 2021). Devereux (2016) noted that food insecurity can be addressed most directly by

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[4] See COVID-19 Policy Response (CPR) Portal | IFPRI: International Food Policy Research Institutehttps://public.tableau.com/app/profile/ifpri.td7290/viz/CPRPORTAL/Overview

giving food insecure people food aid or the means to access food (conditional or unconditional cash transfers).

Against this backdrop, we hypothesize four propositions to guide our empirical investigation on the associations between household food security, on the one hand, and COVID-19 induced income losses, wealth endowment effects, social capital, and government/NGO safety net programs.

Hypothesis 1: *Income effect:* Several studies consistently verified that poor households spend a higher proportion of their income on food than do high-income households[5] (Akter & Basher, 2014; Smith & Frankenberger, 2018; Deaton & Deaton, 2020). The implication is that income losses could immediately translate into low access to food and exacerbate the food insecurity of poor households. As the COVID-19 pandemic significantly affected both employment income and non-employment income sources of households, we hypothesize that income losses because of COVID-19 led to an immediate negative effect on household food security. This is so because majority of households in Nigeria are vulnerable to shocks and lack adequate coping mechanisms to cushion their food security from even short-term income loss.

Hypothesis 2: *Wealth endowment effect*: Poor and less endowed households that lack access to livelihood assets, such as natural capital (land) and physical capital (livestock), are more vulnerable to shocks and exposed to more severe food insecurity under shocks than better-endowed households. We hypothesize that land and livestock ownership reduce the likelihood of households falling into a more severe food insecurity situation induced by the COVID-19 pandemic.

Hypothesis 3: *Social capital effect*: Support mechanisms between friends, relatives and family members is a long-standing practice among African communities, especially when households experience with shocks. However, as COVID-19 indiscriminately affected all households at the same time, it has likely disrupted the functioning of existing social support mechanisms in times of adversity. We hypothesize that COVID-19 undermined the longstanding social support mechanisms to an extent that social networks and relationships did not significantly prevent households from increased food insecurity.

Hypothesis 4: *Safety net programs effect*: Governments and NGOs operating in many developing countries, including Nigeria assert that they provided large-scale support, in cash or in-kind, to vulnerable households to mitigate the negative effects of COVID-19 on food security. We hypothesize that these interventions helped prevent households from plunging into severe food insecurity.

3 Methodology

3.1 Sampling and data

The selection of the four states where households were sampled was based on the existing USAID-Feed the Future (FtF) Global Food Security Strategy (GFSS) Nigeria Country Plan.[6] The targeting strategy of GFSS identified vulnerable populations, including conflict-affected populations, youth, and nutritionally vulnerable smallholder households (USAID, 2018). GFSS focuses on seven of Nigeria's 36 states – Benue, Cross River, Delta, Ebonyi, Kaduna, Kebbi and Niger. Four of the seven GFSS/FtF states (Benue, Delta, Ebonyi, and Kebbi) were selected to represent the four geopolitical zones of Nigeria – North-central, South-south, Southeast, and Northwest, respectively. A sample frame of 67,867 smallholder farmers actively involved in the states' dominant value chain commodities was obtained from the state Ministries of Agriculture and Natural Resources (MANR) of the four states. About 9 percent (6,551) of these farmers had no phone numbers and were subsequently dropped leaving a sample frame of 61,316 farmers. A total of 1031 farm households (Benue 275, Kebbi, 266, Delta 248, and Ebonyi 242) were selected, contacted in advance for their consent, and interviewed via the telephone. Where a farmer declined to proceed with the phone interview or where the phone line is unavailable, a replacement is randomly selected from the sample frame and interviewed. However, since our sample frame consists of only registered farmers involved in major agricultural value chains per state and those having phone numbers, we would like to indicate the limitations of our sampling procedure, the representativeness of our survey sample to the population and the external validity of the findings.

We administered computer-assisted telephone interviews (CATI) to heads of selected households. The survey

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[5] This is consistent with Engel's law that states "*The poorer is a family, the greater is the proportion of the total outgo [family expenditures] which must be used for food.*" (Quoted in Anker, 2011).

[6] "The GFSS country plan for Nigeria adopts a market systems approach as the basis of its state selection and geographic targeting efforts. Market systems are composed of vertically and horizontally linked firms, end markets, input and support service markets, and the environment in which they operate, which may include socio-cultural, geographic and political factors, infrastructure and institutions." (USAID, 2018). See this web link: https://www.usaid.gov/sites/default/files/documents/1867/Nigeria_GFSS_Country_Plan_-_Final_WS_Edits_2.pdf

Table 1 The eight standard Food Insecurity Experience Scale (FIES) questions

FIES Questions[†]	Labelled/coded as:
Q1 Was there a time that you **worried you would not have enough food** to eat because of a lack of money or other resources?	'Worried'
Q2 Were you or a member of your household **unable to eat healthy and nutritious food** because of a lack of money or other resources?	'Healthy'
Q3 Was there a time when you or others in your household **ate only a few kinds of foods** because of a lack of money or other resources?	'Ate few'
Q4 Was there a time when you or others in your household **had to skip a meal** because of a lack of money or other resources?	'Skipped'
Q5 Was there a time when you or others in your household **eat less than you thought you should** because of a lack of money or other resources?	'Ate less'
Q6 Was there a time when your household **ran out of food** because of a lack of money or other resources?	'Runout'
Q7 Was there a time when you or others in your household **were hungry but did not eat** because of a lack of money or other resources?	'Hungry'
Q8 Was there a time when you or others in your household **went without eating for a whole day** because of a lack of money or other resources?	'Whole day'

† Each of the eight questions was asked for two periods: (1) for the three-month period just BEFORE the emergence of COVID-19 in Nigeria, and (2) for the first three-month period SINCE COVID-19 cases were confirmed in Nigeria

questionnaire included modules on household characteristics, primary livelihoods activities and key assets, income changes, employment, labour movement, coping strategies, food security and dietary diversity. The questionnaire was pilot-tested before the survey was implemented. To monitor the quality of survey administration and for data quality control; the interviews were recorded.

Enumerators with field experience in household surveys were recruited and trained rigorously on phone interview facilitation skills and phone survey data management. Prior to the interview, respondents were contacted by survey coordinators in each state to obtain their initial consent. The advance phone calls also eliminated incorrect phone numbers. The final survey was administered in July 2020. Data was cleaned and analyzed using the STATA statistical software package (release-16).

3.2 Variables and measurements

As the paper's focus is on the effects of the COVID-19 pandemic on household food insecurity and dietary diversity,
we first provide the description and measurement of food insecurity and dietary diversity indicators. To examine the four hypotheses put forward in Sect. 2, we pay attention to four key covariates – income losses, wealth endowment/asset ownership, a social capital indicator, and safety net mechanisms of government and NGOs amid the COVID-19 pandemic.

3.2.1 Food insecurity measures

We constructed food insecurity indicators using survey data on the eight-standard experience-based food insecurity experience scale (FIES) questions (FAO, 2016) as described in Table 1. The metric has been widely used in the analysis of food insecurity (Cafiero et al., 2018; FAO, 2016).

Based on the individual's 'yes/no' responses to the eight FIES questions and adapting the FAO's global reference scale of FIES (FAO, 2016) (see Fig. 1), the household's food insecurity condition in the first three months amid the COVID-19 pandemic was categorized as in Fig. 1.

Fig. 1 Food insecurity experience scale (FIES) showing the severity of the eight 'Yes'/'No' FIES questions

Table 2 Share of survey households in FIES-based categories of food (in)security (n = 1031)

FIES-based categories of food security (numbers in parentheses are FIES category codes)	pre-COVID 19 (January -March 2020)		During first three months of the COVID 19 pandemic (April-June 2020)	
	Frequency	Percent	Frequency	Percent
Food secure (1)	588	57.0	71	6.9
Mildly food insecure (2)	170	16.5	82	7.9
Moderately food insecure (3)	79	7.7	130	12.6
Severely food insecure (4)	194	18.8	748	72.6

Based on the food insecurity severity scale depicted in Fig. 1, we defined a household's food insecurity in four ranked categories (Gebre & Rahut, 2021).

1. *Food secure* (= 1): If the household responded 'no' to all the eight questions, i.e., if $Q_1 = Q_2 = Q_3 = Q_4 = Q_5 = Q_6 = Q_7 = Q_8 = 0$
2. *Mildly food insecure* (= 2): If the household respond 'yes' to at least one of the first three FIES questions (i.e., if $Q_1 = 1$ or $Q_2 = 1$ or $Q_3 = 1$) and zeros to the rest of the FIES questions i.e., $Q_4 = Q_5 = Q_6 = Q_7 = Q_8 = 0$
3. *Moderately food insecure* (= 3): If the household responded 'yes' to either Q_4 or Q_5 and zeros to Q_6, Q_7, and Q_8
4. *Severely food insecure* (= 4): If the household responded 'yes' to one or more of the last three FIES questions i.e., $Q_6 = 1$ or $Q_7 = 1$ or $Q_8 = 1$.

The distribution of households by these FIES-based categories pre-COVID-19 and amid the COVID-19 pandemic is presented in Table 2. A significant number of households were pushed into more severe food insecurity conditions amid the pandemic. For instance, the share of households experiencing '*severe food insecurity'* (code 4) increased from about 19 percent pre-COVID-19 to 73 percent during the first three months of the pandemic, a differential increase of over 50 percentage points. During the pandemic, only 7 percent of survey household were 'food secure'; about 8 percent were 'mildly food insecure', and 13 percent were 'moderately food insecure'.

3.2.2 Dietary diversity measure

We constructed a household dietary diversity indicator using the 'yes/no' responses to the eleven food groups from which food was consumed by a household over a given reference period(see appendix Table 9). Following Vhurumuku (2014) we constructed the household dietary diversity score (HDDS) as follows.

1. Re-group the 11 food groups into 7 food groups as per Table 9.

2. Create a binary response (1 = yes) if the household consumed any food from the specific food group during the reference period.
3. Sum horizontally the binomial variables to generate a count value.
4. The new variable, the HDDS, ranges from a minimum of zero to a maximum of seven.

3.2.3 Independent variables

Table 3 lists and describes the independent variables used in the analytical models. In line with the hypotheses presented in Sect. 2, we pay a particular attention to livelihood indicators (job/income loss); asset and wealth indicators (land and livestock ownership); social capital indicators (remittances or assistance from friends and family members); and external intervention indicators (support from government and NGOs). We also include other controls, including those on demographic characteristics, geographic factors, and information access.

3.3 Analytical models

3.3.1 Ordered logit model

An ordered logit model is commonly used when the dependent variable is an ordered categorical outcome from categories that are mutually exclusive and with multinomial distribution. The household's FIES indicator is an ordered outcome variable with four categories as defined in Sect. 2. A household may fall into one of the four FIES condition (dependent variable y). In general, the ordered categories can be coded as $j = 1, \ldots, m$, where m is the number of categories. In our analysis, we let y_i takes values $j = 1, 2, 3, 4$ that represents the household's FIES category. Defining y_i^* as the latent unobserved measure of the ith household FIES status that progressively crosses high thresholds, we specify an index model for y_i^* for individual i as in Eq. 1 (Cameron & Trivedi, 2010):

$$y_i^* = x_i' \beta + u_i \tag{1}$$

Table 3 Descriptions and measurement of independent variables

Variable name	Description and measurement
Livelihood variables	
HH income loss amid COVID-19 (%)	Percent of household income lost in the first three months (April—June 2020) of amid COVID-19
HH member lost job (0/1)	HH member lost job amid COVID-19 (1 = yes; 0 otherwise)
HH livelihood on-farm (0/1)	Household's main livelihood activity is farming (1 = yes; 0 otherwise)
Demographic and geographic variables	
HH in rural area (0/1)	HH resident in rural areas (1 = yes; 0 otherwise)
Location north state (0/1)	HH located in northern Nigerian states (1 = yes; 0 otherwise)
HH head male (0/1)	HH head male (1 = yes; 0 otherwise)
HH head age (years)	Age of HH head (in completed years)
HH head married (0/1)	HH head married (1 = yes; 0 otherwise)
Household size (#)	Size of the household (head count)
HH member migrated amid-COVID (0/1)	HH member migrated amid-COVID-19 (1 = yes; 0 otherwise)
Human and social capital variables	
Education secondary (0/1)	HH head completed secondary school (1 = yes; 0 otherwise)
Education above secondary (0/1)	HH head obtained above secondary education (1 = yes; 0 otherwise)
Received family/friends support (0/1)	HH received cash or in-kind support from friends/family (1 = yes; 0 otherwise)
HH assets/wealth indicators	
Land size owned (ha)	Total size of land owned by the household (ha)
Livestock size owned (TLU)	Total number of livestock owned by the household (TLU)
External support and information access	
Received government/NGO support (0/1)	HH received cash or in-kind support from government or non-government sources (1 = yes; 0 otherwise)
Access to amid COVID-19-related info (0/1)	HH had access to information on COVID-19 (1= yes; 0 otherwise)

HH Household, *ha* hectare, *TLU* Tropical livestock unit

Where the $x_i^{'}$ is a vector of regressors, $\beta=$ the parameters to be estimated and u_i is an error term. From Eq. 1, higher values of y_i^* indicate the more severe food insecurity situation of the household. For a 4–category ordered variable, a household's FIES category j can be defined as $y_i =$ j if $\alpha_{j-1} < y_i^* \leq \alpha_j$, for $j = 1, \ldots, 4$. Where α_j indicate threshold values for the jth FIES category. The probability that the ith household falls in the j food insecurity category (P_{ij}) can be presented as in Eq. 2:

$$P_{ij} = P\left(y_i = j\right) = P\left(\alpha_{j-1} < y_i^* \leq \alpha_j\right) = F(\alpha_j - x_i^{'}\beta) - F(\alpha_{j-1} - x_i^{'}\beta) \tag{2}$$

The marginal effects of covariates can be derived using Cameron and Trivedi (2010, p.528).where $F(.)$ is the cumulative distribution function (cdf) of u_i and u_i is assumed to have a logistic cumulative distribution function with $F(z) = e^z/1 + e^z$. The parameters β and the threshold parameters, α_j, are estimated by maximizing the log likelihood of Eq. 3 using the maximum likelihood estimator.

3.3.2 Poisson and negative binomial (NB) models

The HDDS, as constructed in Sect. 3, exhibits the features of count data. Thus, ae employ two variants of count data regression models – the Poisson model and the negative binomial (NB) model. Following Cameron and Trivedi (2010) the probability of the dependent variable Y takes the value of y i.e., $\Pr(Y = y)$ can be specified using the Poisson model as in (Eq. 3):

$$\Pr(Y = y) = \frac{e^{-\mu}\mu^y}{y!}. \tag{4}$$

where $\mu > 0$ with exponential mean parametrization as $\mu = exp(x_i^{'}\beta); y = 1, 2, \ldots, 7$ (i.e., the HDDS values constructed in Sect. 3). The $x^{'}$ are set of independent covariates as specified in in Table 3.

As the Poisson distribution is characterized by the equality of mean and variance (i.e., $E(Y) = Var(Y) = \mu$), it cannot accommodate overdispersion in the data, which is common on most empirical count data where the variance and conditional mean are unequal. To relax this restrictive property of

the Poisson model, we implement the less restrictive negative binomial (NB) model that accommodates overdispersion (Cameroon & Trivedi, 2010). We adopt the quadratic variance NB model in modelling the factors affecting HDDS amid COVID-19 pandemic for our data set. A maximum likelihood estimation method with robust variance–covariance matrix of the estimators (VCE) for both the Poisson and NB models, using the 'poisson' and 'nbreg' Stata commands, respectively.

3.3.3 Robustness check

As a robustness check, we generated indices for FIES and HDDS as continuous variables by summing up the 'yes/no' responses to the eight FIES questions (see Table 1) and the 'yes/no' responses on consumption of the eleven food groups (see appendix Table 9), respectively. We then run OLS regression models for FIES and HDDS on the same set of covariates used in the ordered logit and negative binomial regression models. Interestingly, the direction/sign of the estimated coefficients and marginal effects remain the same for all covariates which implies the robustness our specifications. The OLS estimation results are reported in appendix Table 14.

4 Descriptive findings

4.1 Descriptive statistics of model variables

Table 4 reports summary statistics for the variables used in the econometric models. The results regarding the livelihood variables show that about 88 percent of survey households reported that they had experienced income loss. On average, these households lost about 43 percent of their income during the initial three months of the COVID-19 pandemic compared to their income level in the immediate three months prior to the pandemic. This is consistent with the national level survey findings by the National Bureau of Statistics (NBS) and the World Bank where 79 percent of respondents reported that their households' total income has decreased since the outbreak of the pandemic (World Bank & NBS, 2020). Similar studies (GAIN, 2020; OECD, 2020) also found that farming household income losses may have been compounded because of the COVID-19 pandemic. In terms of jobs, about 42 percent of respondents reported job losses in the first three months of the pandemic. About 57 percent of survey households were dependent on farming as their main source of livelihoods and close to three-fourth of respondents were rural residents.

Majority of the households are headed by middle aged men with the average age of household head being 40 years. As shown in Table 4 more than half of respondents attained

Table 4 Summary statistics of variables (n = 1031)

Variable name	Mean	Std	Min	Max
Livelihood variables				
HH income loss amid-COVID (%)	43.391	27.284	0	100
HH member lost job (yes = 1)	0.419	0.494	0	1
HH livelihood on-farm (yes = 1)	0.573	0.495	0	1
Demographic and geographic variables				
HH in rural area (yes = 1)	0.725	0.447	0	1
Location north state (yes = 1)	0.258	0.438	0	1
HH head male (yes = 1)	0.595	0.491	0	1
HH head age (years)	40.239	11.447	15	85
HH head married (yes = 1)	0.766	0.423	0	1
Household size (#)	8.02	4.485	1	25
Human/ social capital variables				
Education secondary (yes = 1)	0.306	0.461	0	1
Education above secondary (yes = 1)	0.572	0.495	0	1
HH member migrated amid-COVID (yes = 1)	0.096	0.295	0	1
HH assets/wealth indicators/ information				
Land size owned (ha)	3.373	6.830	0	120
Livestock size owned (TLU)	2.283	6.299	0	105
Access to COVID-related info (yes = 1)	0.922	0.268	0	1
Coping strategies				
Used own saving (yes = 1_	0.677	0.468	0	1
Borrowed (yes = 1_	0.443	0.497	0	1
Sold household or farm assets (yes = 1)	0.408	0.492	0	1
Sold livestock (yes = 1)	0.461	0.499	0	1
Received family/friends support (yes = 1)	0.190	0.393	0	1
Received government/NGO support (yes = 1)	0.123	0.329	0	1
Reduced food consumption (yes = 1)	0.595	0.493	0	1
Reduced non-food consumption (yes = 1)	0.431	0.486	0	1

above a secondary education level. In terms of social capital, only 19 percent received some form of support from family or friends, indicating that the effect of COVID-19 pandemic seems to have limited the existing social support mechanisms. Respondents own on average 3.37 hectares of land, but there is considerable variation in landholding size with a standard deviation of 6.83. Household on average own 2.28 units of livestock measured in Tropical Livestock Units (TLU). But with a standard deviation of 6.3, there is a high degree of variability in livestock ownership. This differences in asset ownership likely results in differential resilience capacity of households to COVID-19 induced shocks and increased vulnerability to severe food insecurity for households with fewer assets. Only 12 percent of respondents reported receipt of support, in-kind or in cash, either

from government or NGOs suggesting limited access to the safety net program of for cushioning the adverse effects of the COVID-19 pandemic on food security.

Our survey results indicate that about 60 percent of the respondents reduced consumption of food items as an immediate response to the pandemic, while 43 percent reduced non-food consumption. This adjustment was partly driven by the rising prices of both food and non-food items and the high logistical and distribution costs incurred in making these goods available to the consumers. This follows a priori expectations since expenditure on food items takes up high proportion of total household expenditure of low-income households. Hence, the reduction of both quality and quantity of food items evidently aggravates the situation of food and nutrition insecurity of households (Amare et al., 2020; Headey et al., 2020).

4.2 Transitions in the severity of food insecurity (pre- and amid COVID-19)

Table 5 summarizes transition between FIES food security categories experienced by households between the pre-COVID-19 period and during COVID-19. These transitions are computed from households' responses to each of the eight FIES questions for the three months immediately prior to the start of the COVID-19 pandemic in Nigeria and the first three months of the pandemic. For each question, there are four 'pre- and during' yes/no' combinations of answers: (yes, yes), (yes, no), (no, no); or (no, yes). A 'yes, yes' and 'no, no' responses indicate that there is no change in FIES status during the two reference periods. A 'yes, no' response pattern shows an improvement during the pandemic as compared to the pre-COVID-19 period and a 'no, yes' indicates that the food security situation has worsened during the COVID-19 period.

The results (Table 5) reveal that the food security situation for a majority of survey households was worsened during the pandemic on all the eight FIES indicators. This transition is

also demonstrated by the low correlation coefficients among the responses to the same FIES questions pre-COVID-19 and during the pandemic (see grey-shaded part at the bottom-left quadrant of appendix Table 10). Over 60 percent the respondents reported a 'no, yes' response pattern to five of the eight FEIS questions, implying an increase in household food insecurity. For the last three more stringent FIES questions, 50, 48, and 26 percent of respondents reported a worsening in their food security situation. Only about 2 percent of households on average experienced a positive transition in their food security situation during the COVID-19 pandemic. These few incidences of improvement may be linked to households that were food insecure pre-COVID-19 but amid the pandemic received external support that might have improved their food security. Figure 2 shows changes in the patterns of consumption of foods from various food groups between the immediate pre-COVID period (January-March 2020) and during the COVID period (April-June). Significant number of survey respondents reported reduction in their consumption of dairy, meat, eggs, and fruits (61 percent, 53 percent, 34 percent, and 39 percent of the respondents, respectively) during the first three months of the COVID period. These food items are rich sources of protein, calcium, and multiple vitamins necessary for healthy diet. Our findings corroborate results from a national-level longitudinal household survey conducted in the same period by the National Bureau of Statistics and the World Bank, which reported that between 35 and 59 percent of households that needed to purchase staple foods, like yams, rice and beans, reported that they were not able to buy them (World Bank and NBS, 2020).

5 Econometric results

In this section, we report the estimation results of the ordered logit and negative binomial regression models. We first present the estimation results focusing on the effects of income losses,

Table 5 Households FIES transition, comparison of pre-COVID and amid-COVID household FIES situation (n = 1031)

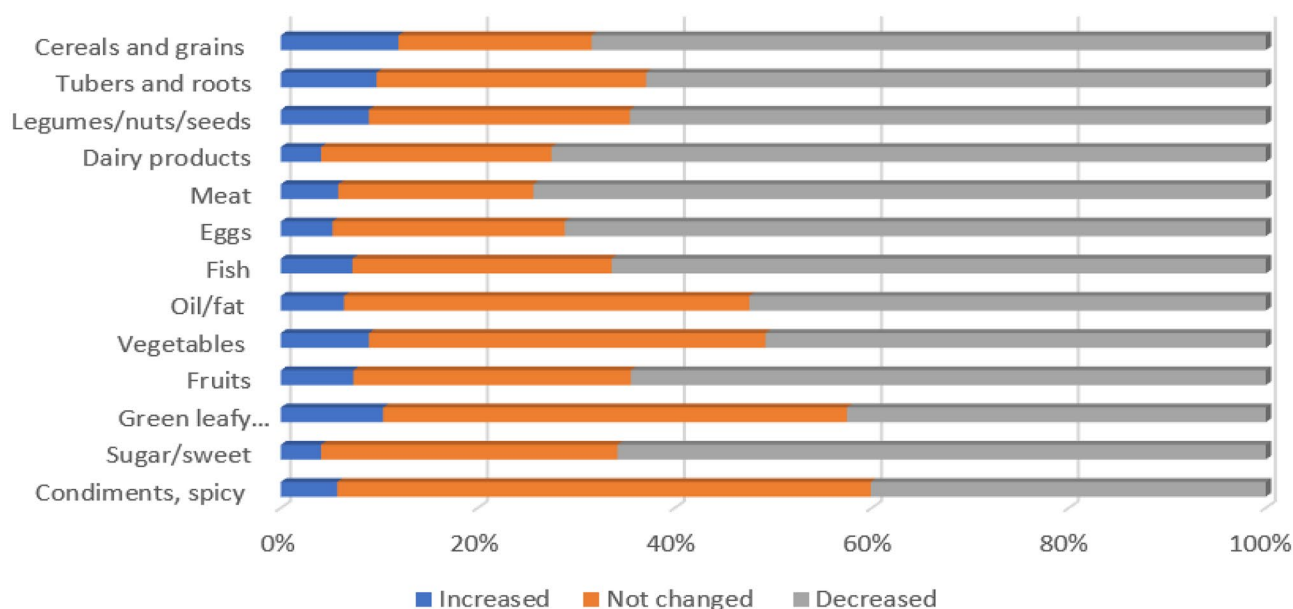| FIES questions	Negative transition (%) (No → Yes)	No transition (%) (No ↔ No)	No transition (%) (Yes ↔ Yes)	Positive transition (%) (Yes → No)
'Worried'	65.86	13.97	17.65	2.52
'Healthy'	61.49	19.69	13.77	5.04
'Ate few'	63.05	17.56	16.49	2.91
'Skipped'	62.17	23.76	12.42	1.65
'Ate less'	63.53	21.24	13.77	1.45
'Runout'	49.85	38.12	10.48	1.55
'Hungry'	48.50	38.31	11.74	1.45
'Whole day'	26.29	67.51	4.36	1.84

Fig. 2 Reported changes in consumption of food groups between the periods three months before COVID-19 (January-March 2020) and during the first three months of COVID-19 pandemic (April-June 2020) in Nigeria (n = 1031)

wealth endowments/ assets, social capital, and government or NGOs safety net program on the severity of food insecurity of households using the FIES measure. We then report estimation results of household dietary diversity using the HDDS measure.

Since the main livelihood activities of households are important in determining their vulnerability to shocks and coping strategies, we first run the ordered logit and negative binomial models with farm vs. non-farm livelihood activities classified as a dichotomous explanatory dummy variable. As a robustness check, we reclassified livelihood activities into four (farm, non-farm business, wage employee, and causal/unemployed) and run the models again. Results from the latter models were reported in appendix Table 12. However, the estimation results from models with four livelihood categories (appendix Table 12) are not statistically different from the results obtained in models with two broad livelihood classifications (i.e., farm vs. non-farm) (Tables 6 and 8). Thus, our specification with farm and non-farm as the two broad livelihood categories is robust.

5.1 Factors affecting household food insecurity experience scale (FIES) scores

Tables 6 and 7 report the results of the ordered logit model estimation; first estimated by controlling geographic and household level characteristics and then with only the factors of interest hypothesized in Sect. 2. The regressors are jointly statistically significant at 1% level (Wald Chi^2

(16) test statistic, p = 0.000). The ordered logit threshold parameters in both estimations appear to be statistically significant, i.e., they are significantly different from each other, so the four FIES categories should not be collapsed into three categories. We focus and report results for the model controlling for the covariates (Table 6). The estimated coefficients of the hypothesized factors on the severity of food insecurity remain sizeable and strongly statistically significant even after controlling for other covariates.

In ordered logit models, in general, positive coefficients indicate that increases in the regressors decrease the probability of the subject being in the 'lower' category, i.e., a positive coefficient increases the probability of the subject being in the 'higher' category as defined in a specific study. In our study, a 'higher' category refers to the household's position in a more severe FIES scale and 'lower' category indicates the household is less food insecure (i.e., more likely food secure).

Examining Hypothesis-1 against the results in Tables 6 and 7, the positive and statistically significant (at 1% level) coefficients of income and job losses show that the severity level of the latent food insecurity indicator variable (FIES) increases with increases in income loss and job loss. This is in accordance with a priori expectation and hypothesis-1 stated in Sect. 2. The marginal effects of these two livelihood related factors further indicate that a one-unit increase in income loss (measured in percentage) and that of job loss (measured in a discrete change against the baseline) reduce the probability of the household being in

Table 6 Estimation results of ordered logit model for Food Insecurity Experience Scale (FIES), coefficients and marginal effects,[†] with control covariates (n=1031)

	Model coefficients		Marginal Effects (ME) of covariates for FIES: 1, 2, 3 and 4							
	Coefficient	Standard error (Robust)	ME, FIES = 1 (dy/dx)	Standard error ME, FIES = 1	ME, FIES = 2 (dy/dx)	Standard error ME, FIES = 2	ME, FIES = 3 (dy/dx)	Standard error ME, FIES = 3	ME, FIES = 4 (dy/dx)	Standard error ME, FIES = 4
HH income loss amid-COVID (%)	0.017***	0.003	-0.001***	0.000	-0.001***	0.000	-0.001***	0.000	0.003***	0.001
HH job affected by COVID-19 (yes=1)	0.446***	0.161	-0.029***	0.010	-0.024***	0.009	-0.027***	0.010	0.080***	0.028
Received family/ friends support (yes=1)	-0.063	0.198	0.004	0.014	0.003	0.011	0.004	0.012	-0.011	0.036
Received gov./NGO support (yes=1)	0.418	0.272	-0.025*	0.014	-0.021	0.013	-0.025	0.017	0.071*	0.043
Land size owned (ha)	-0.019***	0.007	0.001***	0.000	0.001***	0.000	0.001***	0.000	-0.003***	0.001
Livestock size owned (TLU)	-0.033***	0.009	0.002***	0.001	0.002***	0.001	0.002***	0.001	-0.006***	0.002
HH in rural area (yes=1)	-0.043	0.180	0.003	0.012	0.002	0.010	0.003	0.011	-0.008	0.032
Location Northern states (yes=1)	-0.705***	0.181	0.053***	0.016	0.041***	0.011	0.042***	0.011	0.136***	0.036
HH head male (yes=1)	-0.176	0.168	0.012	0.011	0.009	0.009	0.011	0.010	-0.032	0.030
HH head age (years)	-0.013*	0.007	0.001*	0.000	0.001*	0.000	0.001*	0.000	-0.002*	0.001
Household size (#)	-0.007	0.019	0.000	0.001	0.000	0.001	0.000	0.001	-0.001	0.003

Table 6 (continued)

	Model coefficients		Marginal Effects (ME) of covariates for FIES: 1, 2, 3 and 4							
	Coefficient	Standard error (Robust)	ME, FIES=1 (dy/dx)	Standard error ME, FIES=1	ME, FIES=2 (dy/dx)	Standard error ME, FIES=2	ME, FIES=3 (dy/dx)	Standard error ME, FIES=3	ME, FIES=4 (dy/dx)	Standard error ME, FIES=4
HH head married (yes=1)	-0.283	0.211	0.018	0.012	0.015	0.011	0.017	0.013	-0.050	0.036
Education above secondary (yes=1)	-0.383**	0.167	0.025**	0.011	0.020**	0.009	0.023**	0.010	-0.069**	0.029
HH livelihood on-farm (yes=1)	0.007	0.165	-0.000	0.011	-0.000	0.009	-0.000	0.010	0.001	0.030
HH member migrated_COVID-19 (yes=1)	0.450	0.323	-0.026	0.016	-0.022	0.015	-0.027	0.019	0.076	0.050
Access to COVID-related info (yes=1)	0.412	0.283	-0.032	0.024	-0.024	0.017	-0.024	0.016	0.079	0.057
/Cut1	-2.828	0.507								
/Cut2	-1.963	0.507								
/Cut3	-1.128	0.499								
Mean dependent var	3.485	SD dependent var	0.936							
Pseudo r-squared	0.067	Number of obs	1031							
Wald Chi2(16)	84.746	Prob > chi2	0.000							
Akaike crit. (AIC)	1471.253	Bayesian crit. (BIC)	1561.590							

ME Marginal effects, *MEs* for factor variables is the discrete change from the base level, *HH* Household, *ha* hectare, *TLU* Tropical Livestock Unit

† Marginal effects (dy/dx) are average marginal effects (AME), i.e., evaluated at the sample values and then averaged

* $p<0.01$, ** $p<0.05$, *** $p<0.1$

Table 7 Estimation results of ordered logit model for Food Insecurity Experience Scale (FIES), coefficients and marginal effects,[†] with no controls (n = 1031)

Variable name	Model Coefficients		Marginal Effects (ME) of covariates for FIES: 1, 2, 3 and 4							
	Coefficients	Standard error (Robust)	ME, FIES=1 (dy/dx)	Standard error ME, FIES=1	ME, FIES=2 (dy/dx)	Standard error ME, FIES=2	ME, FIES=3 (dy/dx)	Standard error ME, FIES=3	ME, FIES=4 (dy/dx)	Standard error ME, FIES=4
HH income loss amid-COVID (%)	0.017***	0.003	-0.001***	0.000	-0.001***	0.000	-0.001***	0.000	0.003***	0.001
HH job affected by COVID-19 (yes=1)	0.445***	0.158	-0.029***	0.011	-0.025***	0.009	-0.029***	0.010	0.083**	0.029
Received family/friends support (yes=1)	0.050	0.196	-0.003	0.013	-0.003	0.011	-0.003	0.012	0.009	0.037
Received gov./NGO support (yes=1)	0.592**	0.261	-0.034***	0.013	-0.030**	0.012	-0.038**	0.016	0.102**	0.040
Land size owned (ha)	-0.020**	0.009	0.001**	0.001	0.001**	0.000	0.001**	0.001	-0.004**	0.002
Livestock size owned (TLU)	-0.038***	0.011	0.003***	0.001	0.002***	0.001	0.002***	0.001	-0.007**	0.002
/Cut1	-1.809	0.191								
/Cut2	-0.974	0.177								
/Cut3	-0.171	0.168								
Mean dependent var	3.485		SD dependent var 0.936							
Pseudo r-squared	0.044		Number of obs 1031							
Wald Chi2(16)	51.009		Prob > chi2 0.000							
Akaike crit. (AIC)	1486.123		Bayesian crit. (BIC) 1528.914							

ME Marginal effects, *MEs* for factor variables is the discrete change from the base level, *HH* Household, *ha* hectare, *TLU* Tropical Livestock Unit

† Marginal effects (dy/dx) are average marginal effects (AME), i.e., evaluated at the sample values and then averaged

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 8 Estimation results of negative binomial regression model for Household Dietary Diversity Score (HDDS), coefficients and marginal effects (n = 1031)

Variable name	Coefficient	Standard error (Robust)	Marginal effect (dy/dx MEM)	Standard error (MEM)	Marginal effect (dy/dx AME)	Standard error (AME)
HH income loss amid-COVID (%)	-0.001***	0.000	-0.006***	0.002	-0.006***	0.002
HH job affected by COVID-19 (yes = 1)	-0.023	0.015	-0.125	0.083	-0.125	0.084
Received family/friends support (yes = 1)	0.039 **	0.018	0.221**	0.103	0.222**	0.103
Received gov./NGO support (yes = 1)	-0.027	0.028	-0.148	0.150	-0.149	0.151
Land size owned (ha)	0.001	0.001	0.007	0.007	0.007	0.007
Livestock size owned (TLU)	0.002 ***	0.001	0.011***	0.004	0.011**	0.004
HH in rural area (yes = 1)	0.023	0.016	0.126	0.088	0.127	0.088
Location Northern states (yes = 1)	-0.093 ***	0.020	-0.504***	0.108	-0.505***	0.108
HH head male (yes = 1)	0.035 **	0.016	0.191**	0.086	0.192**	0.087
HH head age (years)	0.002 **	0.001	0.009**	0.004	0.009**	0.004
Household size (#)	-0.005 ***	0.002	-0.027***	0.010	-0.027***	0.010
HH head married (yes = 1)	0.028	0.019	0.152	0.104	0.152	0.105
Education above secondary (yes = 1)	0.056 ***	0.016	0.308***	0.087	0.309***	0.087
HH livelihood on-farm (yes = 1)	-0.063 ***	0.014	-0.353***	0.081	-0.354***	0.081
HH member migrated_COVID-19 (yes = 1)	0.004	0.027	0.021	0.151	0.021	0.151
Access to COVID-related info (yes = 1)	0.075 ***	0.028	0.406***	0.147	0.407***	0.147
Cons	1.638 ***	0.045	-	-	-	-
Mean dependent var	5.571	SD dependent var	1.266			
Pseudo r-squared	0.011	Number of obs	1031			
Wald Chi2(16)	146.238	Prob > chi2	0.000			
Akaike crit. (AIC)	3323.176	Bayesian crit. (BIC)	3404.004			

HH Household, *ha* hectare, *TLU* Tropical Livestock Unit, *AME* average marginal effects, *MEM* marginal effects at the mean

* *p < 0.01, ** p < 0.05, *** p < 0.1*

a less severe food insecurity category by 0.1 and 3 percent, respectively. On the other hand, a one percentage point increase in income loss and job loss increases the probability of a household being in the most severe food insecurity by 0.3 and 8 percent, respectively. This implies that the shocks to income and job losses caused by the COVID-19 pandemic exacerbated household food insecurity. Other studies have also shown that even short-term income and job losses have immediate negative effects on households' food security and the vulnerability of household in SSA (Smith & Frankenberger, 2018; Deaton & Deaton, 2020).

Besides the marginal effects, we also report elasticity estimates in Appendix Table 11. These show the percentage change in the probability of a household being in a higher FIES-based category of food insecurity for a one percentage change in the explanatory variables of the model. For instance, examination of the effect of the *'percentage income loss'* variable indicates that a one percent change in income loss reduces the probability of being in the *'food*

secure' category (FIES = 1) by 7 percent; in the *'mildly food insecure'* category (FIES = 2) by 6.1 percent, in the *'moderately food insecure'* category (FIES = 3) by 4.8 percent, and increases the probability of being in the *'severely food insecure'* category (FIES = 4) by about 2 percent.

Land and livestock are two important household assets in rural Africa (Mulwa & Visser, 2020; Wodajo et al., 2020). These assets can be used as productive factors (e.g., expand cultivated land or using livestock as draught animal power); as income sources (e.g., land rent income or selling animals or animal products); and as direct food sources (e.g., milk and meat). The combined effects of these assets could increase the household's capacity to withstand shocks, as stated in hypothesis 2.

Our empirical results vividly demonstrate the role that such assets play in mitigating the risk of household food insecurity due to external shocks. The negative and statistically significant (at 1% level) coefficients of '*land size*' and '*livestock size*' show that the severity level of the latent food insecurity indicator variable, FIES, decreases with increases

in these assets. In other words, households with more of these assets are less likely to fall into the more severe food insecurity categories.

Examination of the marginal effects of the two wealth indicators show that an increase in land or livestock asset holdings at the margin is associated with a 0.1 and 0.2 percent increase, respectively, in the likelihood that the household to be food secure. The marginal effects of these factors further reveal that an increase in land or livestock holdings at the margin reduce the probability of households' being in an extremely severe food insecurity status (i.e., FIES=4) by 0.3 and 0.6 percent, respectively. An important implication of this result is that building the wealth base of households is critical for improving their resilience capacity to shocks (Birhanu et al., 2017; Smith & Frankenberger, 2018). Comparing the two marginal effects, ownership of livestock plays a larger role than land for keeping households' food security during the COVID-19 shocks.

Besides the effects of income/job losses and wealth factors, we are also interested in exploring the role and significance of social capital and safety net programs of government/NGOs in mitigating household food insecurity amid the pandemic. Considering the longstanding nature of social capital among communities in African countries and the government's/NGO's claim on a large-scale provision of assistance (cash, food, and non-food) to the households; we hypothesized (see Sect. 2) that these support mechanisms from both sources could have played a significant role in safeguarding households' food security amid the pandemic. However, contrary to this claim, the results show that social capital and safety net interventions) did not provide statistically significant effects on preventing households from falling into a more severe food insecurity condition. The coefficients of both factors are not statistically significant. The plausible explanations for the insignificance of social capital could be linked to the extraordinary nature of the COVID-19 pandemic which affected everyone and left limited room for individuals and households to support one another as they used to do in the ordinary time. The government/NGO also seem to be too stretched to reach millions of vulnerable households. Logistical challenges, poor infrastructure, inefficiencies, and corrupted practices along the distribution channels could be additional explanations for the inability of external interventions in mitigating household food insecurity in Nigeria (Ozili, 2020). Additionally, Isangha et al. (2021) noted that Nigeria has totally ignored the importance of social workers which has led to palliatives being looted massively and stolen by those tasked with distribution of the relief materials while the well-being of affected people has been left to fate.[7]

The severity of food insecurity and poverty level have spatial heterogeneity in Nigeria due to differences in environmental or socio-cultural factors. For instance, the northern regions of Nigeria have been severely affected by conflicts and security threats (e.g., attacks from the Boko Haram Islamic militants) which have affected the lives and livelihoods of millions of people in the region facing hunger and acute malnutrition (Amare et al., 2018; Balana et al., 2021; Kah, 2017). In this study, we introduced a regional dummy to account for this spatial dimension of the pandemic. The findings suggest that households in the northern region of Nigeria are significantly more likely to fall into the highly severe food insecurity class. The results in Table 6 show that households in northern Nigeria are 70 percent less likely to be food secure compared to their counterparts in the rest of the regions in the country. Similarly, a typical household in northern Nigeria is 13 percent more likely to be in the most severe food insecurity group against households from non-northern regions amid the COVID-19 pandemic. Our finding is consistent with the previous studies (Amare et al., 2018; Ogunniyi et al., 2016) that report the high prevalence of food insecurity and acute malnutrition problems in northern Nigeria. The results suggest that COVID-19 pandemic may have likely aggravated the already existing food insecurity challenges in the northern Nigeria.

5.2 Factors affecting household dietary diversity scores (HDDS)

Table 8 reports the coefficients and marginal effects of covariates of the negative binomial (NB) model estimation. The NB model was run using the HDDS (as defined in Sect. 3.2) as a dependent variable on several covariates (see Sect. 3.2.1). To examine the sensitivity of different food groups (as defined in appendix Table 1) to COVID-19 induced income loss and other factors hypothesized in Sect. 2 such as wealth indicators and social capital; we run a binary logit model for the different food groups. Results from the binary logit models were reported in appendix Table 13.

As the results indicate (Table 8), the regressors are jointly statistically significant at 1% level (Wald Chi[2] (16) test statistic, p=0.000). Thus, the overall fit of the model is good. The mean of the dependent variable, 5.57, and its variance, 1.60, are significantly different, indicating that the equivalence of mean and variance assumption of the Poisson model does not hold, which justifies the use of a negative binomial model in lieu of a Poisson model. The estimated slope coefficients of nonlinear models, such as the negative binomial model, are no longer interpreted as the marginal effects (MEs) of a change in one of the regressors (x_j) on the conditional mean of the dependent variable y. The interpretation of the slope coefficients of nonlinear models and the marginal effects, which

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[7] See this web link: https://guardian.ng/saturday-magazine/covid-19-palliative-and-its-controversies-interrogating-the-looting-spree-dimension/

are calculated using different postestimation methods, have remarkable differences compared to coefficients of linear models. Specifically, in negative binomial models, given the exponential functional form of the conditional mean (Cameron & Trivedi, 2010, p.528), coefficients of the Poisson or NB models can be interpreted as semi-elasticities, i.e., the effect of a one-unit change in the regressor (or a change from zero to one in the case of binary dummy variable) on a proportionate change in the dependent variable.

In this paper, we used calculus methods to calculate the MEs of continuous variables and finite-difference methods for factor variables. Marginal effects in nonlinear models vary at the point of evaluation. The three commonly used evaluation points of MEs are: (1) MEs at the sample values and then average (i.e., average marginal effects (AME)); (2) MEs at the means of the regressors (MEM); and (3) MEs at a representative value of regressors (MER). The three ME values differ for nonlinear models. We reported AME and MEM in Table 8, though both produce very similar results. Cameron and Trivedi (2010) suggest using MEM derived using the '*atmean*' option of the '*margins*' command in Stata. However, depending on the objective of the analysis, one can use either MEM, MER or AME.

Table 8 shows that ten of the sixteen regressors included in the NB model are statistically significant at either the 1 or 5 percent levels. The results show that the direction of influence and statistical significance of the NB model coefficients and the corresponding marginal effects provide consistent information. However, we focus our analysis on the four set of factors hypothesized in Sect. 2.

Livelihood factors The three livelihood related variables considered in the HDDS estimation include percent loss in household income, household's main livelihood activity (i.e., on-farm vs. off-farm), and whether the pandemic affected jobs. Of these, the coefficients of the first two are statistically significant at 1 percent level. As expected, the results show that household's dietary diversity (HDDS) decreases with increasing income loss. Similarly, household's whose main livelihood activity is on-farm consumed fewer food groups compared to households mainly engaged in non-farm business or whose members were employees. The estimated coefficient of the livelihood activity indicator shows the dietary diversity of households with farming as their main livelihood activity is 6.3 percent less than that of non-farm households.

Assets and social capital Livestock ownership and social capital (support from family members, relatives or friends) are shown to have had positive effects on household's dietary diversity during the pandemic. Households that received remittances or other support from family members or friends increased their HDDS by 3.9 percent. A one

percentage point increase in livestock (TLU) holdings leads to a 1.1 percent increase at the margin in the diet diversity of a household. Here, the findings are consistent with a priori expectations and substantiate our hypotheses on the potential role of social capital and wealth.

Government/NGOs interventions An interesting result regards the role of government and NGO support. Despite the claim that governments and donors provided high levels of support to vulnerable Nigerian households during the pandemic, our results do not substantiate the claim. We found that support from the government and NGOs is not statistically significant in positively affecting the dietary diversity of households amid the pandemic. These results lead to rejection of our hypothesis on role of the external interventions to household food security during the COVID-19 pandemic.

Demographic variables Gender of household head, education levels, age, and household size are statistically significant in influencing the dietary diversity of households. These variables, except household size, positively influence dietary diversity. As expected, male headed and households with higher education level have better dietary diversity scores than other households. This is likely linked to the higher economic and income potential of males and educated household heads. In contrast, an increase in household size leads to a fall in the number of food types consumed at the height of the pandemic.

Geographic factors and information access A dummy variable taking a value of one for respondents from the northern regions of Nigeria and zero otherwise was introduced. In terms of nutrition status, northern Nigeria is characterized by a high prevalence of malnutrition, even before the COVID-19 pandemic (Amare et al., 2018, 2021a, b; Fadare et al., 2019). The COVID-19 pandemic has exacerbated the already dire nutritional situation of households in northern Nigeria – households in northern Nigeria are 9.3 percent worse off in their dietary diversity indicator compared to their counterparts elsewhere in the country. Regarding information access, households that have good access to COVID-19 related information are expected to have realized a 7.5 percent increase in dietary diversity than those that do not have adequate access to such information.

6 Conclusions and implications

Like governments in most countries, in response to the COVID-19 pandemic the government of Nigeria introduced restrictive policy measures. These included travel restrictions, lockdowns, and restrictions of several economic and

social activities, particularly in the initial three months of the pandemic between April and June 2020. These measures led to disruption of livelihood activities, job losses, reductions in income, increased food insecurity, and decreased dietary diversity. Using survey data collected from sampled households selected from four Nigerian states and applying descriptive analysis and econometric techniques, this study investigated the effects of the COVID-19 pandemic on the severity of household food insecurity and dietary diversity in Nigeria. The study focused on the effects of changes in four key sets of livelihoods enhancing variables – income and employment, wealth endowments, social capital, and government and NGO safety net programs. These factors were hypothesized to play significant roles in influencing households' food security and dietary diversity situation during the COVID-19 pandemic.

Our results show that income and job losses have significant negative effects on food security and dietary outcomes for households. We found that a household's food security status is highly susceptible to income losses. Regarding the wealth effect, our results show livestock ownership significantly cushioned household from falling into a more severe food insecurity situation amid the pandemic. Results on the role of social capital as a risk coping strategy indicate that the COVID-19 pandemic eroded the capacities of households and communities alike. Hence, social capital did not play the 'usual' risk-mitigating role in the times of shocks. In situation where shocks are isolated incidents, social groups in a community network respond in supporting other members. But the indiscriminate nature of the COVID-19 pandemic made the situation difficult for most people to help one another. In a similar fashion, safety net mechanisms by the government and NGOs were not significant in providing protection to households from severe food insecurity or malnutrition. This may be because such support may either be limited in scale or scope compared to the magnitude of the shock. Regional differences were seen in the likelihood of households facing food insecurity and poor diet quality amid the pandemic. Households in the northern region of Nigeria are more likely to be exposed to severe food insecurity than those in other regions.

Based on these findings, we suggest the following policy propositions: (1) People with casual and unreliable jobs seem more likely to lose those jobs and, so, are susceptible to severe food insecurity in times of shocks. Investment in job creation need to be a policy priority for government to prevent income losses and to improve the resilience of households to shocks. (2) Building the wealth and asset base of households is an important strategy in the long run to reduce vulnerability to shocks. Policy also should encourage livelihood diversification in the form of mixed crop-livestock farming systems, because livestock ownership demonstrated a positive and significant effect on food security during the shock. (3) Safety net programs and other forms of support mechanisms need to have a spatial dimension as one of their targeting criteria in Nigeria. In this regard, the northern regions of Nigeria should be prioritized to ease the household food insecurity and malnutrition burdens that arise there from shocks such as the COVID-19 pandemic.

Appendices

Table 9 Eleven food groups in original HDDS questionnaire re-grouped into seven food groups

Food group	In the last 7 days, has your household consumed *[Food Group]?* 1 = Yes, 2 = No	Re-grouped food groups used for the HDDS count construction
1. Cereals and grains (rice, maize, sorghum, millet…)		Cereals/tubers
2. Tubers and roots (cassava, yam, potatoes…)		
3. Legumes/nuts/seeds (beans, cowpeas, peanuts, lentils, soya, …)		Pulses/legumes
4. Dairy products (milk, butter, yogurt, …)		Dairy
5. Meat (beef, goat meet, sheep meat…)		Meat/Fish/Eggs/
6. Eggs		
7. Fish (shellfish, tuna, dried fish, …)		
8. Oil/fat (palm oil, vegetable oil, shea butter ….)		Oils/fats
9. Vegetables (onion, cabbage, tomatoes, carrots, pepper, pumpkin, …)		Vegetables
10. Green leafy Vegetables (spinach. Broccoli, amaranth, ….)		
11. Fruits (banana, avocado, orange, papaya, mango….)		Fruits

Table 10 Correlation matrix of the eight Food Insecurity Experience Scale (FIES) questions pre- and during the COVID-19 pandemic

FIES Qs.[†]	(V.1)	(V.2)	(V.3)	(V.4)	(V.5)	(V.6)	(V.7)	(V.8)	(V.9)	(V.10)	(V.11)	(V.12)	(V.13)	(V.14)	(V.15)	(V.16)
(V.1)	1															
(V.2)	0.401	1														
(V.3)	0.389	0.486	1													
(V.4)	0.276	0.341	0.493	1												
(V.5)	0.285	0.321	0.427	0.473	1											
(V.6)	0.305	0.31	0.422	0.477	0.532	1										
(V.7)	0.29	0.34	0.374	0.461	0.585	0.543	1									
(V.8)	0.171	0.236	0.27	0.358	0.361	0.399	0.47	1								
(V.9)	0.054	0.007	0.033	0.074	0.065	0.028	0.057	0.006	1							
(V.10)	0.036	-0.023	0.02	0.012	0.036	0.018	0.057	0.054	0.436	1						
(V.11)	0.039	0.029	0.066	0.053	0.074	0.04	0.091	0.051	0.422	0.473	1					
(V.12)	0.066	0.082	0.112	0.127	0.117	0.079	0.122	0.039	0.437	0.404	0.554	1				
(V13)	0.047	0.006	0.067	0.086	0.133	0.079	0.088	0.024	0.446	0.387	0.466	0.556	1			
(V.14)	0.052	0.081	0.127	0.14	0.151	0.202	0.164	0.126	0.308	0.307	0.355	0.483	0.465	1		
(V.15)	0.087	0.062	0.153	0.158	0.168	0.154	0.229	0.078	0.307	0.333	0.384	0.55	0.52	0.52	1	
(V.16)	0.085	0.078	0.147	0.094	0.116	0.149	0.151	0.221	0.154	0.235	0.212	0.291	0.26	0.419	0.428	1

[†] FIES Qs. = Food insecurity experience scale questions. (V.1)-(V.8) FIES questions pre-pandemic. (V.9)-(V.16)FIES questions amid the pandemic. (V.1) = 'Worried'; (V.2) 'Healthy'. (V.3) = 'Ate few'. (V.4) = 'Skipped'. (V.5) = 'Ate less'. (V.6) = 'Run out'. (V.7) = 'Hungry'. (V.8) = 'Whole Day'. Variables (V.9)—(V.16) denote the same FIES questions as in (V.1) (V.8), but responses for the amid COVID-19 period

Table 11 Elasticities of covariates, post-estimation of ordered logit model for Food Insecurity Experience Scale (FIES) (n = 1031)

Variable name	Elasticity FIES = 1 (ey/ex)	Standard error (FIES = 1)	Elasticity FIES = 2 (ey/ex)	Standard error (FIES = 2)	Elasticity FIES = 3 (ey/ex)	Standard error (FIES = 3)	Elasticity FIES = 4 (ey/ex)	Standard error (FIES = 4)
HH income loss amid-COVID (%)	-0.702***	0.139	-0.612***	0.126	-0.484***	0.106	0.171***	0.028
HH job affected by COVID-19 (yes = 1)	-0.173***	0.064	-0.151***	0.058	-0.121**	0.049	0.041***	0.012
Received family/friends support (yes = 1)	0.012	0.036	0.010	0.031	0.008	0.023	-0.003	0.010
Received gov./NGO support (yes = 1)	-0.049	0.032	-0.044	0.030	-0.037	0.027	0.009**	0.004
Land size owned (ha)	0.056***	0.019	0.042***	0.013	0.027***	0.008	-0.022**	0.009
Livestock size owned (TLU)	0.070***	0.018	0.047***	0.009	0.026***	0.004	-0.035***	0.012
HH in rural area (yes = 1)	0.028	0.119	0.024	0.099	0.017	0.072	-0.009	0.037
Location Northern states (yes = 1)	0.164***	0.040	0.122***	0.026	0.072*	0.013	-0.072***	0.023
HH head male (yes = 1)	0.096	0.092	0.077	0.073	0.054	0.050	-0.033	0.033
HH head age (years)	0.479*	0.267	0.391*	0.216	0.279*	0.153	-0.156*	0.090
Household size (#)	0.052	0.142	0.043	0.116	0.031	0.082	-0.017	0.047
HH head married (yes = 1)	0.198	0.147	0.160	0.118	0.112	0.081	-0.067	0.051
Education above secondary (yes = 1)	0.200**	0.086	0.162**	0.068	0.114**	0.046	-0.068**	0.032
HH livelihood on-farm (yes = 1)	-0.004	0.090	-0.003	0.075	-0.002	0.055	0.001	0.028
HH member migrated_ COVID-19 (yes = 1)	-0.043	0.032	-0.039	0.030	-0.032	0.026	0.009**	0.005
Access to COVID-related info (yes = 1)	-0.351	0.242	-0.292	0.203	-0.215	0.151	0.106	0.072

Table 12 Estimation results of ordered logit model (for FIES) and poison model (for HDDS), (with different livelihood activities) (n = 1031)

Variable name	Ordered logit models (for FIES)				Negative binomial (NB) models (for HDDS)			
	Livelihood activities grouped as farm vs. non-farm		Livelihood activities grouped into four categories (with causal/ unemployed as a base category)		Livelihood activities grouped as farm vs. non-farm		Livelihood activities grouped into four categories (with causal/ unemployed as a base category)	
	Coefficient	Std. error (Robust)	Coefficient	Std. error (Robust)	Coefficient	Std. error (Robust)	Coefficient	Std. error (Robust)
HH income loss amid-COVID (%)	0.017***	0.003	0.017***	0.003	-0.001***	0.000	-0.001***	0.000
HH job affected by COVID-19 (yes = 1)	0.446***	0.161	0.466***	0.162	-0.023	0.015	-0.022	0.015
Received family/friends support (yes = 1)	-0.063	0.198	-0.079	0.199	0.039 **	0.018	0.038**	0.018
Received gov./NGO support (yes = 1)	0.418	0.272	0.415	0.274	-0.027	0.028	-0.025	0.027
Land size owned (ha)	-0.019***	0.007	-0.020***	0.007	0.001	0.001	0.001	0.001
Livestock size owned (TLU)	-0.033***	0.009	-0.032***	0.009	0.002 ***	0.001	0.002***	0.001
HH in rural area (yes = 1)	-0.043	0.180	-0.045	0.181	0.023	0.016	0.023	0.016
Location Northern states (yes = 1)	-0.705***	0.181	-0.718***	0.184	-0.093 ***	0.020	-0.092***	0.020
HH head male (yes = 1)	-0.176	0.168	-0.151	0.171	0.035 **	0.016	0.035**	0.016
HH head age (years)	-0.013*	0.007	-0.011	0.007	0.002 **	0.001	0.002**	0.001
Household size (#)	-0.007	0.019	-0.008	0.019	-0.005 ***	0.002	-0.005***	0.002
HH head married (yes = 1)	-0.283	0.211	-0.286	0.211	0.028	0.019	0.028	0.019
Education above secondary (yes = 1)	-0.383**	0.167	-0.337**	0.172	0.056 ***	0.016	0.059***	0.016
HH main livelihood on-farm (yes = 1)	0.007	0.165	-0.101	0.342	-0.063 ***	0.014	-0.068**	0.029
HH main livelihood business (yes = 1)	-	-	0.109	0.391	-	-	0.006	0.032
HH livelihood employee (yes = 1)	-	-	-0.296	0.383	-	-	-0.014	0.031
HH member migrated (yes = 1)	0.450	0.323	0.461	0.325	0.004	0.027	0.006	0.026
Access to COVID-related info (yes = 1)	0.412	0.283	0.434	0.286	0.075 ***	0.028	0.074**	0.027

FIES Food insecurity experience scale, *HDDS* Household dietary diversity score, *HH* Household, *ha* hectare, *TLU* Tropical Livestock Unit

* $p < 0.01$, ** $p < 0.05$, *** $p < 0.1$

Table 13 Estimation results of binary logit models (by food groups defined in HDDS) (n = 1031)

Key variables	Cereals and roots		Legumes and pulses		Dairy		Protein		Oils and fats	
	Coefficient	Std. error (Robust)	Coefficient	Std. error (Robust)	Coefficient	Std. error (Robust)	Coefficient	Std. error (Robust)	Coefficient	Std. error (Robust)
HH income loss amid-COVID (%)	0.004	0.010	-0.009***	0.003	-0.009***	0.003	-0.009**	0.005	-0.028***	0.007
HH job affected by COVID-19 (yes = 1)	-0.129	0.512	-0.029	0.163	-0.021	0.145	-0.077	0.229	0.197	0.353
Received family/friends support (yes = 1)	0.249	0.645	0.096	0.204	0.369**	0.178	0.583*	0.325	0.543	0.514
Received gov./NGO support (yes = 1)	-1.593***	0.525	-0.091	0.245	0.094	0.220	-0.137	0.334	0.449	0.645
Land size owned (ha)	-0.025	0.017	0.025	0.022	0.005	0.011	-0.009	0.011	-0.014	0.013
Livestock size owned (TLU)	0.006	0.024	0.009	0.014	0.034***	0.012	0.031	0.018	-0.011	0.013
	4.253***	0.520	1.433***	0.192	-0.192	0.149	2.448	0.252	4.400***	0.417

HDDS Household dietary diversity score, *HH* Household, *ha* hectare, *TLU* Tropical Livestock Unit

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 14 OLS estimation results for food insecurity experience scale (FIES)[†] and household dietary divert score (HDDS)[‡] (n = 1031)

Variable name	OLS model for FIES			OLS model HDDS		
	Coefficient	Standard error	t-values	Coefficient	Standard error	t-values
HH income loss amid-COVID (%)	0.021***	0.003	7.19	-0.011***	0.003	-4.10
HH job affected by COVID-19 (yes = 1)	0.455***	0.162	2.80	-0.208	0.140	-1.48
Received family/friends support (yes = 1)	-0.056	0.200	-0.28	0.353**	0.173	2.04
Received gov./NGO support (yes = 1)	0.252	0.246	1.03	-0.148	0.214	-0.69
Land size owned (ha)	-0.024**	0.012	-2.04	0.008	0.010	0.83
Livestock size owned (TLU)	-0.043***	0.012	-3.70	0.028***	0.010	2.71
HH in rural area (yes = 1)	0.116	0.177	0.66	0.122	0.153	0.80
Location Northern states (yes = 1)	-1.120***	0.189	-5.94	-1.208***	0.164	-7.37
HH head male (yes = 1)	-0.094	0.167	-0.56	0.313**	0.144	2.17
HH head age (years)	-0.017**	0.007	-2.31	0.012*	0.006	1.89
Household size (#)	0.013	0.019	0.70	-0.033**	0.016	-2.03
HH head married (yes = 1)	-0.213	0.195	-1.09	0.209	0.169	1.24
Education above secondary (yes = 1)	-0.402**	0.165	-2.44	0.600***	0.143	4.21
HH livelihood on-farm (yes = 1)	0.048	0.165	0.29	-0.611***	0.142	-4.29
HH member migrated_COVID-19 (yes = 1)	0.377	0.265	1.43	-0.036	0.230	-0.15
Access to COVID-related info (yes = 1)	0.624**	0.296	2.11	0.404	0.258	1.57
Constant	5.002**	0.485	10.32	7.833***	0.420	18.65
Model diagnostics for FIES				Model diagnostics for HDDS		
Mean dependent var	5.333			Mean dependent var	8.133	
F-test	9.577			F-test	10.839	
Akaike crit. (AIC)	3877.159			Akaike crit. (AIC)	3623.114	
SD dependent var	2.472			SD dependent var	2.159	
Number of obs	1031			Number of obs	1031	
Prob > F	0.000			Prob > F	0.000	
Bayesian crit. (BIC)	3957.987			Bayesian crit. (BIC)	3703.923	

[‡]For the OLS model both FIES and HDDS were measured as continuous variables by summing of the 'yes/no' responses for the eight FIES questions (see Table 1) and the 'yes/no' responses on consumption of the eleven food groups (see appendix Table 9), respectively

* $p < 0.01$, ** $p < 0.05$, *** $p < 0.1$

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Declarations

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