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Household Food Insecurity and Maternal and Child Undernutrition: The Case of Maharashtra

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ABSTRACT

Limited evidence is available on the association between household food security and nutritional status of women and children in the Indian context. In this paper we rigorously examine the association between household food security status and nutritional status of mothers and under-two children using a rich microdata set sourced from the Comprehensive Nutrition Survey Maharashtra (CNSM) 2012 which provides a representative sample of 2630 households with children aged 0-23 months and their mothers. Maharashtra is an interesting case study because the state has experienced a puzzling dissociation between economic growth, nutrition and food security which raises some doubt on the validity of the assertion that food insecurity is an underlying determinant of undernutrition. The answer to the question is important not just in the Indian context but in the context of the broader literature as well. If the answer is positive there are prospects to achieve progress in reduction of undernutrition by ameliorating food security provided other major drivers of undernutrition are taken care of. We use the Household Food Insecurity Access Scale (HFIAS) in measuring household food security status. We apply simultaneous probit models to address the concerns regarding unobserved confounders in estimating the causal effect of household food insecurity on maternal and child nutritional status. Children's nutritional status is assessed using anthropometric indicators - stunting, wasting and underweight; while women's nutritional status is examined using BMI-status – underweight or overweight/obese. Findings indicate household food security status is significantly associated with the indicators of child wasting and child underweight but not with stunting. Household food security status is also a strong predictor of women's underweight status but not overweight/obesity. The findings have important policy implications since they direct towards the need to ameliorate household food access for the purpose of addressing short term nutritional deprivation of mothers and children. However, long term deprivation captured by stunting requires further investigation. Additionally, food security interventions may not effectively address the concerns with obesity. It is important that future research directs its attention to explore the pathways linking lack of food access to nutritional outcomes so that remedial actions can be prompt and effective.

Key words: food security scale, child undernutrition, maternal malnutrition, food access, endogeneity, causality, Maharashtra, India,

1 INTRODUCTION

Food insecurity is believed to be one of the underlying determinants of undernutrition. However, the evidence on this link is not conclusive in the extant literature (Saha et al. 2009; Hackett et al. 2009; Baig–Ansari et al. 2006; Osei et al. 2007; Ali et al. 2013; Haddad et al. 2014; Motbainor et al. 2015; Chandrasekhar et al. 2016). A case in point is Maharashtra ─ one of the wealthier states in India.

Maharashtra's nutrition scenario has been paradoxical. One of the puzzles is the apparent dissociation of economic growth and nutrition and food security indicators. Between 1994 and 2008, Maharashtra's per capita income increased more than one-and-a-half times while its nutrition status remained nearly stagnant according to several measures (Pitre et al. 2009). Until recently Maharashtra had one of the largest child (0-23 months) stunting rates in India (National Family Health Survey 2007). Latest round of National Family Health Survey (NFHS) (NFHS 2017) reports, over the period 2005-06 to 2015-16, prevalence of stunting has declined, however prevalence of wasting and severe wasting have increased, with only marginal decline in the proportion of underweight children. Simultaneously, the nutrition scenario was characterized by high rates of maternal underweight, the percentage of underweight women being just above the all-India rate of 36 per cent in 2008 (NFHS 2007). NFHS-4 reports prevalence of underweight has declined but another indicator of malnutrition – prevalence of overweight has increased. The food security scenario has been equally grim with the state experiencing one of the highest rates of calorie deficiency among Indian states in 2004-05. In 2008, the state ranked 10 out of 17 Indian states by Global Hunger Index (von Grebmer 2008), listed in the category of "alarming hunger". The global comparison of the Hunger Index Rank revealed that Maharashtra is behind Rwanda, Cambodia and Burkina Faso, which are low income countries.

The second aspect of the puzzle is, since 2006 nutritional status of children has improved, primarily due to sharp decline in prevalence of child stunting between 2006 and 2012; however food insecurity continues to be a major concern (Haddad et al. 2014). The paradox signals an apparent lack of correspondence between the two phenomena. The apparent disconnect raises some doubt on the validity of the assertion that household food insecurity is an underlying determinant of undernutrition. In this paper, we raise the question: to what extent household food insecurity contributes to maternal and child undernutrition in Maharashtra. The answer to the question is important not just in the Indian context but in the context of the broader literature as well. If we find a causal association on the above, there are prospects of achieving progress in reduction of undernutrition by ameliorating household food security provided other major drivers of undernutrition are taken care of.

Given the above, we test the following hypothesis in the present study: household food security status (HFS) is a predictor of nutritional status of women and children. The access to a rich micro database sourced from the Comprehensive Nutrition Survey Maharashtra (CNSM) 2012 (IIPS-UNICEF 2012) provides us the opportunity to rigorously test our hypothesis using state-of-the-art technique in food security measurement. Primarily as a response to Maharashtra's alarmingly rising stunting rates, the Maharashtra Nutrition Mission was launched in March 2005 with a focus to universalize coverage of proven nutrition interventions during the 1,000-day window of opportunity. To assess the impact of the Mission the Government of Maharashtra conducted the CNSM in 2012 on a representative sample of more than two thousand children aged 0-23 months and their mothers. The survey collected information on various nutritional behaviours, anthropometry and service access, including HFS which is assessed using Household Food Security Access Scale (HFIAS) (Coates et al. 2007).

The few studies that examine the above relationship in the Indian context (Mukhopadhya and Biswas 2011; Gupta et al. 2013; Chandrasekhar et al. 2016) as well as in the broader literature mentioned above offer rich insight on the nexus between food insecurity and undernutrition. However, these studies have limitations to the extent they do not address the concerns regarding the presence of unobserved confounders in determining the causal effect of household food insecurity on nutritional status of children and women in the households. Failure to adhere to the latter often tends to bias the true measured impact of food security status on indicators of undernutrition, especially in cross section data. Our study is an attempt to address the above gap. We use simultaneous probit models to address the concerns regarding unobserved confounders in estimating the causal effect of household food security status on maternal and child nutritional status. Another contribution of the study is the use of HFIAS – a state-of-the art technique in measuring household food security. The HFIAS is an experiential food security indicator developed by the Food and Nutrition Technical Assistance (FANTA) (Coates et al. 2007). The experiential food security scales are direct measures of access to food, as opposed to indirect or proxy measures like income, food expenditure, household poverty status, dietary intake or nutritional status, which are believed to be causes or consequences of food insecurity in most cases (Ballard et al. 2013). HFIAS has been applied in other Indian settings as well (see Sethi et al. 2016; Chinnakali et al. 2014; Chatterjee et al, 2012), however in different contexts.

Children's nutritional status is assessed using stunting, wasting and underweight; while women's nutritional status is examined using BMI-status – underweight or overweight. Results indicate HFS is significantly associated with child wasting and child underweight but not with stunting. HFS is also a strong predictor of women's underweight but not overweight. These findings have important policy implications since they direct towards the need to ameliorate household food access for the purpose of addressing short term nutritional deprivation of mothers and children. However, long term nutritional deprivation of children (captured by stunting) requires further investigation. It is important that future research directs its attention to explore the pathway linking lack of food access to nutritional outcomes so that remedial actions can be prompt and effective.

The paper has been organized as follows: Section 2 discusses method which includes survey, details, variables and statistical analysis; Section 3 reports results, Section 4 discusses the results and Section 5 concludes with direction of future research and policy recommendations.

2 METHOD

2.1 Data, Study Design and Participants

Data for the present study comes from CNSM 2012 (IIPS-UNICEF 2012). The survey aimed at assessing the nutritional status of children under two through anthropometric measurements and infant and young child feeding practices in rural and urban areas of the state as well as in each of the six administrative divisions of the state – Amaravati, Aurangabad, Konkan, Nagpur, Nasik and Pune. The selection of sample was done separately in rural and urban areas using a multi-stage stratified sampling procedure. The rural sample was selected in two stages, with the selection of Primary Sampling Units (PSUs) which are villages at the first stage. This was followed by random selection of households within each PSU in the second stage among those households where at least one child under two years is residing. In urban areas, a three-stage sampling procedure was followed, selecting wards at the first stage, Census Enumeration Blocks (CEB) at the second stage; and households with at least one child under two years at the third stage. The sample size was determined in terms of the number of under-two children as they were the focus of the survey. Remaining details on survey and sampling techniques are available in CNSM report (IIPS-UNICEF 2012). Data collection was carried out during February-April 2012. The survey collected data on 2,630 households.

2.1.1 Survey Instrument

CNSM used three types of questionnaires: the Household Questionnaire, the Mother's Questionnaire, and Child's Questionnaire. The questionnaire was bilingual, with questions in both Marathi (state language) and English.

The Household Questionnaire was filled by interviewing either head of the household or any adult member of the household available at the time of survey. The section on food security was administered to the household member, primarily involved in the food preparation and means; however questions referred to all the household members and not only the respondent. For all the questions on food security, a reference period of one-month period prior to survey was used. The food security module consists of nine items and four frequency responses (see Appendix A for HFIAS items).

The household questionnaire also collected information on age, sex, relationship to the head of the household and marital status for each person listed. For all persons aged five and above information on literacy status and the highest standard completed was collected. Additionally, information was gathered on the main source of drinking water, type of toilet facility, source of lighting, type of cooking fuel, religion and caste/tribe of the household head, ownership of a house, ownership of agricultural land, ownership of livestock, and ownership of other selected items.

Mother's Questionnaire was administered to all the women in the household, who have at least one (living) child born after 1 January, 2010. Mother's profile including her age, marital status, age at marriage, literacy status, educational attainment, and work status were collected.

Information were also collected on mother's exposure to media, decision making and involvement in community organizations like Self Help Groups (SHG) and maternal health such as pregnancy, fertility history, antenatal care received, food intake, nutritional status and lifestyle indicators such as tobacco use and alcohol consumption.

For every child born after 1st January 2010, separate questionnaire was administered to the mother. The child's questionnaire collected information on child characteristics such as birth date, birth order and sex of the child. CNSM also included questions on infant and young child feeding practices including breastfeeding status, frequency of breastfeeding in 24 hours prior to survey, complementary foods given to the child in 24 hours prior to survey and their frequency.

2.1.2 Variables

Dependent variables: Anthropometric indicators of mothers and children. The nutritional status of the children and their mothers (non-pregnant) was assessed by measuring their heights and weights. Following WHO guidelines (2006), three standard indices of physical growth that describe the nutritional status of children are included in the present analysis: 1) height-for-age 2) weight-for-height and 3) weight-for-age. Each of the three anthropometric indicators is expressed in standard deviation units (z-scores) from the median of the reference population. Children with z-scores below minus two standard deviations (-2 SD) from the median of the reference population are considered malnourished and with z-scores below minus three standard deviations (-as 3 SD) are classified severely malnourished. Children whose height-for-age z-score <-2 SD from the median of the reference population are considered short for their age or stunted. Stunting reflects chronic and persistent nutritional deprivation over a long period of time, aggravated by illness. Children whose weight-for-height z-score < -2 SD from the median of the reference population are classified as thin for their height or wasted. Wasting captures acute malnutrition which might be a result of inadequate nutrition in the recent past. Weight-for-age is a composite index of height-for-age and weight-for-height, and takes into account both chronic and acute malnutrition. Children with weight-for-age z-score < -2 SD from the median of the reference population are underweight children.[1]

The ordered categorical variables *HAZ*, *WHZ* and *WAZ* are created to denote three categories of each indicator of nutritional status – adequate ($-2 <$z-score $<+2$), moderately malnourished ($-3 <$z-score<-2) and severely malnourished (z-score <-3). Accordingly we've the following representation of variables:

$$HAZ = \begin{cases} 0 \ if\ adequate \\ 1 \ if\ stunted \\ 2 \ if\ severely\ stunted \end{cases}$$

[1] Children over two standard deviations from the median weight-for-height of the WHO Child Growth Standards are overweight. We do not model the association of food insecurity with overweight because proportion of overweight children in the sample is not large enough to allow a meaningful investigation.

$$WHZ = \begin{cases} 0 \ \ if \ adequate \\ 1 \ \ if \ wasted \\ 2 \ \ if \ severely \ wasted \end{cases}$$

$$WAZ = \begin{cases} 0 \ \ if \ adequate \\ 1 \ \ if \ underweight \\ 2 \ \ if \ severely \ underweight \end{cases}$$

We also define children's nutritional status as binary variables: adequate if -2<z-score<+2 and malnourished if z-score <-2. Hence,

$$haz = \begin{cases} 1 \ \ if \ stunted \\ 0 \ \ if \ adequate \end{cases}$$

Similarly, we define wasting (*whz*), and underweight (*waz*) as binary variables representing nutritional status in binary form.

We also examine the association between HFS and maternal nutritional status. As indicators of maternal malnutrition we use maternal BMI status with the following categorization: 18.5≤BMI<24.9 classified as normal weight, BMI<18.5 classified as underweight; and BMI≥25 classified as overweight. The following binary variables *m_under* and *m_over* are defined to denote maternal underweight and overweight[2], respectively, as:

$$m\_under = \begin{cases} 1 \ \ if \ underweight \\ 0 \ \ if \ normal \end{cases}$$

$$m\_over = \begin{cases} 1 \ \ if \ overweight \\ 0 \ \ if \ normal \end{cases}$$

Key independent variable: Household food security status (HFS). The key explanatory variable of interest in our analysis is HFS yielded by the 9-item HFIAS. HFIAS categorizes households into four levels of food security status (by access): food secure, mild, moderate and severely food insecure. The mothers were asked 9 questions related to the households' experience of food insecurity in the 30 days preceding the survey. These questions capture 3 main domains of household food insecurity: 1) anxiety and uncertainty about access (1 question), 2) insufficient quality (3 questions), and 3) insufficient quantity (5 questions). Each item starts with an occurrence question that identifies if the condition has been experienced in the household. An affirmative answer is then followed by a frequency-of-occurrence question

[2] This category includes women who are obese (BMI>30). However, only a small fraction (2%) of women in the sample is obese.

to determine if the condition happened rarely (once or twice), sometimes (3–10 times), or often (>10 times) during the reference period. The responses are coded as 0 = never, 1 = rarely, 2 =sometimes, or 3 = often.

Households that rarely experience some anxiety over sufficiency of food are categorized as food secure. Households that worry about not having enough food frequently as well as households that sometimes in last one month could not have their preferred food or have to eat limited variety of food, or food that they really do not want to eat are categorized as mildly food insecure. Households that frequently have to eat food of limited choice and sometimes have to eat lesser quantity of food are categorized as moderately food insecure. Those households that have no food to eat or have to starve day and night are categorized as severely food insecure.

Accordingly variable *fsec3* defines food security status as an ordered categorical variable with three categories of food security status – food secure, moderately food insecure and severely food insecure. We collapse mild and moderate food insecurity into one single category 'moderately food insecure' to get more meaningful results since only 12 percent households are present in each category. However, we retain 'severely food insecure' as a separate category since these households are the most vulnerable ones and should be identified as such for policy making purposes.

Hence *fsec3* is defined as:

$$fsec3 = \begin{cases} 0 \;\; if \; highly \; food \; secure \\ 1 \;\; if \; moderately \; food \; insecure \\ 2 \;\; if \; severely \; food \; insecure \end{cases}$$

We also define HFS as a binary variable in the following manner:

$$fsec = \begin{cases} 1 \;\; if \; food \; insecure \\ 0 \;\; otherwise \end{cases}$$

which collapses moderately food insecure and severely food insecure households into one single category 'food insecure'.

Table 1 reports distribution of households by frequency of experience of food insecurity. We find, 58 per cent of the households never worry about having insufficient food, a little over one-third of the households cannot eat preferred food, 31 per cent have to eat only limited variety of food and about one-fourth have very limited choice of food. About 12 per cent of households report that they had to eat smaller meals or had to cut meal size in the last one month, though it happened rarely. The extreme situation of not having any food to eat was experienced by 12 per cent of the households, among which 8 per cent had this experience rarely. Due to resource constraint, 8 per cent of the households reported sleeping hungry without food and 5 per cent reported having to go hungry without food day and night.

Control variables. In modelling the relationship between child nutritional status and HFS, the control variables included in the equation for indicators of child nutritional status are: household demographics such as household size; household wealth status; and age, gender, level of education and caste of household head; household environmental conditions captured by variables such as whether the house is pucca or not, whether the household has separate room for cooking, whether the household has toilet facility, whether the household has access to piped water and whether the household is located in rural or urban setting; maternal characteristics including maternal educational status, age at marriage, nutritional/health status captured by BMI, height (if<145 cm.), whether mother received at least 3 antenatal care (ANC), mother's decision making power on children's food intake, mother's decision making power with respect to her own earnings, and work status; child characteristics such as age, gender, birth order, birth size, whether the child was low birth weight (LBW), whether the child was age appropriately breastfed, whether the child consumed at least 4 food groups and whether the child received full immunisation. Finally, region (includes Amaravati, Konkan, Nagpur, Nasik and Pune) and setting (rural/urban) were also included as indicator variables.

Association of HFS with maternal nutritional status is examined by controlling for household socio-demographic characteristics and household environmental characteristics mentioned above, as well as additional covariates such as whether mother consumed tobacco, number of times a mother was pregnant, maternal decision making power with respect to her own health, and mother's status of iron and folic acid consumption.

In addition to controlling for the factors related to household demographics included in the equation for nutritional status, the food security equation includes additional household level variables such as the type of ration card possessed by the household (no card, yellow, white or orange)[3], household home ownership and land ownership status, whether the household has some transport, whether the household has some livestock and; maternal characteristics such as mother's decision making power with respect to food purchased in the household and mother's media exposure. In general, the variables included in the food security equation are consistent with the list of socio-economic indicators of food and nutrition security provided in Haddad et al. (1994) and Frankenberger (1992).

Summary statistics. Summary statistics of variables is presented in Table 2. We find, 57% of households are food secure with higher fraction reported for rural areas. Regarding child malnutrition, 23 per cent of children are stunted, with 16 per cent wasted and about 23 per cent underweight, with higher proportion of malnourished children reported in rural areas. However, the extent of severe stunting, wasting and underweight children in rural and urban areas does not differ sizably. The extent of low birth weight babies is almost the same in both

[3] Three card categories are issued: Yellow: families having annual income up to Rs. 15,000/; Orange/Saffron: families having total annual income of more than Rs. 15,000 and less than 1 lakh; white: above poverty line -the families having annual income of Rs. 1 lakh or above (see details in : http://mahafood.gov.in/website/english/PDS.aspx.)

rural and urban areas. Regarding maternal characteristics, nearly one-third of the mothers were married before the legal age of 18 years which make them vulnerable to early pregnancies. Twelve per cent of the mothers have received no formal education, whereas more than one-fifth of the mothers have completed higher secondary school or college level education. A majority of the mothers (69%) are not engaged in any work besides household chores. Sixty-three percent mothers decide on household food purchase with higher proportions deciding on food items given to child. One in every three non-pregnant mothers is thin with BMI <18.5, as opposed to 11 percent non-pregnant mothers who are either overweight or obese. A strikingly higher proportion of underweight mothers is observed in rural areas, while a very high proportion of overweight mothers is noted in urban areas.

Only about 5 percent of the households are headed by women, the proportion being slightly higher in the urban areas than in rural areas. Sixty-six per cent of the households have access to piped drinking water, the proportion being much higher in urban areas. Fifty five per cent of households do not have access to any toilet facility. The situation is worse in rural areas. Nearly 42 per cent of the urban population is in the highest wealth quintile as opposed to only 2 per cent in the rural areas. Twenty per cent of households are headed by persons who do not read or write with higher fraction reported for rural areas compared to urban. About one-fourth of the households have no access to public distribution system (PDS) as they do not possess a ration card, with one-fourth of the households possessing a yellow coloured ration card. In rural areas, the proportion of households having a yellow card (35%) is more than double of that in urban areas (15%).

2.2 Conceptual framework

The underlying theoretical framework for the food security experiential scales rests on non-linear factor analytic models such as the Rasch model (Bond and Fox 2001). These models are located within the broad sphere of Item Response Theory commonly employed to conduct psychometric assessment in education to measure an individual's ability to answer to progressively difficult questions. In the food security literature, the latent variable is food insecurity (rather than ability) and the items representing the underlying construct of interest are arranged along a continuum of severity. Under the above modelling framework, food insecurity is viewed as a continuous, unidimensional and unobservable quantity that varies from household to household. In general, the dichotomous Rasch model is used to analyse dichotomous items (e.g. yes/no) data, whereas the partial credit model (PCM) developed by Masters (1982) is used as an extension of the dichotomous Rasch model for analysing polytomous item data (e.g. never/rarely/sometimes/often).

Psychometric assessment involves estimating fit statistics and severity parameters for final selection of items necessary to construct the scale (see Hamilton et al. 1997a; b for details).[4]

[4] The item severity parameters represent the position of the items along the constructed food security measurement scale. An item with a high positive severity indicates a greater degree of food insecurity (Hamilton et al., 1997b). Individual items are assessed using 'fit' statistics of which 'infit' is an "information-weighted" statistic for each item that is sensitive to responses by households with severity scores in the range near the

Infits in the range of 0.8 to 1.2 are considered to be good and 0.7 to 1.3 are acceptable (Nord et al., 2002). High value of infit indicates a weaker association than expected between that item and the underlying condition of food insecurity and implies, the item may not be suitable for inclusion in the scale.

The theoretical framework for the model on nutritional status follow from the UNICEF conceptual framework described in Black et al. (2008) (see Appendix B for the conceptual diagram).

2.3 Statistical Analysis

First we examine reliability and validity of HFIAS. Next, we empirically investigate the association between HFS and nutritional status.

2.3.1 Reliability and validity of HFIAS

For the purpose of this paper, we've estimated fit statistics and severity parameters for the dichotomous (yes/no) as well as polytomous model.[5] For the later, we use a Rasch partial-credit model. We inspected validity of the Maharashtra HFIAS primarily by examining fit statistics and conditional item independence.[6] Internal reliability of the scale is assessed by estimating Rasch reliability statistic.[7]

We undertake external validation of the HFIAS by examining bivariate association of household food security status captured by HFIAS with selected socio-economic characteristics of the household (by estimating polychoric and tetrachoric correlations)[8] and also examining polychoric correlations between association of HFS with selected food consumption indicators for mothers and children (whether the child had iron rich food, frequency of consumption of dark green leafy vegetables for mothers and so forth).[9]

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severity level of the particular item. 'Outfit' is not weighted and is sensitive to highly improbable responses (outliers).

[5] In doing this analysis we were guided by Dr. Mark Nord from the Voices of Hungry Project, FAO.

[6] Conditional item independence indicates that the items comprising the scale are correlated, but only because of their mutual association with the latent trait which is HFS. Conditional independence may be violated, for example, if there exists confusion between questions that are perceived by the respondent as compared to the equivalent [Ballard et al. 2013).

[7] Rasch reliability statistic is estimated as modelled variance divided by the total variance where total variance is the sum of modelled variance and error variance (standard statistical meanings, as one would find in any analysis of variance).

[8] If two ordinal variables are obtained by categorizing a normally distributed underlying variable and those two unobserved variables follow a bivariate normal distribution then the (maximum likelihood) estimate of that correlation is the polychoric correlation. If two ordinal variables are obtained by categorizing a normally distributed underlying variable and those two unobserved variables follow a bivariate normal distribution then the (maximum likelihood) estimate of that correlation is the tetrachoric correlation provided both variables have only two categories (Greene and Hensher, 2009).

[9] External validation implies that the data collected from that instrument are tested against a gold standard measure of the construct of interest. Unfortunately, there is no 'gold standard' against which the experiential measure could be compared (Hamilton et al., 1997b), food insecurity being a latent trait. Hence the relationship between food security measures and other measures known to affect food security are compared which include household food expenditures, food intake, absolute income, income relative to poverty and household reports of

2.3.2 HFS & Maternal & Child Nutritional Status

We test our key hypothesis on the association between HFS and child nutritional status using the following empirical strategy: i) examining bivariate association between HFS and nutritional indicators for children and mothers; ii) estimating multivariate association of HFS with maternal and child nutritional status using appropriate empirical models which control for selected household demographic/socio-economic/environmental characteristics as well as maternal/child characteristics.

2.4 Empirical Models

Following Wolfe and Behrman (1984), we employ latent variable specification to model the relationship between our key variables – child and maternal nutritional status and household food security status. Latent variables are not directly measurable, but are represented by a set of manifest variables, which act as indicators.

2.4.1.1 HFS & Child Nutritional Status

Ordered Probit Model

Our baseline models are Ordered Probit (Oprobit) models estimated for three categories of child nutritional status – stunting, wasting, and underweight, represented by the variables *HAZ, WHZ, WAZ*, respectively. Three categories of HFS represented by the variable *fsec3* is the key explanatory variable of interest in each equation.

The Oprobit model for each indicator of child nutritional status is specified in the following manner. Let the latent nutritional status be denoted by HAZ^*,WHZ^* and WAZ^*, respectively for stunting, wasting and underweight. The underlying model for stunting consists of an equation relating the latent nutritional status HAZ^*, and food security status *fsec3** to background characteristics of the households, represented by vector x_1 in the following manner:

$$HAZ_i^* = \gamma\, fsec3_i^* + x_{1i}\beta_1 + \varepsilon_{1i} \qquad (1)$$

where *i*= 1, 2……2571, β_1 is a column vector of unknown parameters, γ is an unknown scalar which measures the effect of HFS on child nutritional status, ε_{1i} is the error term assumed to be distributed standard normal. x_1 includes selected household, maternal and child characteristics mentioned in Section 3.1.2 as control variables.

Hence, HAZ^* has observable counterpart HAZ generated by observability condition:

food insufficiency or nutritional/health indicators such as dietary inadequacy in adult women (Tarasuk and Beaton, 1998); individual calorie intake (Kendall, 1996); depressive symptoms in adolescents (Kelinman et al., 1998) and so forth.

$$HAZ = \begin{cases} 0 \; if \; \mu_{-1} < HAZ^* \leq \mu_0 \\ 1 \; if \; \mu_0 < HAZ^* \leq \mu_1 \\ 2 \; if \; \mu_1 < HAZ^* \leq \mu_2 \end{cases}$$

where $\mu_i - s$ are the threshold parameters.

*fsec3** is generated by observability condition:

$$fsec3 = \begin{cases} 0 \; if \; \mu'_{-1} < fsec3^* \leq \mu'_0 \\ 1 \; if \; \mu'_0 < fsec3^* \leq \mu'_1 \\ 2 \; if \; \mu'_1 < fsec3^* \leq \mu'_2 \end{cases}$$

Where μ'_i indicates thresholds as above.

Similarly, the equations for wasting and underweight are:

$$WHZ_i^* = \delta \, fsec3_i^* + x_{2i}\beta_2 + \varepsilon_{2i} \qquad (2)$$

$$WAZ_i^* = \theta \, fsec3_i^* + x_{3i}\beta_3 + \varepsilon_{3i} \qquad (3)$$

All models are estimated using stata's *oprobit* command, accompanied by the *svy* command to account for survey design.

Recursive Bivariate Ordered Probit Model

In modelling the relationship between HFS and child nutritional status we improve our baseline models by taking account of the fact that there might be potential endogeneity in the relationships due to the same set of unobservable influencing both variables. For example, both maternal/child nutrition and HFS can be positively influenced by land reform measures initiated by a new political regime resulting in more secure land rights, increased productivity and enhanced standard of living. Accordingly we estimate the following models.

First, following Greene (2012) we estimate recursive bivariate ordered probit (RBOprobit) models with three categories of child nutritional status and HFS (*fsec3*) as joint dependent variables, with the latter appearing as an ordinary pre-determined variable on the right hand side (RHS) of the nutrition equation. The model belongs to a general class of simultaneous equation models discussed by Heckman (1978), Maddala (1983), and Greene (2012). What makes it recursive is the fact that the potentially endogenous explanatory variable *fsec3* appears as pre-determined variable on the RHS, however, anthropometric indicators (*HAZ or WHZ or*

WAZ) do not appear on the RHS of the equation for *fsec3*. Additionally, *fsec3* appears on the RHS of food security equation only as observed (Greene 2012).

We elaborate below the model specifications for stunting (*HAZ).* Specifications for *WHZ* and *WAZ* would be similar. The underlying model for stunting consists of two separate equations relating the *HAZ** and *fsec3** to background characteristics of the households, represented by vectors x_2 and x_0 respectively.

$$fsec3_i^* = \beta_0\, x_{0i} + \varepsilon_{0i} \tag{4}$$

$$HAZ_i^* = \gamma' fsec3_i + \beta_1' x_{2i} + \varepsilon_{1i}' \tag{5}$$

Where β_0 and β_1' are column vectors of unknown parameters, γ' is the unknown scalar which measures the effect of HFS on nutritional status, ε_{0i} and ε_{1i}' are the error terms assumed to be distributed standard normal. x_{0i} and x_{2i} are vectors of control variables detailed in in Section 3.1.2. Full efficiency in estimation and an estimate of γ' are achieved by full information maximum likelihood (FIML) estimation (Greene 2012).

Parameters of the model in Equations (4)-(5), are estimated using maximum likelihood technique. If nutritional status and food security status are jointly determined, estimating the Oprobit equation (Equation 5), as above, in isolation, will give a biased estimate of γ' (Greene, 2012). The possible joint determination of HAZ_i^* and *fsec3** are accounted for by allowing the errors ε_{0i} and ε_{1i}' to be distributed according to a standard bivariate normal distribution with correlation as shown below:

$$E(\varepsilon_{0i}) = E(\varepsilon_{1i}') = 0$$

$$Var(\varepsilon_{0i}) = Var(\varepsilon_{1i}') = 1$$

$$Cov(\varepsilon_{0i,}\varepsilon_{1i}') = \rho$$

The above model allows us to conduct an endogeneity test to check the potential endogeneity of *fsec3*, by testing the significance of 'ρ'. The single equation Oprobit model outlined in Equation 4 is a special case of the RBOprobit with$\rho = 0$. If ρ is not significantly different from zero, one concludes that the system is recursive and single equation Oprobit estimation maybe suitable for the present purpose. Our coefficient of interest in equation 5 is γ' .

Similarly our coefficients of interest for *WHZ*, WAZ** are δ' and θ' respectively in the following models:

$$WHZ_i^* = \delta' fsec3_i + \beta_2' x_{2i} + \varepsilon_{2i}'$$

$$WAZ_i^* = \theta' fsec3_i + \beta_3' x_{3i} + \varepsilon_{3i}'$$

All models are estimated using Stata's *bioprobit* command.

Recursive Bivariate Probit Model

For robustness, instead of considering three categories of nutritional status and HFS, we use binary specifications of child nutritional indicators such as *haz*, *whz or waz* for stunting, wasting and underweight, respectively. Binary food security status is indicated by *fsec*. A recursive bivariate probit (RBprobit) model[10] can be used to examine the effect of HFS on child nutritional status in this case since both of the jointly estimated dependent variables are now binary. The essence of the model is similar to the RBOProbit model sketched in the previous section. In fact the latter is an extension of the RBprobit model with more than two categories of the dependent variable. The RBprobit model is estimated using Stata's *biprobit* command, accompanied by the *svy* option.

2.4.1.2 HFS & Maternal Nutritional Status

We examine the impact of HFS on maternal underweight and overweight status in separate models, the indicators representing different dimensions of nutritional deficiency – undernutrition and over nutrition, respectively.

Thus, we estimate the relationship between maternal malnutrition and HFS by jointly estimating the variables maternal underweight (*m_under*) and *fsec* and the variable representing maternal overweight (*m_over) and fesc*, in separate models.

Identification

Both sets of models (RBOprobit and RBprobit) are estimated by imposing exclusion restrictions even though it is not strictly necessary as "identification by functional form" is possible which only requires variations in the set of exogenous regressors (Wilde, 2000).[11]

One of the identifying variables in food security equation is *RPDS* denoting the type of ration card possessed by the household. This variable is not included as a covariate in the nutritional status equation since having a ration card may have a direct impact on HFS (Gopichnadran et

[10] The bivariate Probit model with an endogenous dummy belongs to the general class of simultaneous equation models with continuous and discrete endogenous variables introduced by Heckman (1978). In his systematic review of multivariate qualitative models Maddala (1983) lists this model among the recursive models for dichotomous choice (Model 5). Within this parametric framework the hypothesis of exogeneity of the dummy can be defined as the absence of correlation between the error terms of the two equations, and submitted to statistical test. Whenever the exogeneity hypothesis cannot be rejected, the model can be simplified to an univariate Probit model.

[11]Because identification by functional form relies heavily on the assumption of bivariate normality, it is common practice to impose exclusion restrictions to improve identification.

al. 2010) but not on anthropometric indicators. The variables *ownhouse, ownland* and *livestock* are also included in food security equation alone since these variables represent ownership of fixed tangible assets like dwelling and land; and asset ownership ameliorates HFS by allowing consumption smoothing which helps mitigate risk and uncertainty (Barrett, 2002). Another variable included in food security equation alone is *transport*. Two other variables related to maternal characteristics –*foodpurchase* and *media* are also included in the *fsec3* equation alone. There exists adequate empirical evidence in the literature that women's decision making power with respect to household food purchase is likely to influence HFS positively (Chiputwa and Qaim 2016). Mother's exposure to media (print/electronic) is expected to positively contribute to HFS. This variable is not included in the equation for nutritional status since impact of maternal exposure to media on children's nutritional outcome is expected to be channelized through its impact on HFS.

3 RESULTS

3.1 Internal Reliability and Validity of the Scale

The basic dichotomous nine-item HFIAS denoted as R1 (yes=1, no=0) has infits in the range 0.62-1.29, with high outfits reported for the items 'worried', 'preferred food', 'hungry' and 'wholeday'and somewhat low infits reported for the items 'fewer' and 'smaller'(Table 3). Reliability of the Maharashtra aggregate scale is good at .818, however, the residual correlation between 'smaller' and 'fewer' (.63) is high (Table 3A).

[Table 3 and 3A here]

Next a polytomous model is estimated using a Rasch partial-credit model (scale R2 in Table 4). The infits range between 0.69-1.5; the infit of worried being slightly above the acceptable range. Residual correlation between 'smaller' and 'fewer' (assessed at the first threshold) is high again (.72) (Table 4A).

[Table 4 and 4A here]

Maharashtra HFIAS is conceptually valid which is evidenced by the fact that the severity ordering of items has been preserved across different settings (see Hamilton et al. 1997a;b for details) — the items corresponding to anxiety and quality of food (e.g. worried, preferred food, limited variety) being at the lower end of the scale and the items relating to drastic reduction in adult intake (for example, hungry and whole day) being at the higher end of the scale. In between lie the questions on graduated reduction in quality or intake ('food not want' or 'smaller meal'). In general, the Maharashtra HFIAS is internally reliable and valid. However, for future applications there exists scope for improvement by dropping one of the items 'fewer' or 'smaller' or tweaking the wordings slightly so as to more clearly differentiate between the meaning of the two items.

3.2 External validation

3.2.1 Household food security status and household socio-economic characteristics

Results of bivariate association between HFS and selected household socio-economic characteristics are reported in Table 5.

[Table 5 here]

We report strong association of HFS with household wealth status (rho .38, p<.000), with proportion of moderately food insecure and severely food insecure households decreasing steadily across the poorest to the richest households. Both categories of food insecurity are higher in households with yellow card holders which represent the poorest segment of households as opposed to white card holders representing above poverty line households (rho .05, p<.000). A higher proportion of food secure households live in pucca houses (rho .43, p<.05) and own some transport (rho -.24, p<.05) while these proportions decline with increase in the severity of food insecurity. Statistically significant association of HFS is also noted with respect to education of household head (rho -.24, p<.000), maternal educational status (rho -.38, p<.000), maternal decision making power with respect to household food purchase (rho -.05, p <.05) and whether mother has exposure to print or electronic media (rho .38, p<.05). Finally, severity of food insecurity increases across urban to rural households, however the coefficient is not significant.

Regarding the association of HFS with maternal and child food consumption pattern (Table 6), we find the proportion of children receiving iron rich food decreases significantly in severely food insecure households (rho -.05, p<0.05). Proportion of children consuming food from at least 4 food groups is declining across food secure (33%) to severely food insecure households (20%), however rho (.14) is not statistically significant. Interestingly, we find significant association of HFS with frequency of consumption of various food items by mothers in the last month—seasonal vegetables (rho .03, p<0.000), dark green leafy vegetables (rho .12, p<0.000), seasonal fruits (.16, rho<0.000), egg (.09, p<0.05), fish (rho .12, p<0.05) and chicken (rho 0.06, p<0.1).

[Table 6 here]

3.3 Impact of HFS on Child Nutritional Status

Results of unadjusted models reported in Table 7 indicate HFS is positively and significantly associated with three categories of stunting (rho 0.16, p<0.05), while the association is weakly significant with respect to wasting (rho 0.18, p<0.1) and insignificant with respect to underweight. Driven by this mixed evidence, we now turn towards the results of fully adjusted models which control for potential predictors of child nutritional status.

[Table 7 here]

The results of multivariate models are reported in Table 8.

[Table 8 here]

We report marginal effects of HFS on child nutritional status for the baseline oprobit model and for the simultaneous Probit models.[12] However, for the RBOprobit models we report coefficients only since estimating marginal effects in RBOprobit models is rather complicated and statistical softwares like Stata/Nlogit do not routinely estimate them.[13] In reporting the results we focus primarily on the RBOprobit/RBprobit models since those models address the concerns regarding endogeneity. The results of baselines Oprobit models are reported for the purpose of comparison only.

Results change dramatically in fully adjusted multivariate models. As reported in Table 8, stunting in no longer significant when potential confounders are adjusted for in our empirical models. The co-efficient ($\acute{\gamma}$) of *fsec3* in the equation for stunting (*HAZ**) in the RBOprobit model is positive but insignificant. The positive sign indicates, as a household switches status from food secure to moderately food insecure and severely food insecure, the likelihood that a child will be stunted or severely stunted increases. However, the relevant coefficients in the equations for wasting ($\acute{\partial}$) and underweight (θ') are now significant as opposed to polychoric correlations for unadjusted models reported in Table 7.

Results also change dramatically when we compare the above results from the simultaneous ordered Probit models with those from the baseline Oprobit models. While the impact of *fsec3* on *WHZ* is insignificant in the single equation Oprobit model, it becomes significant in the RBOprobit specification. Similarly, impact on *WAZ* is weakly significant in the former while it is much stronger in the latter specification. It is only with respect to *HAZ* that results remain robust in both specifications. In all three models, ρ is significant hence justifying the importance of specifying simultaneous equation models rather than single equation ordered Probit for the purpose of modelling the food security-undernutrition linkage.

Next we report the results of binary specification of the variables in RBprobit models. As before, the impact of HFS (*fsec*) is found to be significant for all indicators of nutritional status except for stunting (*haz*). One percentage point increase in the probability of being food insecure increases the risk of being wasted by 0.08 percentage points and the risk of being underweight by 0.16 percentage points, holding constant the effect of other predictors of nutritional status. The coefficient of ρ is significantly different from zero in all models except for stunting. [14]

[12] The complete results of the fully adjusted models are not reported but are available on request. .
[13] We are in the process of exploring estimation of marginal effects in the recursive bivariate ordered probit specification.
[14] When we use the *svy* prefix, Stata does not spit out the LR test of $\rho=0$. However, the p-value for the LR test is equivalent to the p-value on /athrho in the model output.

3.4 HFS and Maternal Malnutrition

Bivariate estimation of the association of HFS with maternal nutritional indicators in unadjusted models report, prevalence of underweight increases from food secure (34%) to moderately food insecure households (41%), however the relationship is weakly significant (rho .07, $p<0.068$) (Table 7). Prevalence of overweight decreases with increasing food insecurity, however the correlation is statistically insignificant.

As before, results change markedly when we control for possible predictors of maternal nutritional status and account for potential endogeneity of *fsec* (Table 8). We find that impact of HFS on maternal underweight status (*m_under*) is now positive and significant while the impact on overweight status (*m_over*) is still insignificant. One percentage point increase in the probability of food insecurity increases the risk of being underweight by 0.17 percentage points, controlling for potential drivers of maternal nutritional status. The coefficient of ρ is significantly different from zero for the model on *m_under*, but not for the model on *m_over*.

4 Discussion

In discussing the results it is important to keep in mind that since, we have incorporated the survey design in our data analysis and estimation method, the reported results should be generally representative of the population (given the survey design is stratified random sampling).

Evidence on the association between the food security indicator and nutritional indicators is mixed. Certain key ideas emerge. First, in examining the relationship between the two indicators, it is important to address the concern regarding potential endogeneity of HFS. Results of the baseline model change remarkably when we account for endogeneity within the framework of simultaneous ordered Probit/Probit models. It is only with respect to stunting and overweight that ρ is not significant which imply that in these cases the two sets of variables – nutritional indicators and food security indicators – may not be jointly determined and the relationship can be examined using single equation Probit models.

Second, household food insecurity is not able to explain child stunting in any of the models. This result is plausible given the fact that stunting represents chronic undernutrition driven more by longer term factors such as maternal nutritional deficiency rather than short-term food insecurity. Similar results have been reported in other population such as East Gojjam Zone in Ehiopia (Motbainor et al. 2015), Ghana (Saaka and Osman 2013) and Cambodia (McDonald et al. 2014). The above notion is confirmed by the fact that the maternal stature and LBW status of children have emerged to be strong predictors of stunting for under-five children in the literature (Aguayo et al. 2016; Garett and Ruel 1999)[15], with lack of access to improved sanitation being another major contributor. Incidentally, according to the latest release of NFHS-4 data, only 52% households in Maharashtra use improved sanitation facility which is

[15] Even in the present study, in all specifications maternal stature and child's LBW status emerged as significant predictors (results not reported but available upon request).

slightly above all-India average of 48 per cent and far below the average of 98 per cent in Kerala. A younger age group (6–23 months) of children in the present sample may be another reason for the lack of an association between stunting and food insecurity (see Ali et al. 2013). Finally, in order to explore the true relationship between stunting and HFS it may be necessary to incorporate time dimension of food insecurity by distinguishing between chronic and transient food insecurity. However, HFIAS is unable to accommodate temporal element in its present form since all questions refer to last ‘30 days’. Given that dietary diversity might be a good predictor of child stunting (Motbainor et al. 2015) it is also possible that diet of younger children are protected against food shock during a period of food insecurity and scarcity (Leonard 1981), so that we do not see any impact of HFS on child stunting. Accommodating temporal dimensions in food security measurement might capture such household responses.

Household food insecurity has strong predictive power for child wasting– a result which seems to be driven by the fact that wasting reflects acute malnutrition which could be influenced by short term HFS. Lack of access to food causes inadequate feeding practices and also breeds reduced immunity to disease which interacts with lack of availability of food increasing the risk of wasting. The result is aligned with UNICEF model (UNICEF 1990) which sketches an explanatory model for wasting prevalence (Fernandez et al. 2002) and identifies insufficient access to food as an underlying cause of wasting. We find similar results reported in Motbainor et al. (2015) for East Gojjam Zone, Ehiopia

In all models, household food insecurity strongly influences the incidence of underweight in children – children coming from /moderately food insecure households as well as from severely food insecure households being more likely to be underweight. The outcome can be explained by the fact that children from food-insecure households are more likely to consume diet low in energy and micronutrients which in turn is a risk factor for being underweight. Association of food insecurity with low total energy intake in children has been reported previously in the literature (Oh and Hong, 2003).

We find household food insecurity to be a risk factor for maternal underweight as well. Similar results have been reported in other populations such as Cambodia (McDonald et al. 2014) and Columbia (Isanaka et al. 2007). As with the case of child underweight, this finding is also explained by low total energy intake caused by inadequate access to food. Additionally, in the face of household food insecurity mothers also resort to coping strategies by which they compromise their own energy intake to meet their children’s need (Isanaka et al. 2007). However, we do not find any association of HFS with maternal overweight. This finding may reflect the fact that in developing country contexts, household food insecurity might be associated with lack of availability of even the least expensive energy dense food that might lead to overweight. The result is consistent with similar population from developing countries such as Columbia, where adults and children from resource poor households resort to fewer purchase of commercial energy dense food like fried snacks/chips or soda, as opposed to similar population from the US where individuals from food insecure households facing limited resources consume less expensive and more calorie-dense food to maintain caloric intake at less cost, exposing themselves to greater risk of being overweight (Drewnowski 2004).

Last but not the least findings from the present study indicate that overall HFIAS is a reliable and valid instrument to measure food insecurity in the given population. However, for future applications of HFIAS, internal validity needs to be improved. Outfits for some of the items such as 'worried', 'preferred food', 'hungry' and 'whole day' are high indicating erratic response pattern, even though high outfit is not a major reason for excluding an item from the food security scale. Infits of the items 'fewer' and 'smaller' are somewhat depressed possibly because these items are conditionally correlated. Further exploration of wordings of such problematic items is suggested for future research. HFIAS correlates well with several socio-economic and demographic household characteristics. Additionally, it correlates well with selected food consumption indicators of mothers and children. Similar associations have been reported with respect to experiential scales in the Indian context (Agarwal et al. 2009, Maitra 2017) as well as in the context of the broader literature (Hamilton et al. 1997b; Kleinman et al. 1998; Hackett et al. 2009; Tarasuk and Beaton 1999; Kendall, 1996; Karkpatrick and Tarasuk 2008; and so forth).

5 Conclusion

On the whole, we report mixed evidence with respect to the association between household food insecurity and maternal and child nutritional status. Household food insecurity predicts child wasting and underweight but not child stunting. Furthermore, household food security status emerges as a risk factor for maternal underweight, but not for maternal overweight. In general, an experiential food security indicator such as HFIAS has good potential to be a valid and reliable instrument to measure household food insecurity in Maharashtra.

The findings of the study have important policy implications. Overall, these findings indicate the need to ameliorate household food access for the purpose of addressing nutritional deprivation of mothers and children. However, for tackling child stunting potential solutions may lie elsewhere, in the direction of addressing maternal nutritional deficiencies within the notion of first '1000 days' of life or in ensuring access to improved drinking water and sanitation of which the latter is a glaring problem in Maharashtra. Further research is necessary in this direction in terms of exploring the determinants of stunting which we haven't discussed in detail in the present study. Food security interventions should be effective in confronting maternal underweight, however, different set of policies may be necessary for dealing with the concerns with overweight or obesity. The impact of food insecurity on overweight/obesity could be different in a developing country setting, as opposed to developed country settings. Exploring factors driving food choice might give richer insight into the above issue. In general, it is important that future research directs its attention to explore the pathways linking lack of food access to nutritional outcomes so that remedial actions can be prompt and effective.

Our finding on the applicability of HFIAS as a food security indicator in Maharashtra directs attention to the need for a uniform indicator to capture household food insecurity in India. Given the huge concern with hunger and food insecurity in this emerging economy it is high time that the national statistical system moves towards a uniform tool to measure food insecurity across diverse settings in the country. If experiential indicators can capture food insecurity reliably resources should be invested in researching how these indicators can be developed further to suit the hugely diverse cultural and food habits in India. For example, we suggest, it may be a useful experiment to modify recall period of longer duration such as 12 months in the food security module, in order to be able capture the temporal dimension of food insecurity. If it is possible to capture seasonality and also distinguish between chronic and transient food insecurity – it might throw further light on the association of household food security with chronic indicators of undernutrition such as stunting.

Table 1. Percent distribution of households by frequency of food insecurity (18-item HFIAS), Maharashtra, 2012

Food insecurity experience in one month prior to survey	Frequency of food insecurity					Number of households
	Never	Rarely	Some times	Often	Total	
Worry about insufficient food	57.9	24.2	14.5	3.4	100.0	2,624
Inability to eat preferred food	63.4	21.0	14.0	1.6	100.0	2,617
Had to eat limited variety of food	68.6	17.6	11.8	2.1	100.0	2,624
Had to eat certain food items without choice	74.5	15.5	9.0	1.0	100.0	2,628
Had to eat smaller meals	79.7	12.3	7.6	0.4	100.0	2,627
Had to eat fewer meals	81.8	11.2	6.6	0.3	100.0	2,627
Had no food to eat	87.8	7.6	4.3	0.3	100.0	2,626
Had to sleep without food	92.3	5.2	2.4	0.0	100.0	2,626
Had to go day and night without eating any food	95.5	3.0	1.5	0.0	100.0	2,627

Table 2: Summary statistics of variables, Maharashtra 2012

Dependent Variables	**Description**	**Total**	**Rural**	**Urban**
Child nutritional indicators				
Categorical variables				
HAZ	=0 if adequate	.772	.752	.797
	=1 if stunted but not severely stunted	.153	.166	.130
	=2 if severely stunted	.075	.078	.070
WHZ	=0 if adequate	.836	.829	.845
	=1 if wasted but not severely wasted	.118	.123	.112
	=2 if severely wasted	.046	.048	.043
WAZ	=0 if adequate	.774	.750	.803
	=1 if underweight but not severely underweight	.160	.182	.134
	=2 if severely underweight	.065	.066	.063
Binary variables				
haz_s	=1 if stunted, else 0 (adequate)	.228	.248	.203
whz_w	=1 if wasted, else 0 (adequate)	.163	.171	.155
waz_u	=1 if underweight, else 0 (adequate)	.225	.248	.197
Maternal nutritional indicators				
m_under (binary)	=1 if underweight, else 0 (normal)	.323	.409	.220
m_over (binary)	=1 if overweight/obese, else 0 (normal)	.110	.039	.193
Key Independent Variables				
fsec3 (categorical)	=0 if HH is food secure	.572	.502	.659
	=1 if mild/moderately food insecure, else 0	.294	.322	.259
	=2 if severely food insecure	.132	.175	.080
fsec (binary)	= 1 if HH is food insecure, else 0	.427	.498	.340
Control Variables				
HH socio-economic characteristics				
hhsize	household size	6.4 (.08)	6.6 (.12)	6.3 (.12)
genderhead	=1 if female headed, else 0	.048	.028	.074
headlit	=0 if omitted base case, if HH head does not read/write	.196	.242	.140
	=1 if HH head has below primary education, else 0	.144	.165	.117
	=2 if HH head has middle to senior level education, else 0	.494	.492	.496
	=3 if HH head has college/university level education	.165	.100	.245
headage	age of HH head	66.2 (.02)	72.3 (0.35)	58.8(.03)
caste	=0 if SC, omitted base group	0.153	.124	.184
	=1 if ST, else 0	0.249	.350	.132
	=2 if OBC, else 0	0.2493	.213	.290
	=3 if others, else 0	0.348	.313	.395
RPDS	=0 if, HH has white card omitted base case	0.048	0.028	0.072

	=2 if HH has no ration card, else 0	.238	0.258	0.236
	=3 if orange card, else 0	.448	.367	.543
	=4 if yellow card, else 0	.256	.347	.149
wealth	=0 if HH belongs to poorest quintile, omitted base case	0.200	.345	.028
	=1 if second wealth quintile, else 0	0.2048	.321	.056
	=2 if middle wealth quintile, else 0	0.1964	.231	.158
	=3 if fourth wealth quintile, else 0	0.2029	.081	.351
	=4 if highest wealth quintile, else 0	0.1956	.021	.411
ownhome[2]	=1 if owns home, else 0	.872	.954	.773
ownland[2]	=1 if owns land, else 0	.450	.679	.169
transport[2]	=1 if at least some, else 0	.509	.515	.501
livestock[2]	=1 if HH does not own any livestock	.404	.634	.122
HH environmental characteristics				
hhtype:	=1 if kachha/semi-pucca , else 0 (pucca)	0.372	.223	.552
cook_place	=1 if no separate room for kitchen, else 0			
piped	=1 if HH does not have access to piped water, else 0	.666	.486	.887
toilet	=1 if HH has access to toilet facility, else 0 (no facility)	.554	.335	.823
Maternal characteristics				
mschool	=0 if no school, omitted base case	.116	.143	.082
	=1 if primary, else 0	.058	.076	.035
	=2 if secondary to middle, else 0	.614	.663	.553
	=3 if above secondary, else 0	.211	.117	.328
agemarriage	=1 if mother's age at marriage<18	.297	.367	.210
foodpurchase[2]	=1 if mother decides HH food purchase alone or jointly, else 0	.631	.605	.662
decisionfood	=1 if mother decides food items to be given to the child jointly or alone, else 0	.778	.783	.772
decisionmoney	=1 if mother decides how to spend her own earnings jointly or alone, else 0	.773	.772	.779
decisionhealth[1]	=1 if mother takes decision on her own health care jointly or alone, else 0	.671	.674	.667
lowheight[3]	=1 if mother's height < 145 cm	10.6	11.0	10.2
ANC	=1 if mother received at least 3 ANC	.906	.867	.954
ironfolic[1]	=0 if mother consumed iron folic acid (IFA) more than 90 days	.567	53.2	60.9
media	=1 if mother does not have media, (print/electronic) exposure , else 0	.253	.363	.117
work	= 1 if mother has not worked in last 12 months, else 0	.686	.535	.871
tobacco[1]	=1 if yes, else 0	.877	.836	.927
Pregnancy[1]	Number of times a mother was pregnant	2.11(1.18)	2.15 (1.18)	2.08 (1.18)
Child characteristics				
childage	age of child in completed months	11.3 (.17)	11.1(.25)	11.5 (.24)
childegender	=1 if girl, else 0 (girl)	.447	.439	.458

LBW[3]	=1 if LBW, else 0	.201	.210	.194
birthorder	=1 if first order, else 0 (higher order)	.431	.409	.447
BF_age_appr	=1 if child age-appropriately breastfed, else 0	0.731	.745	.709
Seven_Fgr_recoded	=1 if child received food from >4 food groups	.088	.091	.085
IM_nw	=1 if child received full immunisation, else 0 (partial)	.371	.340	.409
setting	=1 if urban, else 0 (rural)	.55		
region	=0 if Amaravati, omitted base group	.10		
	=1 if Aurangabad, else 0	.17		
	=1 if Konkan, else 0	.25		
	=1 if Nagpur, else 0	.08		
	=1 if Nasik, else 0	.17		
	=1 if Pune, else 0	.21		

Note: [1]Included in the equation for maternal nutritional status (underweight/overweight) alone. [2]Included in food security equation alone.[3]Included in equation for stunting/severe stunting alone

Table 3: Item severity parameters and fit statistics for basic dichotomous scale Scale R1, N=2585

Item	Parameter	Error	Infit	Outfit
worried	-3.71	0.10	1.31	12.34
preferred	-2.71	0.09	0.87	6.96
variety	-1.85	0.09	0.83	1.55
nochoice	-0.95	0.09	0.95	1.56
smaller	-0.12	0.09	0.63	0.40
fewer	0.34	0.10	0.62	0.47
nofood	1.67	0.11	0.89	1.05
hungry	3.02	0.14	0.82	6.95
wholeday	4.31	0.19	1.07	10.51

Table 3A: Item residual correlations for R1

Item	worried	preferred	variety	nochoice	smaller	fewer	nofood	hungry	wholeday
worried	1.00	0.03	-0.20	-0.25	-0.14	-0.17	-0.20	-0.14	-0.15
preferred	0.03	1.00	0.17	0.03	0.01	-0.06	-0.12	-0.14	-0.18
variety	-0.20	0.17	1.00	0.31	0.10	0.01	-0.08	-0.12	-0.13
nochoice	-0.25	0.03	0.31	1.00	0.06	0.06	-0.03	-0.11	-0.15
smaller	-0.14	0.01	0.10	0.06	1.00	0.63	0.12	-0.03	-0.05
fewer	-0.17	-0.06	0.01	0.06	0.63	1.00	0.20	0.03	-0.02
nofood	-0.20	-0.12	-0.08	-0.03	0.12	0.20	1.00	0.16	0.04
hungry	-0.14	-0.14	-0.12	-0.11	-0.03	0.03	0.16	1.00	0.40
wholeday	-0.15	-0.18	-0.13	-0.15	-0.05	-0.02	0.04	0.40	1.00

Table 4: Item severity parameters and fit statistics for for Scale R2. Partial-credit Rasch model analysis. Item-threshold parameters N=1143

	Rasch-Thurstoneinfit			Rasch-Thurstone outfit			Overall	
Item	1	2	3	1	2	3	Infit	Outfit
worried	1.29	1.45		62.05	2.35		1.56	1.78
preferred	0.88	1.13		1.06	1.52		1.05	1.01
variety	0.82	1.02		2.35	1.66		0.91	0.90
nochoice	0.93	0.87		0.91	0.68		0.91	0.84
smaller	0.69	0.81		0.48	0.46		0.67	0.52
fewer	0.74	0.75		0.50	0.97		0.68	0.53
nofood	0.91	0.95		0.72	0.68		0.92	0.72
hungry	1.15	0.90		1.57	213.29		1.13	2.43
wholeday	1.16	1.09		2.07	1.26		1.19	2.10

Table 4A: Inter-item residual correlations for R2

items	**worried**	**preferred**	**variety**	**nochoice**	**smaller**	**fewer**	**nofood**	**hungry**	**wholeday**
worried	1.00	0.01	-0.17	-0.18	-0.08	-0.11	-0.13	-0.10	-0.09
preferred	0.01	1.00	0.24	0.13	0.09	0.03	-0.05	-0.09	-0.10
variety	-0.17	0.24	1.00	0.41	0.21	0.13	0.02	-0.05	-0.05
nochoice	-0.18	0.13	0.41	1.00	0.24	0.23	0.11	0.00	-0.04
smaller	-0.08	0.09	0.21	0.24	1.00	0.72	0.28	0.09	0.06
fewer	-0.11	0.03	0.13	0.23	0.72	1.00	0.35	0.16	0.09
nofood	-0.13	-0.05	0.02	0.11	0.28	0.35	1.00	0.32	0.21
hungry	-0.10	-0.09	-0.05	0.00	0.09	0.16	0.32	1.00	0.55
wholeday	-0.09	-0.10	-0.05	-0.04	0.06	0.09	0.21	0.55	1.00

Table 5: Association of food security status with selected socio-economic indicators, Maharashtra 2012				
	food secure	**mild/moderately food insecure**	**severely food insecure**	**rho**[1]
wealth quintile				-.38***
poorest (=0)	.415	.336	.249	
second	.537	.318	.145	
middle	.489	.342	.168	
fourth	.570	.347	.083	
richest	.857	.126	.016	
Ration card				.05***
white (=0)	.783	.178	.038	
No card	.440	.381	.178	
orange	.658	.251	.090	
yellow	.503	.313	.184	
Household type				.43**
If household lives in pucca house (=0)	.766	.180	.053	
If household lives in kachha/semi-pucca house	.458	.361	.179	
HH has some transport-				-.24**
none (=0)	.493	.316	.190	
atleast some	.649	.273	.077	
Education of household head				-.24***
no education (illiterate) (=0)	.487	.309	.203	
less than 5 years (elementary)	.523	.276	.200	
6-11 years (middle)	.567	.322	.110	
12 and above (high)	.725	.217	.058	
Mother's education				-.38***
no school (=0)	.3231	.348	.329	
primary/middle	.312	.428	.259	
middle/senior	.579	.305	.116	
above senior	.767	.196	.036	
If mother takes decision on food purchase jointly with others				-.05**
no (=0)	.539	.336	.127	
yes	.596	.290	.114	
If mother takes decision on earnings jointly with others				-.15
no (=0)	.500	.307	.192	
yes	.596	.290	.114	
If mother has exposure to media				.38 **
yes (=0)	.635	.279	.086	
no	.392	.339	.269	
Setting				-.23
Rural (=0)	.502	.322	.175	
Urban	.659	.259	.080	

Note: ***, **, * Implies significance at 1%, 5% and 10% level, respectively. [1]Reported results are polychoric correlations which represent correlation between ordered categorical nutritional indicators and household socio-economic indicators in continuous/categorical/binary form. If two ordinal variables are obtained by categorising a normally distributed underlying variable and those two unobserved variables follow a bivariate normal distribution, then the (maximum likelihood) estimate of that correlation is the polychoric correlation (Greene and Hensher, 2009).

Table 6: Association of food security status with selected maternal & child food consumption indicators, Maharashtra 2012				
Variables	**food secure**	**mild/moderately food insecure**	**severely food insecure**	**rho[1]**
Child received food from >=4 groups				-.07
no (=0)	.901	.918	.942	
yes	.099	.082	.058	
Child received iron rich food				-.05**
no (=0)	.938	.922	.971	
yes	.062	.078	.029	
mothers food consumption				
frequency of consuming milk last one month				
daily/alternate days	.387	0.4232	0.337	-.007*
weekly	.069	0.036	0.053	
never/occasionally	.543	0.539	0.610	
frequency of consuming dark leafy veg last one month				
daily/alternate days	.763	.684	.639	.12***
weekly	.168	.270	.297	
never/occasionally	.068	.040	.062	
frequency of consuming seasonal vegetables last one month				.03***
daily/alternate days	.451	.414	.368	.03***
weekly	.259	.307	.385	
never/occasionally	.289	.275	.247	
frequency of consuming seasonal fruits last one month				
daily/alternate days	.263	.202	.104	0.16***
weekly	.288	.255	.200	
never/occasionally	.449	53	.692	
frequency of consuming pulses and bean last one month				
daily/alternate days	.836	.753	.679	-.07
weekly	.112	.187	.211	
never/occasionally	.052	.059	.109	
frequency of consuming egg last one month				
daily/alternate days	.143	.084	.108	.09**
weekly	.378	.430	.343	
never/occasionally	.478	.481	.548	
frequency of consuming fish last one month				
daily/alternate days	.072	.048	.032	
weekly	.293	.293	.251	
never/occasionally	.635	.654	.717	
frequency of consuming chicken last one month				
daily/alternate days	.656	.267	.077	.06*
weekly	.569	.298	.132	
never/occasionally	.565	.295	.140	
Note: ***, **, * Implies significance at 1%, 5% and 10% level, respectively. [1]Reported results are polychoric correlations.				

Table 7: Association of HFS with maternal/child nutritional status (unadjusted), Maharashtra 2012.				
	food secure	mild/moderate	severe	rho[1]
child nutritional status				
stunting				
child not stunted	.803	.739	.712	.16**
stunted	.146	.170	.145	
severely stunted	.051	.090	0.1429	
underweight				
normal	.810	.737	.698	.18
underweight	.14	.190	.185	
severely underweight	.049	.072	.116	
wasting				
normal	.844	.841	.794	.08*
wasted	.118	.116	.123	
severely wasted	.038	.044	.084	
maternal nutritional status				
mother underweight	.338	.405	.375	.07*
mother overweight	.196	.123	.078	-.23

Note: [1] polychoric correlations reported for children and tetrachoric correlations reported for mothers. ***, **, * Implies significance at 1%, 5% and 10% level, respectively.

Table 8: Association of household food security status with maternal/child nutritional status , Maharashtra 2012: Adjusted Multivariate models			
Model	**mild/moderately food insecure**	**severely food insecure**	**food insecure**
Child nutritional status			
Ordered[1]			
HAZ	.0139 (.01)	.0116 (.02)	– –
WHZ	.0026 (.013)	.0024 (.020)	– –
WAZ	.0264* (.015)	.0219 (.022)	– –
Recursive Bivariate Ordered Probit[2]			
HAZ	.3223 (.23)	.4721 (.41)	–
WHZ	.3232** (.16)	.6315** (.25)	–
WAZ	.5613*** (.17)	.8001*** (.29)	–
Recursive Bivariate Probit[3]			
hazs	–	–	.0390 (.07)
whzw	–	–	.0838** (.03)
wazu	–	–	.1575***. (.03)
Maternal nutritional status			
Recursive Bivariate Probit[4]	–	–	
m_under	–	–	.1677** (.08)
m_over	–	–	-.2748 (.64)

Note: ***, **, * Implies significance at 1%, 5% and 10% level, respectively. All results relate to fully adjusted models.

[1]Reported results are marginal effects. Models include child nutritional status and HFS as ordered categorical variables. Control variables in the equation for stunting include household characteristics: household size, age, education, gender and caste of household head, household's wealth status, whether the household is pucca, whether the household has access to piped water, whether the household has access to toilet facility; maternal characteristics: mother's age of marriage, maternal education level, whether mother worked in last 12 months, whether mother received at least 3 ANC, if maternal height <145 cm, maternal decision making power regarding food given to child and regarding spending her own earnings; and child characteristics: child's age, gender , birth order, whether child is appropriately breastfed, whether child received atleast 4 food groups, whether child had low birth weight (LBW) and finally setting (rural/urban) and region (Amaravati, Aurangabad, Konkan, Nasik and Pune). The equation for wasting and underweight do not include the variables LBW and maternal height status but include maternal BMI status and whether child received full immunisation.

[2] Models include child nutritional status and HFS as ordered categorical variables. In addition to the household characteristics mentioned above, plus setting and region; food security equation also controls for additional covariates such as the type of ration card owned by the household, home and land ownership status, whether the household access to some transport and whether the household possesses some livestock. Additional maternal characteristics include mothers' decision making power regarding household food purchases and whether mother has media exposure. Reported results are coefficients.

[3]Model includes nutritional status and food security status as binary variables. Reported results are marginal effects.

[4]Model includes maternal nutritional status and food security status as binary variables. Reported results are marginal effects. In addition to all variables mentioned in the equation for wasting and underweight, equation for maternal underweight also controls for additional covariates such as whether the mother consumes tobacco, number of times mother was pregnant, mothers' decision making power with respect to her own health, whether mother consumed iron and folic acid for more than 90 days.

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Appendix A

Table A: Household Food Insecurity Access Scale: Measurement Tool (HFIAS)

	Items	**Abbreviatio**
1	In the past four weeks, did you worry that your [household] would not have enough food?* (anxiety) Yes/No	worried
2	In the past four weeks, were you or any household member not able to eat the [kinds of foods you preferred] because of a [lack of resources]?* (inadequate quality) Yes/No	preferred foo
3	In the past four weeks, did you or any household member have to eat [a limited variety of foods] due to a lack of resources?*]?* (inadequate quality) Yes/No	variety
4	In the past four weeks, did you or any household member have to eat some foods [that you really did not want to eat] because of a lack of resources to obtain other types of food?*]?* (inadequate quality) Yes/No	nochoice
5	In the past four weeks, did you or any other household member have to eat a smaller [meal] than you felt you needed because there was not enough food?* (insufficient quantity) Yes/No	smaller
6	In the past four weeks, did you or any household member have to eat [fewer meals in a day] because there was not enough food?* (insufficient quantity) Yes/No	fewer
7	In the past four weeks, was there ever no food to eat of any kind in your household because of lack of resources to get food?* (insufficient quantity) Yes/No	nofood
8	In the past four weeks, did you or any household member go to sleep at night hungry because there was not enough food?* (insufficient quantity) Yes/No	hungry
9	In the past four weeks, did you or any household member go a whole day and night without eating anything because there was not enough food?* (insufficient quantity) Yes/No	wholeday

Note: *Each of these nine questions have how often follow-ups with response options ‘rarely’, ‘sometimes’ and ‘often’.

Appendix B

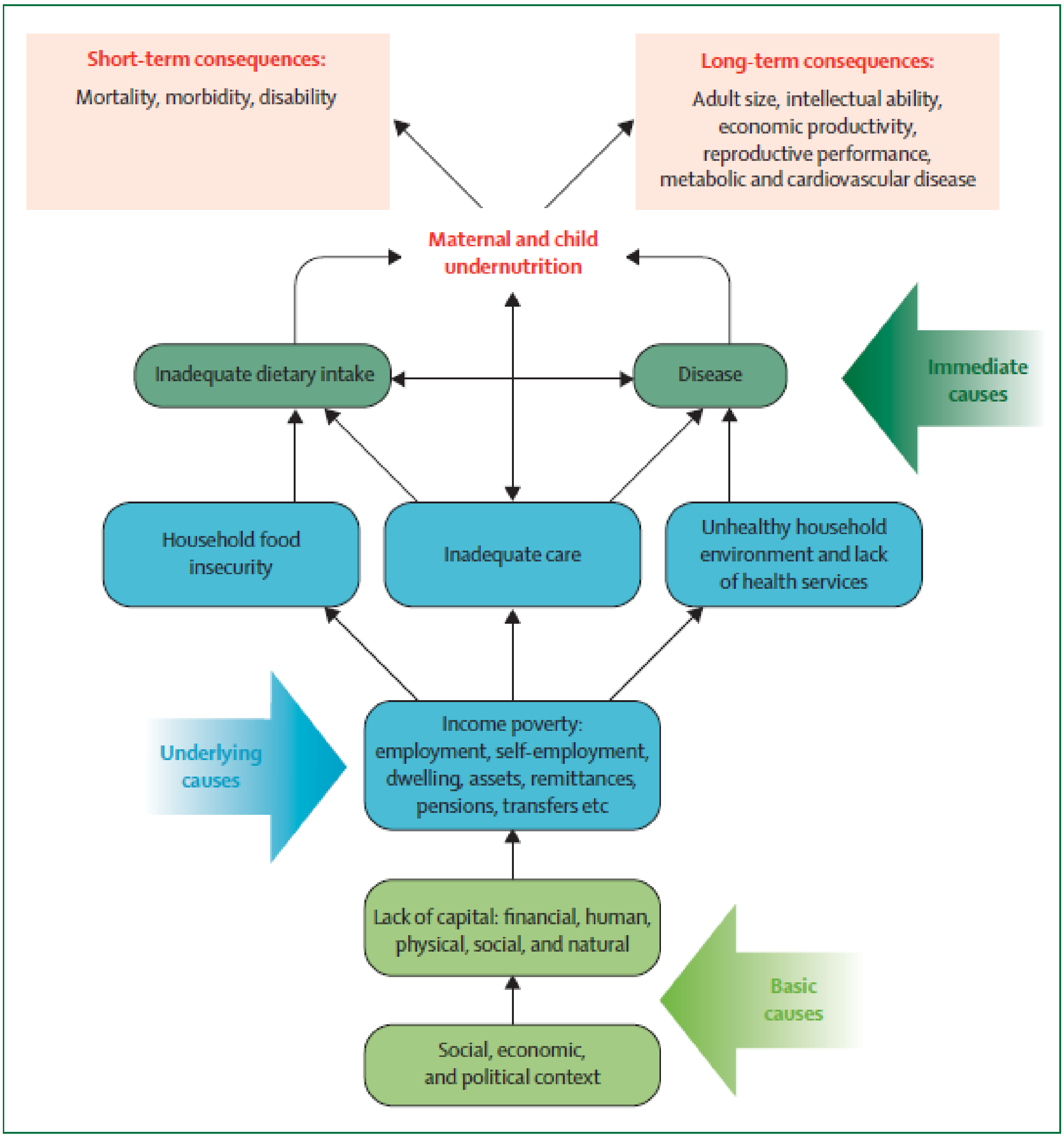

Figure 1: Framework of the relations between poverty, food insecurity, and other underlying and immediate causes to maternal and child undernutrition and its short-term and long-term consequences

Figure 1A: Coceptual framework to understand the relationshp between maternal/child nutritional status and household fod security status.
Source: Black et al. 2008