IFPRI Discussion Paper 02167

January 2023

Effects of Weather and Food Market Risks on Household Agriculture-Nutrition Linkage

Micro-level Insights from India

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Abstract

Agriculture-nutrition linkages in developing countries remain complex and continue evolving as weather and market risks intensify due to climate change and other geopolitical and socioeconomic factors. Knowledge gaps remain regarding the exact interrelationship among these dimensions of agriculture-nutrition linkages. This study aimed to partly fill this knowledge gap by assessing how the associations between home production of various food groups and household/individual level nutritional outcomes are affected by weather anomalies and price risks of these food groups in the market, using panel data from India. Our results indicate that, generally, the associations between home production and nutritional outcomes are greater under more normal weather, with rainfall and temperature during the production season being closer to the historical median, potentially because of greater productivity realized and sufficient harvest that can be consumed throughout the year. The associations are also greater when households face greater market price fluctuations of food commodities conditional on the distance to the market, potentially because such price risks lead to reduced food purchases from the market. These effects generally hold not only during the average month but also during the lean month, indicating robustness against seasonality. These results also hold more consistently in remote areas than in areas closer to the market. Overall, our results suggest that efforts to promote nutrition-sensitive agriculture in developing countries should also consider evolving patterns of weather risks and agrifood market price risks to improve their effectiveness.

Keywords: agriculture-nutrition linkage, weather risk, price risk, seasonality, panel data, India

Acknowledgments

We would like to thank the Government of India and The Indian Council of Agricultural Research (ICAR) for providing financial support to conduct this study. We also benefited from constructive dialogue and feedback from the ICAR. Authors are responsible for all remaining errors.

1. Background

In developing countries where malnutrition is prevalent, and agrifood markets are often underdeveloped, smallholders' home production often contributes to the nutrition of household members (Ruel et al., 2018; Fan et al., 2019), including consumption quantity, dietary diversity (Sibhatu & Qaim 2018), and anthropometrics like stunting, underweight, wasting, and body mass index (BMI) (Takeshima et al., 2020). At the same time, improved access to the agrifood market is considered to make household members' nutrition status less dependent on home production of food (e.g., Huang & Tian 2019; Gupta et al., 2020).

However, knowledge gaps remain as to how the linkage between households' food production and nutritional outcomes interacts with other factors, including weather risks, market price risks, and seasonality, despite the concerns raised in the literature. For example, severe and abnormal weather events like droughts or excess rains that cause floods can damage crops, and abnormal temperature or precipitation can reduce yields (Raiten & Combs 2019). While livestock outputs can be somewhat less vulnerable to weather risks, high temperatures can still affect feed intake and milk production (e.g., Fan et al., 2019). Secondly, market risks like price fluctuations of food commodities can affect how market access contributes to nutritional intake. When markets are accessible but imperfect or underdeveloped, price fluctuations can be significant due to markets' inability to smooth out price movements across space and time (Kumar et al., 2015; Shively & Sununtnasuk 2015). In such a case, even with accessible markets, the separability between production and consumption decisions breaks down, and farm production can directly affect consumption and, consequently, nutrition (Ruel et al., 2018). Thirdly, the seasonality of agricultural production and nutrition status common in developing countries can potentially lead to significant seasonal variations in the linkage between households' food production and nutritional outcomes (e.g., Bevis et al., 2019; Gross et al., 2020). However, empirical evidence on these dimensions of agriculture-nutrition linkage is scarce in the literature.

This study partly aims to fill these knowledge gaps, using panel data on India from the Village Dynamics in South Asia (VDSA) project. The data contain information on monthly food consumption, market prices of food items, production activities, and historical and current rainfall and temperature data. Precisely, we assess how the production of key food groups of commodities (namely grains, pulses, dairy, vegetables, and fruits) by the household affected household consumption of these food groups, as well as key anthropometric figures of children and women in the household (namely, stunting, underweight, wasting, and BMI). We then explore how those effects of home production on household nutrition are mitigated by the weather anomalies during the production season but enhanced by greater market price fluctuations. We also show how these effects on food consumption vary between an average month and a lean month (when consumption is low).

India offers an ideal context for this study. Despite agrifood market growth in recent years, malnutrition remains prevalent in India, and the agricultural sector continues to employ a significant share of workers, while at the same time, overweight and obesity are also becoming common among adults (Takeshima et al., 2021). Its vast geographic area also offers diverse patterns of weather anomalies and market price fluctuations experienced by farmers, which we can exploit to assess their effects on agriculture-nutrition linkage accurately.

This study contributes to various strands of literature. It contributes to the general literature on nutrition-sensitive agriculture, agriculture-nutrition linkages (Ruel et al., 2018; Fan et al., 2019), and studies focusing on India (e.g., Gupta et al., 2020; Nichols 2020; Rao & Raju 2020; Dutta et al., 2020) by providing additional evidence from India. It also contributes to the literature discussing the potential roles of climate change (Raiten & Combs 2019), market imperfection (Kumar et al., 2015; Shively & Sununtnasuk 2015), as well as the seasonality of agriculture-nutrition linkages (Gross et al., 2020) by providing related evidence. Specifically, this study explicitly estimates how weather risks affect agriculture-nutrition linkages, unlike previous studies that only conceptualizes such pathway (Raiten & Combs 2020). Similarly, this study explicitly estimates how price volatility, an indicator of market risks, affect agriculture-nutrition linkages, an element not investigated by previous studies (Kumar et al., 2015; Shively & Sununtnasuk 2015). Lastly, this study explicitly estimates the seasonal variations in the extent of agriculture-nutrition linkage.

The remaining of this paper is structured as follows. Section 2 describes the empirical approach. Section 3 describes data and descriptive statistics. Section 4 discusses the empirical results. Finally, section 5 concludes.

2. Empirical approach

Our empirical approach assesses how household-level consumption of commodities from each food group is associated with whether the household grew crops in the corresponding food group, conditional on other exogenous factors. We then delve deeper into how these associations vary depending on the climate shocks that affect households' food production and market risks, such as price volatility of agricultural commodities, which can pose risks for households using the market as the source of food items. Furthermore, we assess how nutrition indicators at the individual level (anthropometrics of women and children) are associated with the same set of variables as above.

We first estimate a household-level model

$$Y_{ijt} = \alpha + \beta_X X_{ijt} + \beta_{XW}\left(X_{ijt} \cdot W_{it}\right) + \beta_W W_{ijt} + \gamma Z_{it} + c_i + \varepsilon_{ijt} \qquad (1)$$

in which Y_{ijt} is the value of consumption of food group j (either annual average, or that of lean month) by household i in year t.[1] Variable X_{ijt} is a binary indicator of whether household i grew food group j in t. Variables Z_{it} include other household variables that affect consumption, measured at the beginning of year t, such as household demographics, asset values, financial shocks, as described in the later section. Variables W_{ijt} measure weather and market risks experienced in areas for food group j, where i resides in year t. Specifically, W_{ijt} include rainfall

[1] We use consumption "values" rather than quantities as outcome variables because values can be aggregated across different commodities within each food group. We also show in Appendix A that using values rather than quantities still offers generally unbiased (or conservative if biased) estimates of the effects of home production on consumption quantities. This is because commodity prices are usually comparable to or lower for households producing these commodities than non-producing households. Same consumption values for producing-households and non-producing households, therefore, indicate that producing-households must be consuming similar, or in some cases even higher, quantities of those food groups than non-producing households are.

risks and temperature risks measured as historical percentiles, and standard deviations (or CV) of monthly average prices of major crops within each food group.

Variables Z_{it} include other household variables that affect consumption, measured at the beginning of year t, such as household demographics, asset values, financial shocks, as described in the later section.

Notations β_X corresponds to the average effects of home production on household consumption, while β_{XW} measures how shock variables W_{ijt} further affect the effects of home production. Notations α, γ, are estimated parameters, c_i is unobserved fixed effects, and ε_{ijt} is idiosyncratic errors.

We then assess the effects on anthropometric outcomes of individual children and women in the household. Specifically, we estimate

$$Y_{ikt} = \alpha + \beta_X X_{ijt} + \beta_{XW}\left(X_{ijt} \cdot W_{it}\right) + \beta_W W_{it} + \gamma Z_{it} + \gamma_k Z_{ikt} + c_{ik} + \varepsilon_{ikt} \qquad (2)$$

In (2), Y_{ikt} denotes various anthropometric outcomes of member k in household i at t, These outcome variables include whether a child 5 years old or younger is not stunted (height-for-age z-score > –2), not underweight (weight-for-age z-score > –2), not wasted (arms circumference z-score > –2), and whether a woman 15 years of age or older has BMI falling within a normal range of 18.5 and 23.[2] Z_{ikt} is exogenous, time-variant characteristics of k, and c_{ik} is unobserved individual fixed effects. Notations of other variables are the same as in (1).[3]

Time periods for outcome and exogenous variables

Conditional on household and individual-fixed effects c_i and c_{ik}, endogeneity between X_{ijt} and Y_{ijt} is likely to be minimal. However, to further reduce the potential endogeneity issues, we measure X_{ijt}, W_{ijt} based on information between July in year *t* - 1 to June in *t*, while measuring consumption values based on figures during January through December in year *t*. This way, production decisions and outputs are more likely to be pre-determined compared to consumption decisions. Furthermore, variables Z_{it} and Z_{ikt} are measured in July in year *t* – 1, so that they are more likely to be pre-determined and exogenous to Y_{ikt} as well.

Other exogenous variables

Variables Z_{it} include other household or individual variables that affect the nutritional outcomes, including (a) household demographics; (b) asset related variables; (c) financial shock variables.

Household demographics include household head characteristics (age, gender, and years of education completed), which can change between survey rounds depending on events like the

[2] Studies suggest that normal values for BMI can vary depending on, for example, sub-regions in the world (Chang et al. 2003). In Asia, several studies indicate that ranges for normal BMI are between 18.5 and 23, different from those commonly used for non-Asian countries (Usfar et al. 2013).

[3] We specify the relations between anthropometric outcomes and household food production as a static regression that is commonly used in the literature rather than dynamic regression (e.g., Hagos et al. 2014; Carletto et al. 2017; Abay & Hirvonen 2017; Holland & Rammohan 2019; Otterbach & Rogan 2019; Mary et al. 2020; Chegere & Stage 2020; Tasic et al. 2020; Vu & Rammohan 2022).

death or outmigration of a previous household head. The number of household members across gender and age groups (children 14 years old or younger, working-age members aged between 15 and 60 years old, elderly who are 61 years old or older) are also included to account for changes in household-level food consumption needs and labor endowments.

Asset-related variables include farmland owned, the total value of agricultural equipment owned, the total value of livestock owned based on their local prices, and the total value of other household assets owned.

Financial shock variables include the death of the household head and other earning members, which is likely to significantly affect household incomes. The variables also include net indebtedness at the beginning of the survey period (including the amount owed, the amount lent, and the amount saved in the bank), which can affect the household's ability to purchase food. Factors that affect the food production costs are proxied by wages, particularly the male labor wages for land preparation. In countries like India, spatial and temporal wage variations can often be substantial (Jayachandran 2006; Munshi & Rosenzweig 2016). Given the significant reliance on labor as production inputs for various food groups, wage fluctuations can lead to significant variations in food production costs.

Further to household level variables Z_{it} described above, other exogenous variables Z_{ikt} in individual-level regressions (2) on anthropometrics include age, gender (for children) and year of education completed of each individual.

Lastly, household-level variables Z_{it} include interactions of dummy variables indicating survey year (2010, …, 2014), and regions (South, West and East)[4] to capture any residual temporal variations in region-specific factors that affect outcome variables.

3. Data and descriptive results

3.1 Data

Our primary data are farm household-level panel data from the Village Dynamics in South Asia (VDSA) project of the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) (ICRISAT 2022) (*VDSA data* hereafter). Details of the survey are described on the VDSA project website.[5] The scope of the ICRISAT-VDSA dataset was to collect detailed information on households' agricultural production activities, nutrition indicators like household food consumption, and anthropometrics of women and children, among other data. The sampling frame of the data consists of a total of 18 purposively selected villages in 5 Southern Indian states (Andhra Pradesh, Gujarat, Karnataka, Madhya Pradesh, and Maharashtra) and 12 purposively selected villages in 3 Eastern Indian states (Bihar, Jharkhand, and Orissa). Based on the census of households in each of these villages, households were classified into four groups according to farm size and land ownership, from which a predetermined number of households were randomly selected and interviewed annually between 2010-2014. After dropping observations with missing

[4]Regions are defined as marked in Figure 1.
[5]http://vdsa.icrisat.ac.in/vdsa-microdoc.aspx.

data, a total of 6,666 household observations (aggregated from 5 survey rounds) from 1,515 panel households, and a total of 1,147 individual observations of children 5 years or younger, and 14,531 individual observations of women of reproductive age from these households, were used for the analysis. Figure 1 illustrates the locations of these 18 villages and 12 villages in Southern India and Eastern India, respectively.

We also used weather data from GIS data for geographical coordinates of villages in VDSA samples. Historical monthly rainfall data were extracted using Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS) (Funk et al., 2015), while historical monthly temperature data were extracted using NOAA (2022).

3.2 Descriptive results validating empirical approach

Table 1 summarizes the descriptive statistics of the outcome variables and exogenous variables.

Outcome variables
The sample households typically consume grains worth 900 Rupees/month and other groups like pulses, meat, dairy, vegetables, and fruits, each worth between 100 and 500 Rupees/month. During the lean month (lowest consumption month in the year), grain consumption is about 600 Rupees/month, and other food groups' consumption may be roughly half that of average months.

At the individual level, 38.5, 70.2, and 72.7 percent of children 5 years or younger are not stunted, are not underweight, having sufficient arms circumference. Among women 15 years of age or older, 45.3 percent have BMI within the normal range.

Exogenous variables
The surveyed households typically have 2 and 1 working-age male and female, respectively, and one boy and girl under 14 years old. Most household heads are male, 48 years old on average, and 4 ~ 5 years of formal education. Most households are smallholders, owning about 1 ~ 1.5 ha of farmland, generally asset and resource-poor, and facing labor markets with an hourly wage of 22 rupees/hour. Typical households also have 55,000 and 10,000 Rupees of debt at mean and median, respectively.

About 70 ~ 80 percent of households grow grains, pulses, meat, dairy, and vegetables, while about 40% grow fruits. Most households are in areas that experienced less than average rainfall and temperature relative to historical normal. Typically, the households observed a 0.2 coefficient of variation (CV) in the price of each food group, except for fruits, for which the price CV is about 0.4.

While most households did not experience the change of household head or death of a key income-earning member, 1 and 0.5 percent experienced such loss during the previous year.

4. Results

4.1 Effects of home production on consumption by major food groups

Table 2 (upper panel) summarizes the estimated effects of whether the household grew each food group during July in year t and June of year t + 1 on the monthly average consumption of the corresponding food group during January through December in year t + 1. For example, on average, growing grain crops at home led to 12.184 (rupees) higher average grain consumption per month per household. The statistically significant positive effects of home production are also observed for pulses (3.8 rupees), dairy (24.6 rupees), vegetables (2.7 rupees), and fruits (5.6 rupees). These findings suggest that, on average, growing these food group commodities at home led to a significant increase in the consumption of these commodities.

Importantly, for many food groups, these positive effects are statistically significantly magnified if the weather is closer to normal. For example, the positive impact of growing grains at home on grain consumption is further raised by 12.282 (rupee) if the rainfall is one standard deviation (SD) closer to the normal rainfall (50th percentile of historical distribution) and 5.723 if the average temperature is one SD closer to the normal temperature. Similarly, the effects are raised by 8.469 and 17.826, respectively, if the standard deviation and CV of grain price variability are 1SD higher. These statistically significant positive effects are observed for price risk in dairy and fruits, as well as rainfall and temperature for vegetables and fruits. While these positive effects are not always statistically significant, none of them is statistically significantly negative, suggesting that the sets of results are generally consistent with other.

The lower panel of Table 2 further shows that the positive effects observed on average consumption largely hold also for lean-season months. In fact, for all studied food groups, engagements in the home production of each food group led to significantly higher consumption of the respective food group in the lean month. Furthermore, similar to Table 2, these positive effects are more than often significantly magnified if rainfall and temperature are more normal, and market price risks of corresponding food group commodities are greater. Similar to Table 2, while these effects are not always statistically significant, none of them are statistically significantly negative.

4.2 Effects of home production of major food groups on anthropometrics of women and children

Table 3 and Table 4 present the effects of home production of each food group on whether a child has sufficient height-for-age (not stunted) (Table 3 upper panel), weight-for-age (not underweight) (Table 3 middle panel), arm circumference (Table 3 lower panel), and whether a woman's BMI falls in the normal range (Table 4).

Quite a few coefficients are positive, which indicate that a household's home production of each food group has effects of reducing child stunting, underweight or insufficient arm circumference, or women achieving normal BMI. These positive effects are magnified if rainfall and temperature are closer to the historical median, and market price risks of respective food groups are greater. Similar to Table 2, while not all coefficients are statistically significantly positive, none of the

coefficients are statistically significant negative, suggesting that the evidence of counter hypothesis is generally absent.
There are also certain variations in patterns across food groups. Production of grains and pulses generally has broader effects on stunting, underweight, arms circumference, and BMI, which tend to be enhanced under normal weather and high market price risks. Production of vegetables reduces stunting and wasting and improves BMI, with greater effects of weather risks on the latter. Production of fruits reduces underweight, particularly in the face of greater price risks, and also improve arms circumference. Home production of dairy products has somewhat weak effects, though positive, on stunting and underweight, particularly under more normal weather.

Generally, however, these findings are consistent with the earlier studies that greater diversity of household food production contributes to improved anthropometrics of children and women (e.g., Takeshima et al., 2020). Pulses can provide more micronutrient than cereals and can naturally improve micronutrient levels with or without additional fortification (McDermott & Wyatt 2017). Positive effects of vegetables and fruits are consistent with earlier evidence on wasting (Hirvonen et al., 2021) and BMI (Hooshmand & Udipi 2013), and reduced deficiency of micronutrients (Sié et al., 2018) that affect anthropometric growth, like Vitamin A and iron (Gowele et al., 2021) and dietary fiber (Poole et al., 2021).

Somewhat positive effects of dairy are also generally consistent with earlier studies showing the effects on reduced anthropometric failure and malnutrition (Scherbaum & Srour (2018)), particularly in vegetarian diets (Pandey & Kashima, 2021). However, the effects of dairy production might be less detectable because of a high share (86 percent) of households producing dairy products in the data (Table 1).

Statistically insignificant coefficients of weather and market risks (for example, for vegetables and fruits on stunting and underweight, or pulses on wasting) may reflect that weather anomalies can affect different micronutrients in these food groups in different ways, leading to differential effects on stunting, underweight, or arms circumferences. For example, micronutrients in pulses that contribute more to arms circumference may be less vulnerable to weather anomalies than those that contribute more to stunting or underweight, and similarly vice versa for vegetables and fruits. Similarly, differential effects of market risks may reflect heterogeneity in quality between home-grown and market traded commodities. For example, micronutrients in pulses important for arms circumference may be provided more from home-grown pulses, while micronutrients for height or weight may be provided more from pulses in the market, so that the effects of home production on arms circumferences may be less affected by market price risks. These hypotheses should be, however, more formally investigated in future studies.

4.3 Robustness check

Our primary specifications estimated the effects of production decisions X_{ijt} one by one for each food group j, instead of including X_{ijt} for all food groups in estimation as the latter leads to potential multi-collinearity among X_{ijt} for different food groups. To check the robustness of our results, however, we also estimated the latter models for anthropometric regressions, and show them in Table 5 and Table 6 (which correspond to results in Table 3 and Table 4, respectively). Results shown in Table 5 and Table 6 are generally consistent with those in Table 3 and Table 4, albeit with reduced statistical significance. Therefore, our results from Table 3 and Table 4 are robust.

Furthermore, Table 7 through Table 11 further show how the estimated coefficients and their statistical significance from Table 2 through Table 4 vary between areas differentiated by distance to the nearest food markets (remote areas and close areas). These are estimated separately for subsamples split by median distance to the markets (10km). Table 7 through Table 11 suggest that, average effects of home production are generally more positive and more statistically significant in remote areas, consistent with earlier studies (e.g., Ruel et al., 2018; Takeshima et al., 2020). Such differences are reversed in a few cases for close areas (for example, Table 10), and pulses and vegetables for BMI (Table 11)). However, patterns in close areas are less consistent, with significantly negative effects observed in some cases. Patterns in remote areas are more consistent without any statistically significant negative effects, as in Table 2 through Table 4. Our results are therefore robust, particularly in remote areas.

5. Conclusions

Agriculture-nutrition linkages in developing countries remain complex and continue evolving as weather and market risks intensify due to climate change and other geopolitical and socioeconomic factors. Knowledge gaps remain regarding the exact interrelationship among these dimensions of agriculture-nutrition linkages.

This study aimed to partly fill this knowledge gap by assessing how the associations between home production of various food groups and household/individual level nutritional outcomes are affected by weather anomalies and price risks of these food groups in the market, using panel data from India. Our results indicate that, generally, the associations between home production and nutritional outcomes are greater under more normal weather, with rainfall and temperature during the production season being closer to the historical median, potentially because of greater productivity realized and sufficient harvest that can be consumed throughout the year. The associations are also greater when households face greater market price fluctuations of food commodities conditional on the distance to the market, potentially because such price risks lead to reduced food purchases from the market. These effects generally hold not only during the average month but also during the lean month, indicating robustness against seasonality. These results also hold more consistently in remote areas than in close areas. Overall, our results suggest that efforts to promote nutrition-sensitive agriculture in developing countries should also consider evolving patterns of weather risks and agrifood market price risks to improve their effectiveness.

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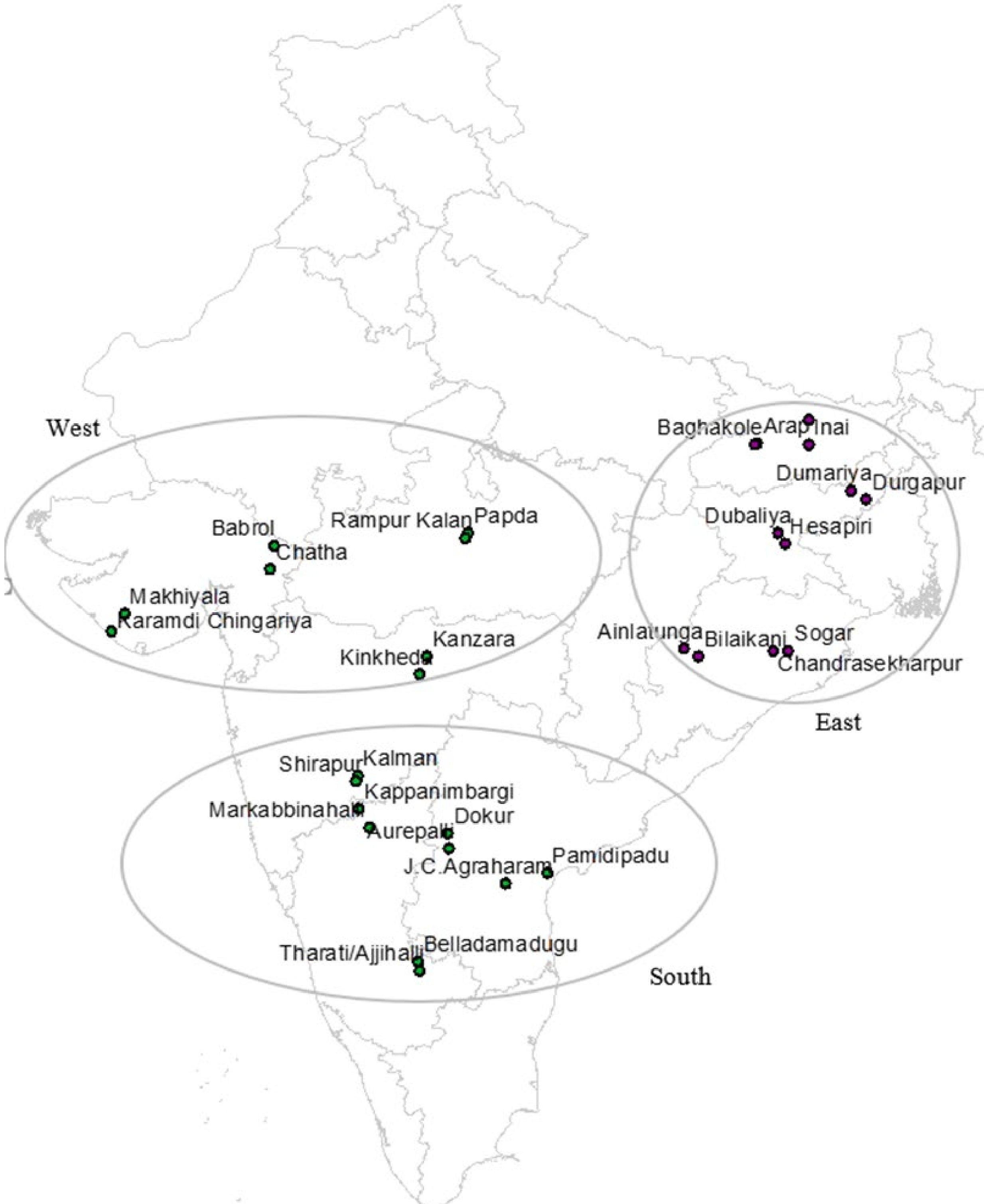
Figure 1. Locations of villages in VDSA India sample (2010-2014)



Source: Authors' compilation from VDSA data.

Table 1. Descriptive statistics (household level)

Variables		Mean	Median	Std.dev
Outcomes				
Average consumption value per month (Rupee per month per household)	Grains	955.337	866.321	549.519
	Pulses	236.876	203.667	152.265
	Dairy	487.663	334.5	560.041
	Vegetables	315.772	279.167	185.511
	Fruits	112.239	85.417	108.413
Consumption value in lean month (Rupee/household)	Cereals	645.653	579.500	488.896
	Pulses	139.443	118.000	117.057
	Dairy	258.641	140.000	376.2268
	Vegetables	185.810	163.000	136.236
	Fruits	36.905	16.000	61.373
No child stunting (yes = 1)		0.385	0.000	0.487
No underweight (yes = 1)		0.702	1.000	0.457
No low arm circumference (yes = 1)		0.727	1.000	0.446
BMI is normal (yes = 1)		0.453	0.000	0.498
Exogenous variables				
Growing each food group or not (yes = 1)	Grains	0.802	1.000	0.398
	Pulses	0.660	1.000	0.474
	Dairy	0.862	1.000	0.344
	Vegetables	0.704	1.000	0.456
	Fruits	0.384	0.000	0.486
Rainfall percentile (%)		28.830	32.143	14.662
Temperature percentile (%)		20.733	21.429	16.514
Price variations (coefficient of variation)	Cereals	0.208	0.191	0.074
	Pulses	0.270	0.248	0.106
	Dairy	0.174	0.165	0.064
	Vegetables	0.240	0.213	0.110
	Fruits	0.416	0.388	0.149
Wages for land preparation for adult male (Rupee/hour)		22.078	21.158	9.173
Farmland owned (ha)		1.532	0.800	2.369
Value of household assets (1000 Rupees)		173.810	61.000	481.634
Value of farm equipment owned (1000 Rupees)		36.562	2.450	154.389
Value of livestock owned (1000 Rupees)		29.329	12.800	53.827
Household member (0-14 years old, male)		0.726	1.000	0.924
Household member (0-14 years old, female)		0.671	1.000	0.949
Household member (15-60 years old, male)		1.769	2.000	1.100
Household member (15-60 years old, female)		1.634	1.000	0.962
Household member (>= 61 years old, male)		0.267	0.000	0.454
Household member (>= 61 years old, female)		0.230	0.000	0.428
Household head is different from previous year (yes = 1)		0.008	0.000	0.009
Primary income earner died (yes = 1)		0.004	0.000	0.064
Household engages in nonfarm income earning activities (yes = 1)		0.795	1.000	0.404
Amount of debt (1,000 rupees)		55.631	10.000	176.544
Amount owned by others (1,000 rupees)		6.825	0.000	44.751
Amount of savings (1,000 Rupees)		22.079	0.000	125.467
Household head age (years)		47.989	48.000	14.428
Household head gender (1 = female)		0.044	0.000	0.205
Household head education (years)		5.215	4.000	4.564
Individual-level				
Children				
Age		2.434	2.750	1.391
Gender (1 = female)		0.486	0.000	0.500
Years of education		0.039	0.000	0.327
Women				
Age		39.548	38.000	16.424
Years of education		5.683	5.000	5.009

Source: Authors' computations.

Table 2. Effects on consumption values of various food groups in average and lean month (effects of one-standard deviation changes)

Variables	Food groups														
	Grains			Pulses			Dairy			Vegetables			Fruits		
	Consumption in average month														
F	12.184***	12.241***	12.424***	3.849***	3.921***	4.117***	24.608***	24.574***	24.683***	2.673*	3.284*	2.732*	5.581***	5.354***	5.414***
F*R	12.282***			0.388			-3.818			2.480**			3.151**		
F*T		5.723*			-0.672			0.022			5.730***			2.005*	
F*P			17.826***			1.340*			7.159***			-0.703			2.859*
	Consumption in lean month														
F	32.766***	34.763***	32.953***	9.364***	9.193***	9.335***	4.979*	6.455**	5.262*	9.893***	9.466***	8.409***	2.008**	2.268**	2.118**
F*R	15.196***			0.430			-1.749			0.502			1.320		
F*T		5.100			1.808**			-6.767			4.763***			0.463	
F*P			14.459***			0.100			1.949			5.402***			1.421*
Other time-variant exogenous variables	Included for both average month and lean month														
Region*year interactions	Included for both average month and lean month														
Constant	Included for both average month and lean month														
Sample size	6,666														
Average panel rounds	4.4														

Source: Authors' estimations. Asterisks indicate statistical significance: *** 1% ** 5% * 10%

Note: F = growing respective food group (yes = 1, no = 0); R = rainfall shocks; T = temperature shocks; P = price risks. Variables in all models are jointly significant.

Table 3. Effects on child nutrition outcomes of various food groups (effects of one-standard deviation changes)

Variables	Food groups														
	Grains			Pulses			Dairy			Vegetables			Fruits		
	no child stunting														
F	3.475	3.262	2.839	3.454	4.020	5.472*	5.392*	4.422	5.200	6.328**	6.298*	5.868*	3.569	4.142	3.553
F*R	-1.579			0.809			-1.196			-4.152			-3.376		
F*T		7.259*			6.908**			-3.331			0.511			3.728	
F*P			6.862*			6.192*			-3.315			0.368			0.457
	no child underweight														
F	-4.994	-5.236	-5.976	9.178***	9.408***	8.836**	1.317	1.430	2.911	-1.976	-1.523	-3.037	5.098*	4.641*	5.001*
F*R	-2.560			-3.941			5.967*			-5.274			1.881		
F*T		7.762**			5.558**			-6.109			3.683			-2.944	
F*P			9.094**			-3.204			-2.768			2.731			9.797***
	no wasting														
F	0.837	0.645	0.650	5.964*	6.056**	5.977*	1.557	-0.495	0.680	-6.861	-5.307	-5.372	6.025*	6.193*	6.056*
F*R	5.580***			1.134			-2.570			3.795			-5.912		
F*T		-2.545			0.365			-6.862			9.001**			0.484	
F*P			9.860**			-1.082			3.107			-5.771			0.062
Other time-variant exogenous variables	Included for all of child stunting, underweight, wasting models														
Region*year interactions	Included for all of child stunting, underweight, wasting models														
Constant	Included for all of child stunting, underweight, wasting models														
Sample size	1,147														
Average panel rounds	2.7														

Source: Authors' estimations. Asterisks indicate statistical significance: *** 1% ** 5% * 10%

Note: F = growing respective food group (yes = 1, no = 0); R = rainfall shocks; T = temperature shocks; P = price risks. Variables in all models are jointly significant.

Table 4. Effects on anthropometrics of various food groups (women BMI being normal) (effects of one-standard deviation changes)

Variables	Food groups														
	Grains			Pulses			Dairy			Vegetables			Fruits		
F	-0.364	-0.551	-0.598	0.911	0.993	1.444*	0.321	0.321	0.356	1.135	1.601*	1.602*	-0.919	-0.968	-0.900
F*R	1.401***			1.107**			0.609			0.248			1.646*		
F*T		0.144			0.577			-0.223			2.017*			-0.454	
F*P			0.858			2.010***			-0.268			1.210*			-1.132
Other time-variant exogenous variables	Included														
Village*year interactions	Included														
Constant	Included														
Sample size	14,531														
Average panel rounds	3.4														

Source: Authors' estimations. Asterisks indicate statistical significance: *** 1% ** 5% * 10%

Note: F = growing respective food group (yes = 1, no = 0); R = rainfall shocks; T = temperature shocks; P = price risks.
Variables in all models are jointly significant.

Table 5. Effects on anthropometrics of various food groups (no child stunting) (effects of one-standard deviation changes)

Variables	Food groups														
	Grains			Pulses			Dairy			Vegetables			Fruits		
	no child stunting														
F	3.394	1.839	1.508	3.340	4.890	5.991*	4.831	4.616	6.565*	6.166**	6.917**	5.961**	3.203	3.821	3.056
F*R	-1.523			2.644			-1.103			-3.660			-3.094		
F*T		5.791			5.377*			-3.746			-0.889			2.421	
F*P			7.380*			6.559*			-2.150			-0.075			-2.360
	no child underweight														
F	-5.817	-6.484	-5.756	8.979**	9.194**	9.222***	1.678	1.640	3.291	-2.009	-0.233	-2.104	4.298	4.280	2.797
F*R	0.439			-4.433			5.874			-5.071			3.216		
F*T		7.290*			4.171*			-6.727			2.765			-4.910	
F*P			10.580***			-3.112			-2.762			0.596			9.661***
	no wasting														
F	0.837	0.645	0.650	5.964*	6.056**	5.977*	1.557	-0.495	0.680	-6.861	-5.307	-5.372	6.025*	6.193*	6.056*
F*R	5.580***			1.134			-2.570			3.795			-5.912		
F*T		-2.545			0.365			-6.862			9.001**			0.484	
F*P			9.860**			-1.082			3.107			-5.771			0.062
Other time-variant exogenous variables	Included for all of child stunting, underweight, wasting models														
Region*year interactions	Included for all of child stunting, underweight, wasting models														
Constant	Included for all of child stunting, underweight, wasting models														
Sample size	1,147														
Average panel rounds	2.7														

Source: Authors' estimations. Asterisks indicate statistical significance: *** 1% ** 5% * 10%

Note: F = growing respective food group (yes = 1, no = 0); R = rainfall shocks; T = temperature shocks; P = price risks.
Variables in all models are jointly significant.

Table 6. Effects on anthropometrics of various food groups (women BMI being normal) (effects of one-standard deviation changes)

Variables	Food groups														
	Grains			Pulses			Dairy			Vegetables			Fruits		
F	-0.384	-0.731	-0.663	0.990	1.012	1.517*	0.324	0.201	0.297	1.103	1.664*	0.791	-1.013	-1.092	-0.979
F*R	1.112*			0.579			0.311			-0.635			1.384*		
F*T		-0.199			0.550			-0.335			2.104*			-0.758	
F*P			0.768			2.038***			-0.385			1.192			-1.150
Other time-variant exogenous variables	Included														
Village*year interactions	Included														
Constant	Included														
Sample size	14,531														
Average panel rounds	3.4														

Source: Authors' estimations. Asterisks indicate statistical significance: *** 1% ** 5% * 10%

Note: F = growing respective food group (yes = 1, no = 0); R = rainfall shocks; T = temperature shocks; P = price risks. Variables in all models are jointly significant.

Table 7. Effects of consumption of various food groups in remote areas

Variables	Food groups														
	Grains			Pulses			Dairy			Vegetables			Fruits		
	Consumption in average month														
F	13.698**	14.016**	14.948**	4.011***	3.854***	4.488***	19.961***	22.530***	21.308***	2.909*	5.236***	4.747**	5.003***	5.122***	5.211***
F*R	13.391**			2.240**			-1.724			1.848*			1.937		
F*T		1.192			-1.222			1.904			9.031***			4.903**	
F*P			19.295***			2.578***			7.320**			-6.034			1.163
	Consumption in lean month														
F	39.456***	40.545***	40.109***	10.358 **	10.061***	10.491 **	9.094***	11.143**	9.863***	11.335***	12.348***	9.653***	3.750**	3.973***	3.701**
F*R	22.843***			2.573***			-3.152			-0.643			1.334		
F*T		11.481**			0.070			-1.875			4.673**			3.800**	
F*P			17.378***			2.040**			5.384*			5.183*			0.287
Other time-variant exogenous variables	Included for both average month and lean month														
Region*year interactions	Included for both average month and lean month														
Constant	Included for both average month and lean month														
Sample size	3914														
Average panel rounds	4.3														

Source: Authors' estimations. Asterisks indicate statistical significance: *** 1% ** 5% * 10%

Note: F = growing respective food group (yes = 1, no = 0); R = rainfall shocks; T = temperature shocks; P = price risks. Variables in all models are jointly significant.

Table 8. Effects of consumption of various food groups in close areas

Variables	Food groups														
	Grains			Pulses			Dairy			Vegetables			Fruits		
	Consumption in average month														
F	10.219*	9.391*	11.209**	3.772**	4.061**	3.697**	28.716***	25.537***	27.765***	1.296	1.028	1.579	6.285***	5.765***	5.103***
F*R	10.677***			-1.769			-2.847			4.127			4.886**		
F*T		5.972			-0.419			1.467			-1.584			-1.975	
F*P			12.521**			-1.789			7.939*			-0.586			4.516**
	Consumption in lean month														
F	23.829***	27.180***	24.691***	7.882***	8.498***	7.679***	-1.816	-0.875	-0.123	6.301**	5.496**	5.690**	-0.720	-0.169	-0.267
F*R	2.142			-2.188*			2.244			3.745			2.152		
F*T		-4.559			-3.153**			-8.293*			1.984			-2.130	
F*P			5.173			-3.669*			-2.757			4.239			2.699**
Other time-variant exogenous variables	Included for both average month and lean month														
Region*year interactions	Included for both average month and lean month														
Constant	Included for both average month and lean month														
Sample size	2752														
Average panel rounds	4.4														

Source: Authors' estimations. Asterisks indicate statistical significance: *** 1% ** 5% * 10%

Note: F = growing respective food group (yes = 1, no = 0); R = rainfall shocks; T = temperature shocks; P = price risks.
Variables in all models are jointly significant.

Table 9. Effects on anthropometrics of various food groups (remote areas)

Variables	Food groups														
	Grains			Pulses			Dairy			Vegetables			Fruits		
							no child stunting								
F	1.794	1.437	3.686	0.300	1.711	0.552	8.197	11.198	9.096	-0.404	-2.035	-8.726	7.294	7.834	7.157
F*R	-2.927			-0.234			-3.503			-5.584			-1.010		
F*T		15.459**			7.371*			6.166			-2.727			9.479	
F*P			12.899*			12.146**			3.169			12.950			-2.783
							no child underweight								
F	1.573	1.350	1.939	12.877***	13.599***	12.099***	1.642	3.510	-1.444	3.124	5.579	23.873*	4.294	4.101	4.134
F*R	0.823			-6.378			4.288			-1.652			1.587		
F*T		4.302			7.622**			2.723			5.539			-3.138	
F*P			-0.131			--6.475			-5.187			-9.641			10.095**
							no wasting								
F	-0.078	-0.612	1.299	10.746**	11.236**	11.006**	7.612	1.116	5.568	-13.177	-1.175	16.722*	7.756*	8.223	7.959
F*R	8.510***			1.841			-3.693			3.241			-5.967		
F*T		3.462			1.574			-11.446			25.630***			8.039	
F*P			13.346**			-0.635			-2.893			-4.982			-0.779
Other time-variant exogenous variables	Included for all of child stunting, underweight, wasting models														
Region*year interactions	Included for all of child stunting, underweight, wasting models														
Constant	Included for all of child stunting, underweight, wasting models														
Sample size	601														
Average panel rounds	2.6														

Source: Authors' estimations. Asterisks indicate statistical significance: *** 1% ** 5% * 10%

Note: F = growing respective food group (yes = 1, no = 0); R = rainfall shocks; T = temperature shocks; P = price risks. Variables in all models are jointly significant.

Table 10. Effects on anthropometrics of various food groups (close areas)

Variables	Food groups														
	Grains			Pulses			Dairy			Vegetables			Fruits		
	no child stunting														
F	5.600	5.366	7.963	0.466	0.296	0.526	4.558	3.955	6.083	10.855**	11.197**	10.237**	1.200	1.908	0.993
F*R	-0.675			2.427			-4.228			-6.112*			-5.018		
F*T		2.346			4.393			-4.988			-0.983			1.108	
F*P			15.155***			4.330			-10.861			3.614			2.832
	no child underweight														
F	-11.617	-13.006*	-11.216*	7.837	7.919	7.758	2.647	4.839	6.502	-5.772	-6.647	-6.476	2.186	1.799	-0.963
F*R	-5.881			-1.960			6.647			-7.772			1.802		
F*T		12.919**			4.574			-13.430*			9.314			-1.075	
F*P			9.837			-2.516			-10.873			5.400			11.350***
	no wasting														
F	3.808	4.422	6.393	3.145	3.139	2.917	-2.837	-3.315	-6.628	-2.872	-2.671	-3.290	4.575	5.065	4.808
F*R	2.771			0.235			-3.587			5.049			-5.383		
F*T		-4.873			-0.142			-4.947			-2.503			-0.578	
F*P			11.619**			-2.594			10.982			-0.173			0.912
Other time-variant exogenous variables	Included for all of child stunting, underweight, wasting models														
Region*year interactions	Included for all of child stunting, underweight, wasting models														
Constant	Included for all of child stunting, underweight, wasting models														
Sample size	546														
Average panel rounds	2.7														

Source: Authors' estimations. Asterisks indicate statistical significance: *** 1% ** 5% * 10%

Note: F = growing respective food group (yes = 1, no = 0); R = rainfall shocks; T = temperature shocks; P = price risks. Variables in all models are jointly significant.

Table 11. Effects on anthropometrics of various food groups (women BMI being normal)

Variables	Food group														
	Grains			Pulses			Dairy			Vegetables			Fruits		
Remote															
F	-0.535	-0.438	-0.493	-0.367	0.449	0.184	-0.526	-1.016	-0.744	0.147	1.034	-0.170	-1.568	-1.130	-1.112
F*R	1.693**			1.098*			1.994*			0.529			2.353**		
F*T		0.922			2.202**			-1.751			2.065			-0.230	
F*P			2.539**			1.275*			-1.519			0.652			-1.060
Sample size								601							
Average panel rounds								2.6							
Close															
F	-0.173	-0.442	-0.498	2.624**	2.395**	2.378**	1.047	1.065	1.100	2.590*	2.354*	1.679	-0.240	-0.611	-0.394
F*R	0.464			0.555			-0.628			-1.196			0.362		
F*T		-0.531			-1.068			0.968			2.321			-0.857	
F*P			-1.672			0.126			0.220			3.203**			-1.283
Sample size								546							
Average panel rounds								2.7							

Source: Authors' estimations. Asterisks indicate statistical significance: *** 1% ** 5% * 10%

Note: F = growing respective food group (yes = 1, no = 0); R = rainfall shocks; T = temperature shocks; P = price risks.
Variables in all models are jointly significant.

Appendix A: Differences in prices of major commodities faced by producing households and non-producing households

Table 12 shows the differences in average prices of key commodities in each food group, and whether they are statistically significantly higher, or lower, for households producing each of these commodities. These figures show that, for a majority of commodities, prices faced by producing households are similar or lower than prices faced by non-producing households.

Table 12. Difference in reported prices, by producers and nonproducers of each food group

Food groups	Crops	Average prices (Rupee per kg)[a]	
		producing households	non-producing households
Grains	Finger millet	17.679	18.180***
	Maize	11.912***	11.713
	Paddy	13.155	13.115
	Pearl millet	12.892	13.598***
	Rice (fine)	26.537	27.025***
	Rice (PDS)	4.296***	3.760
	Rice (super)	39.702***	37.074
	Sorghum	19.248	20.180***
	Wheat	18.306	21.389***
Legumes / pulses	Black gram	19.417***	14.856
	Chickpea	15.466***	12.179
	Green gram	21.983***	16.297
	Horse gram	22.005	22.630***
	Lentil	15.382	15.250
	Pigeonpea	19.703***	15.803
	Sunflower	29.324	29.819***
Meat	Chicken	147.262	153.770***
	Fish	110.101	114.042***
	Mutton	298.539***	281.454
Dairy	Buffalo milk	31.441	31.497
	Cow milk	24.269	24.242
Vegetables	Brinjal	23.490	24.617***
	Cabbage	24.343	29.760***
	Carrots	24.170	26.109***
	Cauliflower	32.898	33.833***
	Cucumber	22.013	24.079***
	Okra	30.461	33.628***
	Onion	24.925***	22.430
	Spinach	24.059	27.012***
	Tomato	23.574	23.544
Fruits	Mango	43.542	42.895
	Papaya	23.842	23.737

Source: Authors' calculations. Asterisks indicate the statistically significantly higher values than the other type of households. ***1% **5% *10%

[a]Price for egg is Rs. per dozen.

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