

Food Inflation and Child Health in Pakistan

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Research Article

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Abstract

Childhood stunting is one of the most serious health problems of Pakistan with significant interregion variations in the nutritional situation. This paper aims to evaluate the impact of food inflation on childhood stunting among children under the five years of age, especially with respect to exposure during pregnancy and infancy at district levels in Pakistan. The analysis is based on two waves of Pakistan Demographic and Health Surveys (PDHS) 2012–13 and 2017–18 and monthly food price data collected from the Pakistan Bureau of Statistics (PBS). Furthermore, the environmental indicators are based on satellite-based Normalized Difference Vegetation Index (NDVI). Child nutritional outcome is measured in terms of stunting in childhood and height-for-age z-scores (HAZ). The relationship between early-life exposure to food inflation and child health outcomes is estimated using ordinary least-squares (OLS) and mother fixed-effects models. The results show that stunting in childhood is still prevalent in Pakistan and there is significant spatial variation among districts. The regression results indicate that exposure of food inflation in pregnancy leads towards higher childhood stunting, whereas food inflation in infancy and child growth outcomes is less vulnerable and robust across the different model specifications. These findings also indicate that regional variations in child nutrition outcomes are related to environmental and agricultural conditions. Overall, the results indicate that nutrition security for mothers during pregnancy is important and food security policies are needed to reduce child health risks in Pakistan.

Keywords

Child Health, Stunting, Maternal Nutrition, Food Inflation, and Height-for-Age Z-Score.

1. Introduction

1.1 Background of the Study

Children health plays vital role in human development as healthy children are more likely to be healthy adults who are able to participate effectively in the productive workforce (Currie & Almond, 2011; Case & Paxson, 2010; Victora et al., 2008). Early child health relies on proper nutrition which is essential for healthy brain development, immune system function and child survival. On the other hand, nutritional deprivation in the first five years of life can cause permanent harm to both physical and cognitive growth, impacting health outcomes and educational outcomes and the potential productivity in later life (Black et al., 2013; Ford et al., 2018). Likewise, it has been demonstrated that adverse early environments and poor fetal nutrition have detrimental impacts on health across the lifespan Barker (1995) and Barker and Clark (1997).

Similarly, Wu et al. (2004) emphasized the importance of proper maternal nutrition during the gestation period for healthy fetal growth and child development.

Malnutrition is one of the most severe early life shocks have detrimental long-term effects on the health of children in many developing nations (Barker 1995; Barker and Clark 1997; Victora et al. 2008; Ford et al. 2018). There are several forms of it, such as wasting (weight for height below), stunting (height for age below), underweight (weight for age below), and deficiencies in vitamin and mineral. Malnutrition in children results in stunting or impaired growth. Childhood stunting is especially notable because it is an indicator of poor physical growth, cognitive performance, education, and work productivity as adults (Arndt et al., 2016; Woldemichael et al., 2022). The World Health Organization (2017) estimates that 149.2 million children's under five years old are affected by stunting in most of the South Asian countries. It has also been reported in the previous studies that malnourished children in Pakistan, India and Bangladesh have significant representation in the world (UNICEF, 1996, Bhutta et al., 2004). Stunting among children which is a serious nutritional problem has increased from 36.3% to 40% in Pakistan, as reported by the World Bank (2023).

There are still great challenges ahead for Pakistan in child nutrition and health. The income of poor household is affected by rising food prices of staple items hence they limits their access to acquire healthier food during pregnancy and early childhood period. Thus, food inflation aggravated food insecurity and poor nutrition status among the vulnerable households in Pakistan (Bhutta et al. (2008), (Tharwani et al., 2023). A strengthened correlation between food prices and increased risks of childhood stunting and other negative nutrition outcomes has been observed in previous studies (Arndt et al., 2016; Woldemichael et al., 2022; and Headey & Ruel, 2023). The National Nutrition Survey 2018 (NNS) suggests that the prevalence of stunting, wasting, underweight and micronutrient deficiencies among children is still high across the country. Similarly, Bhutta et al. (2013) found that child under nutrition is one of the most important public health and human development problems in Pakistan. While the problem of stunting among children is widespread throughout the country there is a significant variation between provinces, districts and rural-urban areas. Therefore, this study analyzes each district separately to determine specific nutritional challenges and provide targeted policy interventions.

Research problem:

Food inflation in Pakistan has been significant in the past 20 years, placing many households at risk of experiencing chronic malnutrition. High food prices of staple food items negatively impact the poorest families who have limited funds to buy adequate amounts of nutritious foods and are at risk for food insecurity. In times of food inflation households may adjust their diets by decreasing food consumption or redirecting household spending towards other essential services but away from health care. Such changes may negatively impact maternal nutrition during pregnancy and early childhood nutrition, thereby raising the likelihood of early childhood chronic malnutrition and stunting. According to a World Bank report, the proportion of stunted children in Pakistan who are shorter than their age exceeds 40% which indicates a major nutritional problem. While childhood stunting is a serious public health problem in Pakistan, there is not much empirical literature available regarding the role of food inflation at the district level in the poor nutrition situation of children. This study thus examines the impact of food inflation exposure during critical periods (pregnancy, infancy) with childhood stunting among children under the age of 5.

RESEARCH GAP

While a significant number of studies have focused on child malnutrition, food insecurity and health of mother, few studies have focused on the direct link between food inflation and child nutrition in Pakistan. Although previous research has tended to focus on food insecurity or household poverty, there has been little work that specifically considers the effect of high food prices on health outcomes of children. Moreover, previous studies have tended to focus on a national or provincial level analysis, and may mask significant intra-regional heterogeneity within districts. This study aims to fill these gaps by examine the relationship between district level food inflation and childhood stunting, based on the monthly food price data provided by Pakistan Bureau of Statistics (PBS) and the child health data provided by the Pakistan Demographic and Health Surveys (PDHS 2012-13, 2017-18). Special emphasis is placed on the exposures experienced during pregnancy and infancy, which are the times in a child's lifetime when growth and development is most critical. This study highlights the variation at the district level to offer new evidence for policies to address maternal and child nutrition in Pakistan.

Research Question:

1. Is there any relationship between food inflation and children's health outcomes in Pakistan under age of 5?

Research objective:

The aim of this study is to explore the association of District level food inflation with child health outcomes in Pakistan. In particular, the study uses ordinary least-squares (OLS) and mother fixed-effects regression models to examine the relationship between food inflation exposure in pregnancy and infancy and the probability of childhood stunting (defined as height-for-age Z score < -2 SD) for children under five years of age.

2. Literature Review

2.1 Theoretical Literature on Child Health

The health capital model by Grossman (1972) forms the theoretical basis for this study. Grossman viewed health as a cumulative product of investment that people employ to cut down their consumption of other forms of capital. Investment in nutrition, healthcare, sanitation and other health-enhancing inputs leads to better health (Grossman 1972), which in turn leads to higher productivity and better well-being of the people. Lack of good health, on the other hand, diminishes productivity and causes significant economic and social losses. Later research was built on Grossman's model by adding biological, demographic, and socioeconomic factors to explain health outcomes. This framework offers a valuable foundation for comprehending how a variety of factors, such as increasing food prices and household resource constraints, could influence child health outcomes through diminished investments in nutrition and healthcare.

Furthermore, the theoretical basis of this research supported by “Fetal Origins Hypothesis” presented by D. J. P. Barker (1998). They suggest that nutritional and environmental factors in the fetal period, infancy and early childhood have a long-term impact on human health and development. This theory suggests that poor nutrition at these sensitive times may cause irreversible growth stunting, because children who are stunted early in life do not have a lot of catch-up growth potential. Thus, early growth is thought to be a reliable indicator of later growth and health.

Maternal biological factors, fertility behavior, and education are important factors that affect pregnancy outcomes and child development (Easterlin 1978; Easterlin, Pollak and Wachter 1980; Behrman et al. 1982). Similarly, Schultz (1984), Caldwell (1979), and Caldwell et al. (1983) found that maternal age, birth spacing, health care utilization, immunizations, sanitation, and nutrition are significant factors affecting child health. All these studies underscore the importance of both

intra-household decision making and social-economic factors influencing child nutrition outcomes.

The importance of maternal nutrition for fetal growth and pediatric health has consistently been recognized. The Developmental Origins of Health and Disease (DOHaD) hypothesis was proposed by Barker (1995) and Barker and Clark (1997) and suggests that nutrition during fetal development can have a long-term impact on health across the lifespan. In the same way, Rasmussen (1992), Rasmussen and McGuire (1996), and Rosso et al. (1981) showed that under nutrition of the mother has a negative effect on fetal growth, lactation, and infant nutritional status. Early-life under nutrition has been shown to have a strong association with stunting in childhood, weakened immune function, delayed cognitive function, and diminished human capital accumulation, and emphasis on child nutrition is an important factor in long-term economic development by (Wu et al., 2004; Victora et al., 2008; Black et al., 2013; Kinsey et al., 2006 and Case and Paxson, 2010). The effects poor health in early childhood has a negative impact on schooling, working life, and adult health. As a group, these studies support the theoretical case for studying the potential links between food inflation, maternal nutrition, and child health outcomes (Currie and Almond, 2011; Almond and Mazumder (2011; Persson and Rossin-Slater, 2018).

2.3 Food inflation to Child Health and Nutrition Security

Food inflation is an important development policy challenge in many of the low- and middleincome countries, as food prices increase, the purchasing power of vulnerable households is constrained with less nutritious alternatives or redirect their food expenditure to other household essentials such as health care (Yamano et al., 2005; Taffesse and Carruth 2006; D'Souza & Jolliffe, 2011; Shimeles and Woldemichael, 2013). Moreover, the previous research on child nutrition (Tandon & Landes, 2014; Barrett, Garg, and McBride, 2016; Arndt et al., 2016) also claimed that repeated food price shocks can contribute to perpetuating poverty traps and exacerbating the vulnerability of households to food insecurity and malnutrition. Emphatic evidence from developing countries invariably shows that food price shocks have a negative impact on child nutrition (Ibikunle et al., 2022; Brown et al., 2023; Headey & Ruel, 2022; Headey & Ruel, 2023). Recently, Woldemichael and Shimeles, 2022; Sahiledengle et al., 2023) found that food inflation during pregnancy had a strong association with childhood stunting while that of infancy was relatively less.

Although an increasing amount of international literature exists, empirical evidence linking food inflation and child health is limited in Pakistan. Previous research has focused on food insecurity, maternal nutrition, or social and economic impacts of inflation, but not on the immediate impacts on children's nutrition. Bhutta et al., 2008, and Tharwani et al., 2023, proposed that high food prices have led to maternal anemia, low birth weight, and increased infant mortality. In addition to the above, the impacts of price rise of food items on school enrolment, child's work, food insecurity, and economic development have been studied by Morote (2000), Hou et al. (2016), Afzal et al. (2010), Afzal et al. (2011), Zehra (2020) and Awan and Imran (2015). But very few studies have focused directly on the relationship between exposure to food inflation during pregnancy and childhood and child nutrition outcomes in Pakistan.

Thus, there are a number of research gaps that still need to be addressed. First, no empirical studies have been conducted in Pakistan to analyze the relationship of food inflation and child health during pregnancy and infancy by addressing variation across district. Secondly, previous research has rarely used spatial GIs mapping analysis technique to identify the geographic distribution of food inflation and stunting. This study tries to fill these gaps by linking districtlevel food price data provided by Pakistan Bureau of Statistics (PBS) with pooled data from Pakistan Demographic and Health Surveys (PDHS 2012-13 and 2017-18). The study highlights on exposure during pregnancy and infancy thereby providing new evidence on the link between food inflation and childhood stunting, and policy-relevant insights to enhance maternal and child nutrition in Pakistan.

3. Methodology framework

3.1 Data source and sample selection

This study uses several data sources to explore the linkages between food inflation and health outcomes of children in Pakistan. Child health and demographic information were obtained from the Pakistan Demographic and Health Surveys (PDHS) 2012–13 and 2017–18. The anthropometric measurements taken for the children, as well as the characteristics of the children's mothers, household socioeconomic characteristics, and geographic identifiers, are reported in detail in these nationally representative surveys. The analysis is carried out for the children aged 6-59 months

and the nutritional status of children is described by height-for-age zscores (HAZ). A child is considered stunted according to the World Health Organization (WHO, 2006) Child Growth Standards, if height-for-age z-score falls below minus two standard deviations from the reference population.

The food price data of Pakistan was collected by the Pakistan Bureau of Statistics (PBS) on monthly basis for 2005 to 2018. Prices of major staple food commodities are collected from 76 markets in 40 cities in Pakistan every month by the PBS. Data were aggregated and then matched and linked with PDHS observations according to district identifiers, month and year of birth to create food inflation exposure measures for children. These steps were followed as in Woldemichael, Kidane and Shimeles (2022).

To account for differences in food consumption patterns, calorie weights were derived from the revised Food Composition Table (FCT) for Pakistan (2001). Food consumption rate data from the Household Integrated Economic Survey (HIES) 2018 were joined with the calorie information data using the food item codes. These weights were then translated into calorie weighted food price indices which consider the relative nutritional importance of the staple food commodities in household consumption. In other words, household food consumption from purchased food, own production, in-kind receipts and gifts were combined for each food item. Standardized conversion factors for foods were used to convert quantities to kg prior to calorie estimation. Outliers of per capita food consumption were detected, and the value replaced by the corresponding median value to reduce the impact of extreme values. The amounts of food consumed were then multiplied by the calorie content of each food, and shares of calories consumed by each food were calculated as a percentage of total household calorie consumption.

The household calorie shares in each of the four provinces were averaged to obtain the provincial calorie weights.

The food consumption module from the HIES 2018 was used to create expenditure weights. Household expenditure on each food item was obtained by adding expenditures on purchased items, own production, in-kind receipts and gifts. Total household food expenditure was then calculated as the sum of expenditure on food items. Individual food category expenditure shares were obtained as the percentage of total household food expenditure, and then the average share was computed for each province to produce provincial expenditure weights. The expenditure

weights are used in conjunction with the calorie weights used in the food price indices in the analysis.

The Normalized Difference Vegetation Index (NDVI) derived from Landsat satellite images and processed in Google Earth Engine (GEE) was used as a measure of environmental conditions. Each monthly NDVI observation was cross-referenced with the survey records, by matching the district identifier with the month and year of the observation. NDVI can also be used as an indicator of local environmental and agroecological conditions that can affect agricultural production, food availability, household welfare, and the nutritional status of children (Woldemichael & Shimeles, 2022).

The final analytical dataset was created by matching the child-level data from the PDHS with the monthly food price data from the PBS, the calorie and expenditure weights, and the NDVI data at the district level with common district, month, and year identifiers. This compound measure allows scientists to investigate the relationship between food inflation and local environmental factors in pregnancy and early childhood with measures of child nutrition in Pakistan.

Table 3.1: Data Sources and Variable Description

Variable Category	Data Source	Description
Food Price Data	Pakistan Bureau of Statistics (PBS)	Monthly district-level food price data (2005–2018) covering major staple food commodities including wheat, rice, eggs, pulses.
Child Health Outcomes	Pakistan Demographic and Health Survey (PDHS) 2012–13 and 2017–18	Child anthropometric indicators including height-forage z-scores (HAZ) and stunting status for children aged 6–59 months.
Child Characteristics	PDHS 2012–13 and 2017–18	Child age, sex, birth order, vaccination status, vitamin A supplementation, and breastfeeding duration.
Maternal Characteristics	PDHS 2012–13 and 2017–18	Maternal age, educational attainment, and other demographic characteristics.
Household Characteristics	PDHS 2012–13 and 2017–18	Household wealth index, sanitation facilities, place of residence, and socioeconomic conditions.
Food Consumption Weights	Household Integrated Economic Survey (HIES) 2018–19	Expenditure weights used in constructing food price indices and inflation measures.
Calorie Weights	Food Composition Table for Pakistan	Calorie conversion factors used to construct calorieweighted staple food price indices.
Environmental Conditions (NDVI)	Landsat 5 and Landsat 8 Satellite Imagery (Google Earth Engine)	Monthly Normalized Difference Vegetation Index (NDVI) data used to capture environmental and agricultural conditions at the district level.

Geographic Variables	PDHS and PBS	District codes used for merging child health, food prices
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Source: Compiled from PDHS (2012–13; 2017–18), Pakistan Bureau of Statistics (PBS), Household Integrated Economic Survey (HIES), Food Composition Table for Pakistan, and Landsat satellite imagery, Pak admin 3

3.2 Identification Strategy

This paper investigates how food inflation during pregnancy and the first year of life affects nutrition, particularly stunting, for children between 6 and 59 months. The study uses monthly district-level food inflation data and the month/year of each child’s birth to create food inflation exposure profiles for each child during the prenatal period (which includes the nine months before birth) and the first six months of life . As a result, children born in different districts at different times have different levels of exposure to changing food prices. This approach shows the relationship between food price increases and the nutrition of children.

The analysis entails a range of control variables included stepwise to reduce the impact of observable confounding variables. These variables comprise child attributes (age, gender, birth order), mother-related variables (age, education), household variables (economic status, sanitation and residential location). Normalized Difference Vegetation Index (NDVI) is incorporated to explain the local agricultural productivity and environmental factors that may affect food prices and nutrition outcomes for children.

The empirical analysis entails three successive restrictive specifications. The first specification constitutes a baseline Ordinary Least Squares (OLS) model that controls for child, maternal, household, and geographic characteristics that are observable. The second specification presents district fixed effects to cover unobserved district characteristics which are time-invariant. The third specification introduces mother fixed effects, comparing siblings with the same mother but exposed to different food-price environments during pregnancy or infancy. This approach accounts for all time-invariant maternal and household factors such as genetic factors, long-term socioeconomic status, parental preferences, and other unobserved sibling-specific characteristics.

Even with these controls, the estimates should be interpreted as associations and not causal effects. The combination of a rich set of covariates, district fixed effects, mother fixed effects and NDVI makes it less likely that observed and time-invariant unobserved confounding plays a role. Time-varying shocks at the district or household level, however, such as local economic recessions,

conflict, floods, disease outbreaks or changes in household income, could still be correlated with food inflation and child nutritional outcomes. Therefore, the empirical strategy greatly improves identification as well as the results do not entirely remove the possibility of residual confounding.

Finally, standard errors are clustered at the district level to allow for possible correlation in unobserved shocks that affect children in the same district. Clustering provides for robust statistical inference by allowing for the error terms to be correlated within districts, where common economic or environmental conditions might simultaneously influence food inflation and child nutritional outcomes.

3.3 Construction of Food Inflation and NDVI Exposure Measures

The explanatory variables of interest in this study are the exposure to food inflation during pregnancy and the exposure to food inflation during infancy. These measures were created by matching monthly food price information at the district level from the Pakistan Bureau of Statistics (PBS) with the month and year of birth of the people in the Pakistan Demographic and Health Surveys (PDHS). These exposure measures are constructed in a similar manner to that of Woldemichael, Kidane and Shimeles (2022) who analyzed the link between early-life exposure to food inflation and child nutrition outcomes. Developing the food price index started with the process of creating a food price index of major food staples consumed in Pakistan – wheat, rice, eggs and pulses. The index was built based on the calorie adjusted and expenditure adjusted weights, based on the approach in the food inflation literature (Woldemichael, Kidane, & Shimeles, 2022).

The month and year of birth were used to identify the nine months prior to each child's birth, consistent with the gestation period for prenatal exposure. The average food inflation exposure during gestation was computed as the average of the district-level monthly food inflation rates recorded during these 9 months. Similarly, the study constructs an indicator of exposure in infancy by averaging the district-level food inflation rates that occurred in the first six months of life.

Formally, the average inflation exposure for child i during pregnancy is calculated as:

$$\text{Inflation}^{\text{Utero}}_i = \frac{1}{9} \sum m = -9^{-1} \pi_{idm},$$

where (π_{idm}) denotes the monthly food inflation rate in district (d) during month (m) of the child's prenatal period.

Likewise, average inflation exposure during infancy is defined as:

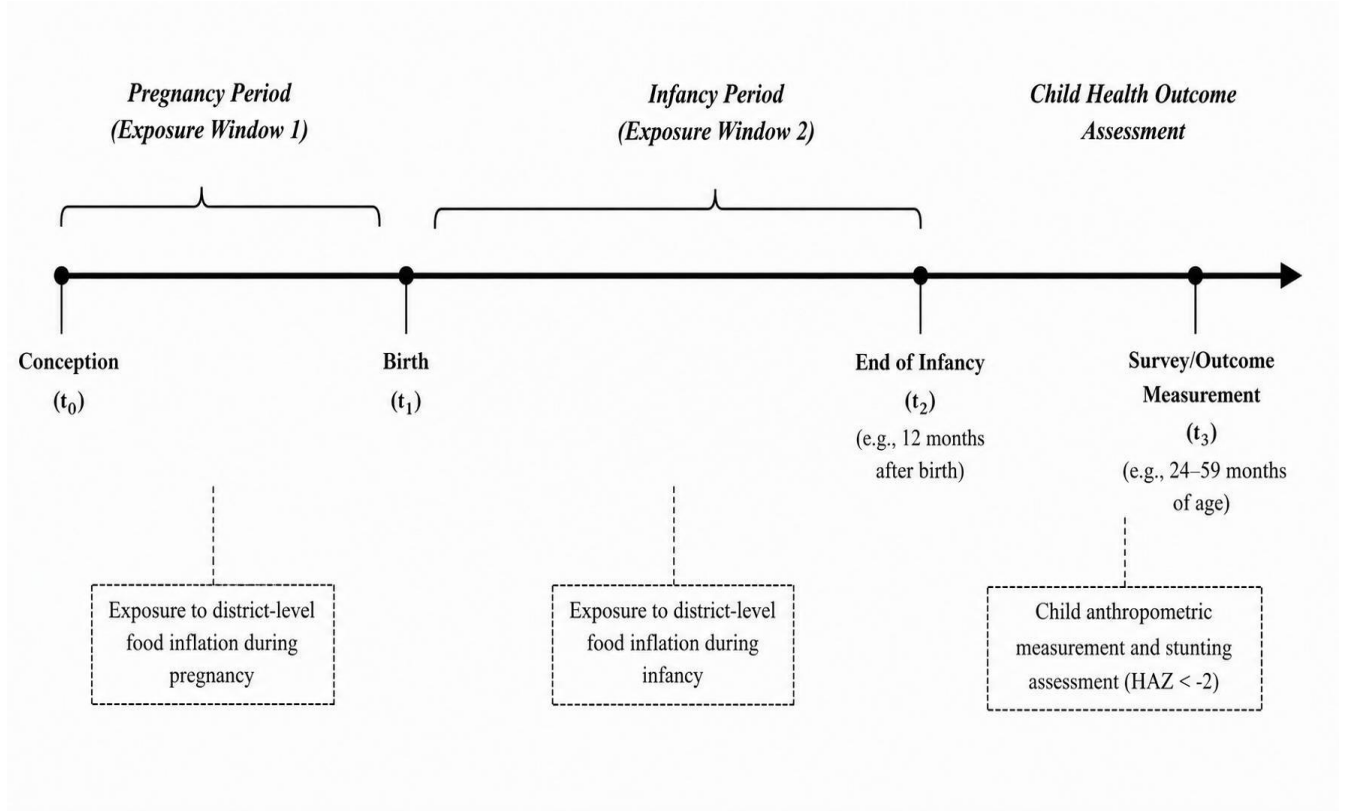
$$\text{Inflation}^{\text{Infancy}}_i = \frac{1}{6} \sum_{m=1}^6 \pi_{idm},$$

Where (π_{idm}) shows the monthly inflation rate in district (d) during month (m) are averaged over the first six months after birth of child.

Considering the average inflation across these exposure windows reflects the cumulative pricing environment faced by the household in the bio critical phases of child growth and minimizes the short-term monthly fluctuations. Therefore, every child is attributed to food inflation exposure measures over a certain period: one for average exposure during gestation and the other for average exposure during the initial stage of infancy. These summed measures serve as the primary explanatory variables in the entire empirical analysis.

The Normalized Difference Vegetation Index (NDVI) was used to quantify exposure to environmental conditions. Satellite-derived monthly 'Normalized Difference Vegetation Index (NDVI)' data from Landsat were processed in the Google Earth Engine and correlated to district identifiers, to be aggregated across each child's prenatal and infancy exposure periods. The mean NDVI was then determined for the pregnancy and infancy periods. These are proxies for local agricultural productivity, environmental conditions, and environmental shocks that could affect food availability and nutritional outcomes for children (Woldemichael, Kidane, & Shimeles, 2022). One of the key benefits of this approach is the monthly exposure measures used, instead of annual. Monthly food price data better reflect to more precisely estimate the relationship between food inflation in early life and child health outcomes short-term variations in food inflation during key developmental windows than annual averages and help.

Figure1. Early-Life Exposure Timeline



3.4 Empirical Model and Estimation Strategy

This research uses a linear probability model (LPM) to evaluate the relationship between the likelihood of a child being stunted and exposure to food inflation during pregnancy and infancy.

An LPM is suitable because the dependent variable is binary; a child is either stunted (1) or not (0). A notable benefit of the LPM is that the estimated coefficients represent changes in probability of stunting, due to changes in exposure to food inflation, and can be explained directly.

The baseline empirical specification is given by:

$$Stunting_{\{ijdt\}} = \alpha + \beta_{1Inflation}^{\{Utero\}\{ijdt\}} + \beta_{2Inflation}^{\{Infancy\}\{ijdt\}} + \gamma NDVI^{\{Utero\}\{ijdt\}} + \delta NDVI^{\{Infancy\}\{ijdt\}} + X'_{ijdt}\theta + \lambda_d + \tau_t + \varepsilon\{ijdt\}$$

Where, $(Stunting_{ijdt})$ shows child health outcome stunting status among child i born to mother j which is located near the district d at time t . $(Stunting_{ijdt})$ is a binary indicator that takes the value of one if child (i) is stunted at the time of the survey, and zero otherwise. The

$(Inflation^{Utero}_{ijdt})$ denotes the average monthly food inflation experienced during the nine months preceding birth, while $(Inflation^{Infancy}_{ijdt})$ represents the average monthly food inflation during the child's first six months of life. Additionally, $(NDVI^{Utero}_{ijdt})$ and

$(NDVI^{Infancy}_{ijdt})$ are the average environmental conditions during pregnancy and infancy, respectively.

The vector $(X'_{ijdt}\theta)$ contains observed control variables, including child, maternal, household, and paternal characteristics. District (λ_d) fixed effects are control for unobserved constant time characteristics across districts, while survey-year, regional, and birth-cohort controls are progressively introduced in subsequent specifications to account for broader temporal and spatial differences. The error term is denoted by (ε_{ijdt}) .

The empirical analysis proceeds sequentially. Model (1) estimates the baseline association between food inflation exposure and child stunting while controlling only for age and month of birth. Subsequent models progressively incorporate child, household, maternal, paternal, geographic, survey year-by-region, and age-by-birth cohort controls to examine the sensitivity of the estimated associations to alternative model specifications.

To mitigate the risk of confounding due to unobserved time-invariant maternal and household factors, the analysis is further extended with mother fixed-effects models, which compare siblings born to the same mother, but with different food price exposure during pregnancy and infancy. Lastly, the strength of the findings is evaluated by re-estimating the models with Height-for-Age Z-score (HAZ), a continuous measure of children's nutritional status, instead of the binary stunting measure. To reduce the impact of common economic or environmental shocks on the relationship between food prices and child nutrition outcomes, robust standard errors are clustered at the district level in this analysis.

3.5 Mother Fixed-Effects Model

The baseline OLS model, which includes a comprehensive collection of observed characteristics related to children, households, parents, and the environment, and while controlling for these variables, some of the associations may still be influenced by unobserved characteristics that are linked to food inflation exposure and the nutritional outcomes of children. Examples of such factors are parental preferences, genetic endowments, household socio-economic status which is of a greater duration, health literacy, etc., and other unobserved family characteristics. The OLS estimates would be biased if these factors correlate with children's exposure to food inflation.

To minimize this source of bias, the study estimates a mother fixed-effects model comparing siblings born to the same mother, who were exposed to different food pricing situations during the mothers' pregnancy and the infants' early developmental period. This approach to making within-family comparisons eliminates a range of maternal and household attributes that are constant across siblings, such as the genes, the parental tastes, the enduring socioeconomic position, and various time-invariant attributes of the household. Thus, the exposure of siblings born at different times to varying food inflation rates.

The mother fixed-effects specification is expressed as:

$$Stunting_{ijt} = \alpha + \beta_{1Inflation}^{\{Utero\}\{ijt\}} + \beta_{2Inflation}^{\{Infancy\}\{ijt\}} + \gamma NDVI^{\{Utero\}\{ijt\}} + \delta NDVI^{\{Infancy\}\{ijt\}} + X'_{ijt}\theta + \mu_j + \varepsilon_{ijt}$$

where (μ_j) represents the mother fixed effect, capturing all unobserved characteristics that are constant for a given mother across births. The vector $(X'_{ijt}\theta)$ contains child-specific characteristics that vary between siblings, including age, sex, birth order, month of birth, and other observed child-level controls. To address within-district correlation of the error terms the robust standard errors are clustered at the district level.

The mother fixed-effects approach greatly strengthens the empirical analysis by holding constant all time-invariant maternal and household characteristics, but it does not rule out bias arising from factors that change over time within families or districts. For example, changes in household income, employment, local economic conditions, conflict, flooding, disease outbreaks, or nutrition

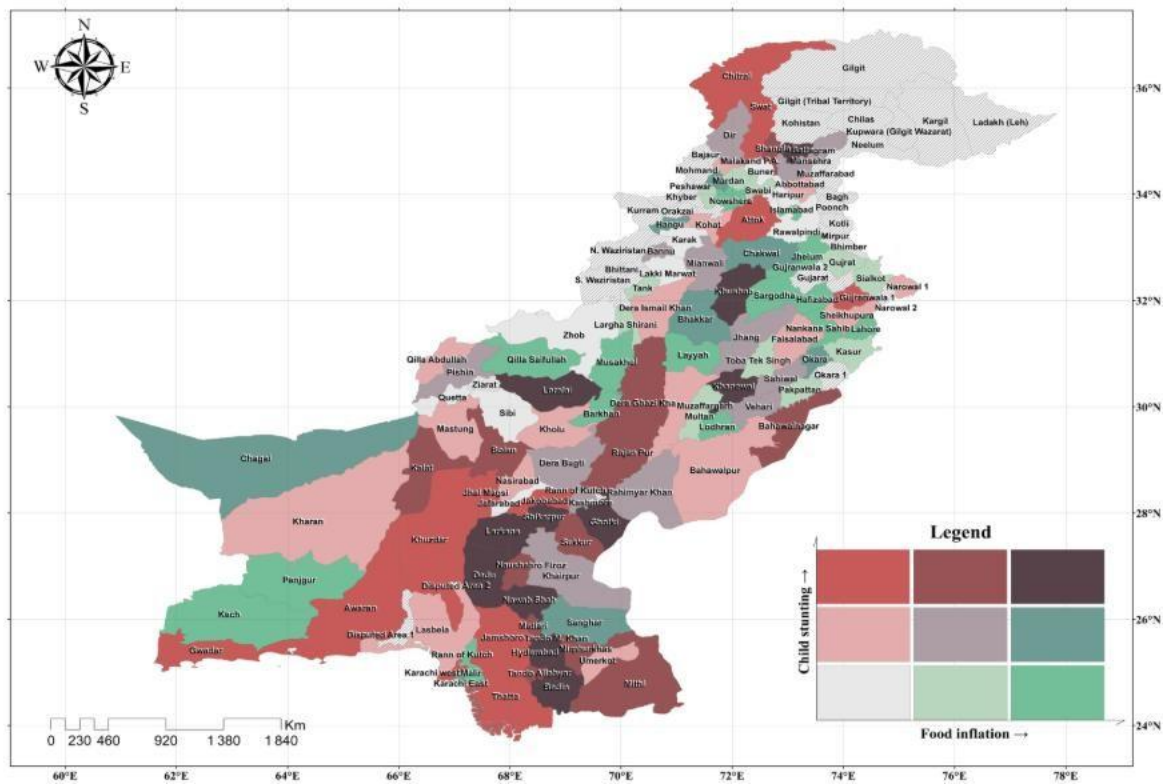
programmes occurring between sibling births may still influence both food inflation exposure and child nutritional outcomes. Consequently, the estimates from the mother fixed-effects model should be interpreted as associations that are robust to unobserved time-invariant maternal and household heterogeneity rather than definitive causal effects.

4. RESULTS AND DISCUSSION

The link between childhood health outcomes and early life exposure to food inflation in Pakistan is discussed in this section. The analysis starts with the use of spatial maps to show the distribution of food inflation geographically and the stunting of children across districts. This shows regions with disparities in the price of food and the nutritional status of children. Furthermore, descriptive statistics are presented for the characteristics of the study sample and the main variables used in the analysis. Before diving into the regression results, the chapter analyzes the food price increase for certain staple food items. To begin with, the OLS estimates are presented in relation to the exposure to average food price inflation while the respondent was pregnant and during the child's infancy, and the likelihood of the child being stunted under more affluent model configurations. Then, the focus shifts to mother fixed-effects models, where the subject is limited to siblings from the same mother in order to address unobserved time-invariant maternal and household factors. The robustness checks are provided with an alternate indicator of child nutrition. Lastly, the main findings suggest about child nutrition and food security policies in Pakistan.

4.1 Spatial Distribution of Food Inflation and Child Stunting in Pakistan

The bivariate spatial distribution of food inflation and childhood stunting is shown in Figure 2 for the districts of Pakistan. Prevalence of childhood stunting is plotted along the vertical axis of the legend, and food inflation is plotted along the horizontal axis of the legend, with all increased upward and all increased to the right. The map shows food price pressures and child undernutrition together in a single classification, showing the geographical distribution of cooccurrence of these two indicators at the district level.



This spatial distribution shows that there is significant spatial variation in food inflation and childhood stunting. Districts in the upper-right part of the legend (dark purple) have high scores on both indicators and are the most vulnerable districts. These districts are mostly at the center of the Sindh province, such as Larkana, Tando Muhammad Khan, Ghotki, Badin, Shikarpur, Hyderabad, and Dadu. Other high vulnerability districts include Khanewal and Khushab in southern Punjab, Loralai in Balochistan, Battagram in Khyber Pakhtunkhwa and Nawab Shah in Sindh. These districts are clustered, and adverse economic conditions are associated with poor nutritional outcomes of children in certain geographic regions.

However, there are several districts in northern and central Punjab that have relatively low levels of childhood stunting irrespective of the differences in food inflation. The pattern suggests that the association between food inflation and child nutrition outcomes is not exclusive, and geographic differences exist. Other social, economic and environmental conditions such as household income, maternal education, healthcare accessibility, sanitation and local food security conditions may also affect child health at the district level.

The bivariate classification is used to further accentuate contrasting spatial patterns. Higher food inflation but relatively low stunting rates could indicate a higher level of resilience among

households, a more robust healthcare system, or a better social protection system, which helps manage the impact of food inflation on households' nutrition status. On the other hand, districts where food inflation is moderate, but stunting is high indicate that other structural factors such as chronic poverty, poor health care, and poor sanitation pose a significant influence on child malnutrition that is independent of short-term food price changes.

High food inflation and high childhood stunting rates at the district level suggest that higher food prices could significantly impact household food consumption and nutrition levels during essential periods of childhood development. These are likely to hasten the prevalence of chronic undernutrition, especially for poor families.

Overall, figure 2 offers descriptive evidence of the extent to which food inflation is locally associated with childhood stunting in Pakistan. The map does not make any causal claims, but it does show clear geographical differences and gives a good justification for the econometric analysis outlined in subsequent sections. The results also indicated that there is a need for geographically specific nutrition and food security interventions to be more effective than a uniform national policy in reducing childhood malnutrition.

4.2 Descriptive Statistics

Descriptive statistics for the variables in the empirical analysis are shown in Table 1. There are 16,313 children in total analytical sample from the Pakistan Demographic and Health Surveys (PDHS) 2012-13 and 2017-18. However, due to missing data, the number of observations varies slightly across variables. For example, valid measurements for Height-for-Age Z-score (HAZ) are available for only 4,812 children because anthropometric data were only collected for a subset of eligible children in the survey. The average NDVI during infancy can be calculated for 16,309 observations due to a couple of missing geographic matches. In the sample, the prevalence of stunting is nearly 12.7%. This shows that chronic undernutrition is still a concern in child health in Pakistan. The average Height-for-Age Z-score (HAZ) is -1.75 . Children in the sample are on average significantly below the median of the WHO Child Growth Standards.

Table 1. Summary Statistics

	Mean	SD	Min	Max
Utero_inflation	5.67	7.84	-9.98	29.96

Infancy_inflation	13.60	17.40	-14.49	74.40
NDVI_utero	2.42	1.33	0.00	5.23
NDVI_infancy	7.11	6.11	0.00	28.75
haz_z	-1.75	1.75	-6.00	5.81
stunted	0.13	0.33	0.00	1.00
child's age	31.54	15.49	6.00	59.00
wealth index	2.98	1.44	1.00	5.00
Observations (N)	16313			

The descriptive statistics reflect the different levels of early childhood exposure to food inflation for the children in the sample. For example, the average month-on-month food inflation during pregnancy is 5.67%, while the average month-on-month food inflation during infancy is 13.60%. The wide ranges of both variables reflect significant time and place differences in food price exposure across districts and birth cohorts. This variation justifies the empirical evaluation of the relationship between exposure to food inflation and the nutritional status of children.

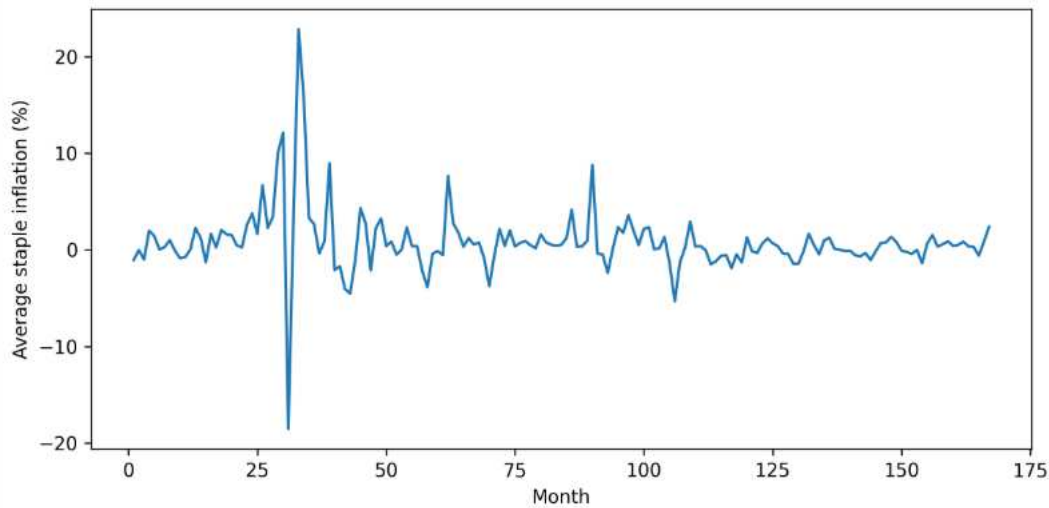
There are also significant differences in environmental conditions across the sample. The mean NDVI values in pregnancy and infancy capture the variations in vegetation and farming conditions across the districts. NDVI is incorporated in the empirical analysis as a measure of the environmental context, which is likely to affect agricultural production, food supply, and the food security of households, and consequently, the nutritional status of children.

The mean household wealth index shows that on average; a household's socioeconomic status is 2.98 on a 5-category scale. The socioeconomic status differences indicate how varying degrees of socioeconomic status would affect households on how well they can handle increasing prices of food. These differences are very significant; therefore, these will be included as control variables in the regression analysis. Overall, the descriptive evidence demonstrates substantial variation in child nutritional outcomes, food inflation exposure, environmental conditions, and household socioeconomic characteristics. This variation is adequate for examining the association between early childhood exposure to food inflation and children's health outcomes in the subsequent empirical analysis.

4.3 Trends in Food Commodity Prices

The trend of inflation for staple food items in Pakistan from 2005 to 2018 is shown in figure 3. The time-series graph shows monthly observation as the horizontal axis and the vertical axis shows the percentage change in the average staple food inflation. As shown in the figure, there has been a significant time variation in food inflation during the study period, with considerable fluctuation in food prices.

Figure 3: Time series line graph of monthly staple food inflation in Pakistan (2005–2018)



Note: The figure presents district-level monthly staple food inflation constructed from market price data obtained from the Pakistan Bureau of Statistics (PBS). The inflation measure is based on the prices of major staple food commodities and captures temporal variation in food prices across the study period. These fluctuations provide the basis for examining how exposure to food price shocks during pregnancy and infancy is associated with child nutritional outcomes.

As shown in Figure 3, the price trend of staple foods had significant fluctuations during the study period, and many periods of significant increases in food inflation. Such variations suggest that the food price environment for households was significantly different, depending on when their pregnancy and early childhood occurred. Hence, children who were born during periods of high food inflation may have been more vulnerable to malnutrition than those who were born during periods of relatively stable food prices.

This variation in observed results is significant in the context of Pakistan where the poor spend a significant proportion on food. Increased staple food prices can increase food poverty and decrease the ability of vulnerable households to access the quantity and quality of food they need. This has a potential impact on the nutrition of the mother during pregnancy and nutrition of children during infancy, which can have adverse effects if the food inflation rate increases in the future.

From an economic point of view, food inflation is a negative real income shock which limits consumption choices of households. Households may cut back on food intake when food prices increase or may cut down on spending on the healthier food they desire in favor of lower cost alternatives or may redirect spending from health and other essentials to food to ensure food needs are fulfilled. These coping mechanisms will likely have negative effects on pregnancy and early childhood nutrition when it is most needed for healthy growth and development.

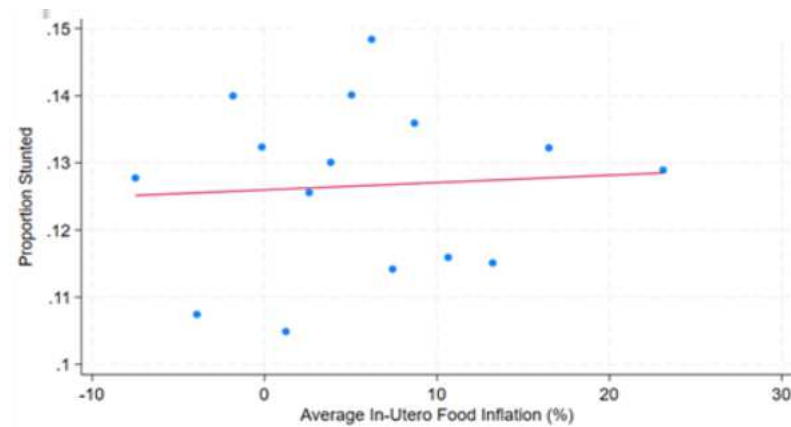
4.4 Graphical Evidence on Food Inflation and Child Stunting

This study applies to the identification method based on the significant month-to-month fluctuations in food inflation. The analysis is then able to explore the hypothesis that exposure to food inflation in early childhood is linked to childhood stunting and other adverse nutritional outcomes by connecting these temporal fluctuations of food prices to the individual birth histories. The results of the data analysis in this section are presented graphically as follows.

4.4.1 Utero Food Inflation Exposure and Childhood Stunting

The relationship between food inflation exposure and childhood stunting is shown in figures 4 and 5 for two critical periods of early-life development: the prenatal period (in utero) and infancy. The scatter plots along with the fitted linear regression lines offer descriptive evidence on association between food inflation and childhood stunting relative to districts in Pakistan. The positive slope of the fitted regression line in both figures indicates that for each 10 percentage increase in food inflation, the prevalence of stunted children increases by 0.1 percentage points. Childhood stunting is linked to exposure to high food inflation in ultrahigh food inflation during fetal development is associated with childhood stunting. However, Figure 4 shows the correlation between the average food inflation in pregnancy and stunting in childhood by districts in Pakistan.

Figure 4: In-Utero Food Inflation Exposure and Child Stunting



Note: The figure illustrates the association between average food inflation during pregnancy and the proportion of stunted children. The fitted regression line indicates a positive relationship between prenatal food inflation exposure and childhood stunting.

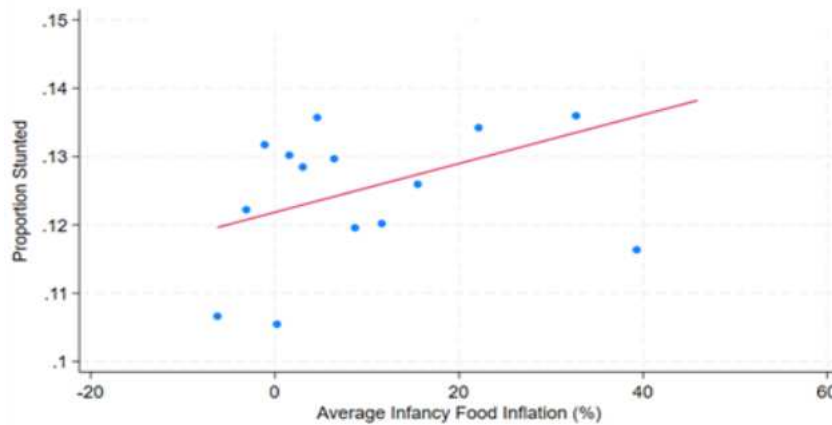
As shown in **Figure 4**, districts experiencing higher food inflation during pregnancy generally exhibit a higher prevalence of childhood stunting. Although there is some variation across districts, the upward-sloping regression line indicates a positive association between prenatal food inflation exposure and adverse child nutritional outcomes. The dispersion of observations suggests that the strength of this relationship varies geographically, reflecting differences in local socioeconomic and environmental conditions.

From an economic perspective, rising food prices during pregnancy reduce household purchasing power and may limit access to adequate maternal nutrition. Poor maternal nutrition during this critical developmental period can adversely affect fetal growth and increase the likelihood of chronic undernutrition during early childhood. Although the figure provides descriptive rather than causal evidence, the observed pattern is consistent with the hypothesis that prenatal exposure to food inflation contributes to poorer child nutritional outcomes.

4.4.2 Infancy Food Inflation Exposure and Childhood Stunting

Figure 5 illustrates the relationship between food inflation during infancy and childhood stunting across districts in Pakistan.

Figure 5. Infancy Food Inflation Exposure and Child Stunting



Note: The figure illustrates the relationship between food inflation during the first year of life and childhood stunting. The fitted regression line indicates a positive association between food inflation during infancy and the prevalence of childhood stunting.

As shown in **Figure 5**, higher levels of food inflation during infancy are also associated with a greater prevalence of childhood stunting. Compared with the prenatal relationship shown in Figure 4, the observations display greater dispersion around the fitted regression line, suggesting that the relationship varies more substantially across districts. This pattern indicates that household characteristics, caregiving practices, healthcare access, and local socioeconomic conditions may influence how food price shocks affect child nutrition after birth.

From an economic perspective, rising food prices reduce the purchasing power of households, particularly among low-income families that allocate a substantial proportion of their income to food expenditure. In response, households may reduce food consumption, substitute nutritious foods with lower-cost alternatives, or reallocate expenditure away from healthcare and other essential needs. These coping strategies may compromise children's nutritional intake during infancy, a critical period of physical growth and development.

Overall, the graphical evidence suggests a positive association between food inflation exposure and childhood stunting during both pregnancy and infancy. Although these figures do not establish a causal relationship, they provide preliminary descriptive evidence that supports the econometric analysis presented in the subsequent sections.

4.5 Baseline Regression Results

Table 2 shows the Ordinary Least Squares (OLS) estimates of the relationship between exposure to food inflation during pregnancy and infancy and child stunting in Pakistan. The six specifications progressively introduce child, household, parental, geographic, survey year, region and age, birth cohort controls to examine whether the estimated associations are robust to increasingly comprehensive model specifications.

Table 2. OLS Estimates of the Effects of Exposure to Food Inflation while in Utero and during Infancy on Stunting

	(1)	(2)	(3)	(4)	(5)	(6)
utero_inflation	.0010 [*] (0.0004)	0.0004 (0.0005)	0.0005 (0.0005)	0.0005 (0.0005)	0.0006 (0.0005)	0.0010 (0.0007)
infancy_inflation	-0.0005 [*] (0.0002)	-0.0004 (0.0003)	-0.0003 (0.0004)	-0.0003 (0.0004)	0.0000 (0.0004)	0.0014 (0.0008)
ndvimean_utero	-0.0101 [*] (0.0044)	-0.0092 [*] (0.0042)	-0.0055 (0.0037)	-0.0011 (0.0037)	-0.0008 (0.0040)	-0.0019 (0.0041)
ndvimean_infancy	-0.0014 (0.0010)	-0.0001 (0.0013)	-0.0002 (0.0013)	-0.0003 (0.0013)	-0.0001 (0.0013)	0.0001 (0.0013)
Age & month of birth	Yes	Yes	Yes	Yes	Yes	Yes
Child controls	No	Yes	Yes	Yes	Yes	Yes
Household controls	No	No	Yes	Yes	Yes	Yes
Mother controls	No	No	Yes	Yes	Yes	Yes
Father controls	No	No	Yes	Yes	Yes	Yes
Geographic controls	No	No	No	Yes	Yes	Yes
Survey year × region	No	No	No	No	Yes	Yes
Age × birth cohort	No	No	No	No	No	Yes
Observations	16309	10119	10023	10023	10023	10023
R-squared	0.0103	0.0189	0.0261	0.0299	0.0336	0.0356

Notes: Robust standard errors are in parentheses. The outcome variable is a dichotomous variable (STUNTED = 1 for a stunted child, 0 for a non-stunted child). All specifications include age and month of birth fixed effects. Child, household, maternal, and regional controls are incrementally added to each specification.

*** p < 0.01, ** p < 0.05, * p < 0.10.

The results show that there is a positive relationship between food inflation during pregnancy and the likelihood of stunting in children. The baseline specification (Model 1), month-to-month inflation while in utero is positively associated with stunting ($\beta = 0.0010$, $p < 0.10$), implying that a one-unit increase in average monthly food inflation during pregnancy is associated with a 0.10 percentage-point increase in the probability of a child being stunted. Although the magnitude of the estimated effect is modest, persistent increases in food prices during pregnancy may substantially reduce households' purchasing power, limiting maternal access to adequate nutrition during a critical period of fetal development.

When Model (2) presents characteristics of the children, the coefficient drops to 0.0004 and is statistically insignificant. The estimated coefficient stays positive, but insignificant in Models (3) through (6), with values between 0.0005 and 0.0010. Although the association is not robustly significant after additional controls are introduced, the consistently positive coefficients suggest that higher food inflation during pregnancy is associated with an increased probability of child stunting.

The estimated association between food inflation during infancy and child stunting is weaker. The coefficient is negative and statistically significant in the baseline model specifications ($\beta = 0.0005$, $p < 0.10$). However, after additional child, household, parental, geographic, and cohort controls are included, the estimated coefficients become statistically insignificant and eventually change sign in Model (6). These findings suggest that there is no robust evidence of an independent association between food inflation during infancy and child stunting once observable characteristics are taken into account.

The environmental controls offer further information on the links between local environmental conditions and child nutrition outcomes. Average NDVI during pregnancy is negatively associated with child stunting in Models (1) and (2), indicating that more favorable vegetation conditions are associated with a lower probability of stunting. After household, parental, and geographic controls are added, this association becomes statistically insignificant. This suggests a portion of the relationship is explained through the socioeconomic and environmental factors represented by these additional controls. Average NDVI during infancy is negative across most specifications and statistically insignificant throughout the analysis. This suggests there is little evidence of an independent relationship with child stunting.

The decrease in observations from 16,309 in Model (1) to 10,119 in Model (2) is due to childlevel control variables resulting in listwise deletion of those with missing values. In Model (3), the sample decreases to 10,023 observations because of missing information in household, maternal, and paternal characteristics. Models (4) – (6) have the same sample size, which means the geographic controls, survey year $\times$ region interactions, and age $\times$ birth cohort interactions do not add missing cases. Thus, the last four specifications are estimated with the same analytical sample, which means that the estimated coefficients differ because of the model specifications and not the sample.

The models' explanatory power improves as more controls are added, with R-squared values increasing from 0.0103 in Model (1) to 0.0356 in Model (6). In general, the preliminary OLS results indicate that, of the two stages of food inflation exposure, food inflation during the pregnancy period has a stronger and more consistent positive association with child stunting than food inflation during the infancy period. The results highlight the need to consider the prenatal period as a sensitive window of child development, and also indicate that the estimated relationships should be interpreted as associations, not as causal effects.

4.6 Mother Fixed-Effects Results

Table 3 shows the mother fixed-effects estimates of the relationship between exposure to food inflation during pregnancy and infancy and child stunting. The mother fixed-effects specification is different from the baseline OLS models, in that it compares siblings born to the same mother and raised in different food price environments during pregnancy and infancy. This approach controls for all unobserved maternal and household characteristics that remain constant across siblings, such as genetic endowments, parental preferences, long-term socioeconomic status, and other time-invariant family characteristics, thereby reducing potential bias arising from these unobserved factors.

Table 3. Mother Fixed Effects Estimates of the Effects of Exposure to Average Inflation while in Utero and during Infancy on Stunting

	(1)	(2)	(3)
Month-to-month inflation while in utero	0.0014*** (0.0005)	0.0013** (0.0005)	0.0010 (0.0008)
Month-to-month inflation during infancy	-0.0004	-0.0003	0.0011

	(0.0003)	(0.0003)	(0.0010)
Average NDVI while in utero	-0.0526***	-0.0528***	-0.0650***
	(0.0179)	(0.0178)	(0.0197)
Average NDVI during infancy	-0.0038**	-0.0037***	-0.0034**
	(0.0014)	(0.0014)	(0.0015)
Age & month of birth	Yes	Yes	Yes
Child controls	No	Yes	Yes
Age × birth cohort	No	No	Yes
Observations	8847	8798	8798
R-squared	0.0149	0.0220	0.0279

Notes: Mother fixed-effects models are estimated to control unobserved time-invariant maternal and household characteristics. Robust standard errors are reported in parentheses.

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

The results indicate that the positive association between food inflation during pregnancy and child stunting remains after controlling for unobserved time-invariant maternal and household characteristics. In Model (1), month-to-month inflation while in utero is positively associated with child stunting ($\beta = 0.0014$, $p < 0.01$). The results estimated in coefficient remains positive and statistically significant in Model (2) ($\beta = 0.0013$, $p < 0.05$) after child-level controls are introduced. While the coefficient decreases slightly and becomes statistically insignificant in Model (3) after the age × birth cohort interactions are included, it retains a positive sign in all specifications. This consistency indicates that prenatal exposure to higher food inflation remains associated with a higher probability of child stunting, even after controlling for maternal and household unobservable that are fixed over time.

The economic reasoning provided here supports the proposition that rising food costs while pregnant create a financial barrier for mothers to obtain the necessary nutrition for herself and her developing fetus. Given that the mother fixed-effects model examines siblings from the same family, the positive correlation is less likely to be the result of ongoing variations in the household background and more likely to be due to the varying food pricing circumstances across pregnancies.

However, food inflation in infancy is not significantly related to child stunting in any of the three specifications. The findings of coefficients are small, statistically insignificant and alter signs in the final specification. These findings suggest that, after controlling for both observed characteristics and unobserved time-invariant maternal and household heterogeneity, there is

limited evidence of an independent association between food inflation during infancy and subsequent stunting.

The environmental controls remain important predictors of child nutritional outcomes. Average NDVI during pregnancy is negative and statistically significant across all three specifications, showing that more favorable vegetation and agricultural conditions are consistently associated with a lower probability of child stunting. Likewise, average NDVI during infancy is also negative and statistically significant in all specifications, although its estimated magnitude is considerably smaller than that of prenatal NDVI. Together, these findings suggest that favorable environmental conditions during both pregnancy and infancy are associated with improved child nutritional outcomes.

The mother fixed-effects models are estimated on a smaller sample than the baseline OLS models because identification is obtained only from mothers with at least two observed children in the survey. Consequently, mothers with only one observed child do not contribute to the estimation and are excluded from the analysis, reducing the sample from 16,309 observations in the baseline OLS model to 8,847 observations in Model (1). The sample declines slightly further to 8,798 observations in Models (2) and (3) owing to listwise deletion resulting from missing values in the child-level control variables. No additional observations are lost when age $\times$ birth cohort interactions are introduced in Model (3), indicating that these variables are fully observed for the remaining estimation sample.

The explanatory power of the mother fixed-effects models increases modestly as additional controls are incorporated, with the R-squared rising from 0.0149 in Model (1) to 0.0279 in Model (3). Overall, the mother fixed-effects results reinforce the baseline findings by showing that the positive association between prenatal food inflation and child stunting persists even after controlling for unobserved time-invariant maternal and household characteristics.

Simultaneously, as there is a loss of statistical significance in the most restrictive specification, this implies that the magnitude of the association should be interpreted with caution, and seen as correlational, rather than as providing definitive proof of a causal relation.

4.7 Robustness Check Using Height-for-Age Z-Score (HAZ)

In order to assess the robustness of the baseline results, the regression models are re-estimated using Height-for-Age Z-score (HAZ) as the dependent variable rather than the binary stunting variable. The stunting variable is a dichotomous variable that classifies children as stunted or non-stunted, whereas HAZ provides a continuum regarding the nutrition status of a child. A lower HAZ value indicates poorer linear growth and higher levels of chronic undernutrition. If the estimated associations are true for both outcome variables, then it indicates higher reliability of the results.

Table 4 presents these results. Across all six models, food price inflation during pregnancy is associated with a negative impact on HAZ scores. In the baseline model (Model 1), the estimate for prenatal food inflation is -0.0176, which is significant at the 1% level. This negative result of variable is significant across all models even though it slightly decreases with the inclusion of additional controls. These results show that greater exposure to food inflation during pregnancy is consistently associated with worse child growth, measured using HAZ scores. This supports the baseline stunting analysis that demonstrated greater prenatal food inflation was associated with a greater probability of child stunting. Given that lower HAZ scores reflect poorer nutritional status, the negative coefficients here support prior findings.

Table 4. Robustness Check: OLS Estimates Using Height-for-Age Z-score (HAZ)

	(1)	(2)	(3)	(4)	(5)	(6)
	-0.0176***	-0.0172***	-0.0152***	-0.0159***	-0.0092***	-0.0103**
Utero_inflation	(0.0038)	(0.0038)	(0.0035)	(0.0034)	(0.0035)	(0.0049)
Infancy_inflation	-0.0031	-0.0028	-0.0041*	-0.0042**	0.0060**	-0.0045
	(0.0023)	(0.0022)	(0.0021)	(0.0021)	(0.0025)	(0.0049)
NDVImean_uter0	0.1696**	0.1562**	0.0504	-0.0913**	-0.1053**	-0.0918*
	(0.0662)	(0.0649)	(0.0528)	(0.0435)	(0.0447)	(0.0466)
NDVImean_infancy	0.0182	0.0190	0.0219*	0.0178	0.0155	0.0120
	(0.0117)	(0.0117)	(0.0113)	(0.0114)	(0.0110)	(0.0111)
Age & month of birth	Yes	Yes	Yes	Yes	Yes	Yes
Child controls	No	Yes	Yes	Yes	Yes	Yes
Household controls	No	No	Yes	Yes	Yes	Yes
Mother controls	No	No	Yes	Yes	Yes	Yes
Father controls	No	No	Yes	Yes	Yes	Yes
Geographic controls	No	No	No	Yes	Yes	Yes

Survey year × region	No	No	No	No	Yes	Yes
Age × birth cohort	No	No	No	No	No	Yes
Observations	4810	4795	4745	4745	4745	4745
R-squared	0.0859	0.1013	0.1901	0.2099	0.2420	0.2485

Notes: The dependent variable is the child's height-for-age z-score (HAZ). Lower HAZ values indicate poorer nutritional status. Robust standard errors are reported in parentheses.

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

The association between food inflation during infancy and HAZ is less consistent. The coefficient is negative but not statistically significant for Models (1) and (2). It is negative and statistically significant for Models (3) and (4), and turns positive and statistically significant for Model (5). Finally, it returns to a negative value that is not statistically significant for Model (6). The lack of a stable pattern for these specifications shows little evidence for a strong relationship between food inflation during infancy and the long-term nutritional status of children after further controls were introduced.

The impacts of environmental factors differ across the models. During pregnancy, average NDVI is positively associated with HAZ in the first two specifications, which shows that during better vegetation periods, child growth improves. However, when geographical controls are included, the estimated coefficient is negative and statistically significant. This directional change suggests that the relationship between environmental factors and HAZ is model dependent and could capture relationships of vegetation and geography and several other socio-economic variables. On the other hand, average NDVI during infancy is generally small and statistically insignificant in most models, providing little evidence for a relationship to child growth.

The robustness analysis incorporates a considerably smaller sample than the primary stunting analysis because valid anthropometric data is accessible for only 4,810 children. In Model (2), the sample observation slightly decreases to 4,795 due to of child-level control variables inclusion, which is a result of listwise deletion from the absence of data. In Model (3), the addition of household, maternal, paternal, and geographical control variables decrease the sample further, to 4,745 observations, as some of these variables contain missing data. No further observations are lost across Models (4) to (6), suggesting that all remaining controls are completely observed within the analytical sample.

The model become greatly improves with the inclusion of more controls, with the R-squared rising from 0.0859 in Model (1) to 0.2485 in Model (6). Overall, the robustness analysis backs up the main findings of the study. Although the size of the estimated coefficients varies since HAZ is a continuous measure and not a binary outcome, the consistently negative link between prenatal food inflation and children's HAZ scores provides further evidence that negative food price conditions during pregnancy are associated with worse child nutritional outcomes. The consistent findings across both nutritional indicators strengthen confidence that the main conclusions are not influenced by the chosen outcome measure.

4.8 Discussion of Findings

The findings clearly show that experiencing high food inflation during pregnancy is linked to poorer nutritional outcomes for children in Pakistan. In the baseline OLS models, mother fixedeffects specifications, and robustness analysis using Height-for-Age Z-scores (HAZ), prenatal food inflation shows the expected relationship with child nutrition. While the statistical significance varies across different models, the consistent signs of the coefficients indicate that difficult food price conditions during pregnancy increase the risk of childhood undernutrition.

These findings are consistent with the origins of health and disease hypothesis of Hanson and Gluckman (2014) suggested that during fetal development, the nutrition available determines the growth and health outcomes of children. The increase in food prices, and the subsequent decrease in food purchasing power, softens access to high quality food while pregnant. Compromised maternal nutrition may cause damage to the growth of the fetus and elevate the risk of adverse nutritional outcomes during early childhood.

Unlike the stable connection between food inflation in infancy and child nutrition, the reverse is less certain. With regards to the OLS and mother fixed-effects models, the coefficients for inflation in infancy, after adding more controls, tend to be smaller and statistically insignificant. Analyses evaluating HAZ also reveal, across models, a lack of consensus. This illustrates the sensitivity of child development in the prenatal period as opposed to the postnatal period. This is in line with the reasoning that the nutritional shocks of pregnancy have a stronger lasting impact on growth than those postpartum.

The analysis of environmental variables emphasizes the importance of local farming conditions. The consistently negative relationship between prenatal NDVI and stunting in the mother fixedeffects models implies that good vegetation conditions relate to better nutritional outcomes for children. This finding supports the notion that better environmental conditions boost agricultural productivity, increase food availability, and enhance household food security. However, the variation in the prenatal NDVI findings in the HAZ robustness analysis indicates that the link between environmental conditions and child growth is affected by the model used, so it should be interpreted carefully.

Overall, the results suggest that pregnancy is a sensitive time when bad food price shocks can have lasting effects on children's nutrition. Although the research includes many observed controls, district fixed effects, mother fixed effects, and environmental factors, the estimates should be seen as strong associations rather than absolute causal effects. Household and districtlevel shocks that change over time may still impact both food inflation and child nutrition.

The evidence calls for policies that shield pregnant women from the impact of food price shocks. During periods of food inflation, measures to strengthen maternal nutrition, such as targeted food assistance, nutrition support initiatives, and social protection for the most vulnerable households, can improve child nutrition and reduce chronic under nutrition in Pakistan.

4.9 Policy Implications

There are several policy implications for enhancing the nutrition status of children and to prevent stunting in Pakistan from findings of this study. First, the national priority of reducing stunting in children should be maintained as it has long-term impacts on human capital, education outcomes, labor productivity, and economic growth. The spatial analysis also shows significant geographic variations of high food inflation and child stunting outcomes in the same districts suggests that the country needs policy interventions focus on the districts where the prevalence of childhood stunting is found to be high. Therefore, there is need to focus on appropriate policies instead of having uniform national policies. Second, the results highlight the need to improve prenatal care and maternal nutrition programs it may be more effective in improving child health outcomes. Malnutrition during pregnancy can have adverse effects which can be mitigated by maternal nutrition programs, micronutrient supplementation and targeted food assistance programs. Third,

policies which reduce the impact of food price shocks on vulnerable households will be likely to improve child welfare outcomes. Enhancing social protection measures, cash transfer initiatives and nutrition-sensitive safety nets would mitigate the risk of young children experiencing chronic under nutrition during high food inflation periods and ensure they are able to consume enough food. Last but not least, investments in agricultural productivity, climate resilience and rural development can have a positive impact on children's health are a key factor identified in this study.

5. Conclusion

Although Pakistan has seen improvement in child health and nutrition in last few decades, but a significant proportion of children remain unduly deprived of nutrition. The spatial analyses presented in this study clearly indicate that there are geographic disparities in child health outcome is geographically localized. The empirical findings suggest that prenatal exposure to food inflation is associated with childhood stunting than postnatal exposure. The results also revealed that the fetal period is a highly sensitive time of child development, and that economic shocks may impact the growth and nutrition outcomes of children in the long-term. Environmental and household factors impacting child health outcomes are also considered. The results shows that the stunting among children in Pakistan is not attributed to a single factor, but rather a combination of social and environmental factors. The findings indicate that there is a need to improve the nutrition programs for mothers and children overall, particularly the nutrition of pregnant women, from a policy perspective. To sum up, this study contributes to the existing literature on child health and nutrition, and reveals the strong link between childhood stunting and conditions during critical periods of development. Improving the nutrition status of mothers, mitigating inequalities within districts and enhancing household food price shock resilience will be important to reduce the impact of childhood stunting and long-term human development in Pakistan. . Future investigation should be done on other pathways that might connect food price shocks to children's nutrition and understand the effectiveness of food policy interventions in reducing the impact of food price shocks.

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