Early-Year Milk Price and Child Stunting in Zambia

Chungmann Kim

Department of Agricultural and Consumer Economics

University of Illinois Urbana-Champaign

ck24@illinois.edu

Abstract

This study investigates the impact of early-life food price fluctuations on child stunting in Zambia, focusing on milk—a key nutrient source during critical growth periods. By linking historical food price data with the 2018 Zambia Demographic Household Survey (DHS), we create a comprehensive dataset to analyze how price increases during a child's early years (particularly from 12 to 24 months) correlate with stunting outcomes. The results indicate that elevated milk prices in early childhood are significantly associated with a higher risk of stunting for children aged 24 to 59 months, with effects notably pronounced in urban areas and among low-income households. This study uniquely identifies the critical timing during which price spikes in nutrient-dense foods like milk contribute to stunting, providing essential insights for targeting interventions. Our findings offer a valuable foundation for policy strategies aimed at safeguarding vulnerable groups from nutritional deficits in times of economic strain, thereby reducing long-term health disparities associated with early-life malnutrition.

Keywords: Price Shock, Child Malnutrition, Food Security, Zambia

JEL Classification: I15, Q18, O12

1 Introduction

Child undernutrition remains a critical global issue, with nearly 30% of children under five years of age experiencing stunting or wasting Delia Grace et al. [2018]. These conditions are defined by height-for-age or weight-for-height z-scores that fall at least two standard deviations below the 2006 World Health Organization (WHO) standard. Food price fluctuations are a primary determinant of child malnutrition Behrman and Deolalikar [1988]. During the global food price crisis of 2007–2008, numerous households were forced to reduce both the quantity and quality of food consumed Sanogo [2009], which led to widespread undernutrition. Sharp food price increases have especially detrimental effects on nutrition among vulnerable groups, such as children in low- and middle-income countries Headey et al. [2018]. Even brief periods of poor nutrition in early childhood can have lasting consequences Alderman [2006], D'Souza and Jolliffe [2014]. While extensive research has been conducted on the relationship between food prices and child malnutrition, only a few studies consider the specific biological periods when children are most susceptible to economic shocks. Understanding this temporal sensitivity is essential to understand the mechanism linking food price fluctuations and malnutrition Woldemichael et al. [2022].

In Zambia, a sharp rise in food prices occurred in late 2015 Bertelsmann Stiftung [2018], yet the effects of this inflation on child nutrition, particularly among young children, remain insufficiently studied. In this paper, we link historical food price data to the latest Zambia Demographic Health Survey (DHS) 2018 to examine the relationship between early-childhood food prices—specifically fresh milk and mealie meal—and stunting among children under five years of age. Our analysis accounts for child and household characteristics and includes various fixed effects to ensure robust results. Additionally, we assess how the impact of food prices varies across socioeconomic groups.

Our findings suggest that elevated milk prices during early childhood significantly increase the risk of stunting among children under five, particularly those aged 24 to 59 months who have completed their critical first two years. This heightened vulnerability may be due to milk's role as an essential dietary supplement post-breastfeeding Organization [2021]. The effect is particularly pronounced in urban areas and among poorer households. Specifically, a 1% increase in milk prices between 12 and 24 months is associated with an increase in stunting rates of 0.906% to 1.711% in urban settings.

The structure of the paper is as follows: Section 2 provides a literature review; Section 3 describes the data used in the analysis; Section 4 presents descriptive statistics; Section 5 outlines the empirical model and identification strategy; Section 6 discusses the results; Section 7 presents robustness checks; and Section 8 concludes with policy implications and limitations.

2 Literature Review

The relationship between food prices and consumption among vulnerable populations is critical to understanding child health outcomes. Economists have historically approached nutrition as a function of wealth and food availability [Behrman and Deolalikar, 1988]. During the global food price crisis of 2007–2008, significant efforts were made to assess the crisis's impact on welfare at the country, regional, and household levels [Arndt, 2016, D'Souza and Jolliffe, 2014]. For example, studies by de Brauw [2011] and D'Souza and Jolliffe [2012] demonstrate an inverse relationship between food prices and child nutrition in El Salvador and Afghanistan, respectively. Specifically, de Brauw [2011] found that rising domestic food prices in 2008 were associated with a decline in height-for-age among children under five.

Price effects on nutrition are not uniform but vary across socioeconomic groups. Households with different income levels face distinct constraints in coping with economic shocks. Wealthier households may liquidate assets to maintain consumption levels [Carter and Lybbert, 2012]. Additionally, wealthier households typically consume a more diversified diet with relatively expensive foods, in line with Bennett's law [Bennett, 1941]. As prices increase, these households have the flexibility to substitute for cheaper foods, whereas poorer households, who already consume low-cost foods, have limited options for substitution [D'Souza and Jolliffe, 2014]. Jensen and Miller [2008] highlight that as prices rise, the poorest households have fewer options to switch to alternative foods compared to less impoverished groups. In such scenarios, poorer households prioritize caloric intake over nutrient-rich foods, resulting in chronic malnutrition over the long term [de Brauw, 2011].

While the relationship between prices and nutrition has been extensively examined, dietary diversity has only recently become a focal point for economists. Much of the economic analysis on hunger has concentrated on caloric intake, often disregarding the implications of micronutrient deficiencies, which can lead to chronic health conditions such as stunting [D'Souza and Jolliffe, 2014]. Semba et al. [2016] emphasize that protein intake is crucial for combating child malnutrition, especially in low-income countries. This study has spurred further research into the importance of animal-sourced diets rich in catalytic proteins, which are essential for bone and skeletal muscle development [Headey et al., 2018]. In extensive work across 49 countries, Headey et al. [2018] found that the prices of animal-sourced foods significantly influence children's linear growth and consumption patterns. Subsequent research by Headey and Alderman [2019] examined relative caloric prices across various food categories in 176 countries, demonstrating that higher milk prices correlate with increased child stunting rates globally. Further studies have confirmed the positive association between milk consumption and improved linear growth in multiple contexts [Grace et al., 2014, Iannotti, 2014, Hoddinott et al., 2015, Haile and Headey, 2023].

Although a substantial body of nutrition-economics literature has identified economic factors as primary contributors to malnutrition, few studies consider the timing of exposure to food inflation, a critical determinant of health outcomes [Woldemichael et al., 2022]. Timing is essential; stunted children frequently remain stunted, with limited evidence of catch-up growth within the first five years in developing countries [Leroy, 2014, Martorell et al., 1994]. Environmental-nutrition literature addresses this by linking early-life temperature and rainfall anomalies to malnutrition metrics [McMahon and Gray, 2021, Randell et al., 2020]. For instance, higher rainfall during early life has been shown to enhance women's adult health outcomes [Dewey and Begum, 2011, Maccini and Yang, 2009]. In rural Zimbabwe, Hoddinott and Kinsey [2001] observed that children exposed to droughts between 12 and 24 months of age suffered up to 2 cm of growth loss.

The quality of diet in early childhood has lasting effects on development, making it crucial to introduce nutrient-rich complementary foods during the critical 6–24 month period to prevent growth faltering [Dewey and Begum, 2011, Organization, 2021]. These studies collectively suggest that dietary and environmental exposures within the first two years of life are pivotal to long-term growth outcomes.

The mechanisms linking food prices and child malnutrition in developing countries are multifaceted and context-specific, with factors such as timing playing a crucial role [Arndt, 2016, Woldemichael et al., 2022]. This study focuses on Zambia, drawing on several foundational observations: (1) an increasing share of household expenditure on dairy products [Harris et al., 2019],

(2) the importance of animal-source proteins in early childhood development [Organization, 2021], (3) the critical dietary transition from breastfeeding to complementary foods within the first two years of life, and (4) evidence that stunting, once established, is difficult to reverse [Leroy, 2014, Martorell et al., 1994].

Our contribution to the literature is twofold: first, we analyze how early-life food prices impact stunting in later years, using historical price data on both staple and nutrient-dense foods. Second, we investigate how the price effects vary by region and household socioeconomic characteristics, enhancing understanding of economic influences on child malnutrition.

3 Data

3.1 Child Nutrition

We utilize household survey data from the Zambia Demographic Health Surveys (DHS) 2018 [International, 2018] to capture key variables essential for our empirical analysis. The DHS data provides extensive information on child nutrition, including child anthropometric measurements. Specifically, we use child stunting as the nutritional outcome, defined as a height-for-age z-score (HAZ) below two standard deviations from the World Health Organization standards [Organization, 2006].

Beyond the nutritional outcome, we incorporate household-level attributes (e.g., wealth index, household size, number of under-five members, mother's education level), livestock and agricultural assets (e.g., ownership of livestock, agricultural land, and dairy cows), child-level characteristics (e.g., child age in months, sex), and health environment variables (e.g., poor water source indicator).

Alderman and Headey [2018] recommend focusing on children who have completed their first two years of life when examining child growth determinants. Furthermore, children who remain in the environments where they initially became stunted, as is common in developing countries, often show minimal catch-up in growth later in life [Leroy, 2014]. Thus, we restrict our sample to children older than 24 months, resulting in data availability for 4,541 children from 494 clusters. A complete description of the dataset is provided in Appendix 1.

3.2 Zambia Price Data

We use district-level monthly price data from the Zambia Central Statistical Office (CSO), covering the period from January 2013 to December 2018, to align with the DHS 2018 data. Our analysis centers on the prices of mealie meal (Zambian Kwacha per 25 kg) and fresh milk (Zambian Kwacha per 500 ml) to infer consumption patterns of both staple and nutrient-dense foods. Mealie meal, made from ground dry maize, is used to prepare Nshima, Zambia's staple food, and represents a substantial portion of household food expenditure.

We select fresh milk for three reasons: (1) dairy products account for a growing share of Zambia's food expenditure basket [Harris et al., 2019], (2) dairy products (e.g., milk) are consumed more frequently and in larger quantities compared to other animal-sourced foods (e.g., flesh foods, eggs) [Headey et al., 2018], and (3) milk consumption within the dairy category is particularly associated with improvements in child linear growth, as evidenced by multiple studies [Choudhury and Headey, 2017, Grace et al., 2014, Rawlins, 2014, Walker, 1991].

3.3 Linking DHS to Average Prices in the Key Developmental Period of Child Growth

Historical price data enables us to construct a price measure (referred to as the early-year average price) that captures price movements during the key developmental period specific to each child. The price index is calculated as follows:

$$\text{Early Year Average Price}^{C}_{d,b(t)} = \frac{1}{N-n+1}\sum_{t=n}^{N}\text{Price}^{C}_{d,b(t)} \tag{1}$$

where the subscript d denotes the district, b represents the birth year-month for each child, n and N indicate the start and end months defining the key developmental period, and the superscript C refers to the commodity, either fresh milk or mealie meal.

We determine b based on the year-month of the survey and the child's age in months. This allows us to calculate the average price of each food item during the critical period when children are introduced to complementary foods in the Zambian context. The criteria for defining the relevant time boundaries (n and N) will be explained in detail in the next section.

4 Descriptive Analysis

4.1 Prevalence of Stunting

To contextualize age-specific trends in malnutrition, we plot the prevalence of stunting by child age in Figure 1. The graph illustrates the predicted stunting rates among urban children in Zambia by age group, using data from the Zambia Demographic and Health Surveys (DHS) for 2007, 2013, and 2018. The stunting rates, measured as the percentage of children with a height-for-age z-score below two standard deviations, are plotted along the age range from 1 to 59 months.

For each survey year, the stunting rates increase with age, peaking between 18 and 24 months, and then plateauing or gradually decreasing after this age range. The trend lines for 2007 and 2013 are similar in shape and level, while the 2018 line generally shows lower stunting rates across the age spectrum.

Additionally, we compare the difference between the 2018 data and an age-gender specific reference based on the combined 2007 and 2013 data across age groups. This difference line hovers near zero in the earliest ages and then remains below zero for most of the age groups, indicating a lower stunting rate in 2018 relative to the earlier reference years. A marker is placed around the age group corresponding to children who would have been 12 months old in October 2015, the time of a noted price shock. This marker identifies a specific cohort potentially affected by this event. Overall, the graph presents stunting rates by age and year, showing changes in predicted stunting levels over time and including reference points and markers for additional context.

(Insert Figure 1 here.)

However, as shown in Figure 2 in rural areas, however, there is no observable difference between the age-gender specific reference (based on the combined 2007 and 2013 data) and the 2018 DHS data across age groups. The difference line, which compares 2018 stunting rates to the reference, remains close to zero across most age groups, indicating that stunting rates in rural areas did not exhibit the same decline observed in urban areas. This suggests stability in rural stunting levels between the 2007-2013 baseline and 2018, with no significant reduction across the age spectrum.

(Insert Figure 2 here.)

4.2 Diet Transition: From Breastfeeding to Milk Complement

To understand how changes in food prices affect child malnutrition, it is essential to examine the dietary transition that occurs during early childhood, particularly within the specific context of Zambia. This period typically involves a shift from exclusive breastfeeding to the introduction of complementary foods, including milk-based supplements, which play a critical role in a child's nutritional intake.

In Zambia, this dietary transition is crucial, as children move from relying solely on breast milk to requiring additional sources of nutrition that provide essential proteins, fats, and micronutrients. Identifying the age groups undergoing this transition helps to pinpoint those most vulnerable to fluctuations in food prices. By understanding these diet patterns, we can better assess which groups of children are at the greatest risk of adverse nutritional impacts due to rising prices of key foods, such as milk and other animal-sourced products.

(Insert Figure 3 here.)

Figure 3 shows the declining trend in breastfeeding rates among Zambian children, with a sharp drop after the first year of life. By the age of 18–24 months, breastfeeding has become uncommon. In contrast, milk consumption rates increase steadily as children grow older, reflecting a shift toward milk-based dietary complementation.

A clear rural-urban divide is apparent in these dietary patterns. Urban children experience a faster decline in breastfeeding and an earlier transition to milk complementation than their rural counterparts. Milk consumption rates are approximately 8% in urban areas, about twice as high as in rural areas.

The 12–24 month age range emerges as a critical period for analyzing the relationship between food prices and child malnutrition. During this second year of life, children undergo a major dietary transition from breastfeeding to milk complementation. This period also marks the onset of cumulative effects of malnutrition, especially stunting [Headey et al., 2018].

4.3 Price Trends in Zambia (2013–2018)

Figure 4 presents price trends in Zambia from 2013 to 2018. We first take the natural logarithm of each price series and adjust for inflation using the monthly Consumer Price Index (CPI) provided by the World Bank [Bank, 2022]. To capture seasonality and smooth periodic fluctuations, we calculate a 3-month rolling average for mealie meal prices, reducing short-term variation that may not significantly impact consumer experiences.

To address missing values, we apply linear interpolation over time. Additionally, we exclude districts with fewer than 30 months of price data collected by the Central Statistical Office (CSO) for each commodity. After this adjustment, district-level food prices are available for 64 out of 72 districts. This data processing approach preserves the underlying price trends while accounting for seasonal and periodic variations as shown in Figure 4 which demonstrates the price data processing results.

(Insert Figure 4 & 5 here.)

Inflation in Zambia rose sharply in October 2015, peaking in February 2016. This surge was triggered by a steep depreciation of the Kwacha against the US dollar, driven by multiple factors: declining copper prices linked to China's economic slowdown, uncertainty in the mining sector, a stronger US dollar, a deteriorating current account balance, a widening fiscal deficit, and a downgrade of Zambia's sovereign rating [Bertelsmann Stiftung, 2018].

5 Methodology

5.1 Model Specification

We estimate the following reduced-form specification to model child stunting status as a function of food price measures and household- and child-level characteristics, inspired by the nutrition production function [Behrman and Deolalikar, 1988]:

$$y_i = \beta_0 + \beta_1 \cdot \frac{1}{N-n+1} \sum_{t=n}^{N} \log \text{price}_{b,d(t)}^{\text{Fresh Milk}} + \beta_2 \cdot \frac{1}{N-n+1} \sum_{t=n}^{N} \log \text{price}_{b,d(t)}^{\text{Mealie Meal}}$$
$$+ \theta \cdot \text{HH}_h + \phi \cdot \text{Child}_i + \gamma \cdot \text{FE} + \epsilon_i$$

where the variable y_i denotes the stunting status of child i (a binary dependent variable equal to 1 if the child is stunted) in household h and cluster c. HH_h represents a vector of observed characteristics of household h, Child_i represents a vector of child-level variables, and ϵ_i is an idiosyncratic error term.

The main variable of interest is the inflation-adjusted milk price during month t of early life (where $t = [12, 24]$ represents the month of exposure), which varies by district d and birth cohort (or year-month of birth) b. We also control for the simultaneous price change of mealie meal, the main staple food in Zambia. Since household purchasing decisions are influenced by relative price movements, omitting this variable could bias our coefficient of interest [D'Souza and Jolliffe, 2014].

We introduce various fixed effects, γ, to the model to further isolate the effect of changes in milk price. Fixed effects (FE) are specified at either the cluster or household level, capturing both observed and unobserved time-invariant characteristics within these groups. With these fixed effects, the relationship between price and nutrition status is identified primarily from cluster- or household-level variations in prices.

To test the robustness of our model, we alter the exposure boundary of the price indices to $t = [0, 12]$ and re-estimate the model. This approach helps to validate that linking second-year milk prices with stunting status is an effective strategy to investigate the mechanism between early-year milk prices and child stunting. We expect no significant coefficients when adjusting the price boundary to $t = [0, 12]$, as most children in Zambia at this age rely predominantly on breastfeeding rather than milk consumption (see Figure 3).

Although estimating the reduced-form relations does not provide structural coefficients, it offers a reliable framework for analyzing how changes in market prices relate to various health outcomes [Behrman and Deolalikar, 1988]. Reduced-form demand estimates for health, nutrition, and other health-related inputs are common in the literature [D'Souza and Jolliffe, 2012, 2014, Headey et al., 2018, Headey and Alderman, 2019, Headey and Martin, 2016].

5.2 Estimation Strategy

We estimate parameters using both the linear probability model (LPM) and the correlated random effects (CRE) probit model. The linear probability model with fixed effects simplifies the interpretation of coefficients, though it only provides a linear approximation to the average partial effects.

As an alternative estimation strategy, the CRE probit model incorporates traditional random effects as a special case and allows us to test the key random effects assumption that heterogeneity is independent of time-varying covariates [Wooldridge, 2013a]. In this approach, we model the unobserved cluster or household effect as a function of the data, which introduces what is known as the Mundlak effect [Wooldridge, 2013b]. Specifically, we add the means of time-varying covariates (e.g., price measures) to the model and estimate them with random effects probit. This approach enables us to obtain the average partial effects for each commodity price, providing a more comprehensive understanding of the distribution of effects across the sample.

6 Results

6.1 Descriptive Statistics

Table 1 in the Appendix provides descriptive statistics for the variables included in the model, disaggregated by region and wealth group. Across wealth groups, we observe a decreasing trend in negative characteristics associated with child or household conditions, such as stunting rate, use of a bad water source, recent diarrhea incidence, and the number of children under five in the household, as wealth increases. In contrast, positive indicators such as mother's education level, ownership of dairy cows, and ownership of livestock increase with wealth. Due to district-level data collection, there is minimal variation in prices across groups.

Mother's education levels are notably higher in urban areas compared to rural areas, where only 3% of mothers have completed secondary school. Although we use a region-adjusted wealth index, urban households are nearly three times wealthier than rural households. As expected, a substantial majority of rural households own land for agriculture (80.7%) and livestock (67.5%), whereas ownership of land (22.3%) and livestock (17.6%) is considerably lower in urban areas. Furthermore, a significantly smaller proportion of children in urban areas are exposed to a bad water source compared to their rural counterparts.

Given that (1) there is a clear distinction between urban and rural areas and (2) DHS samples are stratified by cluster and by urban/rural areas within each cluster, we split the sample by region in the empirical analysis.

6.2 Balance Test

To assess baseline differences in nutritional status, we focus on children aged 24 to 60 months who had already completed their first two years of life by the time of analysis. Table 1 presents balance tests at birth between two groups: those who were less than 12 months old at the time of the October 2015 price shock and those who were 12 months or older. Key nutritional indicators, including birth weight, birth size (categorized as average, larger than average, smaller than average, very large, and very small), and early feeding practices (whether the child was given anything other than breast milk within the first three days), show minimal differences between groups.

(Insert Table 1 here.)

For instance, the difference in birth weight is -0.038 kg, and the difference in the proportion of children classified as "average" size at birth is -0.001. None of the differences across these measures are substantial, suggesting that there were no systematic baseline differences in nutritional status at birth between the groups. This balance test indicates that our analysis is not likely to be confounded by pre-existing differences in birth-related nutritional factors between children who were less than 12 months old and those who were 12 months or older during the price shock, according to the 2018 Zambia DHS data.

6.3 Estimation Results

Our primary estimation results are presented in Appendix 3. Focusing on the relationship between relative price movements and stunting, the main parameter of interest is the milk price coefficient.

This coefficient is statistically significant and positive, indicating that an increase in early-year milk prices (at $t = [12, 24]$ months) is associated with a higher stunting rate on average. The association is notably more robust among children in urban areas, which aligns with the dietary transition patterns shown in Figure 2. Since urban children typically cease breastfeeding and transition to milk-based complementary feeding earlier than their rural counterparts, they are more likely to be affected by increases in milk prices during this critical developmental period.

In contrast, we find the effect of mealie meal prices to be statistically insignificant, suggesting that early-life stunting is less sensitive to staple food prices, consistent with the findings of Arndt [2016]. For comparison, we report both the coefficients from the Linear Probability Model (LPM) and the average partial effects from the Correlated Random Effects (CRE) probit model with varying levels of fixed effects. While the signs of the estimates remain consistent across models and fixed effect levels, the magnitudes are lower in the CRE probit model but increase when household fixed effects are included.

We also test for wealth specific price effects as shown in Figure 6. The four graphs illustrate how food price changes impact stunting risk across wealth groups in urban and rural Zambia. In urban areas, Fresh Milk shows a strong association between higher milk prices and increased stunting, especially among poorer children, suggesting that milk price stability could reduce malnutrition in low-income urban households. In contrast, "Fresh Milk - Rural" shows minimal impact of milk prices on stunting in rural areas, likely due to continued breastfeeding or alternative diets. Both "Mealie Meal - Urban" and "Mealie Meal - Rural" indicate little effect of mealie meal prices on stunting, implying that stunting is less sensitive to staple food prices. Overall, these results highlight the need for targeted interventions, with milk price support potentially benefiting urban low-income families the most.

7 Robustness Check

Zambia experienced multiple drought events during the study period of 2013 to 2018 [Chipili, 2021]. To account for these weather events, which may influence both price fluctuations and child nutritional outcomes, we incorporate extreme weather variables into our model. Monthly mean temperature and precipitation data are sourced from the Moderate Resolution Imaging Spectroradiometer (MODIS) and the Climate Hazards Group Infrared Precipitation with Stations (CHIRPS) datasets.

Specifically, we use the MYD11C3 Version 6 MODIS product to obtain monthly Land Surface Temperature and Emissivity (LST&E) values, which are available at a spatial resolution of 0.05 degrees (approximately 5,600 meters at the equator) [Wan et al., 2021]. CHIRPS provides high-resolution (0.05 degrees) precipitation data spanning semi-global latitudes (50°S–50°N) based on a combination of satellite observations and in situ station data, capturing precise precipitation patterns [Funk et al., 2015]. Using Zambia's district shapefile, we extract district-level mean temperature (°C) and precipitation (mm) for each month from 2002 to 2018.

For this analysis, we define a month as "extremely hot" if the district's monthly temperature exceeds the 95th percentile relative to the full 2002–2018 temperature record. Similarly, a month is classified as "extremely dry" if district-level precipitation falls below the 5th percentile relative to the historical precipitation record. We then generate binary indicators for these extreme weather events — "hot" and "no rain" — based on the occurrence of these conditions during key developmental periods for each child. These indicators are averaged to obtain district-level monthly means for each period.

To validate our approach of linking second-year prices to stunting outcomes, we expand the analysis to include alternative exposure periods: the first year of life ($t = [0, 12]$) and the prenatal period ($t = [-10, 2]$), demonstrating the robustness of our second-year price-stunting linkage.

As demonstrated in Appendix 5, the association between second-year milk prices and stunting in urban areas remains robust across various model specifications, even as additional confounding factors, such as droughts and extreme heat events, are introduced. Although the magnitude of this association decreases with the inclusion of these variables, the core linkage persists, indicating resilience to potential biases arising from the endogeneity of price measures.

In Appendix 6, we further confirm the specificity of the second-year price effect by altering the time boundary (t) to include either the first year ($t = [0, 12]$) or the prenatal period ($t = [-10, 2]$). These adjustments yield no significant association, which aligns with the observation that most children in Zambia consume minimal milk and rely primarily on breastfeeding during their first year of life (see Figure 2).

8 Conclusion

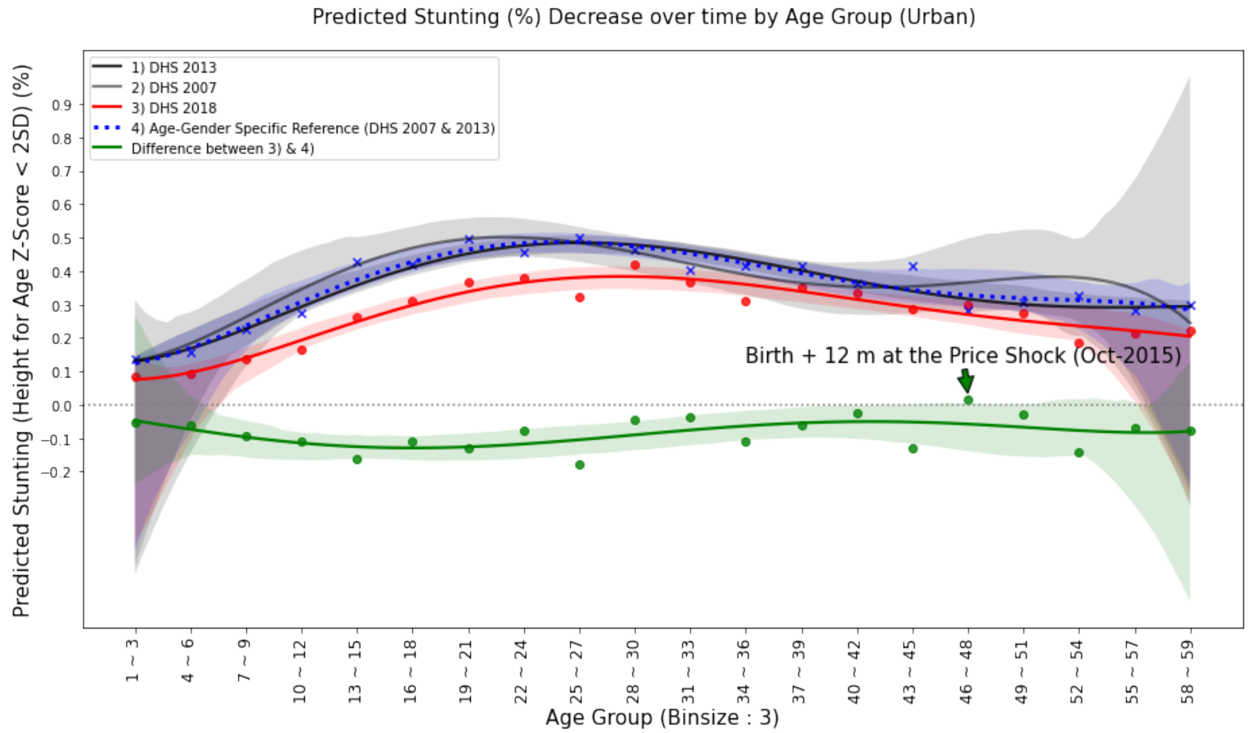
Understanding the timing at which price changes most strongly impact chronic malnutrition helps to pinpoint critical intervention periods to reduce stunting risk. Identifying groups vulnerable to price fluctuations provides further insight into underlying mechanisms. Our analysis reveals that early-year milk prices are significantly associated with stunting among poorer urban households, likely due to dietary transitions in these areas (see Figure 2). Specifically, a 1% increase in milk prices during months 12 to 24 is statistically associated with a 0.906% to 1.711% increase in stunting rates in urban areas. This finding aligns with Thomas and Strauss [1992], who reported that higher dairy prices are associated with shorter stature in children, with a stronger effect observed in urban settings.

The evidence suggests that high milk prices during the early years of life, especially the second year, constitute a major risk factor for stunting among children aged 24 to 59 months in Zambia, particularly in urban settings where breastfeeding is often supplemented with milk at an earlier stage compared to rural areas. The sensitivity to milk prices in the early years likely reflects the critical role of milk as a key supplement to breastfeeding. Our findings extend previous work by Headey et al. [2018], who highlighted the importance of animal-source foods but did not emphasize the timing of price increases as a determinant of stunting risk.

Although our econometric models control for a broad array of factors and remain robust across different specifications and adjustments for price endogeneity, we underscore that these results indicate associations rather than causal relationships. Nevertheless, our study highlights the significant impact of early-life animal-source food prices, such as milk, on child stunting, and we hope it encourages further research aimed at uncovering the causal mechanisms underlying this relationship.

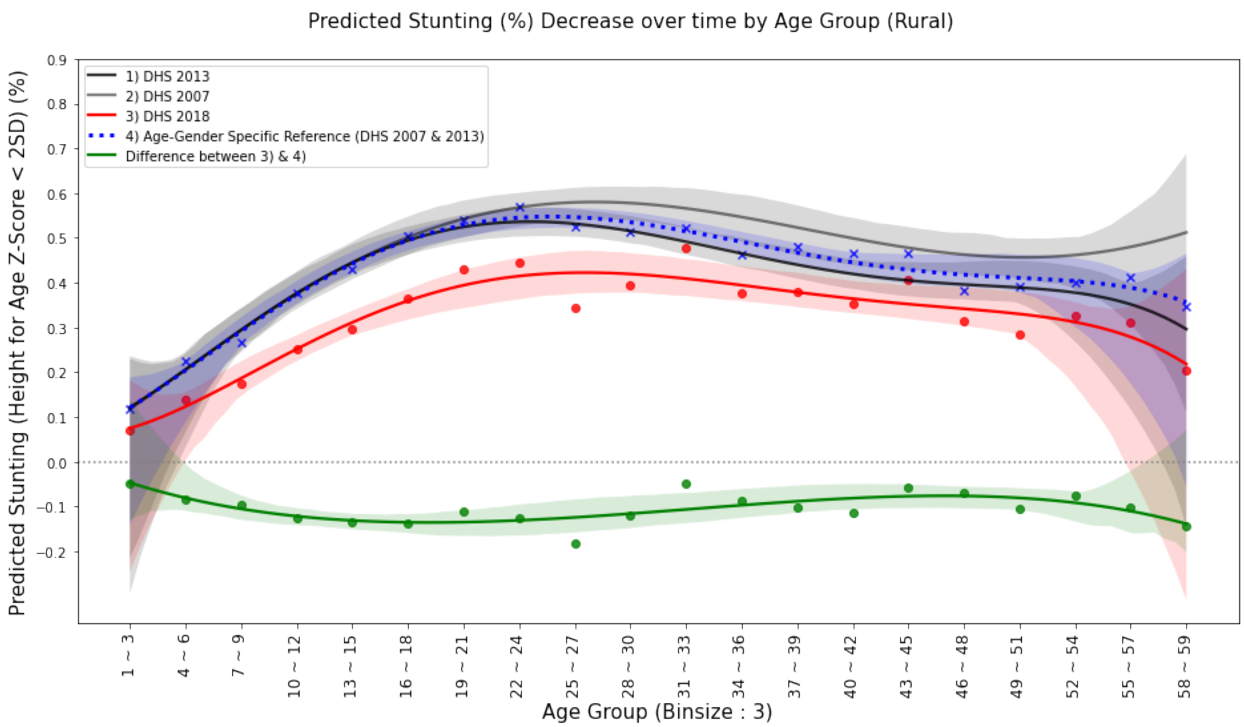
9 Figures, Tables

Figure 1. Predicted Stunting Prevalence by Age Group in Urban Zambia



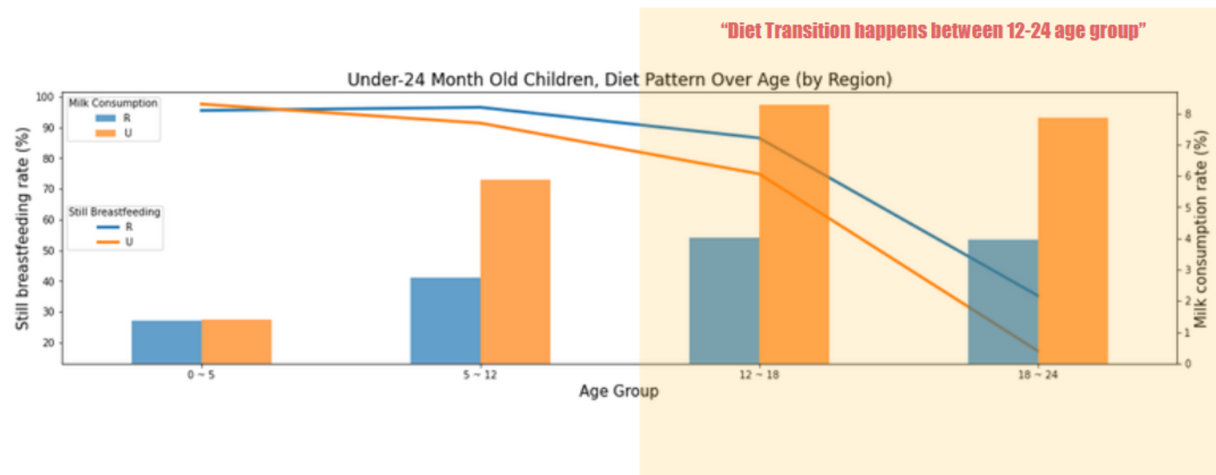
Note: Predicted stunting prevalence (percentage of children with height-for-age z-scores below -2 SD) by age group in urban Zambia, shown with fourth-degree polynomial trend lines fitted to DHS data from 2007, 2013, and 2018. Each line represents the stunting trend for a survey year, with shaded confidence intervals around the lines. The 2018 trend line generally falls below those of 2007 and 2013. A dotted reference line combines data from 2007 and 2013, with a green line showing the difference between this reference and 2018. An arrow marks the cohort that was 12 months old during the Oct, 2015 price shock.

Figure 2. Predicted Stunting Prevalence by Age Group in Rural Zambia



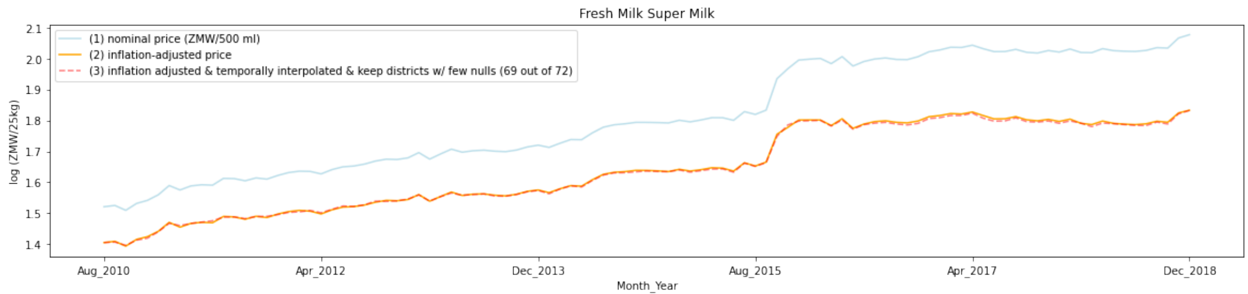
Note: Predicted stunting prevalence (percentage of children with height-for-age z-scores below -2 SD) by age group in rural Zambia, shown with fourth-degree polynomial trend lines fitted to DHS data from 2007, 2013, and 2018. Each line represents the stunting trend by survey year, with shaded confidence intervals around each polynomial line. The 2018 line generally overlaps with the 2007 and 2013 lines, indicating minimal change in stunting rates across years in rural areas. The dotted blue line represents the combined age-gender specific reference based on 2007 and 2013 data, while the green line shows the difference between the 2018 trend and this reference.

Figure 3. Dietary Patterns of Breastfeeding and Milk Consumption Among Zambian Children Under 24 Months

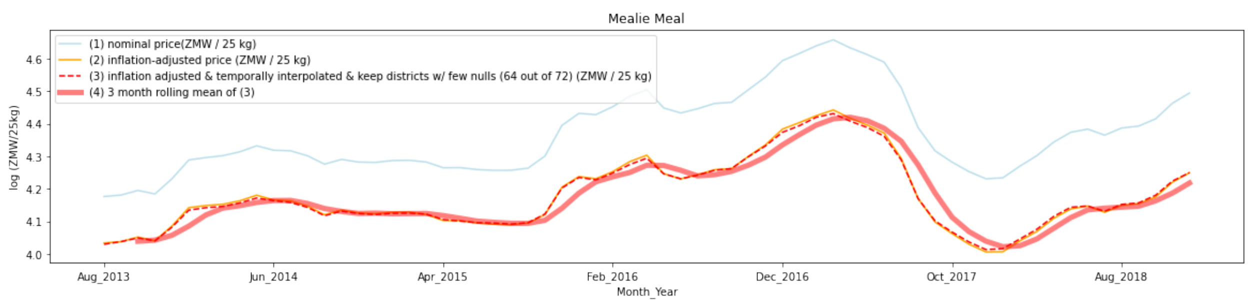


Note: Dietary patterns of breastfeeding and milk consumption among Zambian children under 24 months, separated by rural (R) and urban (U) regions. The left y-axis shows the percentage of children still breastfeeding, while the right y-axis indicates the percentage of children consuming milk. Breastfeeding rates decline sharply with age, especially in urban areas, where the decrease is more pronounced between 12 and 24 months. In contrast, milk consumption rates increase slightly with age, with urban children consistently showing higher milk consumption compared to rural children. The shaded area between 12 and 24 months highlights the critical period of dietary transition from breastfeeding to milk complementation.

Figure 4. Monthly CPI-Adjusted Prices of Key Commodities in Zambia

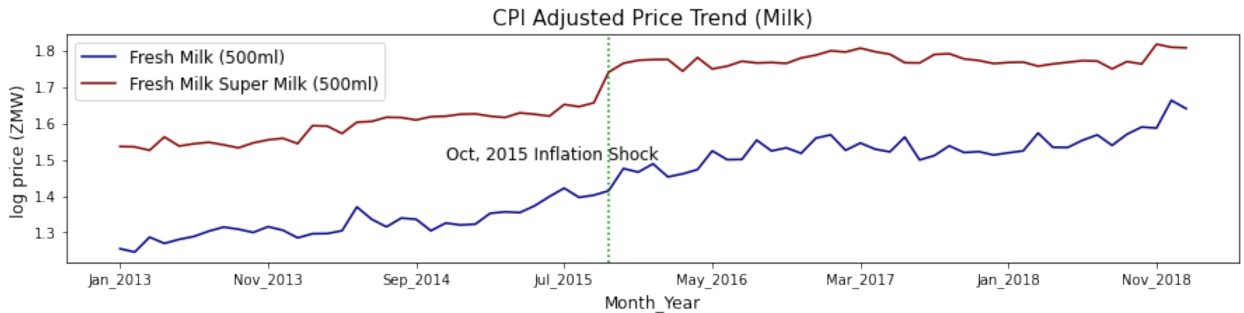


Note: The graph shows the processed monthly prices for Fresh Milk (500ml) and Fresh Milk Super Milk (500ml) in Zambia. Starting with nominal prices, we adjust for inflation using the monthly Consumer Price Index (CPI) and apply linear interpolation to handle missing data. Districts with fewer than 30 months of data are excluded, preserving trends while smoothing gaps. The dashed orange line indicates the inflation-adjusted and interpolated series, retaining price data for 69 out of 72 districts.

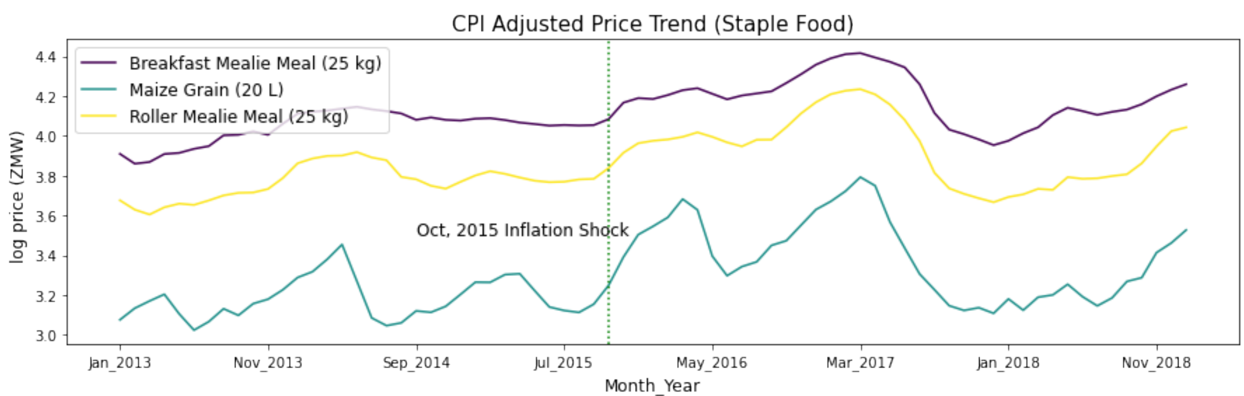


Note: This graph shows the processed monthly prices for Mealie Meal (25 kg), Maize Grain (20 L), and Roller Mealie Meal (25 kg) in Zambia. Similar to milk, nominal prices are adjusted for inflation and interpolated where data is missing. Additionally, a 3-month rolling average (red line) smooths seasonal fluctuations, preserving underlying trends. Data is retained for 64 out of 72 districts after adjustments.

Figure 5. Monthly CPI-Adjusted Prices of Key Commodities in Zambia

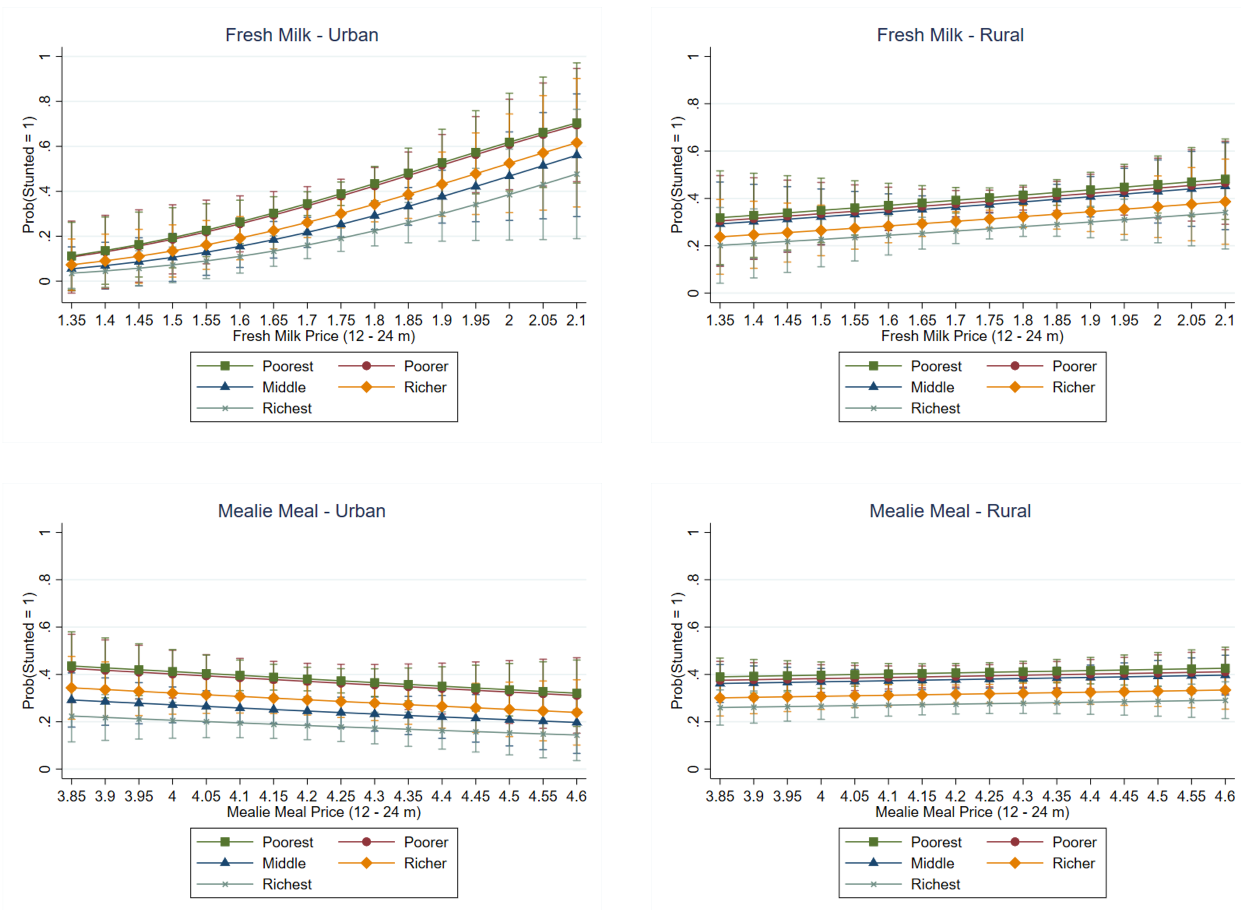


Note: Monthly CPI-adjusted price trends for Fresh Milk (500ml) and Fresh Milk Super Milk (500ml) in Zambia. Nominal prices are adjusted for inflation and displayed as logarithmic values. The orange line represents inflation-adjusted and interpolated prices, retaining data for 69 out of 72 districts after handling missing values. The October 2015 inflation shock is marked with a dotted vertical line to indicate its timing.



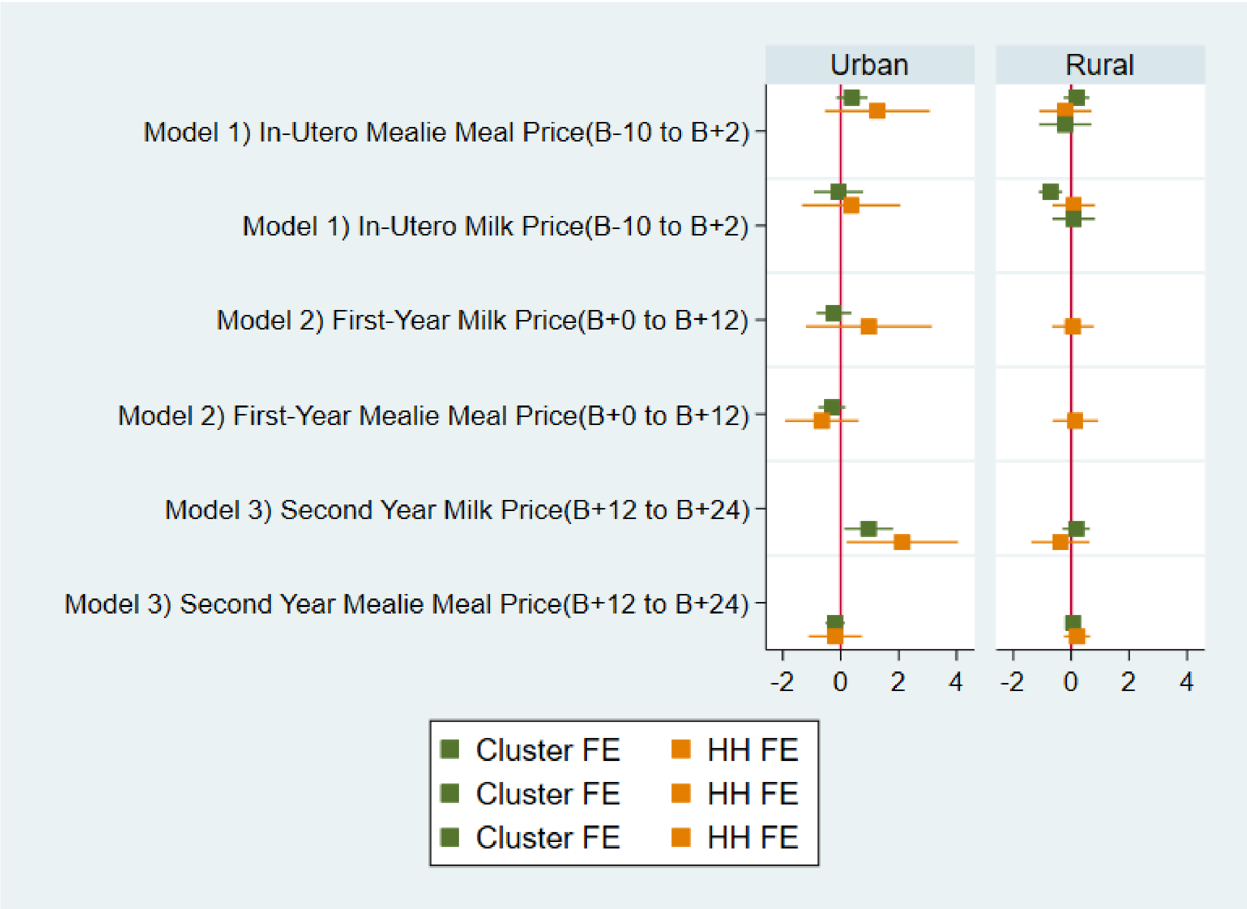
Note: Monthly CPI-adjusted price trends for staple food items in Zambia: Breakfast Mealie Meal (25 kg), Maize Grain (20 L), and Roller Mealie Meal (25 kg). Prices are adjusted for inflation and shown as logarithmic values. For Mealie Meal prices, a 3-month rolling mean (solid red line) is applied to smooth seasonal fluctuations. The dashed orange line shows inflation-adjusted and interpolated prices, with data retained for 64 out of 72 districts after adjustments. The October 2015 inflation shock is indicated by the dotted vertical line.

Figure 6. Wealth-Specific Results



Note: The graphs illustrate the probability of stunting among Zambian children aged 12–24 months across different wealth groups (Poorest, Poorer, Middle, Richer, Richest) for urban and rural regions. The x-axis shows the respective prices (in log form) for Fresh Milk and Mealie Meal, while the y-axis indicates the probability of stunting (Stunted = 1). Error bars represent confidence intervals. In urban areas, stunting probability shows a stronger positive association with milk prices, particularly for poorer groups, while mealie meal prices have minimal impact on stunting across all wealth groups.

Figure 7. Robustness Test - Different Time Boundaries



Note: Marginal effects from models using different time boundaries. Results show that milk prices are positive and significant only when exposure occurs between 12-24 months in urban areas, both at cluster and household levels.

Table 1: Descriptive Statistics by Region and Wealth Group

	Urban		Rural		Poorest		Poorer		Middle		Richer		Richest		Total	
	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
Stunting rate (%)	0.319	0.466	0.368	0.482	0.418	0.493	0.399	0.490	0.351	0.477	0.314	0.464	0.214	0.411	0.352	0.478
Age-by-month	40.823	10.272	41.173	10.463	40.815	10.455	41.083	10.167	41.383	10.417	41.209	10.759	40.912	10.240	41.063	10.403
Child Sex (Male =1)	0.502	0.500	0.496	0.500	0.508	0.500	0.486	0.500	0.491	0.500	0.479	0.500	0.527	0.500	0.498	0.500
Birth Order (The Larger, the Older)	0.910	0.287	0.872	0.334	0.885	0.319	0.881	0.324	0.872	0.334	0.889	0.314	0.897	0.304	0.884	0.320
Still Breastfeeding (Yes = 1)	0.009	0.093	0.020	0.139	0.021	0.143	0.015	0.123	0.021	0.143	0.013	0.112	0.007	0.083	0.016	0.126
Bad Source of Water (Yes = 1)	0.102	0.303	0.429	0.495	0.448	0.497	0.353	0.478	0.312	0.464	0.268	0.443	0.152	0.359	0.326	0.469
Had Diarrhea Recently (Yes =1)	0.096	0.295	0.093	0.291	0.114	0.318	0.091	0.287	0.083	0.276	0.096	0.294	0.076	0.266	0.094	0.292
Mother Age at First Birth	19.455	3.595	18.317	2.871	18.402	3.108	18.335	2.857	18.542	3.064	18.758	2.946	19.733	3.748	18.675	3.161
Mother's Education (Completed Secondary School = 1)	0.261	0.439	0.034	0.181	0.020	0.140	0.040	0.195	0.081	0.273	0.137	0.344	0.350	0.477	0.106	0.307
Head of Sex (Male = 1)	0.768	0.422	0.816	0.387	0.732	0.443	0.786	0.411	0.818	0.386	0.857	0.351	0.866	0.340	0.801	0.399
Log Fresh Milk Price (2nd Year Average)	1.816	0.093	1.841	0.105	1.853	0.113	1.835	0.103	1.832	0.101	1.816	0.092	1.813	0.083	1.833	0.102
Log Mealie Meal Price 3-month Rolling Mean (2nd Year Average)	1.447	0.028	1.454	0.030	1.457	0.030	1.454	0.031	1.452	0.031	1.447	0.029	1.446	0.027	1.452	0.030
Number of Observation	**1430**		**3111**		**1225**		**996**		**867**		**762**		**691**		**4541**	

Summary of key statistics across urban and rural regions, as well as by wealth groups. Indicators include stunting rate, age, child and household characteristics, and food prices.

Table 2: **Balance at Birth by Age at Price Shock (Children Aged > 24 Months)**

	Age ¡ 12 Months at Price Shock			Age ≥ 12 Months at Price Shock			Difference
	N	**Mean**	**SD**	**N**	**Mean**	**SD**	
Birth Weight (kg)	1284	3.313	0.631	2615	3.227	0.602	-0.038
Birth Size							
Average	1719	0.618	0.485	3385	0.616	0.486	-0.001
Larger than Average	1719	0.192	0.394	3385	0.199	0.399	0.006
Smaller than Average	1719	0.079	0.269	3385	0.084	0.277	0.005
Very Large	1719	0.052	0.222	3385	0.052	0.222	0
Very Small	1719	0.023	0.152	3385	0.020	0.141	-0.003
First 3 Days, Given Anything Other Than Breast Milk	670	0.055	0.229	2324	0.059	0.237	0.005

Note: The table compares birth-related characteristics between children who were younger than 12 months and those who were 12 months or older at the time of the October 2015 price shock. Characteristics include birth weight and various categories of birth size (average, larger than average, smaller than average, very large, and very small), as well as early feeding practices (whether given anything other than breast milk within the first three days). Minimal differences across groups suggest no systematic differences in nutritional status at birth.

Table 3: Estimation Results by Region (Urban vs Rural)

	Urban					**Rural**				
	(1) Base	(2) Cluster FE	(3) CRE Probit (Cluster)	(4) HH FE	(5) CRE Probit (HH)	(6) Base	(7) Cluster FE	(8) CRE Probit (Cluster)	(9) HH FE	(10) CRE Probit (HH)
log Fresh Milk Price	0.340**	0.961**	0.906**	2.121**	1.711***	-0.014	0.176	0.242	-0.378	-0.362
	(0.154)	(0.431)	(0.365)	(0.978)	(0.691)	(0.084)	(0.242)	(0.244)	(0.515)	(0.378)
log Mealie Meal Price	-0.089	-0.203	-0.163	-0.195	0.012	0.090	0.062	0.047	0.205	0.207**
	(0.116)	(0.172)	(0.168)	(0.470)	(0.171)	(0.075)	(0.097)	(0.098)	(0.230)	(0.328)
Observations (Number of Groups)	1431	1431(198)	1431(198)	1431(1328)	1431(1328)	3453	3453(347)	3453(347)	3453(3020)	3453(3020)
Household Wealth Index	Yes	Yes	Yes	No	No	Yes	Yes	Yes	No	No
Child Characteristics	No	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
Household Characteristics	No	Yes	Yes	No	No	No	Yes	Yes	No	No
Mother's Characteristics	No	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
Cluster Fixed Effects	No	Yes	No	No	No	No	Yes	No	No	No
Household Fixed Effects	No	No	Yes	Yes	Yes	No	No	Yes	Yes	Yes
Cluster/HH Mean Values Included	No	No	Yes	No	Yes	No	No	Yes	No	Yes

Notes: Coefficients and standard errors are from separate models. Cluster/HH mean values are included for time-varying price measures. CRE probit standard errors are clustered bootstrap estimates, while LPM standard errors are corrected for each clustering level. Asterisks ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Table 4. Robustness Test: Adding Weather Extreme Event to Model specification

	CRE Probit							
	Urban				**Rural**			
	Price Only (Table 1)		Price & Weather Events		Price Only (Table 2)		Price & Weather Events	
	Cluster	HH	Cluster	HH	Cluster	HH	Cluster	HH
log Fresh Milk Price	0.906**	1.711**	0.685*	1.613***	0.242	-0.362	0.232	-0.471
	(0.261)	(0.691)	(0.381)	(0.500)	(0.244)	(0.378)	(0.176)	(0.372)
log Mealie Meal Price	-0.163	0.012	-0.082	-0.762	0.047	0.207**	0.014	0.188***
	(0.168)	(0.171)	(0.173)	(0.136)	(0.098)	(0.682)	(0.097)	(0.072)
Observations (Number of Groups)	1431 (198)	1431 (1328)	1423 (198)	1423 (1303)	3453 (347)	3453 (3020)	3147 (347)	3147 (2768)

Note: Coefficients and standard errors are from separate models. CRE Probit standard errors are clustered bootstrap estimates. Each model includes controls, cluster indicators, and both year and month of birth indicators (not shown). Asterisks ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

References

H. Alderman. Long term consequences of early childhood malnutrition. *Oxford Economic Papers*, 58(3):450–474, April 2006. ISSN 0030-7653, 1464-3812. doi: 10.1093/oep/gpl008. URL https://academic.oup.com/oep/article-lookup/doi/10.1093/oep/gpl008.

Harold Alderman and Derek Headey. The timing of growth faltering has important implications for observational analyses of the underlying determinants of nutrition outcomes. *PLOS ONE*, 13 (4):e0195904–e0195904, April 2018. doi: 10.1371/journal.pone.0195904. Number: 4.

Channing Arndt. Effects of food price shocks on child malnutrition: The Mozambican experience 2008/2009. *Economics and Human Biology*, page 13, 2016.

World Bank. Zambia Consumer Price Index, 2022. URL https://data.worldbank.org/indicator/FP.CPI.TOTL.ZG?locations=ZM.

Jere R. Behrman and Anil B. Deolalikar. Chapter 14 Health and nutrition. pages 631–711. 1988. doi: 10.1016/S1573-4471(88)01017-4.

M.K. Bennett. Wheat in national diets, 1941. 18(2), 37–76.

Bertelsmann Stiftung. BTI 2018 - Zambia Country Report. Technical report, Gütersloh: Bertelsmann Stiftung, 2018.

Michael R. Carter and Travis J. Lybbert. Consumption versus asset smoothing: testing the implications of poverty trap theory in Burkina Faso. *Journal of Development Economics*, 99(2):255–264, November 2012. ISSN 03043878. doi: 10.1016/j.jdeveco.2012.02.003. URL https://linkinghub.elsevier.com/retrieve/pii/S0304387812000077.

Jonathan M. Chipili. Inflation Dynamics in Zambia (Policy Brief No.742), 2021.

Samira Choudhury and Derek Headey. What drives diversification of national food supplies? A cross-country analysis. *Global Food Security*, 15:85–93, December 2017. ISSN 22119124. doi: 10.1016/j.gfs.2017.05.005. URL https://linkinghub.elsevier.com/retrieve/pii/S2211912416301377.

Alan de Brauw. Migration and child development during the food price crisis in El Salvador. *Food Policy*, page 13, 2011.

Delia Grace, Paula Domingues-Salas, Silvia Alonso, Mats Lannerstad, Emmanuel Muuunda, Nicholas Ngwili, Abbas Omar, Mishal Khan, and Eloghene Otobo. The influence of livestock-derived foods on nutrition during the first 1,000 days of life. Technical report, Nairobi, May 2018.

Kathryn G. Dewey and Khadija Begum. Long-term consequences of stunting in early life: Long-term consequences of stunting. *Maternal & Child Nutrition*, 7:5–18, October 2011. ISSN 17408695. doi: 10.1111/j.1740-8709.2011.00349.x. URL `https://onlinelibrary.wiley.com/doi/10.1111/j.1740-8709.2011.00349.x`.

Anna D'Souza and Dean Jolliffe. Rising Food Prices and Coping Strategies: Household-level Evidence from Afghanistan. *Journal of Development Studies*, 48(2):282–299, February 2012. ISSN 0022-0388, 1743-9140. doi: 10.1080/00220388.2011.635422. URL `http://www.tandfonline.com/doi/abs/10.1080/00220388.2011.635422`.

Anna D'Souza and Dean Jolliffe. Food Insecurity in Vulnerable Populations: Coping with Food Price Shocks in Afghanistan. *American Journal of Agricultural Economics*, 96(3):790–812, April 2014. doi: 10.1093/ajae/aat089. Number: 3.

Chris Funk, Pete Peterson, Martin Landsfeld, Diego Pedreros, James Verdin, Shraddhanand Shukla, Gregory Husak, James Rowland, Laura Harrison, Andrew Hoell, and Joel Michaelsen. The climate hazards infrared precipitation with stations—a new environmental record for monitoring extremes. *Scientific Data*, 2(1):150066, December 2015. ISSN 2052-4463. doi: 10.1038/sdata.2015.66. URL `http://www.nature.com/articles/sdata201566`.

Kathryn Grace, Molly Brown, and Amy McNally. Examining the link between food prices and food insecurity: A multi-level analysis of maize price and birthweight in Kenya. *Food Policy*, 46: 56–65, June 2014. doi: 10.1016/j.foodpol.2014.01.010. URL `https://linkinghub.elsevier.com/retrieve/pii/S0306919214000244`.

Beliyou Haile and Derek Headey. Growth in milk consumption and reductions in child stunting: Historical evidence from cross-country panel data. *Food Policy*, 118:102485, July 2023. ISSN 03069192. doi: 10.1016/j.foodpol.2023.102485. URL https://linkinghub.elsevier.com/retrieve/pii/S0306919223000830.

Jody Harris, Brian Chisanga, Scott Drimie, and Gina Kennedy. Nutrition transition in Zambia: Changing food supply, food prices, household consumption, diet and nutrition outcomes. *Food Security*, 11(2):371–387, April 2019. ISSN 1876-4517, 1876-4525. doi: 10.1007/s12571-019-00903-4. URL http://link.springer.com/10.1007/s12571-019-00903-4. Number: 2.

Derek Headey, Kalle Hirvonen, and John Hoddinott. Animal Sourced Foods and Child Stunting. *American Journal of Agricultural Economics*, 100(5):1302–1319, October 2018. ISSN 0002-9092, 1467-8276. doi: 10.1093/ajae/aay053. URL https://onlinelibrary.wiley.com/doi/10.1093/ajae/aay053.

Derek D Headey and Harold H Alderman. The Relative Caloric Prices of Healthy and Unhealthy Foods Differ Systematically across Income Levels and Continents. *The Journal of Nutrition*, 149(11):2020–2033, November 2019. ISSN 00223166. doi: 10.1093/jn/nxz158. URL https://linkinghub.elsevier.com/retrieve/pii/S0022316622164886.

Derek D. Headey and William J. Martin. The Impact of Food Prices on Poverty and Food Security. *Annual Review of Resource Economics*, 8(1):329–351, October 2016. ISSN 1941-1340, 1941-1359. doi: 10.1146/annurev-resource-100815-095303. URL https://www.annualreviews.org/doi/10.1146/annurev-resource-100815-095303.

John Hoddinott and Bill Kinsey. Child Growth in the Time of Drought. *Oxford Bulletin of Economics and Statistics*, 63(4):409–436, September 2001. doi: 10.1111/1468-0084.t01-1-00227. Number: 4.

John Hoddinott, Derek Headey, and Mekdim Dereje. Cows, Missing Milk Markets, and Nutrition in Rural Ethiopia. *The Journal of Development Studies*, 51(8):958–975, August 2015. doi: 10.1080/00220388.2015.1018903. Number: 8.

D.A. Bunn-and C.P. Stewart. 2014. L.L. Iannotti, C.K. Lutter. Eggs: The Uncracked Potential for

Improving Maternal and Young Child Nutrition among the World's Poor. *Nutrition Reviews*, 2014.

ICF International. The Demographic and Health Surveys Program, 2018. URL `https://dhsprogram.com`.

Robert T. Jensen and Nolan H. Miller. The impact of food price increases on caloric intake in China. *Agricultural Economics*, 39:465–476, November 2008. ISSN 01695150, 15740862. doi: 10.1111/j.1574-0862.2008.00352.x. URL `https://onlinelibrary.wiley.com/doi/10.1111/j.1574-0862.2008.00352.x`.

J.-P. Habicht and E.A. Frongillo. J.L. Leroy, M. Ruel. Linear Growth Deficit Continues to Accumulate beyond the First 1000 Days in Low-and Middle- Income Countries: Global Evidence from 51 National Surveys. *Journal of Nutrition*, 2014.

Sharon Maccini and Dean Yang. Under the Weather: Health, Schooling, and Economic Consequences of Early-Life Rainfall. *American Economic Review*, 99(3):1006–1026, May 2009. doi: 10.1257/aer.99.3.1006. Number: 3.

R. Martorell, L. Khan, and D. Schroeder. Reversibility of stunting: epidemiological findings in children from developing countries. *Economics European journal of clinical nutrition*, 1994.

Kathryn McMahon and Clark Gray. Climate change, social vulnerability and child nutrition in South Asia. *Global Environmental Change*, 71:102414, November 2021. ISSN 09593780. doi: 10.1016/j.gloenvcha.2021.102414. URL `https://linkinghub.elsevier.com/retrieve/pii/S095937802100193X`.

World Health Organization. WHO Child Growth Standards Based on Length/Height, Weight and Age, 2006.

World Health Organization. Infant and young child feeding counselling: an integrated course. Trainer's guide, second edition., 2021.

Heather Randell, Clark Gray, and Kathryn Grace. Stunted from the start: Early life weather conditions and child undernutrition in Ethiopia. *Social Science & Medicine*, 261:113234, September 2020. ISSN 02779536. doi: 10.1016/j.socscimed.2020.113234. URL https://linkinghub.elsevier.com/retrieve/pii/S0277953620304536.

C.B.Barrett S. Pedersen and B. Wydick. 2014. R. Rawlins, S.Pimkina. Got Milk? The Impact of Heifer International's Livestock Donation Programs in Rwanda on Nutritional Outcomes. *Food Policy*, 2014.

I Sanogo. The global food price crisis and household hunger: a review of recent food security assessment, 2009.

Richard D. Semba, Michelle Shardell, Fayrouz A. Sakr Ashour, Ruin Moaddel, Indi Trehan, Kenneth M. Maleta, M. Isabel Ordiz, Klaus Kraemer, Mohammed A. Khadeer, Luigi Ferrucci, and Mark J. Manary. Child Stunting is Associated with Low Circulating Essential Amino Acids. *EBioMedicine*, 6:246–252, April 2016. ISSN 23523964. doi: 10.1016/j.ebiom.2016.02.030. URL https://linkinghub.elsevier.com/retrieve/pii/S235239641630069X.

Duncan Thomas and John Strauss. Prices, infrastructure, household characteristics and child height. *Journal of Development Economics*, 39(2):301–331, 1992. ISSN 0304-3878. doi: https://doi.org/10.1016/0304-3878(92)90042-8. URL https://www.sciencedirect.com/science/article/pii/0304387892900428.

S.M. Grantham-McGregor J.H. Himes and S.M. Chang. S.P. Walker, C.A. Powell. Nutritional Supplementation, Psychosocial Stimulation, and Growth of Stunted Children: The Jamaican Study. *American Journal ofClinical Nutrition*, 1991.

Zhengming Wan, Simon Hook, and Glynn Hulley. MODIS/Aqua Land Surface Temperature/Emissivity Monthly L3 Global 0.05Deg CMG V061, 2021. URL https://lpdaac.usgs.gov/products/myd11c3v061/.

Andinet Woldemichael, Daniel Kidane, and Abebe Shimeles. Food Inflation and Child Health. *The World Bank Economic Review*, 36(3):757–773, August 2022. ISSN 0258-6770, 1564-698X. doi: 10.1093/wber/lhac009. URL https://academic.oup.com/wber/article/36/3/757/6593822.

Jeff Wooldridge. CRE Models for Unbalanced Panels – Correleated Random Effects Panel Data

Model. IZA Summer School in Labor Economics. Michigan State University., 2013a. URL https://conference.iza.org/conference_files/SUMS_2013/slides_4_unbalanced_iza.pdf.

Jeff Wooldridge. Nonlinear Models – Correleated Random Effects Panel Data Model. IZA Summer School in Labor Economics. Michigan State University., 2013b. URL https://conference.iza.org/conference_files/SUMS_2013/slides_2_nonlin_iza.pdf.