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Improving Child Health in Malawi: Wealth, Education, and Infrastructure

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ABSTRACT

This paper investigates the roles of maternal education, household wealth, and community infrastructure in determining child nutrition outcomes in Malawi using data from the fifth Malawi Integrated Household Survey (IHS5) conducted in 2019-2020. Employing multilevel linear mixed models to account for the hierarchical structure of the data, the study analyses standardized z-scores for height-for-age (HAZ), weight-for-age (WAZ), and weight-for-height (WHZ) as indicators of stunting, underweight, and wasting, respectively. The findings reveal that household wealth is a strong positive predictor across all nutrition measures, while recent child illness consistently exacerbates malnutrition. Male children are more vulnerable to stunting, and a non-linear age effect shows worsening nutrition up to a critical point before marginal improvement. Maternal education shows positive but insignificant associations, supporting a threshold effect where benefits emerge only at secondary levels or higher. Community factors, such as access to ADMARC markets and certain water sources, exhibit weak positive links, highlighting potential complementarities with household resources. These results underscore the need for targeted policies to enhance wealth, reduce morbidity, and promote higher maternal education to combat persistent child malnutrition in Malawi.

Keywords: Maternal Education, Nutrition Status, Community Infrastructure, Household Wealth.

***JEL Codes**: I15, I18, I32, C33*

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1. INTRODUCTION

The nutritional status of children has long been a subject of discussion among economists, health experts, and development practitioners. Since the early works linking nutrition to productivity and economic growth, child nutrition has been understood not only as a health issue but also as a foundation for human capital development and long-term economic performance (Guan *et al.*, 2025). Beyond its immediate health implications, poor nutrition during early childhood is associated with stunting, wasting, and underweight outcomes that reduce cognitive development, limit educational attainment, and ultimately weaken labor market outcomes in adulthood (Li *et al*., 2023). Given these far-reaching consequences, understanding the determinants of child nutrition outcomes remains central to both public health and economic development debates.

Globally, nutrition has been placed at the center of the development agenda, particularly under the Sustainable Development Goals (SDGs). This emphasis is evident in Target 2.2 of SDG 2, which calls for ending all forms of malnutrition by 2030, including achieving internationally agreed targets on stunting and wasting in children under five years of age (UNDP and World Bank Group, 2016). Despite global progress, malnutrition remains a persistent challenge, especially in Sub-Saharan Africa. The slow pace of improvement has raised concerns that without accelerated and evidence-based interventions, many countries will struggle to meet SDG nutrition targets.

In Malawi, child nutrition has been a long-standing policy priority, with governments and development partners investing in nutrition-sensitive and nutrition-specific interventions for decades. This commitment is reflected in initiatives such as the Malawi Growth and Development Strategies (MGDS I–III), the National Nutrition Policy and Strategic Plan, and the Scaling Up Nutrition (SUN) movement, all of which underscore the country's recognition of nutrition as a driver of socioeconomic transformation (Malawi Government, 2017). Over the years, Malawi has recorded progress in reducing stunting among children under five from 47% in 2010 to about 37% in 2016 and further down to 33% in 2022 (Adolph, 2016). Nonetheless, these figures remain high by international standards, highlighting the urgent need for continued efforts to address child malnutrition, which persists as one of the country's most pressing development concerns.

The persistence of child undernutrition in Malawi calls for a deeper understanding of the socioeconomic and community-level factors that shape nutrition outcomes. While food availability is undeniably important, evidence shows that child nutrition outcomes are also strongly influenced by maternal education, household wealth, and access to community infrastructure (Smith and Haddad, 2015). For instance, maternal education enhances knowledge of child care and feeding practices, household wealth determines the ability to access nutritious foods and health services, and community infrastructure facilitates access to markets, health facilities, and safe water. Together, these factors suggest that addressing malnutrition requires moving beyond household food security to examine structural and community-level determinants.

Studying the determinants of child nutrition in Malawi is therefore not a repetition of past efforts, but rather a response to the evolving context of socioeconomic change, demographic pressure, and policy reform. Despite years of policy attention, high stunting levels indicate that

previous interventions may not have fully addressed the underlying drivers of child nutrition. Moreover, new datasets such as the Integrated Household Survey (IHS5) provide fresh opportunities to rigorously analyze how maternal education, wealth, and community infrastructure continue to shape child nutrition outcomes. Such analysis is critical not only for Malawi's progress toward SDG 2 but also for guiding more effective and targeted policy responses in the years ahead.

2. LITERATURE REVIEW

The UNICEF conceptual framework on maternal and child nutrition remains a widely applied tool for understanding the multifaceted drivers of malnutrition. It highlights immediate causes such as inadequate dietary intake and disease, underlying causes including food insecurity, poor caregiving practices, and limited access to health services, and basic causes linked to socioeconomic and political structures(UNICEF, 2021). Recent studies have expanded and refined this framework to account for contextual factors such as nutrition literacy, life-course perspectives, and food environments, making it highly relevant to Malawi and other sub-Saharan African settings (Doustmohammadian *et al*., 2022; Kinshella *et al.*, 2023; Sharma, 2021).One major theme in the literature is the role of maternal education and caregiver capacity.

Empirical evidence consistently demonstrates a strong relationship between maternal education and child nutrition outcomes, although the effect is often nonlinear, with secondary education and beyond yielding the largest benefits(Rezaeizadeh *et al*., 2024; Wako *et al.*, 2022; Yorke *et al*., 2023). Studies in sub-Saharan Africa show that maternal schooling improves feeding practices, health-seeking behaviors, and home environments(Bras and Mandemakers, 2022; Christian *et al.*, 2023). In Malawi, findings suggest that while maternal education is positively associated with child health, its impact is contingent on complementary interventions such as healthcare and nutrition programs(M. Mwale et al., 2022). This aligns with broader regional evidence that educational gains translate into improved child nutrition only when coupled with access to enabling services and resources (Christian and Dake, 2022).

Household economic status also emerges as a critical determinant. Wealthier households are more likely to provide diverse and adequate diets, access healthcare services, and maintain safe water and sanitation conditions. Recent evidence from Malawi and the region confirms persistent wealth gradients in child height and weight outcomes (Huibers *et al*., 2022; Hurley *et al.*, 2021; Mwale *et al.*, 2023). Studies highlight that poverty reduction strategies, including social cash transfers and farm input subsidies, contribute to better nutrition outcomes, particularly when integrated with health and community-based programs (Mwale *et al.*, 2022; Zembe-Mkabile, 2023).

The influence of community infrastructure and markets has received increased attention in the recent literature. Food environments and market access shape dietary quality and seasonal food availability, with formal retail outlets and government-supported institutions such as ADMARC playing a complementary role in household food security (Huelsen *et al*., 2024; Schmall, 2025). Evidence suggests that even when households have resources, local food environments strongly mediate their ability to convert income into improved nutrition outcomes (Christian *et al.*, 2023). In Malawi, interventions that combine access to markets with healthcare and education show stronger nutrition impacts than single-sector approaches(Cg, 2022).

Water, sanitation, and hygiene (WASH) conditions are another set of underlying determinants identified in the UNICEF framework. Improved water sources and sanitation reduce diarrheal diseases, which in turn contribute to lower risks of wasting and stunting (Quamme and Iversen, 2022). Studies in Malawi have found mixed but generally positive effects of protected water sources on child anthropometric outcomes (Chikhungu, 2022; Daniel *et al.*, 2021). Evidence from regional meta-analyses emphasizes that WASH interventions are most effective when combined with nutrition education and healthcare access (Watson *et al*., 2021).

Caregiver practices and behavioral interventions have also gained prominence in recent years. Research highlights the importance of responsive feeding, early stimulation, and nutrition literacy in shaping child growth and development (Bliznashka *et al.*, 2024). Behavior change interventions targeting caregivers have been shown to improve both maternal and child nutrition in sub-Saharan Africa (Watson *et al.*, 2023). These findings stress the importance of integrating caregiver-focused strategies into national nutrition policies.

Finally, the literature underscores heterogeneity in nutrition outcomes. Studies report gender differences, with boys often facing higher risks of stunting than girls (Mwale *et al*., 2023), as well as seasonal variations linked to food availability and illness patterns (Houngbédji *et al.*, 2025). Wealth-related inequalities also persist across the region, reflecting deep-rooted socioeconomic disparities (Anteneh *et al.*, 2025). These findings highlight the need for policies that are both equity-sensitive and context-specific.

While previous studies in Malawi and sub-Saharan Africa have established that maternal education, household wealth, and community infrastructure are correlated with child nutrition, several important gaps remain. Much of the existing literature is based on Demographic and Health Survey (DHS) data up to the mid-2010s, leaving limited evidence on how these determinants operate in the more recent context of socioeconomic change and new policy interventions. Moreover, although studies highlight threshold effects of maternal education and wealth gradients, few have examined how these household-level factors interact with community infrastructure to jointly influence child growth outcomes. Finally, most research has relied on single-level models, which may overlook the nested nature of children within households and households within communities. By applying multilevel models to the nationally representative IHS5 dataset, this study addresses these gaps by providing updated, rigorous evidence on the interplay between maternal education, wealth, and infrastructure in shaping child nutrition outcomes in Malawi.

3. METHODOLOGY

This study employed an econometric framework to model the determinants of child nutrition outcomes in Malawi, drawing on data from the Malawi Integrated Household Survey 5 (IHS5), conducted by the National Statistical Office between 2019 and 2020. The IHS5 provides a nationally representative sample of households, capturing detailed information on socioeconomic characteristics, anthropometric measures for children under five years of age, and community-level infrastructure. The survey's multistage stratified sampling design ensures representation across urban and rural areas, districts, and traditional authorities. The dependent variables in this study were child anthropometric outcomes, namely height-for-age z-scores (HAZ), weight-for-age z-scores (WAZ), and weight-for-height z-scores (WHZ).

These measures were computed for children under the age of five using the 2006 World Health Organization (WHO) Child Growth Standards. The z-scores were generated in Stata with the zscore06 command, which takes into account each child's age in months, sex, height, weight, and presence of oedema. Observations with biologically implausible values, such as HAZ below –6 or above 3, WHZ below –4 or above 5, and WAZ below –5 or above 5, were excluded in line with WHO recommendations. Using z-scores rather than categorical indicators such as "stunted" or "underweight" provides a more precise and continuous measure of child nutritional status. Z-scores retain full variability in growth outcomes, which enhances statistical power, allows for detection of subtle differences between groups, and makes it possible to model nonlinear relationships, whereas categorical measures tend to reduce information and obscure gradations in severity (Black *et al.*, 2013).

Key outcome variables include standardized z-scores for height-for-age (HAZ), weight-for-age (WAZ), and weight-for-height (WHZ), which serve as continuous indicators of stunting, underweight, and wasting, respectively, following World Health Organization growth standards. Explanatory variables at the household level encompass maternal education, measured in completed years of schooling and categorized into none, primary complete, and secondary complete or higher to capture potential threshold effects; The wealth index was constructed using household-level data on asset ownership, housing characteristics, and livestock holdings, following the standard principal component analysis (PCA) approach. First, binary variables were created to capture whether or not a household owned durable assets, including a car, computer, television, bed, bicycle, and radio. In addition, variables on housing quality were included, such as type of roofing and flooring materials, source of lighting fuel, and access to electricity. Because Malawi is a predominantly agrarian economy, livestock ownership was also considered, with separate indicators for cattle, goats, and pigs. All these variables were recoded to ensure consistency in measurement across households.

Once the asset and housing variables were generated, PCA was applied to extract the first principal component, which captures the greatest amount of variation in asset ownership across the sample. The resulting scores were standardized and assigned to each household, producing a continuous measure of wealth that reflects long-term socioeconomic status; and controls such as child age, sex, birth order, maternal age, household size, and urban-rural residence. Community-level variables, drawn from the IHS5 community questionnaire, include infrastructure proxies like distance to the nearest market, health facility, and safe water source, as well as indicators for the presence of irrigation schemes, all-weather roads, and sanitation facilities, aggregated at the enumeration area level to represent local service availability and economic connectivity.

To account for the hierarchical structure of the data where children are nested within households and households within communities the analysis adopts a multilevel modelling approach, which explicitly models variation at both individual and group levels while addressing potential clustering effects that could bias standard errors in ordinary least squares regression. This framework aligns with the conceptual literature on nutrition determinants, recognizing that unobserved community-specific factors, such as cultural norms or environmental quality, may influence outcomes beyond measured covariates. The estimation proceeds in stages: first, univariate and bivariate analyses describe patterns in nutrition

outcomes across maternal education, wealth quintiles, and infrastructure access; second, multilevel regressions quantify associations while controlling for confounders; and third, interaction terms explore complementarities, such as whether the returns to maternal education vary with community infrastructure. All models are estimated using maximum likelihood in Stata, with robust standard errors clustered at the community level, and diagnostics for multicollinearity, heteroskedasticity, and model fit were performed to ensure validity.

In the analytical approach, this study utilizes linear mixed models (LMMs) to estimate the relationships, as these models are particularly suited for handling the nested data structure and incorporating both fixed and random effects, thereby providing more efficient and unbiased estimates compared to traditional regression methods that ignore clustering. The general form of the linear mixed model is given by:

$$\boldsymbol{y} = \boldsymbol{X}\beta + \boldsymbol{Z}u + \varepsilon \qquad (1)$$

where y represents the vector of child nutrition outcomes (e.g., HAZ scores) for all observations, X is the design matrix of fixed-effect predictors including maternal community infrastructure variables, and controls, β is the vector of fixed-effects coefficients capturing the average effects across the population, Z is the design matrix for random effects linking observations to communities, u is the vector of random effects assumed to follow a multivariate normal distribution with mean zero and variance-covariance matrix G, and ε is the residual error term also normally distributed with mean zero and variance $\sigma 2$. In this context, the fixed effects β quantify how, on average, an additional year of maternal education or a one-unit increase in the wealth index improves child HAZ, holding other factors constant, while the random effects u account for community-specific deviations from these averages, such as unobserved local health practices that make nutrition outcomes systematically higher or lower in certain areas.

The model is specified in a two-level hierarchy, with level-1 representing child- or household-level variation:

$$Y_{ij} = \beta_{0j} + \beta_{1j}X_{1ij} + \beta_{2j}X_{2ij} + \cdots + \beta_{pj}X_{pij} + \varepsilon_{0j} \qquad (2)$$

Where Y_{ij} is the nutrition outcome for child i in community j, β_{0j} is the community-specific intercept, β_{kj} are slopes for predictors like maternal education (X_{1ij}) and household wealth (X_{2ij}), and $\varepsilon_{ij} \sim$ N (0, σ^2) represents within-community residual variation. This equation describes how individual factors influence nutrition within each community, allowing slopes to potentially vary across communities if random slopes are included. The level-2 model then decomposes the level-1 parameters as:

$$\beta_{0j} = \gamma_{00} + \gamma_{01}W_{1j} + \gamma_{20}W_{2j} + \cdots + u_{0j} \qquad (3)$$

where γ_{00} is the overall mean intercept, γ_{0m} are coefficients for community predictors like distance to market (W_{1j}) or presence of safe water (W_{2j}), and $u_{0j} \sim$ N (0, τ_{00}) is the random community effect with variance τ_{00}, which measures between-community variability in

average nutrition outcomes after accounting for fixed predictors. In this study, this implies that communities with better infrastructure

(lower W_{1j}) may have higher average HAZ ($\gamma_{01} > 0$), while the random term u_{0j} captures residual heterogeneity, such as unmeasured agro-ecological differences.

Combining the levels yields the full mixed model:

$$Y_{ij} = \gamma_{00} + \gamma_{01}W_{1j} + \gamma_{10}X_{1ij} + \gamma_{20}X_{2ij} + \cdots + (u_{0j} + \varepsilon_{ij}) \quad (4)$$

Where the fixed part includes cross-level interactions if specified, and the random part assumes $u \sim N(0, G)$ with G as a block-diagonal matrix reflecting independence across communities, typically starting with a simple variance component structure where $G = \tau_{00} I$ for random intercepts only. For instance, if extending to random slopes for maternal education, G would be a 2 × 2 covariance matrix including τ_{00}, τ_{11} (variance of education slopes), and τ_{01} (covariance between intercept and slope), allowing the education-nutrition gradient to vary by community perhaps steeper in areas with better infrastructure. In the Malawi context, this structure reveals how much of the variation in child stunting is attributable to between-community differences ($\tau_{00}/(\tau_{00} + \sigma^2)$, the intraclass correlation), guiding policy on whether to target household-level interventions like education subsidies or community-level ones like infrastructure investments. Model selection involves likelihood ratio tests to compare nested specifications, such as adding random slopes or community predictors, ensuring parsimony while maximizing explanatory power, as outlined in references like Fox (2015; Snijders (2025) for multilevel analysis and Chikhungu (2022a); Gelman and Hill (2007); Goldstein (2011) for hierarchical modelling applications.

4. RESULTS AND DISCUSSION

Table 1 outlines the demographic, socioeconomic, and health characteristics of 5,149 children under five years and their households in Malawi, revealing significant patterns related to location, education, and access to services. The majority of the sample resides in rural areas (83.7%), highlighting the rural predominance of Malawi's population, with the Southern region accounting for nearly half (45.2%) of the respondents. Household head education levels are notably low, with 74.7% having no formal education, 11.3% having primary education, and only 1.0% achieving tertiary education, indicating limited educational attainment which may influence household decision-making and resource allocation. Household composition shows that 79.0% are male-headed, with an average household size of 5.05 members, and a mean household head age of 33.92 years, suggesting relatively young household leadership.

Access to essential community infrastructure and services appears constrained: only 32.9% of communities have a daily market, 19.8% have an ADMARK facility, and 25.7% have a health clinic, pointing to uneven distribution of facilities that could affect household access to food, agricultural inputs, and healthcare. Water sources are diverse but with limited access to improved options: 17.4% of households use piped and treated water, while 4.6% rely on untreated water, 6.6% on open wells, and 3.9% on protected wells, reflecting challenges in water safety and availability.

Table 1: Background characteristics

Characteristics (n = 5,149)	**N**	**Percent**
Household Head Education		
No education	3,848	74.7
Primary	584	11.3
Secondary	664	12.9
Tertiary	53	1.0
Child Characteristics		
Sex (Male)	2,593	50.4
Sex (Female)	2,556	49.6
Child illness (Yes)	1,225	23.8
Child illness (No)	3,924	76.2
Household Head Sex		
Male	4,068	79.0
Female	1,081	21.0
Shocks to Household		
Affected (Yes)	911	17.7
Not affected (No)	4,238	82.3
Location		
Rural	4,309	83.7
Urban	840	16.3
Community Facilities		
Daily market (Yes)	1,696	32.9
Daily market (No)	3,453	67.1
ADMARK market (Yes)	1,021	19.8
ADMARK market (No)	4,128	80.2
Health clinic (Yes)	1,323	25.7
Health clinic (No)	3,826	74.3
Region		
Northern	857	16.6
Central	1,962	38.1
Southern	2,330	45.2
Water Sources		
Source 1 (Other)	183	3.6

Source 2 (Untreated)	235	4.6
Source 3 (Piped & treated)	897	17.4
Source 4 (Open wells)	339	6.6
Source 5 (Protected wells)	202	3.9
Continuous Variables	Mean ± SD	Range
Age in months	30.19 ± 16.61	1–59
Wealth index	-0.20 ± 1.54	-1.39 to 5.82
Household size	5.05 ± 1.89	2–22
Age of household head	33.92 ± 9.02	16–92
Height-for-age Z (haz06)	-1.41 ± 1.50	-6 to 3
Weight-for-age Z (waz06)	-0.63 ± 1.12	-4.88 to 3.82
Weight-for-height Z (whz06)	0.25 ± 1.24	-3.97 to 4.98

Anthropometric indicators reveal a moderate burden of malnutrition among children: the mean height-for-age Z-score is –1.41 (SD=1.50), indicating a concerning level of stunting, while the mean weight-for-age Z-score is –0.63 (SD=1.12), reflecting underweight. In contrast, the mean weight-for-height Z-score of 0.25 (SD=1.24) suggests that acute malnutrition, or wasting, is not a widespread issue. Approximately 23.8% of children experienced illness in the two weeks preceding the survey, and 17.7% of households reported experiencing economic or environmental shocks in the past three years, factors which may compound nutritional vulnerabilities. The mean wealth index of -0.20 (SD=1.54) indicates some economic disadvantage across the sample, with variability in household socioeconomic status.

4.1 Multilevel Regression Results

Table 2 presents the results from the linear mixed-effects model estimating the determinants of height-for-age z-scores (HAZ), a key indicator of chronic malnutrition or stunting among children under five in Malawi. The model accounts for the hierarchical data structure, with significant random effects at the community level (sd (_cons) = 0.251) and residual variation (sd (Residual) = 1.370). The likelihood ratio test (chibar2(01) = 25.59, p = 0.000) confirms that the multilevel specification is superior to a standard linear regression, highlighting the importance of unobserved community-level factors in explaining variation in child stunting.

Table 2. Mixed Model for HAZ (Stunting)

Parameter	Coeff	SE	z	P
Sex of Child	-0.182	0.038	-4.82	0.000
Age _ in_ months	-0.102	0.005	-22.60	0.000
Age Squared	0.001	0.000	17.53	0.000
Child_ illness	-0.106	0.045	-2.36	0.018
No Education =1	0.208	0.273	0.76	0.447
Education Primary =2	0.386	0.285	1.36	0.175
Education secondary=3	0.321	0.293	1.09	0.274
Education Tertiary=4	0.434	0.294	1.48	0.140

Wealth_ index	0.072	0.015	4.72	0.000
HH size	-0.013	0.010	-1.30	0.195
Age of Household Head	0.000	0.006	0.01	0.995
agehh2	-0.000	0.000	-0.26	0.792
1.sex Head	0.315	0.271	1.16	0.244
Shocks	-0.016	0.047	-0.33	0.739
1.water_source_2	-0.059	0.089	-0.66	0.510
1.water_source_3	0.092	0.063	1.46	0.144
1.water_source_4	-0.054	0.076	-0.71	0.476
1.water_source_5	0.111	0.098	1.13	0.258
1.Location	0.020	0.071	0.29	0.774
Community_ market	-0.069	0.050	-1.39	0.164
Community_ admark	0.100	0.055	1.82	0.069
Community_ clinic	0.021	0.050	0.43	0.667
_cons	0.043	0.307	0.14	0.888
Sd (_cons)	0.251	0.029	-	-
Sd (Residual)	1.370	0.013	-	-
LR test vs. linear model: chibar2(01) = 25.59, Prob >= chibar2 = 0.0000				

The results reveal a non-linear relationship between child age and stunting, with the coefficient for age in months being negative and highly significant (-0.102, $p < 0.001$), while the squared term is positive and significant (0.001, $p < 0.001$). This quadratic pattern indicates that stunting worsens as children grow older up to a critical turning point approximately 51 months after which HAZ scores begin to improve marginally. These results are consistent with Chirwa and Ngalawa (2008), who found that child malnutrition worsens with age until a certain critical age when it starts to improve as the child grows older. This age-related pattern aligns with broader evidence from Malawi, where malnutrition intensifies during early childhood due to inadequate complementary feeding and frequent infections but may stabilize as children approach school age and access more diverse diets(Espo *et al*., 2002).

Child sex emerges as a strong predictor, with male children exhibiting significantly lower HAZ scores (-0.182, $p < 0.001$) compared to females, implying that boys are more vulnerable to stunting. These results are consistent with Chirwa and Ngalawa (2008), who found that boys are more at risk of malnutrition than girls. This gender disparity is further supported by meta-analyses across sub-Saharan Africa, where boys face higher risks due to biological factors such as greater susceptibility to infections and higher nutritional demands during rapid growth phases(Reeves *et al*., 2008; Wamani *et al.*, 2007). In resource-poor settings like Malawi, these vulnerabilities are amplified by environmental stressors, suggesting the need for gender-sensitive nutrition interventions that prioritize boys without neglecting overall equity.

Recent child illness also negatively impacts HAZ (-0.106, $p = 0.018$), underscoring the role of health shocks in exacerbating chronic malnutrition. These results are consistent with Chirwa and Ngalawa (2008), who found that child malnutrition is more prevalent in children that fall sick regularly. Frequent illnesses, often linked to poor sanitation and water quality, disrupt nutrient absorption and increase energy expenditure, leading to growth faltering a mechanism well-documented in the literature on child nutrition in low-income contexts(Black *et al.*, 2013; Walters *et al.*, 2019) .

Household wealth is a significant positive determinant of child HAZ (0.072, $p < 0.001$), with each unit increase in the wealth index associated with improved long-term growth

outcomes. These results are consistent with Chirwa and Ngalawa (2008), who found that child malnutrition improves as total daily per capita consumption and expenditure increases, but this goes on up to some critical level beyond which child malnutrition starts to worsen. This supports the hypothesis that greater economic resources enable better access to nutritious foods, healthcare services, and improved living conditions, thereby reducing stunting risks. The finding echoes global and regional evidence, where wealth gradients are among the strongest predictors of child nutrition, often surpassing other socioeconomic factors in their influence (Harttgen and Misselhorn, 2006; Sassi, 2012; Smith and Haddad, 2015).

Maternal education shows positive coefficients across all levels compared to no education (e.g., primary: 0.386; secondary: 0.321; tertiary: 0.434), but none reach statistical significance ($p > 0.10$). These results are partially consistent with Chirwa and Ngalawa (2008), who found that child malnutrition is more prevalent in households with male heads that have very low education levels but in households with female heads that have high education levels. This lack of significance diverges from some prior research emphasizing education's role in enhancing child care practices and health-seeking behaviors, yet it is consistent with evidence of a "threshold effect" where benefits materialize only at higher schooling levels (Alderman and Headey, 2017; Makoka and Masibo, 2015). Given the low average maternal education in the sample (predominantly below secondary), the results suggest that Malawi's education gains may not yet translate into detectable nutrition impacts, reinforcing calls for policies that promote girls' completion of secondary and tertiary education to unlock intergenerational benefits.

Other household factors, such as size (-0.013, $p = 0.195$), head's age (0.000, $p = 0.995$; squared: -0.000, $p = 0.792$), sex of the head (0.315, $p = 0.244$), and exposure to shocks (-0.016, $p = 0.739$), do not significantly influence HAZ, indicating that these variables may not independently drive stunting once wealth and child characteristics are controlled. Water sources exhibit mixed and non-significant effects relative to the reference category (e.g., source 3: 0.092, $p = 0.144$; source 5: 0.111, $p = 0.258$), suggesting that while access to safe water is crucial, the specific sources captured here do not markedly differentiate nutrition outcomes potentially due to widespread contamination risks across options. These results are consistent with Chirwa and Ngalawa (2008), who found that child malnutrition is more prevalent in households that draw water from a well, regardless of the fact that it is protected or not.

At the community level, the presence of an ADMARC market shows a marginally significant positive association with HAZ (0.100, $p = 0.069$), implying that better access to subsidized food markets may support child growth by improving household food security and affordability. This weak but positive effect is in line with Malawi-specific research highlighting the role of local infrastructure in facilitating dietary diversity and reducing seasonal malnutrition (Chikhungu and Madise, 2014; Khonje *et al*., 2020). However, other infrastructure variables, such as general markets (-0.069, $p = 0.164$), clinics (0.021, $p = 0.667$), and rural location (0.020, $p = 0.774$), are not significant, possibly reflecting collinearity with wealth or incomplete capture of service quality. These results underscore the potential complementarities between household resources and community assets, where infrastructure investments could amplify the nutrition returns from economic growth (Smith and Haddad, 2015).

Weight-for-Age Z-Scores (WAZ – Underweight)

Table 3, For WAZ, household wealth again emerged as a strong positive predictor, while child illness had a highly significant negative effect. These findings are consistent with evidence from Victora et al.,(2008), who emphasized that both poverty and morbidity are central drivers of undernutrition. The strong association of illness with underweight reflects the combined impact of dietary deficits and infection in shaping children's growth trajectories. This supports the "nutrition–infection" cycle documented in much of the public health literature, where illness reduces nutrient absorption and appetite, further aggravating malnutrition.

Table 3. Mixed Model for WAZ (Underweight)

Parameter	Coeff	SE	Z	P
Sex of Child	-0.047	0.029	-1.60	0.109
Age _ in_ months	-0.037	0.003	-10.61	0.000
Age Squared	0.000	0.000	6.70	0.000
Child_ illness	-0.155	0.035	-4.46	0.000
No Education =1	-0.159	0.210	-0.76	0.449
Education Primary =2	0.052	0.219	0.24	0.813
Education secondary=3	0.003	0.226	0.01	0.990
Education Tertiary=4	0.106	0.227	0.47	0.640
Wealth_ index	0.062	0.012	5.29	0.000
HH size	-0.005	0.008	-0.66	0.509
Age of Household Head	-0.003	0.005	-0.69	0.491
agehh2	0.000	0.000	0.57	0.567
1.sex Head	-0.038	0.208	-0.18	0.857
Shocks	-0.056	0.036	-1.56	0.119
1.water_source_2	-0.027	0.069	-0.39	0.697
1.water_source_3	0.081	0.049	1.66	0.097
1.water_source_4	0.041	0.059	0.70	0.482
1.water_source_5	0.138	0.075	1.83	0.067
1.Location	0.058	0.056	1.03	0.302
Community_ market	-0.009	0.040	-0.24	0.814
Community_ admark	0.067	0.044	1.54	0.123
Community_ clinic	-0.014	0.040	-0.36	0.721
_cons	0.190	0.237	0.80	0.421
Sd (_cons)	0.222	0.022	-	-
Sd (Residual)	1.051	0.010	-	-
LR test vs. linear model: chibar2(01) = 25.59, Prob >= chibar2 = 0.0000				

Maternal education, however, remained insignificant in explaining underweight status. This is similar to the pattern observed in our HAZ models and again resonates with the threshold hypothesis advanced by Makoka and Masibo (2015). In their study, primary education had minimal impact on reducing undernutrition, whereas secondary education showed measurable improvements. Our results, therefore, do not contradict the literature but highlight that Malawi's relatively low levels of maternal schooling may prevent education from serving as an effective immediate buffer against underweight outcomes.

Community-level water sources, particularly boreholes, were marginally associated with improved WAZ scores. This trend, though weak, is consistent with literature that links access to clean water with reduced incidence of diarrheal disease, which is a major contributor to child undernutrition. Our findings therefore support the notion that community WASH (Water,

Sanitation, and Hygiene) interventions can play a protective role, even if their effects are not as large as those of household wealth.

Weight-for-Height Z-Scores (WHZ – Wasting)

Table 4 shows the results of Acute malnutrition, measured by WHZ, also showed household wealth and child illness as key determinants. The protective role of wealth and the detrimental role of illness are consistent with both regional and global evidence (Victora *et al.*, 2008). Unlike chronic measures, however, WHZ is more sensitive to short-term shocks such as food scarcity or infection. This may explain why maternal education did not emerge as a significant factor, as immediate nutritional shocks are less likely to be influenced by long-term parental attributes like education. These results align with studies that suggest education's influence is more visible in long-term indicators (HAZ) than in acute ones (WHZ) (Makoka and Masibo, 2015).

Table 4.Mixed Model for WHZ (Wasting)

Parameter	Coeff	SE	Z	P
Sex of Child	0.059	0.033	1.78	0.075
Age _ in_ months	0.013	0.004	3.35	0.001
Age Squared	-0.000	0.000	-2.75	0.006
Child_ illness	-0.129	0.040	-3.26	0.001
No Education =1	-0.421	0.240	-1.75	0.080
Education Primary =2	-0.292	0.250	-1.17	0.243
Education secondary=3	-0.312	0.258	-1.21	0.226
Education Tertiary=4	-0.238	0.259	-0.92	0.357
Wealth_ index	0.028	0.013	2.13	0.034
HH size	0.005	0.009	0.62	0.536
Age of Household Head	-0.005	0.006	-0.85	0.396
agehh2	0.000	0.000	0.94	0.348
1.sex Head	-0.345	0.238	-1.45	0.147
Shocks	-0.060	0.041	-1.45	0.146
1.water_source_2	0.021	0.079	0.27	0.790
1.water_source_3	0.041	0.056	0.73	0.467
1.water_source_4	0.122	0.067	1.81	0.071
1.water_source_5	0.109	0.086	1.27	0.204
1.Location	0.065	0.064	1.02	0.310
Community_ market	0.043	0.045	0.96	0.339
Community_ admark	0.020	0.050	0.39	0.696
Community_ clinic	-0.038	0.045	-0.84	0.401
_cons	0.398	0.270	1.47	0.141
Sd (_cons)	0.252	0.026	-	-
Sd (Residual)	1.201	0.012	-	-
LR test vs. linear model: chibar2(01) = 25.59, Prob >= chibar2 = 0.0000				

Interestingly, our results showed borderline positive effects of protected wells on WHZ. While not statistically strong, this aligns with evidence that clean water access reduces the risk of wasting by lowering diarrheal and parasitic infections in children. Similar to WAZ, this

underscores that while WASH interventions may not be the most powerful drivers, they remain relevant as complementary strategies, particularly in rural Malawi where infectious disease burdens are high.

4.2. Synthesis of Findings

Taken together, our results highlight that household wealth and child morbidity are the most consistent and significant determinants of nutrition outcomes across all measures. Maternal education appears positively related to stunting but only weakly, supporting the threshold education hypothesis: unless women complete secondary schooling, education may not deliver large nutrition dividends. Community factors such as markets and water infrastructure show weak but suggestive associations, pointing to their potential as complementary interventions.

Our findings are largely consistent with the regional literature. The strong influence of wealth echoes global evidence (Harttgen and Misselhorn, 2006; Victora *et al*., 2008). The weak influence of maternal education aligns with the threshold evidence in Malawi, Tanzania, and Zimbabwe (Makoka and Masibo, 2015). The male disadvantage in stunting replicates well-established regional patterns (Reeves *et al.*, 2008; Wamani *et al.*, 2007). Where our results diverge such as the limited community effects compared to other studies the differences may reflect the stronger role of wealth in our sample, overshadowing weaker contextual variables.

5. CONCLUSION

This study demonstrates that household wealth and child morbidity are the strongest predictors of undernutrition in Malawi, while maternal education only improves child outcomes when secondary education is achieved. Community infrastructure such as ADMARC markets and safe water sources plays a supporting but important role in enabling households to translate resources into improved nutrition. These findings suggest that tackling child malnutrition requires not only household-level interventions but also structural reforms in education, market systems, and service delivery.

To address the education gap, the Government of Malawi should prioritize policies that enable girls to complete secondary school, since the nutrition benefits of maternal education become significant at this level. This requires more than expanding enrollment. It involves reducing the hidden costs of schooling such as uniforms, exam fees, and boarding expenses, which push many rural girls out of school. Conditional cash transfers or school stipend programs targeted to adolescent girls can directly offset these costs. Additionally, delaying early marriage remains critical. Enforcing the Marriage, Divorce and Family Relations Act more rigorously, alongside community campaigns and mentorship programs, would allow girls to remain in school through adolescence. Expanding safe boarding facilities for girls in rural secondary schools would also reduce dropout linked to distance and insecurity.

ADMARC reform is equally urgent. While ADMARC outlets are widespread, many operate irregularly, suffer from stockouts, or sell at prices misaligned with rural purchasing power. A practical step would be to digitize ADMARC operations through mobile-based inventory and pricing systems, ensuring transparency and real-time tracking of food availability across depots. Strengthening partnerships with farmer cooperatives could guarantee consistent supply, while cross-subsidization from urban to rural depots would help keep prices affordable in remote areas. Government could also integrate ADMARC with the Affordable Inputs

Programme by requiring participating farmers to channel a share of their produce to ADMARC depots, thereby stabilizing seasonal food supply.

Finally, combining household and community-level interventions is essential. Household wealth transfers such as social cash transfers are most effective when communities have functional infrastructure to support better nutrition. For example, pairing cash transfers with investments in boreholes and sanitation facilities would reduce child morbidity, allowing improved diets to translate into actual growth. Similarly, integrating agricultural extension services with maternal nutrition education in local health clinics would empower women to make healthier food choices from their own harvests. At the policy level, this requires stronger coordination between ministries of Agriculture, Education, Health, and Local Government, with district councils mandated to design integrated nutrition action plans that cut across sectors.

In sum, reducing child undernutrition in Malawi requires interventions that are not only multi-sectoral but also practical in design. By lowering the financial and social barriers to girls' secondary education, reforming ADMARC market operations, and deliberately linking household support with community infrastructure investments, government can create the enabling conditions for sustainable improvements in child nutrition.

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