PATHWAYS FROM AGRICULTURE TO NUTRITION IN INDIA: THE ROLE OF WOMEN'S TIME TRADE-OFFS AND EMPOWERMENT

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Agriculture plays a key role in improving nutrition as a significant proportion of the malnourished population lives in rural areas and depends on smallholder agriculture for their sustenance. About 30 percent of the labor force in agriculture in India are women, and they contribute about 32 percent of their time to agricultural activities. Two essential pathways linking agriculture and nutrition are - women's time use and empowerment. However, we know very little about changes in women's time trade-offs and empowerment due to their engagement in agrarian activities over time and their associations with nutritional outcomes.

This dissertation analyzes both these pathways in a systematic and detailed manner. For this research, we collected primary data from 960 households across 24 villages and three blocks of Chandrapur district in Maharashtra, India. Household composition, agricultural input use, sale of crops, diet diversity, anthropometry and women's empowerment data were first collected in the household survey. The same women were followed through in ten rounds to collect time use and diet data across all agricultural seasons. 502 locally consumed recipes were standardized to obtain precise, contextualized nutrient and cooking time measures. Firstly, we study the patterns of women's time across agricultural seasons and the trade-offs in their time spent on agriculture and nutrition-related activities such as food preparation, domestic work etc. Following that we analyze the relationship between women's time trade-offs and their nutrient intakes – calories, proteins, fats, iron, zinc and vitamin A across seasons. We find that during peak agricultural seasons, work in agriculture translates to increased time constraints and reduction in time spent on

cooking, domestic work, and sleep. Furthermore, these trade-offs are associated with lower intake of nutrients such as calories, proteins, iron, and zinc. Secondly, we analyze the changes in women's empowerment over time and the association with nutritional outcomes. We use an adapted version of the Women's empowerment in agricultural Index (WEAI) to measure empowerment, and our results indicate that - an increase in women's empowerment is associated with an increase in consumption of more micronutrient-rich fruits and vegetables. Specifically, input in decision making and ownership of assets are the main drivers of higher consumption of fruits and vegetables.

BIOGRAPHICAL SKETCH

Vidya Vemireddy is a PhD candidate in Applied Economics and Management, at the Dyson School, Cornell University, USA. Before joining Cornell, she holds a Master's degree in Economics from Boston University and a Bachelors (Hons.) degree in Economics from Delhi's Lady Shri Ram College for Women. Her research fields are: food and agricultural economics, the economics of nutrition, gender and international development. She collected multiple rounds of data over the past two years, on detailed agricultural time use and nutrition from rural Maharashtra, India.

Her other research areas include: analysis of time use, measurement of women's empowerment in agriculture and its impact analysis, determinants of market integration, structural transformation and malnutrition. She has provided her research support to institutes such as TARINA (Technical assistance and Research for Indian Nutrition and Agriculture); Population Council; IIM- Ahmedabad, India; Cornell University, USA; Boston University, USA; TCI etc.).

Outside of her academic interest, she was involved in various institutional activities such as being a being a member of the department's graduate student committee and a mentor at the office of academic diversity. She is an avid traveler and food connoisseur and is a professional blogger on food and travel across the globe.

Dedicated to my grandparents, parents and husband

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CHAPTER 1

THE ROLE OF WOMEN'S TIME IN NUTRITION SENSITIVE FOOD SYSTEMS: PANEL DATA EVIDENCE FROM RURAL INDIA

1. Introduction

In low-and-middle-income countries, particularly Sub-Saharan Africa and South Asia, there has been an expansion in the understanding of pathways through which agriculture affects nutrition. A significant proportion of this literature has explored the role of agriculture as a source of food and income in improving nutrition (Pingali and Rao 2016; Ruel, Quisumbing, and Balagamwala 2018). Research on the impact of agricultural policy and prices in impacting nutrition has been explored in depth. Recent research has shown that women's empowerment in agriculture - plays a key role in improving nutritional outcomes of women and children (Shankar et al. 2017; Sraboni et al. 2014). However, pathways through which women's employment in agriculture impacts their nutrition- has not been adequately studied in the existing literature. The most important, yet highly understudied pathway that impacts women's nutrition is time allocation of women in agriculture.

The problem of malnutrition is complex, persistent and continues to be one of the primary global health challenges affecting millions of people across countries. The period of 2016-2025 has been defined as the "decade of action on Nutrition" by the United Nations (Baker et al. 2018) and eradicating malnutrition has become a key policy priority: as reflected in the Sustainable Development Goals for 2030. 780 out of the 815 million undernourished live in South Asia and Africa (FAO 2017): regions which are heavily dependent on agriculture for sustenance. Recent trends reflect increasing involvement of women in agriculture and feminization of agriculture has been well-documented; particularly in South Asia (Rao et al. 2018). Women also form the backbone for the household economy being involved in sourcing, producing and providing food and nutrition to themselves and their families. *Their central role as both producers and providers of nutrition presents a window of opportunity in effectively improving nutrition through agriculture. However, a clear understanding of the factors/pathways is critical before any intervention.*

Time is the most critical resource that enables women to participate in multiple labor-intensive activities in agriculture. Women's labor force participation in agriculture is about 35 percent in South Asia and about 50 percent in Sub-Saharan

Africa. Thirty-two percent of their time is spent on agricultural activities such as transplanting, weeding, etc. (FAO 2011). Besides their heavy involvement in agriculture, women are also solely responsible for household chores like cooking and cleaning, collecting fuel and water, and care of children and the elderly- particularly in developing countries. Given the multiplicity of roles: time becomes a constraint in ensuring the competing demands of work for pay and household activities. It is important to highlight that women's time trade-off between income-generating and other household activities are binding because they are solely responsible for these activities due to social and cultural norms, considering that providing nutrition is a time-intensive process, constraints imposed due to increased work may impact nutrition outcomes.

In recent discourse, the hypothesis that increasing women's agricultural work can negatively impact their time for providing nutrition to the household has received greater attention (Kadiyala et al. 2014; Komatsu, Malapit, and Theis 2018). Many agricultural-nutrition interventions have shown that agricultural programs and interventions can have consequences on nutrition and health by reducing the time for childcare, food preparation, health-seeking behavior, and leisure through time constraints (Carletto, Corral, and Guelfi 2017; Cunningham et al. 2015; Ruel, Quisumbing, and Balagamwala 2018). However, studies looking at this relationship rigorously and in detail are scant (Johnston et al. 2018). This study addresses this gap in the literature by looking at the relationship between women's time constraints and their nutrient intake in the context of agricultural- nutrition linkages.

Using a unique primary high-frequency panel data of 960 households across ten months from rural Maharashtra, India, this study examines the relationship between the role of women's time and nutritional outcomes for women. We contribute to the literature in several ways: First, this is one of the first paper to present evidence of how women's time constraints affect their nutrition and food consumption in the context of agriculture-nutrition linkages. Earlier studies have independently explored time burdens faced by women in agriculture and the impact of time burdens on nutrition. However, there are no studies that study the complete pathway: from agricultural work to nutrition- through the lens of time use. We explore this pathway by analyzing the relationship between women's opportunity cost of time on their nutrient intakes.

Second, we show how these time constraints change through peak and lean agricultural seasons and their subsequent impacts on nutrient intakes. Recent reviews have highlighted that seasonality plays a critical role in the nutritional status of women and children (Komatsu, Malapit, and Theis 2018; Nitya and Raju 2017;

Rao, Nitya, Gazdar, Haris, Chanchani, Devanshi and Ibrahim 2018). Peak agricultural seasons such as sowing and harvesting can particularly impact women's time for nutrition due to increased pressures from time in agriculture. To our knowledge, this is the first study that uses high-frequency data on time use and diet data which span across all agricultural seasons and activities. It is essential to have such detailed data on the same individuals across all seasons to explore the link between time trade-off and nutrition. The detailed agricultural and non-agricultural time use data- to the level of every activity in agriculture- allows us to quantify the work burdens faced by women, through all seasons and across cropping systems. Our results not only add to the understanding of women's work in agriculture but also add significantly to the literature on time use. This unique and high-frequency data allows us to empirically estimate the relationship using panel data methods.

Finally, we contribute methodologically by standardizing the time taken to prepare 502 locally consumed recipes and their nutrients to measure the impacts of time burdens on time spent on cooking and nutrient intakes. There are two main reasons we do this unique data collection: i) globally, earlier studies explored the choice between food away from home and food at home/ increased consumption of processed food due to increased time constraints for women. However, these typologies do not meet the context of a developing country as food is typically prepared by women at home in the form of recipes due to cultural norms, and these vary significantly across geographies. To explore the impacts on time spent on cooking (nutrition is provided to the household through cooking), an estimate of the time taken to prepare the meals is necessary- posing a methodological challenge. We innovate/contribute methodologically by conducting a first and unique exercise by standardizing the time spent to prepare local recipes; ii) Recipes prepared at home vary significantly in their nutrient content and earlier studies using nutrient intakes do not account for these variations- and hence are very noisy. We overcome this challenge, by collecting nutrient information of each recipe through the recipe standardization process.

Using these primary panel data, we use individual-level fixed effects methodology to estimate the relationship between women's opportunity cost of time and their nutrient intakes. Our results show that women contribute significantly to agricultural as well as non-agricultural activities and face severe time burdens. These time burdens vary by season, and the constraints are much higher during peak seasons of agriculture. The rising opportunity cost of time for women has an adverse effect on nutrient intake. These trade-offs in time lead to lower intake of nutrients such as calories, proteins, iron, and zinc. We also conduct sub-sample analysis to see how cropping patterns, land-ownership and women's education in either enhancing or mitigating the negative effects (Nitya and Raju 2017; Pattnaik et al. 2018; Rao et al. 2018). Women are solely responsible for many household activities such as cleaning, cooking, childcare and this increases their work burdens significantly(Jain, n.d.; Kumar 1995; Newman 2002; Sharma, Nagar, and Chopra 2007). Notably, they contribute to nutrition through their role in food procurement and preparation for the family (Hyder et al., 2015).

1.1. Women's time use patterns in agriculture and non-agricultural activities

Women in low-income countries, spend a significant amount of time in agricultural activities and household activities (Hirway 2009; Kumar 1995). Time use studies across developing countries suggest that women's role in agriculture is increasing. According to a report by UNDP, it is estimated that women in India spend about 9 times more time in unpaid work as compared to men and they spend an average of 300 minutes for a typical work day (Charmes 2015). In South Asia, the trends are towards feminization of agriculture (ILO, 2015). For instance, in Nepal and Pakistan, most working women, work in agriculture (Zaidi, 2018). Research in India shows that women in agriculture experience high workloads (Hirway 2009). This unique and high-frequency data allows us to estimate the relationship rigorously using panel data methods.

Increased demand for time in one activity may lead to trade-offs in other activities performed. Notably, during peak seasons in agriculture, the increased demand for women's time can lead to a reduction in time for nutrition generating activities. Labor requirements and food availability vary by seasons in agriculture, and this leads to changes in women's time allocation patterns (Longhurst 1986, Berhman, Jiggins, etc.)

Given the importance of women's work in care and agriculture activities, there here are very few studies that explore this link between agriculture work and nutrition (Johnston et al. 2018). Seasonal variations, changing activity patterns and varying requirements for energy increase the data needs and complexity of data collection. However, a detailed understating of time allocation in paid and unpaid activities, diet records across all seasons are essential to claim the links between time constraints and nutritional outcomes. A recent review shows limitations in existing data in the South Asian context. Studies are i) cross-sectional which makes it challenging to study variations in time use across seasons, ii) Some either collect agricultural activities or care activities. No datasets are containing a detailed record of all activities across seasons iii) These studies also do not collect time use of males which makes it difficult to look at the contribution of women's work with men (Rao, Nitya, Gazdar, Haris, Chanchani, Devanshi and Ibrahim 2018). Mainly, in India, such complicated time use datasets do not exist which makes it challenging to see the effects across seasons and agricultural activities. In this study, we address these limitations by using a detailed primary data set that captures time use patterns of women and men (960 each) across ten rounds in the year 2017.

1.2. Role of women's time in nutrition

Many studies have analyzed the impacts of changing work patterns of women on their health across disciplines of epidemiology, sociology, and economics (Thomas et al. 1991; Wolfe and Haveman 1983), but none, particularly in agriculture. The incorporation of theoretical models for time allocation under the household production and health production frameworks enabled research to model time costs in non- market/household production activities (Becker 1965; Grossman 1972; Lancaster 1966; Pitt and Rosenzweig 1985). The concept of opportunity cost of time as a way of measuring the price of non-market production such as food preparation shed light on the role of time constraints in influencing demand for food consumption and nutrition. Different strands of literature have contributed to measuring the impact of women's employment and increased time constraints on nutrition and food consumption patterns.

Applications in agricultural economics literature show that a rise in the opportunity cost of time of women increases consumption of food away from home (Baral, Davis, and You 2011; Davis 2014; Gawn et al. 1993; Hamermesh 2007, 2008; Prochaska and Schrimper 1973). Among developing countries, time constraints have a positive effect on the consumption of time-saving foods such as processed bread in Sri Lanka (Senauer, Sahn, and Alderman 1986) and are negatively related to nutrient intake in the case of rural South India (Behrman and Deolalikar 1990; Pitt and Rosenzweig 1985). The use of health production functions shows that increasing women's work hours without a subsequent reduction in hours for domestic work might explain the increase in obesity levels in the US (Cawley 2004; Cawley and Liu 2012)

There are several gaps in the current literature. First, in this literature, studies that use high-frequency data on time use and diet data which span across all agricultural seasons and activities were also not found. It is essential to have such detailed data on the same individuals across all seasons to explore the link between time trade-off and nutrition. We address this gap through analyzing a detailed primary data set, containing information on detailed activity wise time use data. Second, diet quality measures such as nutrient intakes and dietary diversity have not been studied in the context of this relationship in rural and developing economies, barring few (Behrman and Deolalikar 1990; Pitt and Rosenzweig 1985). Several measurement issues arise when nutrient intakes are calculated as they do not account for local preparation methods. In diverse cultural settings, nutrient intakes vary substantially by communities and it necessary to measure these intakes as accurately as possible. However, we found no study that attempts measuring the nutrient intakes using context-specific standardized local recipes. In a developing country context, where meals are prepared and eaten at home, to quantify the time spent for cooking, estimates of time taken to prepare the meals are needed, but there are no studies that collect such information. We overcome these challenges in this paper, by collecting a rich dataset with the time taken to prepare locally eaten recipes and their nutrient content. Finally, most of the studies are focused on the US, barring a few that are developing economy focused. Out of the ones that look at developing countries, none of the studies focus on rural agricultural contexts. They also do not look at women's opportunity cost of time and their intakes specifically. Studies either have measures for the opportunity cost of time or time use, but do not have both. This paper studies this link, in the context of India and agriculture-nutrition linkage.

The rest of this paper is structured as follows. Section 2 discusses the theoretical model. Section 3 lists the details of the field work, data collection process, and measures used in the study. Section 4 describes the method of analysis, which is followed by results in section 7. Finally, we conclude by discussing the policy implications of the contribution is section 6.

2. *A model for women's time allocation and nutrition indicators*

In this paper, we model the impact of the trade-off of time spent in agricultural work vis a vis the time spent in household activities on various nutritional indicators within households. We measure this trade-off through women's opportunity cost of time: which is modeled as wages forgone had the woman worked for the market wage (opportunity cost of time). The relationship can be modeled through a reduced form demand function for nutrient intakes/ diet quality. Theoretically, these relationships are studied in a constrained optimization under the unified household preference framework (Becker 1965; Pitt and Rosenzweig 1985). Originally Becker (1965), integrated the time constraint in the regular utility maximization problem where an individual receives utility from z-products which are home produced. This framework has been applied in health and agricultural economics. In the recent literature reduced form functions have been used in several studies in the US, in the context of looking at factors behind demand for food-away-from home (Cawley and Liu 2012; Chou, Grossman, and Saffer 2004; Davis 2014; Huffman 2010; You and Davis 2010). The applications of this model in a developing country context have been few in comparison. This is the first study in our knowledge that incorporates the time constraints faced by women within the agriculture-nutrition linkages framework. In this framework, utility is generated through nutrition (which we consider as a general health indicator) and taste preferences generated from food consumption. The health aspect of food is generated by the nutrients which are in the utility function. Each of the nutrition indicator is produced through a production process by the food preparer in the household by combining raw food material, food preparers time. The optimal choice of consumption is given by a constrained optimization problem defined on the individual's utility function where, utility is maximized subject to a nutrient production function, time and income constraints.

Utility is defined on *N* which is broadly defined as a nutrition indicator and more specifically, we look at the dietary diversity of women, the macro-nutrient intake (carbohydrates, proteins, fats) and the micro- nutrient intake (Iron, Zinc, VitA). *X* is all other commodities, LT is leisure time available for the food preparer and Z is defined as all the demographic characters such as age, education etc. N is produced by a production function that has constant returns to scale.

$$E1: U = U(N, F^r, F^p, X, LT, CT : Z)$$
$$E2: N = f(F^r, F^p, CT)$$

Where f(.) is a strictly concave function and F^r is a vector of raw food items purchased and need to be converted into a meal for consumption, F^p is a vector of directly consumable foods, CT is the time taken by the food preparer for preparing and cooking the raw foods. We would expect that the $\frac{dN}{dCT} > 0$ i.e holding other factors constant, an increase in the time spent on food preparation should yield more dietary diversity. Women are more likely to pay attention to both the variety as well as the quality of food preparation of they have more time to prepare. However, the direction of the derivative for other nutrition indicators is dependent on the foods that are being used to prepare. The marginal product of each raw and purchased foods will be positive ($\frac{dN}{dF^r}, \frac{dN}{dF^p} > 0$) for some foods and negative for others ($\frac{dN}{dF^r}, \frac{dN}{dF^p} < 0$). For instance, consumption of fruits and vegetables may lead to more vitamins, minerals, etc, whereas consumption of staples such as rice and wheat may lead to more carbohydrates than vitamins. However, each nutrition indicator also has a direct utility for the individual. Therefore, the combined effect of the raw and purchased foods is given by the total derivative: $\frac{dU}{dF^i}=\frac{dU}{dN}\frac{dN}{dF^i}+\frac{dU}{dF^i}$, where $i = raw(r), purchased(p)$. The combined effect may still be positive if the direct positive effect of food purchases on utility $\frac{dU}{dF^i}$ outweighs the first term on the RHS.

These productions of N comes with the time constraint of the food preparer. Since most of the women are solely responsible for cooking, we consider the time constraint faced by the food preparer herself which is given by E4: $LT + CT + WT = 24$. Where, WT is the time allocated for work for pay. The food perarer also faces an income constraint given by E4: $p_r F^r + p_p F^p + p_x X = wWT + V$. The food preparer earns a wage (w) for her work in agriculture which can also be interpreted as the opportunity cost of time. This represents the trade-off between the time spent on work to pay vs the time spent on other activities. Additional income is earned from non-labor income V too such as remittances, interest, etc. She spends this income on consumption of food and non-food items given the price vectors p_r, p_p *and* p_x. The food preparers chooses optimal bundles by maximizing utility subject to full income and time constraints.

$$Max\, u = U\ (N(F^r, F^p, CT), F^r, F^p, X, LT, CT : Z)$$

$$\text{s.t. } p_r F^r + p_p F^p + p_x X = wWT + V$$

$$LT + CT + WT = 24;\ LT \geq 0,\ CT \geq 0 \text{ and } WT \geq 0$$

The Lagrangian is given by:

$$\Phi = U\ (N(F^r, F^p, CT), F^r, F^p, X, LT, CT\ ) + \mu(24 - LT - CT - WT\ ) + \lambda\big(wWT + V - p_r F^r - p_p F^p - p_x X\big)$$

Upon solving the langragian, we obtain the following first order conditions:

(1) LT: $\frac{dU}{dLT} = \mu^*$

(2) CT: $\frac{dU}{dN}.\frac{dN}{dCT} + \frac{dU}{dCT} - \mu^* \leq 0$

(3) WT: $\lambda^* w - \mu^* \leq 0$

(4) F^r : $\frac{dU}{dN}.\frac{dN}{dF^r} + \frac{dU}{dF^r} = \lambda^* p_r$

(5) F^p : $\frac{dU}{dN}.\frac{dN}{dF^p} + \frac{dU}{dF^p} = \lambda^* p_p$

(6) X : $\frac{dU}{dX} = \lambda^* p_x$

(7) $\lambda :\ p_r F^{r^*} + p_p F^{p^*} + p_x X^* = wWT^* + V$

(8) μ: $LT^* + CT^* + WT^* = 24$

Solving for the interior solution, the demand functions for $J = \{F^r, F^p, CT, LT, X\}$ are given by:

$$J = f^j\big(\ w, p_r, p_p, p_x, V; Z\big)$$

Upon substituing these demand functions into the nutrition production fucntion, we can obtain the demand for nuttrition as a function of:

$$N = N(w, p_r, p_p, p_x, V; Z)$$

With an increase in the opportunity cost of time (w), the price of time spent at home increases, shifting the budget constraint. The increase in the marginal cost of producing nutrition has two effects; there is an increase in demand for agricultural work due to an increase in wages. This reduces time spent on cooking but also increases the amount that can be spent on purchasing raw or processed foods. Alternatively, as time spent in cooking decreases, the number of nutrients available may decrease. If the income effect of the increase in wage dominates the substitution effect, we will see an increase in nutrition indicators through an increase in both times spent in agriculture as well as time spent in nutrition-enhancing activities. On the other hand, if substitution effect dominates the income effect, we will say that a rise in wages, leads to a decrease in nutrition through an increase in time spent in agriculture (decrease in time spent in nutrition-enhancing time).

3. Fieldwork, Data collection and Measures

3.1. Fieldwork

We administered three primary surveys for obtaining the data. These surveys were conducted during December 2016 to February 2018 and details of each survey are given in the appendix (See Figure 2 for the timeline).

3.1.1 Context and Sampling

The households were part of a survey conducted by the TCI in 2014 (Gupta, Pingali, and Pinstrup-Andersen 2017). This study was conducted in the rural areas of Chandrapur district of Maharashtra, India (Chandrapur District fact sheet 2014). The district lies in the south-eastern part of Maharashtra, and it was selected for this study because of the differences in the cropping patterns. To the west of Chandrapur, cash crops such as Cotton are cultivated and paddy in the east. More than half of the population in Chandrapur is engaged in agriculture as a source or principal employment (Chandrapur District fact sheet 2014). This district is also characterized by poor nutritional status, particularly in rural areas. According to the National Family Health Survey 2014-2015, about 37.1 percent of women are below normal BMI levels, and about 50 percent of women are anemic(NFHS 2015).

After triangulating the lists from block and village level government institutions, household and village lists were generated. Three blocks were identified during the formative research: Mul, Korpana, and Gondpipri, based on the differences in the cropping patterns. Mul is the paddy growing region, Korpana the cotton growing region and Gondpipri block has households that engage both in paddy and cotton. A total of 24 villages were randomly selected based on the probability proportional to population size sampling method (8 villages per block). Three hundred twenty households per block (40 households per village) were selected based on formative research in 2014 totaling the sample size to 960 households.

3.1.2. Household information

In each of the 960 households a representative woman and man were interviewed, usually the husband and the wife. If there are multiple women in the household, the most actively involved women who are responsible for the household and agriculture was selected. Household information such as household composition, socio-economic status, agricultural practices, and land use, livestock, nonfarm employment, food availability and access and empowerment in agriculture was collected from Men. Women were asked questions on agricultural employment, nonfarm employment, semi-quantitative food frequency questionnaire, home-gardens, household chores, water, sanitation, and hygiene, health (reproductive history, anemia, and health-seeking behavior), child care and empowerment in agriculture. The questionnaires were piloted and were created after conducting focus group discussions and in-depth interviews across the district to understand better the local cropping patterns and allied agricultural activities in which households engage. During June-November 2016, detailed focused group discussions around time allocation patterns in agriculture and dietary intake were conducted. The households that were visited in 2014 were revisited and the same tool was administered in 2016 too to obtain a panel data on detailed household information as described above.

3.1.3. Recipe standardization

Many previous studies use a standard template to measure the dietary diversity of the FAO (FAO,2011). Earlier studies in economics have either used food availability measures and used the food-to-nutrient conversion factors or have used 24 hours recall of ingredients and estimated the nutrient values. This induces a bias in the estimates from high measurement error induced by over/underestimation because the recipes are not contextualized (Deolalikar 2018; Orazem et al. 1999; Webb et al. 2018). These templates often do not capture the local food preferences and food availability that impact nutrient intake within households. Besides, measuring nutrition is extremely difficult as cooking processes and choice of inputs in cooking often vary by context. Mainly, in a diverse country such as India, it is essential to bear in mind that the intakes may vary significantly with context.

Given that most nutrition in rural areas comes from preparing meals at home, it is essential for a method to document the recipes eaten in that context. Since a bulk of the meals are prepared and eaten at home, a new way of incorporating time savings in cooking are needed. This requires documenting the time taken to prepare these meals. To overcome this problem, we collected detailed information on recipes of households and the amount of cooking inputs and time into these foods. Based on the disaggregated data, we create a more standardized and localized food recipe book that can then be used to capture precise nutrient intakes and cooking time estimates. To our knowledge, this is the first study that uses this method at such a scale to obtain precise nutrient intake measures that are relevant and specific to the context.

This research involved standardizing recipes that are eaten for obtaining precise measures of nutrients and the time taken to prepare and cook these recipes. The nutrient information in India is compiled by the National Institute of Nutrition in India (NIN) and captures nutrients available in edible portions of raw foods. Two major issues arise for measuring the nutrient intakes per day across seasons: i) it is difficult to obtain precise estimates of home prepared meals ii) the time-intensive in nature of 24hr dietary recall methods increase the respondent burden significantly (Coates, Jennifer; Colaiezzi, Brooke; Fiedler, Jack; Wirth, James; Lividini, Keith; Rogers 2012). Considering that most households in rural India consumes home prepared meals, it was necessary to arrive at the recipe level estimates for macro and micronutrients. For accurate measurement of nutrient intakes and to reduce respondent burden, we conducted recipe standardization of all the most commonly eaten recipes.

Following the methodology adopted by Harvest plus, we first conducted detailed focused groups to develop a catalog of most of the recipes eaten in the region (Gwatkin et al. 2007). After cataloging, a detailed record of the process, time spent in preparation, cooking, weights of each ingredient used and cooking method were recorded while standardizing the process. However, for the first time ever, the time taken to prepare these meals were also standardized along with the nutrients. Both the time is taken for preparing the material and the actual cooking time on the pot was recorded.

A detailed nutrition data was compiled using the standardized recipes and the nutrient information from the food composition tables from India (Longvah et al. 2017). For each recipe that is commonly made in this region, a dataset was created which contains information on calories (Kcal), macro-nutrients (Proteins, Fats, Carbohydrates), micro-nutrients and cooking time. The catalog of the foods eaten was used to develop a codebook (In English and Marathi) which could be used as a tool in the multi-round survey for collecting 24-hour dietary intake data. The respondent burden was minimized by recalling recipes and associated quantities using standardized cups and spoon measures, instead of recalling ingredients in each recipe.

3.1.4. 24-hour time use and diet recall survey

To obtain data on detailed time allocation patterns of women across agricultural seasons, we conducted a ten round (ten months) primary survey from April 2017 to January 2018. The tools were administered to the same households and individuals who were surveyed for the detailed household information. Each household was visited once every month on a randomly chosen day except the weekends and the representative man, as well as representative women, were interviewed.

Our field experience and focused groups revealed that women are involved in different activities through seasons and it is important to visit them frequently to capture all the activities. Earlier studies (Behrman 1988; Kumar 1995; Orazem et al. 1999) that have collected time allocation patterns of women across seasons, but to our knowledge, this is the first study that tracks women's contribution to household work and agricultural work in such high frequency and detail across the year in rural Maharashtra. The activities in February and March resemble patterns in April. Since most households only crop in the Kharif season, we excluded the data collection for February and March.

In each visit, the index woman was asked to recall her time use and dietary intake in the past 24 hours. The comprehensive list of all the activities was first cataloged using the recommendations from the Indian Time Use Study (Hirway 1979, 2009). These activity classifications were modified and adapted to the local context of Chandrapur district. A detailed 24-hour recall of the diets was also collected for women and children. Income and expenditure data, health information, height and weight (women and children) data was collected on each visit.

4. Methods

For this study, we use data from all the primary surveys mentioned in the previous section. In addition to that, we also use village level data, where, information on daily wages for women and men, market prices of all foods from all the village level markets was collected at each visit (every month) across ten months.

4.1. Measuring diet quality

In this study, we use several variables to measure diet quality. As a part of the ten-month panel study, women were asked to recall recipes eaten in the past 24 hours on a random day, every month. They were also asked to recall the quantities consumed using the standardized measures of cups and spoons. Using the standardized recipe level nutrient information, we calculate individual level daily nutrient intakes for women. These variables are i) Calories ii) Macro-nutrients: Proteins and Fats iii) Micro-nutrients: Iron, Zinc and Vitamin A. Calories typically reflect the energy intake of individuals and is extremely important in determining the overall health of the individual. Similarly, proteins and fats to are essential as they serve the purpose of muscle development and providing the required energy for the body. We exclude carbohydrates in this analysis because of the calorie measures capture the impact of carbohydrates.

Just calories alone are insufficient to make a complete claim about the overall diet quality and micronutrients are a critical part of diets. The recent National family health survey rounds show that iron, zinc and Vitamin A deficiencies are one of the highest in numbers and need immediate attention (ICMR, NFHS). Given the gravity of these deficiencies, we include only these micro-nutrients for the study. Earlier studies in India have not used such micro-nutrient information, and we contribute substantially.

4.2. Estimation

The theoretical model shows nutrient intakes as a function of wages, market prices and non-labor income. Following the theoretical model, we estimate the relationship between opportunity cost of time and nutrition by the following individual fixed effects model:

$$N_{ihvt}^{j} = \beta_0^{j} + \beta_1^{j} Wage_{vt}^{f} + \beta_2^{j} \boldsymbol{P}_{vt} + \beta_3^{j} \boldsymbol{Z}_{ihvt} + \beta_3^{j} \boldsymbol{H}_{hvt} + \epsilon_{ihvt}^{j}$$

Where,

i referes to woman, *j* is specific nutrient, *h*- household, *v* -village, t- season in which the women were interviewed. N_{ihvt}^{j} includes a vector of nutrition indicators: Minimum dietary diveristy of women , Calorie (Kcal), Protien (grams), Fats(grams), Iron(mg), Zing(mg), Vit A(MuG). There is enough variablility in daily nutrient intake which ias affected by both time- varying factors and time-invariant factors.

In cross-sectional settings there is a high probability of omitted variable bias which produces biased and inconsistent coeffecients. Panel data helps in a way that the effect of all the fixed factors that can impact the outcomes are controlled for. However, time-varying factors still need to be controlled. In this study, we are intersted in analyzing the effect of opportunity cost of time on nutrient intake within an individual. In other words, as seasons change- we are interested in the effect that the change in opportunity cost (value of time) has on her nutrient intake. The individual fixed effects control for all the genetics related factors that may impact nutrient intakes such as metabolic rates, tolerance to diseases and immunity. The household level factors such as housing conditons, sanitation ,water facilities and household health and nutrition are also time invariant and are controleld for in the indivdual fixed effects model as they are likely to be correalted with incomes.

In the specification above, $Wage^{f}_{vt}$ refers to village level wages which were collected for each village every month at the day of the survey. These wages signify the opportunity cost of women's time. Availability of food impacts nutrition as women purchase these food items such as raw ingredients to prepare meals. In this context, from our field knowledge we observed that women often buy their weekly groceries from a weekly market nearby to their respective villages. To control for the impact of availability we control for $\boldsymbol{P}_{vt}$, which represents the vector of prices of raw food items purchased from the nearby market. $\boldsymbol{Z}_{ihvt}$ refers to individual level factors that are time varying such as the whether the individual is sick or not at the day of interview. $\boldsymbol{H}_{hvt}$ includes all the household level factors that are time-varying such as the non-food expenditure, whether an individual is sick in the household. Seasonality plays a critical role in nutrition as variations in climate such as rainfall, temperature can impact the consumption of nutrients and the amount of time spent in agriculture. The tasks performed by women varies with seasons – impacting their time spent in agriculture and their involvement in nutrition enhancing activities may be affected due to this variation. To our knowledge, this is the first study that empirically controls for seasonality in this framework to analyze the impacts across seasons. We construct a season variable by clubbing the months based on major agricultural activity periods: Land preparation (April-May), Sowing (June- July), transplanting (August-September) and harvesting (October- November) and December to January.

5. Results

5.1. Sample characteristics

Chandrapur district has a population of 2.2 million as of the Census of India, 2011. Table 1 shows the summary statistics of the sample used for this study. Initially, 960 households were sampled, but six households were dropped out during ten months due to death and permanent migration in these families; totaling the used sample to 954 households. The average size of the families is about 4 reflecting a more nuclear nature of families. The average age of women is around 37 years, and about 47 % of the sample has no education or primary education. The average no. of children under the age of 18 is also meager at 1.14.

Most of these households are agrarian and marginal-small holder farmers with an average landholding size of 3 acres. Twenty-four percent of households have access to irrigation. Otherwise, agriculture is mainly rain-fed in this region. Agricultural activities in agriculture are divided between men and women into many developing countries, and similar patterns are observed in Chandrapur as well (Nitya and Raju 2017). In cotton growing regions women engage in activities such as cotton picking, weeding, fertilizer application, and land preparation activities. In paddy growing regions, weeding, transplanting, harvesting, and post-harvest activities are the activities. Figure 3 shows the activities that women engage in across seasons for both Paddy and Cotton. Figure 4 shows the distribution of time spent in agriculture, cooking, and domestic work. As shown in these figures, the average time spent in agriculture reaches up to 333 minutes in the peak seasons of sowing (July-August) and harvesting (October-November). Due to small land-holdings, most women engage in agricultural wage work even if they own land and the wage rates are the market level wages.

We analyze the men's time use as shown in the second panel of figure 4. Men spend almost equal time when it comes to time in agriculture. However, if we compare the socializing time, men spend about three times more time as compared to women averaging at 175 minutes across seasons. Their contribution to domestic work and food preparation is almost close to zero averaging about 15 minutes and 2 minutes respectively. This reflects that men do not face time constraints as women as they are not involved in household related activities at all. Therefore, we argue that women's wages truly reflect this time trade-off between time in agriculture and time for home based activities while men's wage reflects a pure income effect.

There is a variation in nutrient intakes across seasons as well. The Indian Council for Medical research (ICMR) recommends the recommended daily allowance (RDA) for vital nutrients in diets and these are shown in table 2. These RDA's are defined for men and women separately based on the level of physical activity that they engage in. We compare our daily average intakes for women across seasons with the RDA in table 2. It is important to note that, except calories and fats; all other nutrients fall short of the RDA. Particularly, concerning levels are observed for proteins, Iron, Zinc and Vitamin A.

5.2. Women's opportunity cost of time and nutrition: full sample

Table 5 explores the relationship between the opportunity cost of women's time and nutrition indicators. Consistent from the prediction of the theoretical model, the individual level fixed effects estimates show that an increase in wages decreases the intakes of calories, protein, fats, iron, zinc and vitamin A. All the regressions models across Panels A, B and C contain individual fixed effects. The standard errors are clustered at the individual level. Panel A shows the effects without any controls, and Panel B has included control variables such as market prices of foods, etc. Panel C includes both controls and season dummies. The effects are statistically significant after controlling for all the time-invariant women, community, village level factors. Specifically, it reflects that a 100 rupee increase in a woman's agricultural wages (opportunity cost of time) a day leads to a decline in her calories by 112.3Kcal, 0.7 mg Iron, 0.4 mg of Zinc and 1.5 grams of Protein.

Given that the sample is already well below the RDA, these changes mean a lot and need attention. Since the nutrient intakes are a 24-hour recall once every month, we control for fluctuations of seasons as well as a type of day by including time and day dummies. We also control for price fluctuations in commonly eaten foods. An increase in prices of staples such as rice and wheat lead to a significant increase in intake of protein, fat and Vitamin A suggesting that women substitute cereals with non-staple foods. An increase in the price of spinach, holding other variables constant leads to a significant decrease in intake of all macro and micronutrients except calorie consumption. The sickness of an adult or a child does not seem to affect the intakes of women. It is important to note that male wages do not impact micro-nutrients after controlling for seasonality, suggesting that the time constraints are more important for an individual's nutrition than income constraints, once we account for availability and seasonality factors.

5.3. Women's opportunity cost of time and nutrition: sub-sample analysis

We also conduct various sub-sample analysis to see how land-ownership status, cropping patterns effect this relationship.

Cropping patterns:

Based on the cropping pattern of the household, the opportunity cost may have different effects on the nutrient intakes. As we can see from table 6, the effects vary based on the type of crop that the women belong to. In food crop system (paddy producing region) we see that the time constraint is binding. For all the nutrients, the association is negative and statistically significant. Whereas in cash crop region, we see that there is a positive association with specific nutrients and negative for fat as well as Vitamin A, but none of these are statistically significant. In the mixed crop region too, we see negative associations suggesting more time/labor intensive nature of the crop production process.

Landownership:

We see whether time constraint is more or less binding based on land-ownership. We use the mean land- holding size to categorize the sample and conduct a similar analysis. As reflected in table 7, we find that the association is more significant and much more statistically stronger in the case of households with smaller landholdings as compared to women in households with larger land size. These results reflect that larger land sizes which are reflective of greater incomes play a role in mitigating the negative time effects on nutrition.

5.4. Mechanisms

To understand the mechanisms through which the opportunity cost of time impacts nutrition through time spent on agriculture, we conduct several analyses. First, we show the effect that women's wages have on time use in agriculture, domestic work, sleep, and cooking. We show these effects through different specification in Table 4. All the specifications use individual-level fixed effects, and standard errors are clustered at the individual level. Model 4 uses all controls and season dummies and there we see that 100 rupees increase in market wages for agriculture leads to a 58-minute increase in time for agriculture, 10 min decline in domestic work and 26 minutes decline in time for resting and sleeping. These results suggest that wages affect nutrition through time in agriculture. Therefore, as wage rise, time spent in agriculture rises, time for nutrition reduces, and nutrients are affected negatively.

To categorize the effect of opportunity cost on time spent on cooking, we categorize time spent in meal preparation in two-time slots based on their meal preparation behavior (tables 8,9 and 10). Typically, women cook twice a day once in the morning and once in the evening. To analyze the impact of wages on cooking time, we split to run the individual fixed effects specification on the effect of wages on time spent in cooking. We find that time spent in cooking does not seem to hold an effect directly with wages.

This could be possible as the substitution effect of time might be playing a role and not the income effect. To explore this, we look at the relationship between agricultural time and time spent in cooking (morning and evening), we find that the for every ten additional minutes spent in agriculture cooking time reduces by 4 minutes in the evening, and this result is robust to all specifications. To further explore the direct link of agricultural time on the consumption of nutrients in the evening – we find that, an increase in agricultural time reduces all nutrient intakes during the consumption of evening meal. These results point out to a reduction in cooking time due to increased time in agriculture during the evening meal preparation and a subsequent decline in nutrient intake.

6. Conclusion and Discussion

Using a novel primary panel data and methods, we examine the relationship between women's opportunity cost of time and their nutrition through their nutrient intake. We hypothesize the following- as seasons change, the pressures on women's time in agriculture, and in peak seasons they experience time burdens. These different time pressures induce a trade-off for time spent by women for nutrition-enhancing activities such as cooking and domestic which may have adverse consequences for nutrition. In our analysis, we find that working more extended hours in agriculture, in other words, the rising opportunity cost of time relates to a reduction in nutrient intake in terms of calories, proteins, fats, iron, and zinc.

Using a first of its kind, detailed ten-month time use data for both women and men across seasons, we first show that women disproportionately bear the work burdens as they not only work in agriculture but they also solely involve in domestic work, food preparation, and care related activities. Our analysis shows this distinction very categorically- on an average woman spend almost the same time as men in agriculture, but men spend almost no time in food preparation, domestic work, and care activities while women spend above 300 minutes daily for cooking and domestic work-related activities- such as cleaning the house, washing utensils, clothes, etc. In peak seasons of sowing, transplanting and harvesting we show that women's extra hours in agriculture translate into a reduction in time spent on food preparation. Time pressures in agriculture are also associated with less time in domestic work, sleep and rest related activities which may also impact the overall health of women.

Distinct from earlier studies, we develop a theoretical model and use fixed effects methodology for panel data where we control for all the time-invariant factors such as social structures, norms, and genetic endowments, location and time-varying factors such as market prices of foods, seasonality, changes in non-food expenditures and sickness variables. After controlling, for all these factors, we see that as an increase in women's wage (increasing opportunity cost of time) translates into a reduction in their nutrient intakes. Given that our sample falls well below the recommended dietary allowance suggested for Indian women of reproductive age, the reduction in daily nutrient intakes is attention worthy. These results still hold even after the inclusion of the income of male members of the household, suggesting that time constraints matter.

We analyze the effects of income-rich households by conducting a sub-sample analysis using land ownership - we see that a rising women's opportunity cost (time constraints) are most binding on women who are landless and almost insignificant when it comes to women who own land. To analyze the pathways from agriculture, we split the sample by their cropping pattern – cash crops, food crops, and mixed crop households. Here, we find that paddy growing and mixed crop households have a pronounced negative impact of rising time constraints on their nutrient intake while cotton growing households do not experience the same.

Our field experiences suggest that women think in terms of recipes and not food groups and they also tend to misjudge the time it takes to cook a recipe. One can compare time savings in food preparation between ready to eat food and home cooked food. However, the existing literature stops short when it comes to food prepared at home. We fill these research gaps by methodologically contributing to the existing literature- we conceptualize and standardized 502 recipes that are locally consumed- thus, considering the local context, tastes, and preferences- in terms of the time taken to prepare, cook a recipe and the weights of each ingredient used in every recipe. We find that this method is particularly useful for the collection of panel data.

Our results have several policy implications. First, our results clearly show that the designing of agricultural interventions and development programs must bear in mind the consequences of increased time burdens and the adverse effects on nutrition. The programs should move in the direction of making sure that the benefits of participation in agriculture outweigh the losses such as time. Second, our results suggest that strategies to reduce women's time and work burdens are extremely important. In a rural context, agriculture and domestic work activities are not only time consuming but are also arduous. In such a scenario, it is vital to introduce strategies both in agriculture as well as in domestic work. Time-saving technologies and assets in agriculture or at home can be beneficial strategies, as suggested by (Johnston et al. 2018). Third, the wages earned by women are significantly low and do not offset the constraints of time. There is enough evidence to suggest that improved incomes of women lead to better well-being of the household. Increasing the incomes and strategies to promote their empowerment through the enhanced decision-making power and control over income are imperative.

TABLES

Table 1: Summary statistics (Full sample)

Variable (N=984)	Mean	Min	Max
Ownership of land (acres)	3.04	0	35
No. of children (0-6 years)	0.34	0	3
No. of children (under 18 years)	1.14	0	4
Household size	4.42	0	9
Access to irrigation	0.24	0	1
Access to electricity	0.91	0	1
Women's age	36.96	21	50
Women's Education (%)			
No education		33.6%	
Primary		13.9%	
Secondary		31.9%	
Higher secondary and above		20.5%	

Table 2: Average intake of nutrients across regions and seasons

	Calories (Kcal)	Protein (gms)	Fats (gms)	Iron (mg)	Zinc (mg)	Vit A (MuG)
Recommended dietary allowance (RDA)**	**2850**	**55**	**20**	**21**	**10**	**2400**
April-May	2935.9	18.9	19.8	5.3	3.0	1050
June-July	3103.6	19.1	20.3	5.6	3.2	1172
Aug-Sept	3009.7	18.4	17.3	5.6	3.2	1115
Oct-Nov	3308.0	19.9	21.6	5.8	3.2	1303
Dec-Jan	3251.7	19.1	24.2	5.8	3.1	1557

Table 3: Average intake of nutrients across regions and seasons (N =8332)

	(1)	(2)	(3)	(4)
Time spent in agriculture				
Female wages (Rs./day)	0.904***	0.281***	0.298***	0.578***
	(0.044)	(0.046)	(0.046)	(0.059)
Time spent in cooking				
Female wages (Rs./day)	0.023+	-0.005	-0.008	-0.008
	(0.013)	(0.015)	(0.015)	(0.020)
Time spent in domestic work				
Female wages (Rs./day)	-0.186***	-0.065***	-0.069***	-0.092***
	(0.017)	(0.018)	(0.018)	(0.023)
Time spent in sleeping and resting				
Female wages (Rs./day)	-0.225***	-0.167***	-0.176***	-0.264***
	(0.031)	(0.034)	(0.034)	(0.041)

Note:

i) All regressions use individual fixed effect models. Women who have not participated in agriculture at all across ten months are excluded from the sample.

ii) Standard errors are clustered at the individual level. Significance levels: + 0.10 * 0.05 ** 0.01 *** 0.001

iii) Specification 1 has no controls, 2 is 1+ Male wages, 3 includes all the variables in model 2 and controls , 4 includes all the variables in 3 and seasonality dummy.

Table 4: Effect of opportunity cost of time on daily nutrient intakes of women (N=8332)

	Calories	Proteins	Fats	Iron	Zinc	Vit A
Female wages (Rs./day)	0.014	-0.008***	0.004	-0.002*	-0.002**	0.573*
	(0.237)	(0.002)	(0.004)	(0.001)	(0.000)	(0.278)
Male wages (Rs./day)	2.269***	0.012***	0.017***	0.003**	0.002***	1.767***
	(0.220)	(0.002)	(0.004)	(0.001)	(0.000)	(0.293)
Panel B:						
Female wages (Rs./day)	-0.745**	-0.013***	-0.003	-0.006***	-0.004**	-0.364
	(0.285)	(0.003)	(0.005)	(0.002)	(0.001)	(0.351)
Male wages (Rs./day)	1.562***	0.010***	0.009*	0.003**	0.002**	1.501***
	(0.244)	(0.002)	(0.004)	(0.001)	(0.001)	(0.320)
Female wages (Rs./day)	-1.237***	-0.015***	-0.018***	-0.007***	-0.004***	-1.372***
	(0.299)	(0.003)	(0.005)	(0.002)	(0.001)	(0.385)
Male wages (Rs./day)	0.787**	0.008**	0.000	0.000	0.001	0.556

Note:

i) All regressions use individual fixed effect models. Women who have not participated in agriculture at all across ten months are excluded from the sample.

ii) Standard errors are clustered at the individual level. Significance levels: + 0.10 * 0.05 ** 0.01 *** 0.001

iii) All the regressions include male wages, prices of wheat, rice, and common pulses, sickness of adults/children within the household, non-food expenditure, dummies of seasons.

Table 5: Effect of opportunity cost of time on daily nutrient intakes of women by cropping pattern (N=8332)

	Cal	Protein	Fats	Iron	Zinc	Vit A
Female wages (Rs./day)	0.076	-0.001	-0.012	0.001	0.001	-1.334*
	(0.593)	(0.005)	(0.010)	(0.002)	(0.001)	(0.611)
Male wages (Rs./day)	-3.718	-0.075+	0.077	-0.031	-0.009	6.649
	(4.470)	(0.043)	(0.070)	(0.020)	(0.009)	(4.273)
Female wages (Rs./day)	-17.510**	-0.088	-0.067	-0.101**	-0.041*	-50.620**
	(6.722)	(0.068)	(0.125)	(0.033)	(0.017)	(16.346)
Male wages (Rs./day)	13.753***	0.061*	0.076	0.046**	0.020**	21.102**
	(2.747)	(0.031)	(0.051)	(0.014)	(0.007)	(6.893)
Female wages (Rs./day)	-4.490***	-0.030**	-0.004	-0.017**	-0.007***	-6.120*
	(1.037)	(0.011)	(0.017)	(0.006)	(0.002)	(2.393)
Male wages (Rs./day)	-0.103	0.007	0.002	0.007	0.010	1.202
	(0.814)	(0.012)	(0.014)	(0.006)	(0.007)	(1.081)

Note:

i) All regressions use individual fixed effect models. Women who have not participated in agriculture at all across ten months are excluded from the sample.

ii) Standard errors are clustered at the individual level. Significance levels: + 0.10 * 0.05 ** 0.01 *** 0.001

iii) All the regressions include male wages, prices of wheat, rice, and common pulses, sickness of adults/children within the household, non-food expenditure, dummies of seasons.

Table 6: Effect of opportunity cost of time on daily nutrient intakes of women by cropping pattern (N=8332)

	(1) Calories (KCal) b/se	(2) Protein (g) b/se	(3) Fats (g) b/se	(4) Iron (mg) b/se	(5) Zinc (mg) b/se	(6) Vitamin A (MuG) b/se
Panel A: Cotton growing households (N=3014)						
Female wages (Rs./day)	0.076	-0.001	-0.012	0.001	0.001	-1.334*
	(0.593)	(0.005)	(0.010)	(0.002)	(0.001)	(0.611)
Male wages (Rs./day)	-3.718	-0.075+	0.077	-0.031	-0.009	6.649
	(4.470)	(0.043)	(0.070)	(0.020)	(0.009)	(4.273)
Panel A: Paddy growing households (N=2664)						
Female wages (Rs./day)	-17.510**	-0.088	-0.067	-0.101**	-0.041*	-50.620**
	(6.722)	(0.068)	(0.125)	(0.033)	(0.017)	(16.346)
Male wages (Rs./day)	13.753***	0.061*	0.076	0.046**	0.020**	21.102**
	(2.747)	(0.031)	(0.051)	(0.014)	(0.007)	(6.893)
Panel A: Cotton and Paddy growing households (N=2324)						
Female wages (Rs. /day)	-4.490***	-0.030**	-0.004	-0.017**	-0.007***	-6.120*
	(1.037)	(0.011)	(0.017)	(0.006)	(0.002)	(2.393)
Male wages (Rs. /day)	-0.103	0.007	0.002	0.007	0.010	1.202
	(0.814)	(0.012)	(0.014)	(0.006)	(0.007)	(1.081)

Note:

i) All regressions use individual fixed effect models. Women who have not participated in agriculture at all across ten months are excluded from the sample.

ii) Standard errors are clustered at the individual level. Significance levels: + 0.10 * 0.05 ** 0.01 *** 0.001

iii) All the regressions include male wages, prices of wheat, rice, and common pulses, sickness of adults/children within the household, non-food expenditure, dummies of seasons.

Table 7: Effect of opportunity cost of time on daily nutrient intakes of women by land-ownership

	(1) Calories (KCal) b/se	(2) Protein (g) b/se	(3) Fats (g) b/se	(4) Iron (mg) b/se	(5) Zinc (mg) b/se	(6) Vit A (MuG) b/se
Panel A: <= 3 acres (N=5141)						
Female wages (Rs./day)	-1.339***	-0.017***	-0.021***	-0.008***	-0.005**	-1.753***
	(0.381)	(0.004)	(0.006)	(0.002)	(0.002)	(0.526)
Male wages (Rs./day)	1.145***	0.009**	0.003	-0.001	0.001	0.569
	(0.333)	(0.003)	(0.006)	(0.002)	(0.001)	(0.455)
Panel B: > 3 acres (N=2861)						
Female wages (Rs./day)	-1.056*	-0.012*	-0.012	-0.005*	-0.003+	-0.931+
	(0.500)	(0.006)	(0.008)	(0.003)	(0.002)	(0.552)
Male wages (Rs./day)	0.106	0.004	-0.007	0.001	0.001	0.775
	(0.587)	(0.005)	(0.010)	(0.002)	(0.001)	(0.730)

Note:

i) All regressions use individual fixed effect models. Women who have not participated in agriculture at all across ten months are excluded from the sample.

ii) Standard errors are clustered at the individual level. Significance levels: + 0.10 * 0.05 ** 0.01 *** 0.001

iii) All the regressions include male wages, prices of wheat, rice, and common pulses, sickness of adults/children within the household, non-food expenditure, dummies of seasons.

Table 8: Relationship between time spent in agriculture and time spent in Cooking disaggregated by major meals within a day (Morning and Evening)

	(1)	(2)	(3)	(4) **All controls**
		morning		
	b/se	b/se	b/se	b/se
Time spent in agricultural activities (min)	0.009***	0.000	0.001	0.002
	(0.002)	(0.002)	(0.002)	(0.002)
		evening		
Time spent in agricultural activities (min)	-0.000	-0.004**	-0.003**	-0.003*
	(0.001)	(0.001)	(0.001)	(0.001)

Note:

i) All regressions use individual fixed effect models. Women who have not participated in agriculture at all across ten months are excluded from the sample.

ii) Standard errors are clustered at the individual level. Significance levels: + 0.10 * 0.05 ** 0.01 *** 0.001

iii) Specification 1 has no controls, 2 is 1+ Male wages, 3 includes all the variables in model 2 and controls , 4 includes all the variables in 3 and seasonality dummy.

Table 9: Relationship between time spent in agriculture and nutrients disaggregated by major meals within a day (Morning and Evening)

	(1) Calories b/se	(2) Protein b/se	(3) Fats b/se	(4) Iron b/se	(5) Zinc b/se	(6) VitA b/se
Morning meal						
Time spent in agricultural activities (min)	-0.049	-0.001*	-0.002***	-0.000	-0.000	-0.064
	(0.032)	(0.000)	(0.001)	(0.000)	(0.000)	(0.049)
Evening meal						
Time spent in agricultural activities (min)	-0.123***	-0.002***	-0.004***	-0.001***	-0.000	-0.022
	(0.036)	(0.000)	(0.001)	(0.000)	(0.000)	(0.058)

Note

i) All regressions use individual fixed effect models. Women who have not participated in agriculture at all across ten months are excluded from the sample.

ii) Standard errors are clustered at the individual level. Significance levels: + 0.10 * 0.05 ** 0.01 *** 0.001

iii) All the regressions include male wages, prices of wheat, rice, and common pulses, sickness of adults/children within the household, non-food expenditure, dummies of seasons.

FIGURES

Figure 1: Site map

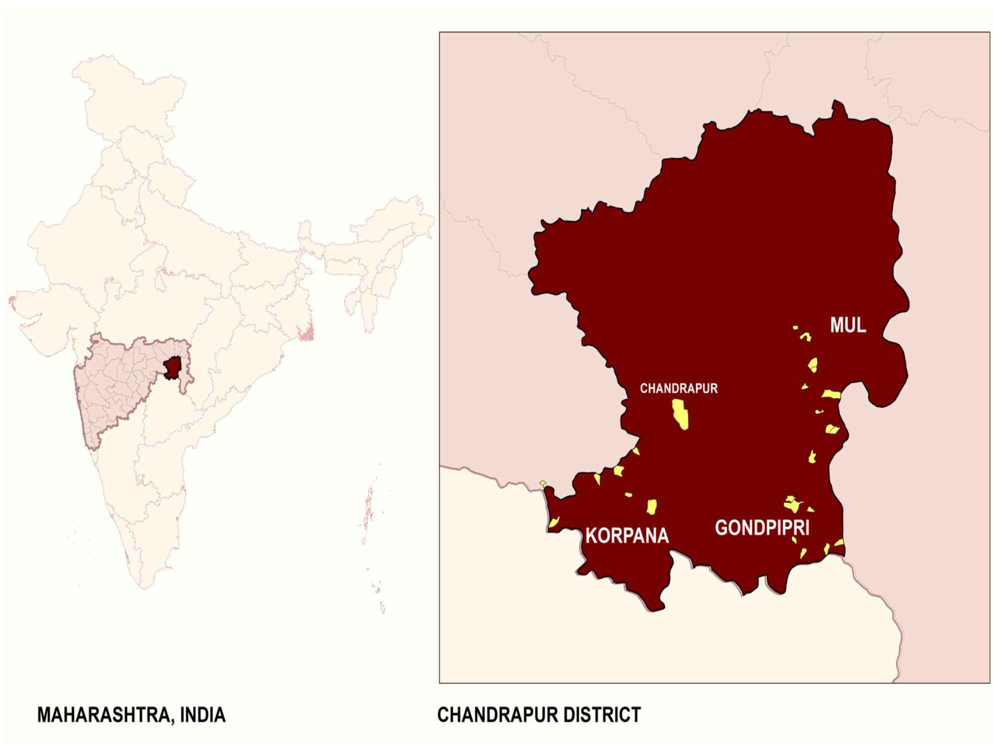


Figure 2: Survey timeline

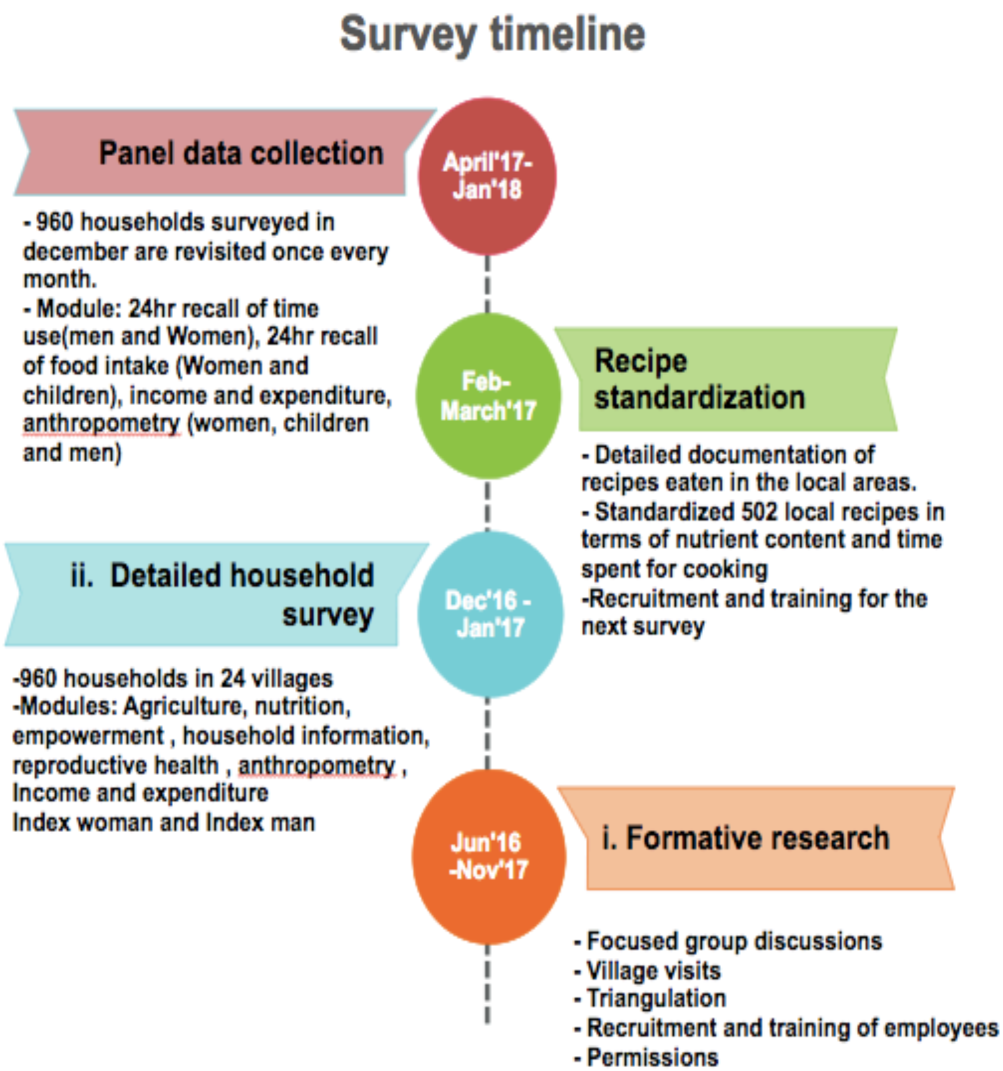
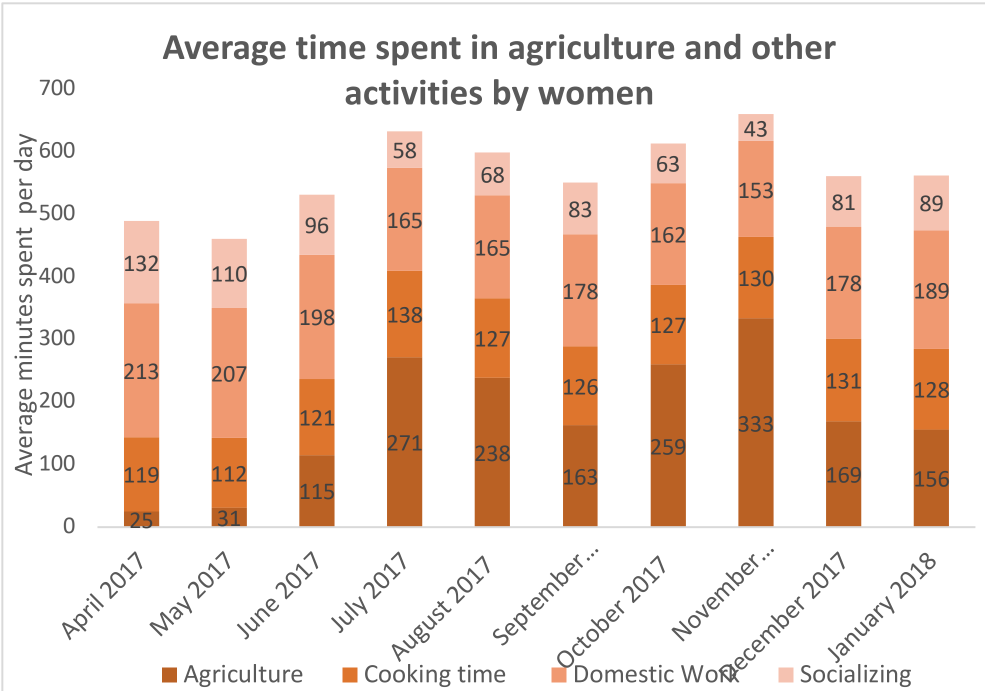
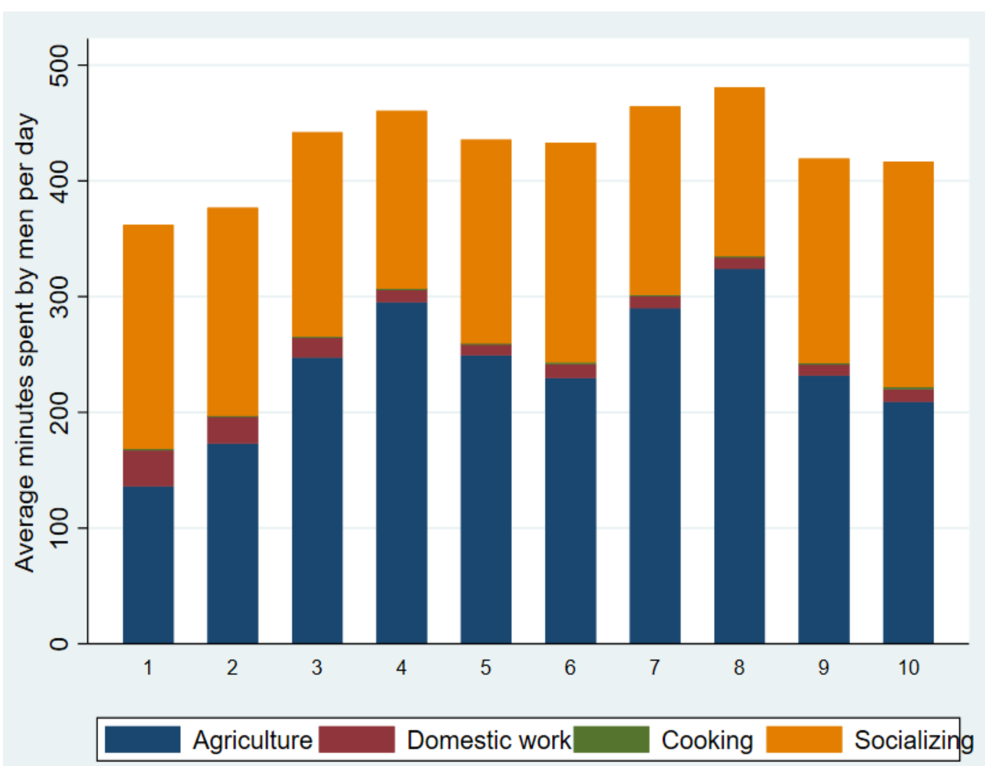


Figure 3: Agricultural activities by women across all seasons

Month	Cotton	Paddy
June	Sowing	Land preparation /transplanting
July	Weeding and fertilizer application	Transplanting
August	Weeding and fertilizer application	Transplanting
September	Land preparation and fertilizer application	Weeding
October	Cotton picking and fertilizer application	Weeding
November	Cotton picking	Harvesting
December	Cotton picking	Harvesting/Storage/Processing
January	Cotton picking	Harvesting/Storage/Processing
February	Relatively free months	Other activities
March	MGNREGA and other activities	Other activities
April	Soil cultivation, banking arrangements and other off farm work	Other activities
May	Soil cultivation, banking arrangements and other off farm work	Other activities

Figure 4: Time spent in agriculture, domestic work, cooking and socializing by women across rounds





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CHAPTER 2

HOW DO NUTRITIONAL OUTCOMES RESPOND TO CHANGES IN WOMEN'S EMPOWERMENT IN AGRICULTURE? PANEL DATA EVIDENCE FROM RURAL INDIA

1. Introduction

In developing countries such as Sub-Sharan Africa and South Asia, a large section of the poor live in rural areas and are immensely dependent on agriculture for their livelihoods. In recent years, research has highlighted the pathways through which agriculture affects nutrition (Ruel, Quisumbing, and Balagamwala 2018a; Rao, Nitya, Gazdar, Haris, Chanchani, Devanshi and Ibrahim 2018). Three of these pathways involve women- as play the most critical role in sourcing, producing, preparing foods for improving nutritional outcomes of themselves and their families. Research suggests that in a given year, women's autonomy in decision making, control over income and time - thus, their empowerment - matter for improving dietary diversity (van den Bold, Quisumbing, and Gillespie 2013). However, changes in empowerment over time and its impacts on nuanced nutritional outcomes have not received attention in the existing literature.

Women constitute about 40 percent of the agricultural labor force in South Asia. According to nationally representative data, the Indian average for women's share of total time-use in agriculture is 32 percent (FAO 2011). Though women play such an essential role in agriculture, they are often malnourished. India has a significant number of anemic women followed by China, Pakistan, Nigeria, and Indonesia. More than half of all women of reproductive age have anemia in India (Government of India 2017). As women's participation continues to remain significant, empowering women in agriculture becomes an essential pathway to improve the nutritional status of women involved in agriculture (Ruel and Alderman 2013).The women's empowerment in agriculture index (WEAI) – the very first measure for women's empowerment in agriculture- has been applied in various survey's in both Africa and South Asia since its introduction (Alkire et al. 2013). Using cross-sectional data from Bangladesh, research shows that increases in women's empowerment in agriculture are positively associated with household-level energy availability and dietary diversity (Sraboni et al. 2014) . In Nepal, women's group membership, reduced workload, and control over income are the domains that have been associated with higher maternal dietary diversity and Body Mass Index (H. J.

L. Malapit et al. 2015).

The literature falls short on two specific areas. First, the WEAI index hasn't been contextualized and the empowerment levels are not analyzed over time as most studies are cross-sectional. The WEAI was initially designed as a tool to monitor women's empowerment for the Feed the Future Initiative, and so far, 19 countries have adopted it. According to Alkire et al. 2013, "The WEAI or adaptations of it can also be used more generally to assess the state of empowerment and gender parity in agriculture (or in other domains), to identify key areas in which empowerment needs to be strengthened, and to track progress over time." Second, all the existing studies look at the relationship between women's empowerment, and their nutritional status is cross-sectional and do not allow us to see how these relationships change once we control for changes in time-varying variables. To track progress, it is vital to understand the consistency of these indicators over time as well as understand what some of the activities within the index that change over a period or do not change over time are.

Using panel data (2014 and 2016) from a primary survey of 960 rural households from Chandrapur district of Maharashtra, India- we study the relationship between empowerment and nutrition over time. First, we analyze the WEAI across the two years and outline the drivers of change. Based on consistency checks and our field experience, we adapt the WEAI to a more well-defined context-specific index (WEAI_S) and analyze changes across domains. We hypothesize that women whose empowerment levels increase over time would improve their nutritional outcomes after controlling for all the time-invariant and potential time-varying factors. We provide the first evidence in measuring the impact of women's empowerment on the quality of diet -the individual-level dietary diversity, calorie intake and iron intake of women. This paper has the following *primary objectives*:

1. Analyze the level of women's empowerment across years and see the consistency of results
2. To construct a more well-defined and context-specific index identify women's empowerment in agriculture in India.
3. To analyze the relationship between women's empowerment in agriculture with dietary diversity, calorie intake and BMI over time?

Our work contributes to an understanding of how women's empowerment can influence nutritional outcomes over time. In this paper we make three important contributions i) First, we extend the existing literature by analyzing the relationship between empowerment and nutrition over time. Second, we focus on tracking changes in empowerment, and how measures can be adapted to context and site-specific factors. Third, we include detailed and precise nutritional outcomes such as micro-nutrient and individual level metrics.

Using primary individual-level panel data in 2014 and 2016 of 960 households, we find that- women who see an increase in their empowerment over time, increase their quality of diet by eating more fruits and vegetables- a more micro-nutrient rich diet. Contrary to previous literature, we see that dietary diversity does not improve with an increase in empowerment. To our knowledge, this is the first time that a study uses panel data on WEAI, adapt to the Indian context and analyzes the levels of empowerment across time. Using novel, detailed and precise individual-level micro-nutrient intake data, we also explore the relationship between empowerment and nutritional outcomes. The rest of this paper is structured as follows. Section 2 discusses methods related to data collection, construction of variables and data analysis. Section 3 presents results and section 4 concludes with recommendations. In the next sections, we highlight the role of empowerment in improving nutritional outcomes and our motivation for understanding this relationship over time.

1.1. Women's empowerment in agriculture index (WEAI)

The measurement of women's empowerment in agriculture has become possible with the introduction of WEAI in 2012 (Sraboni et al. 2014). The Women's Empowerment in Agriculture Index (WEAI) came into effect in 2012 as a multidimensional measure to assess women's access to resources and ability to make decisions in five domains of agriculture: i) production ii) resources iii) control over income iv) leadership and v) time. WEAI is a domain-specific index which was an improvement over many indices- it is agriculture-specific; it can be disaggregated into multiple domains; measures empowerment directly without using proxies such as education and age; and it allows for intra-household differences. After the introduction of WEAI, several field level challenges were experienced either due to the difficulty in asking questions or the relevance of the indicators. To tackle these challenges, the A-WEAI (Abbreviated -WEAI) got introduced (H. J. Malapit et al. 2015). Six of the ten indicators in the original WEAI remain in the A-WEAI. The domains (and sub-indicators) of the original WEAI are as follows: 1) Production (1.1 input in productive decisions, 1.2 autonomy in productive decisions), 2) Resources (2.1 ownership of assets, 2.2 purchase/ sale/ transfer of assets, 2.3 access to decisions on credit), 3) control over income, 4) leadership (4.1 group membership, 4.2 public speaking), and 5) time (5.1 workloads, 5.2 leisure).

In response, IFPRI has modified the original WEAI by reducing the number of sub-indicators from ten to six- autonomy in productive decisions, purchase/ sale/ transfer of assets, public speaking and leisure were (H. J. Malapit et al. 2015). However, contextualization is missing in most tools and applications of the WEAI across countries, and the same activity lists of participation and decision making in agriculture are used. Some of the inclusions are not relevant for an Indian context and are also challenging to elicit a response: for example, ownership of livestock maybe relevant and clearly defined in some countries but may not be relevant for others. Since the WEAI as a measure too has evolved. The empowerment measures using WEAI have been analyzed in several counties such as Mozambique, Bangladesh, Uganda, Guatemala, Nepal etc., but all this analysis is for a given time and we do not know how this index performs over time. Given that this measure was designed for programmatic and intervention use, tracking the change is essential. From a methodological standpoint, it is imperative to know the answers to the following questions: if the sub-indicators that are used can change or not? Are these variables consistent and do not suffer from measurement bias? In this paper, we address these gaps by analyzing the index over time and adapting it to an Indian context.

1.2. Women's empowerment and nutritional outcomes

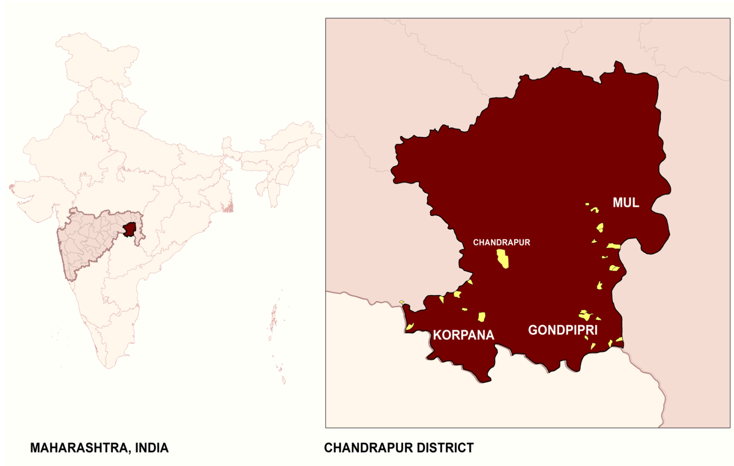
When it comes to nutrition, particularly in the South Asian context, women are involved throughout the value chain in providing nutrition to their families. Through their involvement in agriculture- they produce food, source food for preparing, prepare food and ensure that their families consume the same. Their ability to decide and control income, time on- production, sourcing, and preparation related activities become vital. Out of the six pathways outlined by (Ruel and Alderman 2013), three of them suggest improvements in nutritional outcomes through their women's time use, their health because of their engagement in agriculture and women's empowerment. Improved inputs in decision making and control over income could influence women's ability to choose diverse diets, thus improving their dietary diversity. On the production side, if women can make decisions regarding which crops to plant and control the income produced from selling agricultural produce, they can influence the household and individual level nutritional outcomes by choosing nutrient-rich foods by either purchasing from the increased income or own production. Women with less workload and more leisure time can dedicate more time for food preparation and nutrition-oriented cooking activities. Using nationally representative data from Bangladesh, increases in women empowerment in agriculture measured by the overall WEAI, have been positively associated with increases in dietary diversity and energy availability at the household- level (Sraboni et al. 2014). At the individual level empowerment scores (H. J. L. Malapit and Quisumbing 2015) and its sub-indicators (Zereyesus et al. 2017) have been associated with diet diversity in Ghana and Nepal. To our knowledge, there is only one study that applies the WEAI to the Indian context and finds that production orientation is associated with women's empowerment in agriculture (Gupta, Pingali, and Pinstrup-Andersen 2015).

2. Fieldwork, Data collection and Measure

2.1. Fieldwork and context

The households were part of a survey conducted by the TCI in 2014 (Gupta, Pingali, and Pinstrup-Andersen 2015). This study was conducted in the rural areas of Chandrapur district of Maharashtra. The district lies in south-eastern part of Maharashtra and it was selected for this study because of the differences in the cropping patterns. To the west of Chandrapur, cash crops such as Cotton are cultivated and paddy in the east. More than half of population in Chandrapur is engaged in agriculture as source or main employment (Chandrapur District fact sheet 2014). This district is also characterized by poor nutritional status, particularly in the rural areas. According to National family Health Survey 2014-2015, about 37.1 percent of women are below normal BMI levels and about 50 percent of women are anemic (NFHS 2015). After triangulating the lists from block and village level government institutions, household and village lists were generated. Three blocks were identified during the formative research: Mul, Korpana and Gondpipri, based on the differences in the cropping patterns. Mul is the paddy growing region, Korpana the cotton growing region and Gondpipri block has households that engage both in paddy and cotton. A total of 24 villages were randomly selected based on the probability proportional to population size sampling method (8 villages per block). 320 households per block (40 households per village) were selected based on formative research in 2014 totaling the sample size to 960 households. In 2014, the two main criterion for choosing the female respondent are: the age group was 15- 49 years and they were non-pregnant and non-lactating.

Figure 1: Field location



The formative research for the second round was conducted during June-October 2016. The survey was conducted from December 2016 to January 2017. In the second phase, data was collected on the same households and individuals as the first phase in 2014. The variation of the cropping patterns makes Chandrapur district a unique case for study and this was the primary reason of selection in the first round. The index men were included in the survey if they (and their household) had been residing in the village for 2 years preceding the data collection. *For the second phase* the same individuals were interviewed with the same questionnaire[1]. A total of 74 households had to be completely replaced in the second phase, totaling the sample size used in this study to 884 households and 1768 individuals. Out of these 74 replaced households, 50 households have permanently migrated and are untraceable and there has been a reported death in the families of the remaining 24 households.

2.2. Data and measures

2.2.1. Household information

In each of the 884 households a representative woman and man were interviewed in 2014 and 2016, usually the husband and the wife. If there are multiple women in the household, the most actively involved women who is responsible for the household and agriculture was selected. Household information such as household composition, socio-economic status, agricultural practices and land use, livestock,

[1] The questionnaire that was used for both the phases, were designed by Dr. Soumya Gupta.

nonfarm employment, food availability and access and empowerment in agriculture was collected from Men. Women were asked questions on agricultural employment, nonfarm employment, semi-quantitative food frequency questionnaire, home-gardens, household chores, water, sanitation, and hygiene, health (reproductive history, anemia, and health-seeking behavior), child care and empowerment in agriculture. The questionnaires were piloted and were created after conducting focus group discussions and in-depth interviews across the district to understand better the local cropping patterns and allied agricultural activities in which households engage. The households that were visited in 2014 were revisited and the same tool was administered in 2016 too to obtain a panel data on detailed household information as described above. The WEAI module was modified according to the specifics of agriculture in the Chandrapur District and translated from English to Marathi. The changes included the exclusion of fisheries, inclusion of participation in collection of forest-based produce, and a change in the types of community groups and credit sources present. These changes were arrived at after conducting preliminary focus group discussions and in-depth interviews across the district to understand better the local cropping patterns and allied agricultural activities in which households engage. The same questionnaires were administered in 2016 too to obtain a panel data.

2.2.2. Measuring nutritional outcomes

Minimum Dietary Diversity Score (MDD-W)

We use the Minimum Dietary Diversity for women of reproductive age. This indicator reflects micronutrient adequacy summarized across 11 micronutrients and is defined as a food group diversity indicator (Martin-Prével,Y,2015). The minimum diversity score is calculated by counting the number of food groups consumed yesterday. The score ranges from 0-10: 0 reflecting none of the food groups were consumed and 10 reflecting all the food groups were consumed. We calculate this score for both the years. Groups of women in reproductive age where a higher proportion consume food items from at least five of the ten food groups are likely to have higher micronutrient adequacy than other groups that have a lower proportion of women achieving the threshold of food items from at least five food groups.

Body mass Index

One of the key nutritional indicators is the body mass index of women. In this paper we calculate the BMI of every female respondent in the age group of 15- 49 years in two years – 2014 and 2016. Food intake indicators do not take the activity levels, age and sex of the individual and the measures such as the BMI consider the energy expenditure and health status of an individual (UNICEF, WHO, and World Bank 2015). We use the BMI values of women to represent the nutritional status and the food energy deficiency of women.

Measuring nutrient intakes: A recipe standardization approach

Given that most nutrition in rural areas, comes from preparing meals at home as, it is important for a method to document the recipes eaten in that context. Since the cooking processes and choice of inputs in cooking often vary by context-particularly, in a diverse country such as India, it is important to bear in mind that the intakes may vary significantly with context. Since a bulk of the meals are prepared and eaten at home, a new way of incorporating the actual intake of these nutrients in necessary. However, there is Earlier studies have either used food availability measures and used the food-to-nutrient conversion factors or have used 24 hours recall of ingredients and estimated the nutrient values. This induces a bias in the estimates from high measurement error induced by over/under estimation because the recipes are not contextualized (Behrman 1988; Orazem et al. 1999; Webb et al. 2018). These templates often do not capture the local food preferences and food availability that impact nutrient intake within households.

To overcome these issues, we standardized locally consumed recipes for obtaining precise measures of nutrients. The nutrient information in India is compiled by the National Institute of Nutrition in India (NIN) and captures nutrients available in edible portions of raw foods. Two major issues arise for measuring the nutrient intakes per day across seasons: i) it is difficult to obtain precise estimates of home prepared meals ii) the time intensive in nature of 24hr dietary recall methods increase the respondent burden significantly (Coates, Jennifer; Colaiezzi, Brooke; Fiedler, Jack; Wirth, James; Lividini, Keith; Rogers 2012). Considering that majority of households in rural India, consumes home prepared meals, it was necessary to arrive at the recipe level estimates for macro and micro nutrients. For accurate measurement of nutrient intakes and to reduce respondent burden, we conducted recipe standardization of all the most commonly eaten recipes. Following the methodology adopted by Harvest plus, we first conducted detailed focused groups to develop a catalogue of most of the recipes eaten in the region (Gwatkin et al. 2007). After cataloguing, a detailed record of the process, time spent in preparation, cooking, weights of each ingredient used and cooking method were recorded while standardizing the process. A detailed nutrition data was compiled using the standardized recipes and the nutrient information from the food composition tables from India (Longvah et al. 2017). For each recipe that is commonly made in this region, a dataset was created which contains information on calories (Kcal), macro-nutrients (Proteins, Fats, Carbohydrates), micro-nutrients.

The household survey collected a semi-quantitative food frequency where women were asked to recall what they ate yesterday and how much of it. Standard measurements units such as cups and spoons were used after pilots on the field. We calculate calorie intake and iron intake by using: i) *the standardized values from our unique recipe standardization exercise and ii) the reported quantity of foods eaten in the past 24 hours.* ***Calorie intake*** were calculated for each dish consumed by an individual woman and all the quantities were then summed up to achieve the total calorie intake for the past 24 hours. The calories were obtained from a procedure of standardizing all the recipes on the field and obtaining the nutrient composition from the food composition tables collated by the national institute of nutrition (Longvah et al. 2017)[i].This was done for both the years. This study overcomes one of the main limitations in the earlier literature (H. J. L. Malapit and Quisumbing 2015) by measuring the true calorie intake in the past 24 hours. This can be compared with the WEAI as well, since the WEAI measures recalls the time allocation in the past 24 hours. To use any other calorie measure apart from 24-hour measures may bias the results accordingly. We further disaggregate the calories into calories from the following food groups: cereals; pulses; fruits and vegetables; Meat, fish and Poultry and Dairy. To analyze the source of nutrient intakes we calculate several disaggregated measures – i) absolute calories from food groups ii) share of calorie intake from these food groups out of total calories.

The studies that have explored the link between empowerment and nutritional outcomes haven't been extended to see how these effects translate into micro-nutrient based outcomes. Given the severe problem of anemia in Indian women (National nutrition strategy, 2017), we extend the analysis of this relationship by looking at ***iron intake*** as one of the outcome variables. From the standardized recipes and the calculated iron values using the India food composition tables, we arrive at per recipe iron content. Using this and the individual quantities of consumed portions of the dishes, we calculate the iron intake of each individual woman in the past 24 hours. To our knowledge, this is the first study that looks at this relationship over time.

To analyze the shifts in the consumption of food groups, we calculate the quantities consumed by women for each of the food groups in grams. Each of the recipes consumed in the past 24 hours are allotted to food groups based on the main constituent in the recipes and the total grams consumed are calculated by food group. We also calculate the share measures of each of the food groups in terms of share of grams consumed from `x' food group to identify the shifts in the allocation of within the basket of consumption.

2.2.3. Measurement of women's empowerment in agriculture

Original WEAI and the A-WEAI

For this paper, we conduct three levels of analysis. First, we construct all the ten sub-indicators using original WEAI, the A-WEAI using the 6 sub-indicators and check for consistency. Second, we adapt the indicators using our experience on the field in India and construct the composite score for measuring women's empowerment (WEAI_S). We construct the original WEAI and analyze the responses across the years. There are a total of ten sub-indicators in the original WEAI, and adequacy in each of these sub-indicators are dependent on whether or not a woman meets the adequacy threshold. The adequacy requirements are listed in Appendix 1. For the individual level (women level) empowerment measures, we calculate the women's adequacy score. The women's adequacy score is a weighted average of all adequacies in all the five domains of the index. A woman is adequate in a sub-indicator is she is having at least some input in decisions or participated to some extent. The empowerment indicator is measured as the weighted average of the sub-indicators. Each woman gets a score, which is a continuous variable between 0 and 1. If a woman has not participated in even one domain, she is excluded from the analysis.

Adapting the WEAI for India (WEAI_S)

Based on our field level experience of the WEAI across locations and the inconsistencies in the index, we adapt the A-WEAI to India by choosing the most relevant activities and changing the thresholds for adequacy among each of the sub-indices. Appendix A presents the differences between the construction of the AWEAI and our analysis in detail. All the sub-indicators that are adapted are listed below:

Ownership of assets: In the A-WEAI, both agricultural and non-agricultural asset ownerships are included. In our study, respondents found it difficult to answer ownership related questions on small consumer durables as they are considered as goods for the entire household. Similarly, "ownership of livestock" is also not clearly construable as they are also the property of the entire household. To avoid problems related to measurement issues – we argue that only ownership of agricultural land is best suited for the Indian context because the property rights can be clearly defined through legal contracts.

Control over income*:* In this domain too, we only include activities that are agricultural only. While, the control over income of non-agricultural activities may be relevant for overall empowerment, but for purpose of empowerment in agriculture- we focus only on agricultural activities.

Group membership*:* We use sharper data by including women who are members of only agriculture-based groups such as agriculture/livestock/fisheries producer groups, water groups, forest user group or SHG's.

Workload*:* We consider a woman is adequate in workload if she is working in agriculture more than 6 hours. Given that one agricultural man day is considered as 8 hours, we postulate that if women are working above 6 hours in agriculture base activities then she is considered inadequate.

3. Empirical strategy

We examine the relationship between women's empowerment in agriculture and women nutrition indicators over time through *first difference* model (FD) using the panel data across two years 2014 and 2016 (Wooldridge, 2012). We estimate the following first difference regression equation:

$$\Delta N_i = \delta_0 + \beta_1 \Delta Empowerment_i + \beta_2 \Delta Individual_i + \beta_3 \Delta household_i + \Delta\mu_i ......(1)$$

Where, ΔN_i refers to change in individual level nutritional outcomes such as the dietary diversity score, body mass index and calorie intake. β_1 is the coefficient of interest which identifies the effect of empowerment and nutritional outcomes over time and $\Delta Empowerment_i$ is variable is the women's adequacy score defined from WEAI_S. Standard OLS estimates with cross- sectional data have severe omitted variable bias as many factors cannot be controlled for. However, panel data allows us to remove the omitted variable bias stemming from time constant factors such as tastes, preferences, location, age, education, caste etc. However, time varying factors still need to be accounted for and for the FD estimates to be consistent and have a causal interpretation, the errors must be uncorrelated with the independent variable. One of the concerns with FD estimation is that the independent variable has less variation, however, the differenced empowerment of women varies with only 15 percent of women reflecting no change (Table A3). In this paper, the FD regression removes the heterogeneity driven from all the time-invariant factors and we control for all the potential time-varying factors that can impact the nutritional outcomes of interest.

All the incomes received by the household and individual are likely to change over and we control for change in income from various sources. Previous literature has pointed out that there are differential impacts of different income sources on nutritional outcomes due to missing markets in Sub-Saharan Africa (Villa, Barrett, and Just 2011). Our field experience provides us the reason to believe such effects are possible in rural India too. The rich agricultural data from our survey allows us to account for income from various number of sources. Income earned by women – both from agricultural sources and non-agricultural sources contributes significantly to the health and nutrition of the family (Rao and Pingali 2018; Haddad 1999). Marginal increases in these incomes can influence nutrition in a positive manner. We control for individual level income sources in 1000 Rs. units ($\Delta Individual_i$) as i) women's income from wage labor on the farm ii) wage/salaried income from non-farm income sources from participation in activities such as planting, ploughing, harvesting etc. in the previous season accounted for at the time of the survey.

The household level change variables ($\Delta household_i$) include: income from sale of cash crops, income from sale of cereal crops, income from sale of livestock and livestock products and production diversity. On the production side, income from sale of crops are typically used to purchase inputs for welfare-particularly nutrition and health. If the crops are cash crops, the inputs of nutrition are purchased through the markets and the sale of cereal crops raises income for purchases while reducing cereals for consumption. Since, most of the households are involved in cotton, paddy production, we calculate the change in the value of sale of cash crops and cereals crops. Livestock income has played a very important role in improving nutritional outcomes, therefore we include the livestock income both from the sale of livestock as well as the sale of by-products of livestock (Azzarri et al. 2015).

For this paper, using primary data on crop cultivation, we argue that a simple count of the number of crops cultivated is not an appropriate reflection of the diversity of production. For instance, if a household cultivates two types of pulses – chickpea and black-gram – in subsequent seasons (or the same) then production diversity based on a count- metric would equal two. However, since the basic premise of using production diversity as an explanatory variable for dietary diversity is that it can potentially enhance the diversity of diets we propose computing the metric based on the number of food groups being cultivated in the three different seasons. We accordingly define production diversity as a count of the number of non- staple food groups being cultivated: pulses, spices, vegetables, and fruits - thus summing to a total of 4. The production diversity score therefore can range from 0 to 4 (Sibhatu and Qaim 2018). These food groups are based on crops commonly produced in our field locations. We exclude the cereals food group because they are the most commonly cultivated (and consumed) food group and our interest lies in the role of non- staples in enhancing the diversity of diets.

In all the regressions, we include robust standard errors. As robustness checks, we include clustered standard errors at the village level and individual level. We also test if there are any differences in the estimates by inclusion of a non-linear term of empowerment.

Disaggregated outcomes

To further disaggregate and analyze the patterns of consumption and calorie intake we analyze the relationship between calories consumed from a food group/share of calories from a food group:

$$\Delta calories_i = \delta_0 + \beta_1 \Delta Empowerment_i + \beta_2 \Delta Individual_i + \beta_3 \Delta household_i + \Delta\mu_i \ldots\ldots(2)$$

where, $\Delta calories_i$ refers to calorie intake by food group, share of calories of each food group in total calories.

Even though calorie intake may reflect the nutrition, it does not give us a sense of the proportion that women are allocating to various food groups – which reflects their underlying preferences and eating behavior. To delve into that, using the same regression framework, we include the actual consumption in terms of grams as outcome variables.

$$\Delta consumption_i = \delta_0 + \beta_1 \Delta Empowerment_i + \beta_2 \Delta Individual_i + \beta_3 \Delta household_i + \Delta\mu_i \ldots\ldots(3)$$

where, $\Delta consumption_i$ is the grams consumed from each food group, share of consumption of each food group in total consumption.

Domains of empowerment

In the previous regressions, we look at the overall changes in empowerment as an explanatory factor for changes in nutritional outcomes. However, the WEAI methodology allows us to disaggregate the measure and analyze the contribution of each of the sub-indicators; Input in decision making, ownership of assets, decisions on credit, control over income, group membership and workload. We replicate the above regression equations in 1,2,3 for each of the sub-indicators of the empowerment in the following way:

Where, $\Delta i.Subindicator_i$ reflects the change in each of the sub-domains of

$$\Delta N_i = \delta_0 + \beta_1 \Delta i.Subindicator_i + \beta_2 \Delta Individual_i + \beta_3 \Delta household_i + \Delta\mu_i ......(4)$$

empowerment as listed above. Since adequacy in each of the sub-index ranges from 0 and 1, the change variable has three categories: adequate to inadequate, no change and inadequate to adequate.

4. Results

4.1. Summary statistics

In this paper, the sample is from three blocks across Chandrapur district in Maharashtra. Almost everyone in the sample participates in agriculture. About 70 percent of the sample owns land with an average landholding size of about 3 acres. All women in this sample are in the reproductive age between 15-49 years and, the average age is about 31 years. About 33 percent of women have not received any form of education, and only 5 percent of them have studied beyond high school. Table 1 presents the summary statistics of the change variables for the sample.

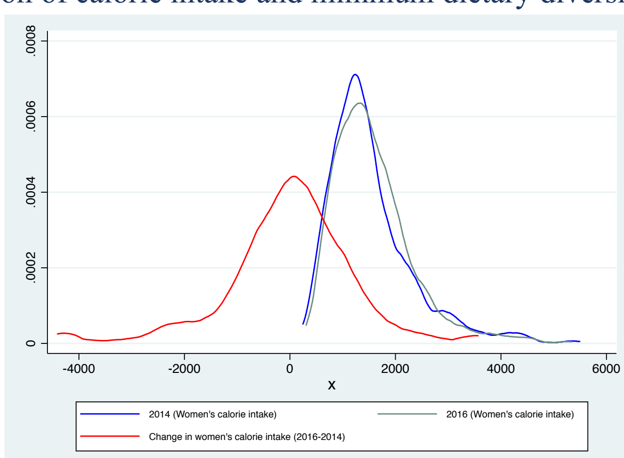
We consider three nutritional outcomes for this study: i) women's dietary diversity scores ii) women's calorie intake and iii) women's body mass intake. All these variables are daily values recorded for the last 24 hours at the time of the survey. We take the change in these variables, which is the difference between the values in 2016 and 2014. As shown in table 1, the average change in dietary diversity was 0.6 which reflects an increase in consumption of 1 food group. In terms of the distribution of the variable as shown in Graph1, we see that there is a rightward shift in the average dietary diversity score for the year 2016 as compared to the year 2014. The change variable; in red color follows a normal distribution. Calorie intake follows a similar pattern in both the years, but the average change is positive at 14.69 Kcal. There is hardly any change in the BMI, and the same is reflected in the average values as well.
Dietary diversity and calorie intake can be affected through both production of crops and income earned as women can purchase the desired food items. Some if the control variables are time invariant such as the preferences, household composition etc. but variables like income from sale of crop, livestock, farm wage income, production diversity is time varying.

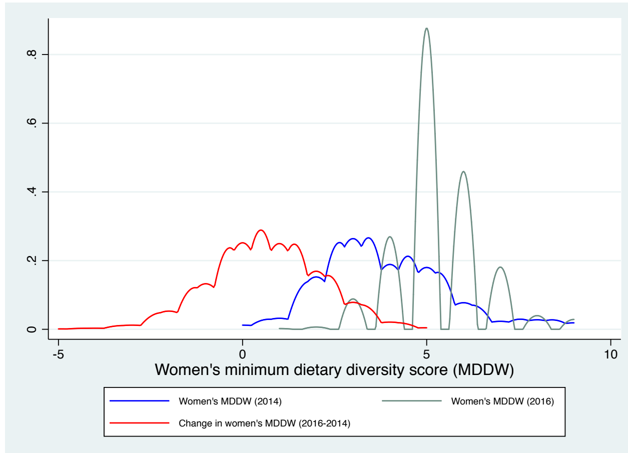
Table 1: *Summary statistics*

Variable	Mean	Std. Dev.	Min	Max
Outcome variables (Δ)				
Women's Dietary diversity score (0-10)	.65	1.50	-5	5
Women's Iron intake (mg)	-1.57	4.97	-49.61	13.09
Women's Calorie Intake (kcal)	14.69	1247.10	-4406.76	3566.53
Women's Body mass index	.28	2.79	-13.80	21.66
Independent variable (Δ)				
Women's empowerment score	-.0021	.26	-.9	.8
Control variables (Δ)				
Value of sale of cash crops ('000 rs.)	-6.56	68.31	-400	400
Value of sale of cereal crop ('000 rs.)	3.23	22.97	-105.5	105.5
Production diversity of non-staples ('000 rs.)	.05	.72	-3	2
Women's non-farm income ('000 rs.)	-1.01	9.92	-90	18
Livestock income ('000 rs.)	1.34	10.93	-40	60.024
Women's farm wage income ('000 rs.)	2.69	4.13	-4	25.5

All the variables are winsorized at 1 % on both the tails to check for outliers

Graph 1: Distribution of calorie intake and minimum dietary diversity scores of women





As shown in Table 1, on an average cash crop sale has reduced by about Rs. 6560 and cereal crop production has increased by about Rs. 3230. For capturing production diversity, we use production diversity score of the non-staples: pulses, fruits, vegetables, and spices. Therefore, the score ranges from 0 to 4. On average, there is an increase in production diversity among non-staples. We exclude the cereals food group because they are the most commonly cultivated (and consumed) food group and our interest lies in the role of non-staples in enhancing the diversity of diets. We also include variables such as the women's non- farm income and livestock income in the control variables. Livestock includes the sale of large, small livestock and the income from sale of by-products of livestock such as milk, eggs.

4.2. Women's empowerment across years

First, we analyze the original WEAI across two years and check for consistency. Looking at the averages, we find that there is a decline in the number of women reporting that they have autonomy in production decisions, self/joint purchase sale of assets, access to decisions on credit, group membership and comfort in speaking in public. On the other hand, there is an increase in the percentage of women reporting input in decision making and workload, ownership of assets, control over income and leisure remain the same. Table 2 reports that the difference in means t-tests results across the years is significant. We find that there are significant differences in autonomy, self/joint purchase/sale of assets, access to decisions on credit, group membership, speaking, workload and leisure. However, the differences are not significant for input in decisions, ownership of assets and control over income.

Table 2: Means of the sub-indicators of empowerment and significance tests for differences across years.

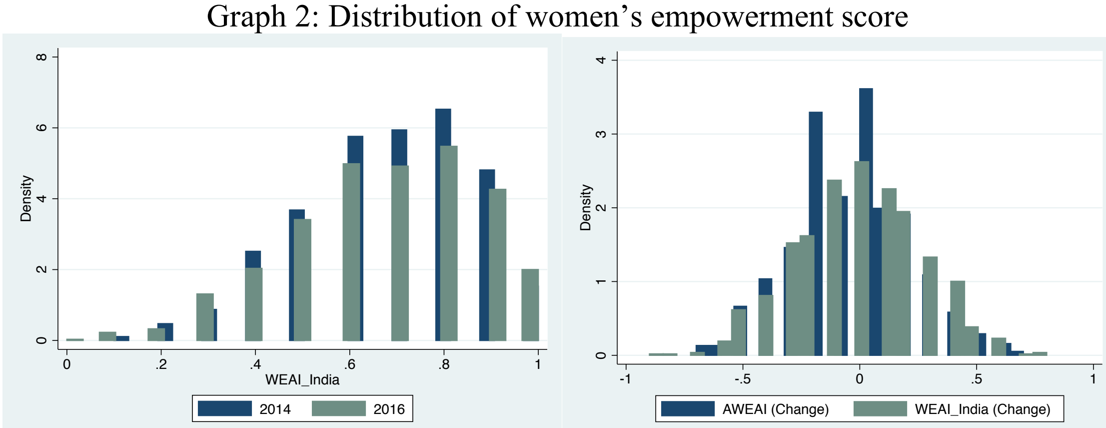
Sub-indicators	2014 (Mean)	2016 (Mean)	Difference	(p-value)
Input in production decisions	0.72	0.74	-0.02	0.34
Autonomy in production decisions	0.74	0.31	0.43	0.00^{***}
Ownership of assets	0.83	0.83	-0.00	0.85
Purchase, sale or transfer of assets (Self/Joint)	0.47	0.39	0.08	0.00^{***}
Access to and decisions on credit	0.74	0.52	0.21	0.00^{***}
Control over use of income	0.93	0.93	0.01	0.50
Group Membership	0.45	0.31	0.14	0.00^{***}
Comfortable in speaking in public	0.71	0.33	0.38	0.00^{***}
Workload	0.93	1.00	-0.07	0.00^{***}
Leisure	0.97	0.88	0.08	0.00^{***}

Our results are in line with the construction of A-WEAI, and we do not include autonomy, purchase, the sale of assets and speaking in public in further analysis. In the original WEAI, autonomy accounts for responses of women engaging in activities. The following are the justifications for removing these indicators from construction- *Autonomy*: The decline in autonomy cannot be explained by any development that took place in this region during 2014-2016. Since it is a subjective measure, it is difficult to attribute the difference. This sub-indicator is not used in the new version of WEAI: A-WEAI due to the difficulties in the implementation on field. *Purchase/Sale of assets (Self/Joint)*: A woman is considered adequate in this domain if she feels that she can take purchase/sale decisions herself/jointly. Our analysis shows a significant decline of about 8 percent in the women who report that they can take these decisions. However, the ownership of these assets is the same across the years. The fact that the same women feel differently despite the same ownership status is unexplainable. *Speaking in public*: Across the two years, there is a 38 percent significant decline in women who report that they feel comfortable speaking in public spheres. The difficulty of construing this indicator is reflected in our results too, and we also drop it from our analysis.

Adapting the women's empowerment index to India (WEAI_S)

As mentioned in section 2, we adapt the A-WEAI to an Indian context (WEAI_S), by using clearly defined and context-specific indicators in measuring women's empowerment. Appendix A1 presents the differences between the construction of the A-WEAI and our analysis in detail. Each woman gets an adequacy score, which is a continuous variable between 0 and 1. If a woman has not participated in even one domain, we exclude her from the analysis. Appendix table A1 shows the comparisons in the construction. On average women's empowerment has not changed across time and the average adequacy score remains to be 0.68, i.e. women are on an average empowered in 3 domains in both years. As shown in table A2, there are significant differences across all sub-indicators except input in decision making. Overall, about 42.4 percent of the women have seen a decline in empowerment, 43 percent have seen an increase and about 15 percent of have their empowerment unchanged (A3). The graphs (3) below show the distribution of WEAI_S across the years, and we see that the distribution follows a similar pattern across the year. When we analyze the changes across the two indicators the A-WEAI and the WEAI_S, WEAI_S appears to follow a much smoother distribution.

Graph 2: Distribution of women's empowerment score



4.3. Does an increase in women's empowerment better nutrition over time?

Table 3 presents the relationship between empowerment and nutritional outcomes: dietary diversity, calorie intake and Body Mass Index of women; over time. In all the specifications shown in the table, we control for all time-varying factors that can explain variation in nutritional outcomes of an individual, such as income from crops, livestock and non-farm income. The variables are first differenced- reflecting the difference in the values in 2016 and the values in 2014. We use only robust standard errors in this regression, but cluster them in following specifications.

After analyzing the relationship across nutritional outcomes over time, we find that- a one unit increase in a woman's empowerment score corresponds to a reduction in her calorie intake by about 447 kcal per day. In other words, if she attains adequacy in one additional domain, her calorie intake reduces by 44.7 calories.

In terms of dietary diversity and Women's BMI, we find no association with the empowerment of women over-time. In a cross-sectional setting, previous literature has shown that women's empowerment and dietary diversity have a positive association. However, our panel data results show that there is no association between dietary diversity and women's empowerment. Our results corroborate the results from previous studies and show no association of empowerment with BMI. In terms of other control variables, production diversity of non-staples matters significantly for all nutritional outcomes. For dietary diversity, the magnitude and the level of significance are very high for production diversity. Diversification of production to one food group corresponding increases dietary diversity in consumption by about one food group. Similarly, holding other variables constant- calorie intake increases by about 182 kcal by producing one additional non-staple crop.

To further analyze the reduction in calorie intake, we break down the consumption patterns by six major food groups: cereals, pulses, fruits and vegetables, MFP and dairy. For each of the food groups, we calculate total grams consumed, consumption share(gms/gms), total calories, the share of calories. The individual-level data on dietary recall and the unique recipe standardization data allows us to get individual level quantities consumed as well as calorie intake amounts based on the dishes they consumed in the past 24 hours.

We analyze the calories and quantities consumed in absolutes as well as shares in the total calories/consumption. In this detailed analysis as shown in table 4, we see a rise in the share of calorie intake from the consumption of fruits and vegetables in the total consumption basket and a decrease in the share of meat, fish, and poultry- suggesting that women who are empowered are readjusting their sources of calorie intakes towards fruits and vegetables over time. In terms of absolute calorie intakes, we find that the calorie intake from the consumption of cereals, pulses, and dairy decrease in absolutes as the empowerment of women increases. A decrease in the share of calorie intake from MFP alone does not mean reduction is nutrition quality as these foods give various other nutrients.

Table 3: Relationship between change in empowerment and change in nutritional outcomes

Change Variables (2016-2014)	**Dietary diversity**	**Calories (Kcal) per day**	**Women's BMI**
Women's empowerment score	0.0478 (0.182)	-446.8^{**} (159.1)	-0.152 (0.385)
Income from livestock sale and produce (Rs.)	-0.00405 (0.00460)	0.493 (4.710)	-0.00267 (0.0106)
Woman's agricultural wage income (Rs.)	-0.0166 (0.0111)	-5.261 (8.442)	-0.0150 (0.0233)
Woman's non-farm income (Rs.)	0.00236 (0.00438)	1.630 (3.633)	-0.00135 (0.0137)
Income from sale of cash crops (Rs.)	-0.000266 (0.000668)	-0.0197 (0.689)	-0.000437 (0.00102)
Income from sale of cereal crops (Rs.)	0.000806 (0.00186)	3.051 (2.019)	0.00301 (0.00480)
Production diversity of non-staples	0.937^{***} (0.0689)	182.7^{**} (63.44)	0.298^{*} (0.136)
Change in access to sanitation (Yes/No)			0.0605 (0.136)
Constant	0.652^{***} (0.0544)	-19.42 (49.92)	0.270^{*} (0.133)
Observations	883	883	882
Adjusted R^2	0.196	0.016	-0.002

$^{+} p < 0.10$, $^{*} p < 0.05$, $^{**} p < 0.01$, $^{***} p < 0.001$

i)Robust standard errors in parentheses. ii) All regressions are first difference regressions and variables are in change terms i.e. iii) difference between 2016 and 2014. The income variables are in '000 Rupee units

Table 4: Relationship between change in empowerment and change in calories and share of calories by food group

	Calories from cereals	Share of calories from cereals in total calories	Calories from pulses	Share of calories from pulses in total calories	Calories from fruits and vegetables	Share of calories from F&V in total calories	Calories from meat and fish	Change in share of calories from MFP in total calories	Change in calories from dairy	Change in share of calories from dairy in total calories
Change in women's empowerment	-122.7^{*} (56.78)	0.0438 (0.032)	157.3^{**} (55.90)	-0.0353 (0.0271)	18.18 (37.32)	0.0421^{+} (0.0223)	-142.0 (114.0)	-0.0474^{+} (0.0279)	-35.51^{+} (18.65)	-0.0156 (0.0105)
Income from livestock sale and produce (Rs.)	1.069 (1.400)	0.000106 (0.000799)	-0.201 (1.378)	0.0000551 (0.000672)	1.198 (0.920)	0.00055 (0.0006)	-1.174 (2.810)	-0.0002 (0.0007)	0.0826 (0.460)	-0.0000 (0.00026)

Woman's agricultural wage income (Rs.)	-4.170 (3.727)	0.000151 (0.00211)	-3.039 (3.669)	-0.00176 (0.00177)	1.853 (2.450)	0.00056 (0.0015)	-1.915 (7.480)	-0.002 (0.0018)	0.826 (1.224)	0.000652 (0.00069)
Woman's non-farm income (Rs.)	1.199 (1.534)	0.000873 (0.000867)	0.760 (1.511)	-0.000230 (0.000729)	-0.663 (1.009)	-0.0002 (0.0006)	0.676 (3.080)	0.00009 (0.0007)	-0.194 (0.504)	-0.00038 (0.00028
Income from sale of cash crops (Rs.)	-0.501^{*} (0.226)	0.000236^{+} (0.000128)	0.204 (0.223)	0.000094 (0.000108)	0.0691 (0.149)	-0.000001 (0.00008)	0.232 (0.455)	0.00006 (0.0001)	0.0153 (0.0744)	0.00002 (0.00004)
Income from sale of cereal crops (Rs.)	0.293 (0.663)	-0.00015 (0.000375)	-0.552 (0.653)	-0.000360 (0.000315)	-0.368 (0.436)	-0.0002 (0.0002	3.864^{**} (1.330)	0.0010^{**} (0.0003)	-0.205 (0.218)	-0.000149 (0.000122)
Production diversity of non-staples	53.91^{*} (20.98)	-0.0186 (0.0119)	40.32^{+} (20.66)	0.0119 (0.01000)	7.856 (13.79)	-0.0031 (0.0082)	40.30 (42.11)	0.0159 (0.0103)	18.07^{**} (6.892)	0.00570 (0.00387)
Constant	184.5^{***} (18.35)	-0.143^{***} (0.0104)	292.7^{***} (18.06)	0.189^{***} (0.00876)	-23.35^{+} (12.06)	-0.023^{*} (0.0072)	102.0^{**} (36.82)	-0.0119 (0.00900)	-5.788 (6.026)	-0.00415 (0.00339)
Observations	883	874	883	874	883	874	883	874	883	874
Adjusted R^2	0.012	0.003	0.008	-0.000	-0.003	-0.001	0.005	0.011	0.005	0.001

From calorie intake alone, we do not know if there is a shift in consumption in terms of proportions towards diverse foods. For an estimate of the shift, it is important to look at the total quantities consumed in each of the food groups. We look at the grams consumed and the shares to understand what proportion of the meal is coming from micro-nutrient rich foods. Table 5 shows that the share of F&V in total consumption rises by 6 percent with a unit increase in empowerment. All other shares are not significantly different- this suggests that women who are empowered are indeed increasing the proportion of fruits and vegetables, without affecting the share of other food groups in their consumption basket. In terms of absolute quantities consumed, empowered women consume fewer cereals, pulses and more dairy products. These results point out that women who are empowered, derive their calories from the consumption of more and more fruits and vegetables. These results are robust even after controlling for all the time invariant factors such as taste, preferences and time varying factors such as income from various sources, production diversity. To test for the robustness, we run these specifications by clustering the standard errors at both the individual and the village levels and the results remain robust (A4). We also run specifications include a squared empowerment term to introduce non-linearities and find that the variation is still explained by the linear empowerment variable. Adding more controls does not alter the results and they remain quite robust to such specifications too.

Table 5: Relationship between change in empowerment and change in consumption (grams) and share of consumption by food group

	Change in consumption of cereals (gms)	Change in share of consumption of cereals in total consumption	Change in consumption of pulses (gms)	Change in share of consumption of pulses in total consumption	Change in consumption of F&V (gms)	Change in share of consumption of F&V in total consumption	Change in consumption of MFP (gms)	Change in share of consumption of MFP in total consumption	Change in consumption of dairy (gms)	Change in share of consumption of dairy in total consumption

Change in women's empowerment	-113.4* (47.57)	-0.00157 (0.0277)	-73.88* (30.79)	-0.0300 (0.0187)	15.05 (27.55)	0.0605** (0.0192)	-0.709 (1.097)	0.00061 (0.000924)	-44.78^{+} (24.36)	-0.0192 (0.0130)
Income from livestock sale and produce (Rs.)	1.803 (1.173)	0.000415 (0.000682)	-0.0495 (0.759)	0.0000959 (0.000461	0.0649 (0.679)	-0.000216 (0.000474)	0.0218 (0.0271)	0.0000006 (0.000023)	0.357 (0.601)	0.000112 (0.000319)
Woman's agricultural wage income (Rs.)	-2.554 (3.122)	-0.00376* (0.00181)	3.255 (2.021)	-0.000770 (0.00122)	13.11*** (1.808)	0.00443*** (0.00126)	-0.0771 (0.0720)	-0.0000727 (0.00006)	0.400 (1.599)	-0.0000 (0.0009)
Woman's non-farm income (Rs.)	1.128 (1.285)	0.0011 (0.0007)	-0.598 (0.832)	-0.0005 (0.0005)	-1.330^{+} (0.744)	-0.0006 (0.0005)	-0.0220 (0.0297)	-0.00002 (0.0002)	-0.306 (0.658)	-0.0002 (0.0004)
Income from sale of cash crops (Rs.)	-0.289 (0.190)	-0.00014 (0.0001)	0.0664 (0.123)	0.0000 (0.0001)	-0.0181 (0.110)	-0.00008 (0.0001)	0.00365 (0.0044)	0.00004 (0.0004)	0.0537 (0.0971)	0.00003 (0.0001)
Income from sale of cereal crops (Rs.)	0.330 (0.555)	-0.0000 (0.0003)	-0.505 (0.359)	-0.0004^{+} (0.0002)	-0.335 (0.322)	-0.00011 (0.0002)	-0.0119 (0.0128)	-0.0002* (0.0001)	-0.182 (0.284)	-0.00013 (0.0002)
Production diversity of non-staples	41.20* (17.58)	-0.00146 (0.0102)	20.52^{+} (11.38)	0.0068 (0.0067)	-8.935 (10.18)	-0.026*** (0.0071)	0.0927 (0.406)	-0.00043 (0.0003)	19.84* (9.001)	0.0082^{+} (0.0048)
Constant	-117.4*** (15.37)	-0.126*** (0.0089)	178.4*** (9.951)	0.130*** (0.006)	78.98*** (8.902)	0.042*** (0.0062)	-0.259 (0.355)	-0.0008* (0.0003)	-10.84 (7.870)	-0.0078^{+} (0.0042)
Observations	883	881	883	881	883	881	883	881	883	881
Adjusted R^2	0.012	0.001	0.007	0.002	0.054	0.036	-0.002	0.004	0.003	-0.000

Standard errors in parentheses
All regressions are first difference regression $^{+}p < 0.10$, $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

A shift towards fruits and vegetables suggests diversification in the food but we do not know if these foods that are being consumed are micro-nutrient rich or not. Our results in the previous table show that women who are more empowered are shifting towards more fruits and vegetable-based diets. We find that both the consumption as well as calorie intake from the fruits and vegetables are increasing, suggesting a plausible increase in iron intake.

Given the immediate need to look at anemia and the high prevalence in this district, for this study we calculate the intake of iron by women in the past 24 hours for both the two years. Table 5 presents the relationship between each of the food groups and the change in iron intake. We find that an increase in consumption of MFP and F&V suggest an increase in the iron intake. But, if we see the specification two, we find that only an increase in the calories consumed from fruits and vegetables is positive and significant for iron intake. This result suggests, that women, who are empowered are not only consuming more fruits and vegetables, but they are also consuming fruits and vegetables that are more iron rich. This suggests an improvement in the quality of F&V that are being consumed in terms of their micronutrient content.

Table 6: Relationship between consumption of food groups and iron intake.

ΔVariables	ΔIron (mg)	ΔIron (mg)
Consumption of cereals (gms)	-0.0000820 (0.000442)	
Consumption of pulses (gms)	-0.00000778 (0.000616)	
Consumption of MFP (gms)	0.0430^{*} (0.0190)	
Consumption of F&V (gms)	0.00129^{+} (0.000728)	
Consumption of dairy (gms)	0.00104 (0.000781)	
Calories from cereals		0.000534 (0.000361)
Calories from pulses		-0.000180 (0.000348)
Calories from meat and fish		0.000108 (0.000171)
Calories from fruits and vegetables		0.00348^{***} (0.000538)
Calories from dairy		0.00148 (0.000957)
Constant	-1.698^{***} (0.222)	-1.341^{***} (0.207)
Observations	884	884
Adjusted R^2	0.007	0.048

Standard errors in parentheses. All regressions are first difference regressions
$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

In table A5, we look at which of the sub-indicators of empowerment explain the changes in consumption of from each of the food groups as outlined in equation 5. We find that relative to a decrease in empowerment, an increase in input in decision making and ownership of assets contribute significantly to the consumption of the share of fruits and vegetables. Increased adequacy in decision making regarding food and cash crops to be planted, livestock raising can influence the types of food planted and the decisions regarding what can be eaten from the income derived from agriculture can influence the consumption of fruits and vegetables.

5. Discussion and conclusions

In this paper, we investigate the role of women's empowerment in agriculture for improving women's nutritional outcomes over time. In the first of its kind, our results indicate that- over time, an increase in women's empowerment leads to a shift towards more micronutrient-rich foods in total consumption of food groups. At first, our results indicate that the calorie intake of women decreases as their empowerment level increases. However, our rich individual-level dietary data and standardized recipe data gives us the opportunity to delve into measures such as quantities consumed and the intake of calories by food group for each woman across time. The rich data and measures allow us to see how women are shifting their consumption patterns and the proportions they are allocating to each of the food groups.

We find that women are consuming more fruits and vegetables. These results suggest a shift toward more fruits and vegetable-based diets. We also find that the calories from F&V translate into the higher iron intake for women suggesting that women with increased empowerment are also choosing F&V's that are more iron-richer. The other food source of iron is the meat, fish, and poultry (MFP) food group. In MFP we do not observe any significant differences with changes in empowerment suggesting no change. To our knowledge, this is the first time that a study uses panel data on WEAI and explores the relationship between empowerment and nutritional outcomes using individual-level micro-nutrient data.

Contrary to earlier studies, once we incorporate the panel data, we do not find any association between dietary diversity and empowerment (Ruel, Quisumbing, and Balagamwala 2018b).Earlier studies use cross-sectional data where the influence of omitted variable bias can lead to biased estimates. Using panel data, we address this issue and control for all the time-invariant factors that can explain nutritional outcomes. Consistent with the literature, we find no effect of empowerment on BMI levels of women.

In addition to bringing out the relative importance of women's empowerment for improved nutrition, our analysis also makes the following methodological contributions. We first provide a consistency check for the WEAI by analyzing the differences across time. By doing so, we provide a list of more consistent context specific, field-based measures for the WEAI and shed light on indicators that change over time - a tool useful for evaluating programs and interventions.

We also adapt the A-WEAI using indicators that more sharply reflect the access and decision-making aspects in the context of Indian agriculture. We do this by focusing on site-specific production activities, real community- specific notions of ownership and agriculture-specific participation in activities, groups, and control over income and credit sources. For instance, by restricting our focus to ownership of agricultural land, we consider the fact that 'ownership' of other assets like livestock, farm equipment and other durables (included in A-WEAI) are not relevant for India. These assets are often household- goods and therefore the definition of 'ownership' does not reflect property rights in any tangible way.

Through our rich data set of standardized local recipes, we develop a new conceptualization of measuring nutrient intakes from commonly eaten recipes- thus more precise measures of both the quantities consumed as well as the micro-nutrients consumed by women. To our knowledge, this is the first step towards studying the relationship between women's empowerment and nutritional outcomes over time and extending the analysis to using individual-level micro-nutrient data for studying these relationships.

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CHAPTER 3

NUTRITION TRANSITION AND STRUCTURAL TRANSFORMATION IN INDIA: A SPATIAL ANALYSIS

1. *Introduction*

The process of structural transformation is vital in determining the implications of food systems for nutrition. Existing research has shown that types and levels of malnutrition vary across countries and associate with the pace of structural transformation. In diverse developing country contexts such as India, the issues surrounding malnutrition, and the stages of structural transformation vary across smaller geographic units in a given country. A need-based, effective and targeted policy is only possible with a clear and deep understanding of the issues at the sub-regional level. However, current knowledge stops short at cross-country associations, but we know nothing about sub-national or sub-regional disparities in the stage of structural transformation – and its implications on malnutrition among women and children.

Among 17 of the Sustainable development goals (SDGs) indicators, 12 of them are directly relevant for nutrition. The focus on malnutrition is crucial because it is majorly responsible for the global burden of diseases (Forouzanfar et al. 2015). While over-nutrition and obesity are significant nutrition problem in high-income countries - low- and middle-income countries, on the other hand, suffer from hunger and insecure access to food. With the ongoing structural transformation across the developing countries, dietary practices are changing. Rising obesity, micronutrient deficiency and non-communicable diseases in addition to the high levels of undernutrition – referred to as the triple burden of malnutrition – is becoming an increasing concern (Gómez et al. 2013). Agricultural productivity growth because of the Green Revolution (GR) which abetted this transformation changed the food systems in developing countries. The concern changed from enough availability of calories to the quality of diet, and micronutrient deficiencies (Gómez et al. 2013). Overweight and obesity further became a challenge as nutrition transition is taking place.

Such changes point out to the lack of our understanding of the multidimensional nature of nutrition in developing countries. The stage of nutrition transition -- nature, level, and determinants of malnutrition -- varies across countries depending upon the nature of growth, agricultural production or the stage of their structural transformation (Pingali and Sunder 2017). Structural transformation involves four main features: i) a falling share of agriculture sector in output and employment; ii) a rising share of economic activity in the industry; iii) rural-urban migration, and iv) a demographic transition in birth and death rates. High-income economies experienced sustained agriculture productivity growth and improvements in the non-farm economy which spurred rapid industrialization as well as economic growth (Timmer 2017). Agriculture productivity growth played a crucial role in its economic transformation and nutrition transition. Studying structural transformation across 29 countries, Webb and Block (2014) argue that countries which provided greater support to agriculture saw a faster reduction in poverty levels which brought about reduction in undernutrition (Patrick Webb and Kennedy 2014). Over time, economic transformation, however, brought about health-related risks such as rising obesity.

While these global disparities in the pace of structural transformation and its implication for nutrition has caught scholarly attention, very little is known about sub-national or sub-regional disparities in the economic transformation – pace and drivers – and its implication for the degree and nature of malnutrition. In most developed countries, like the United States of America (USA), regional convergence in growth rates has been recognized largely due to the structural transformation out of agriculture (Caselli and Coleman II 2001). In a country like India, where there is a great degree of spatial inequality and varying pace of agricultural support and transformation, the association between structural transformation and nutrition remains a moot question. Country level indicators mask wide heterogeneity in nutritional outcomes and the nature of its statistical association with the contributing factors (Maruyama, Unnevehr, and Wang 2014). Undernutrition is mostly clustered in sub-Saharan Africa and South Asia, and among the poorer communities within these regions. According to UNICEF, WHO, and World Bank (2015), close to 70 percent of the undernourished children in 2014 lived in Asia[1].

Given wide differences in the experience of malnutrition across the globe, a uniform global strategy to address malnutrition may be faulty. This begs the question – why have some regions performed well in reducing the incidence of malnutrition, while others have not? Does variation in the role of agriculture and structural transformation at a subnational level explain these differences? Absence of data at a sub-national or sub-regional level been a major concern to identify and compare progress across and within nations (IFPRI 2016). Little, therefore, is known about sub- national or sub-regional variations in nutritional outcomes within a country and the pace of regional structural transformation.

This paper fills in this gap by highlighting the role of agriculture in sub-national development and nutritional outcomes, with a geographical focus on India at a district level. Our choice of analysis comes from the fact that India has one of the highest incidences of undernourished children despite rapid economic growth in the last two decades. At the same time, there has been an increase in the incidence of overweight and obesity, while micronutrient deficiency remains high, suggesting "triple burden of malnutrition" (Meenakshi 2016). Further, our rationalization for considering districts as our unit of analysis comes from the fact that the developing countries are becoming more decentralized in terms of political, administrative and financial systems. Local capacity and political commitment, hence, become more critical for resource allocation for nutritional interventions(Van den Bold, Quisumbing, and Gillespie 2013). Socio- political environment for nutrition is vital for India and has been well documented in the literature (Menon, Raabe, and Bhaskar 2009; Mohmand 2012; Harriss and Kohli 2009; Kohli et al. 2017). The shift to programmatic attention on the district level is evident through the focus of the flagship programs like National Rural Health Missions (NRHM) and National Urban Health Missions (NUHM) in the last decade. Understanding the regional variations in nutritional outcome, therefore, becomes important from the perspective of the public health interventions. The high- burden regions would require correct diagnosis and management in terms of health infrastructure and public health campaigning, preventive measures could prove to be a better strategy in the region where malnutrition incidences are lower (Dang and Meenakshi 2017). Similarly, an understanding of the type of malnutrition (over-nutrition or undernutrition) spatially also helps in designing the nature of these programs for maximum effect.

In this paper, our objectives are as follows: i) To understand the spatial heterogeneity at the district levels in maternal (obesity) and child malnutrition (stunting, wasting and underweight) ii) To identify spatial clusters in terms of low and high burden areas where malnutrition is prevalent, and iii) to understand the underlying role that structural determinants such as agricultural productivity and poverty play in explaining malnutrition levels at sub-national levels. We study the relationship between agriculture and nutrition where agricultural productivity across the states reflects the stage of structural transformation process. Our analysis includes all districts of India and uses spatial regressions, instead of the standard OLS and hence circumvent the issue of spatial non-stationarity. While doing so, we contribute to the literature in multiple fronts. First, we present first evidence on the association between agricultural productivity and malnutrition across districts in India. Second, we use the most recent NFHS data to establish association between nutrition and its determinants using spatial regressions, which controls for neighborhood effects. Third, we use geographically weighted regression models to highlight relative saliency of variables by districts. Fourth, our chosen indicators for nutrition also include overweight and obesity, thereby capturing malnutrition in a broader manner. We must make it clear at the outset that this paper is not an attempt to provide any causal estimates of malnutrition. As the title suggests, we are interested in the association of nutrition with structural determinants. The aim is to highlight how they vary over space, by choice of nutritional indicator and the structural factors that explain these associations.

1.1. Role of agricultural productivity in structural transformation and nutrition

Extant literature on district wide variation in nutritional outcomes across India is sparse. Among them, (A. Ghosh, Gupta, and Spears 2014) focus on the prevalence of child stunting, while (Vepa et al. 2016) focuses on underweight children. These studies are limited in focus not only in the nutritional indicators they look at, but also in terms of the geographical coverage and nature of statistical relationship between nutritional outcomes and its determinants. For example, (A. Ghosh, Gupta, and Spears 2014) focus on 114 districts in the worst affected region of the country. (Vepa et al. 2016) ,on the other hand, though look at a larger set of districts, but these studies are estimate the point relationship between nutritional indicators and its determinants. (Madan et al. 2018) explore the intermediate determinants of malnutrition in children but they do not include obesity measures or structural determinants and do not use spatial methods to assess these relationships. While (Khan and Mohanty 2018) use spatial methods to explain the malnutrition in children, but their analysis does not look at determinants of obesity measures. None of these studies explore the structural determinants such as agricultural productivity. The correlates of poor nutritional outcomes often overlap- such as health, care giving practices, educational attainment, water, sanitation and hygiene, women's status in the society in addition to access to food. There are largely two problems with these approaches. First, these studies overlook at the role of agricultural productivity and structural transformation. Nutrition, its nature and determinants themselves co-evolve along the economic transformation kick-started by growth in agriculture and state support as discussed by Webb and Block (2014). They argue that child undernutrition drastically reduces with poverty reduction only when agriculture is supported as large number of undernourished live in rural areas and through support in agriculture rural incomes rise faster than urban incomes. However, obesity can rise in rural areas too with improved incomes. Therefore, they argue that a targeted agricultural support is required such that the negative consequences are outweighed. This makes a strong case for analyzing spatial clusters with disaggregated data.

Second, there is spatial heterogeneity in both the nutrition outcomes and the underlying factors used to explain them. Geographic approaches are important to address malnutrition at scale, since malnutrition is a multi-scalar issue with complex scalar interactions from the global to the individual, climate, agricultural practices, culture, trade and consumer choice (Beal and Ervin 2017). Hence, any statistical parameters of the association between nutritional drivers and its determinants need to be allowed to vary across regions to capture the observed heterogeneity. While the literature alludes to this detail, empirical estimates for the determinants of malnutrition happen to ignore the fact that point estimates mask great deal of heterogeneity. Spatial heterogeneity in the outcome as well as explanatory variables leads to the statistical problem of "spatial non-stationarity".
Agriculture growth is important to improve incomes of individuals. Increasing agricultural productivity has been the focus for many economies because it is necessary for sustained reduction of poverty and achieve higher standards of well-being. Three major processes constitute economic transformation: i) a falling share of agriculture in economic output and employment, ii) a rising share of urban population relative to rural population, and iii) rising contribution of industry and services in GDP (Timmer 2017). This relative decline in agriculture's contribution in economy is driven by rising agricultural productivity. Better agricultural

productivity leads to improvements in well-being and reduces malnutrition, but paradoxically it leads to higher obesity levels too (P. Webb and Block 2012).
India's agriculture has been underperforming overall with a growth of 2.8 percent from 1991/92 to 2008/09 and as of 2004/5 more than 52 percent of the labor force is directly engaged in agriculture (Gulati et al. 2012). There is a large variation and inter-regional disparities in agricultural performance across states in India. These disparities in agricultural development are attributed to variations in agro-climatic conditions and availability of resources such as irrigation, rural infrastructure etc. Several studies have argued that there is broadly non-convergence in the performance of agriculture across states and the disparities continue to exist (M. Ghosh 2006; Balaji 2014). Given that disparities exist due to varying degrees of access to inputs, district/state specific policy attention is required to raise agricultural performance and level the structural transformation process. The directed attention to agricultural performance is particularly important for sustained and equitable improvements in nutrition while mitigating any negative consequences of obesity and chronic diseases (Patrick Webb and Kennedy 2014).

1.2. Malnutrition in India – trends and regional variation

Nutrition in India has considerably improved in the last 3 decades, but the undernutrition rates in absolute as well as relative number, continue to remain at a very high level (Chatterjee 2007). Over 40 million stunted and 17 million wasted children under the age of 5 years, live in India (Raykar et al. 2015). Child stunting which has declined by a 10-percentage point between 2006 and 2016, but still stands at 38.4%. According to the NFHS 2015-16 data, around 20 percent of the men and women in India can be classified as obese. These trends reflect that multiple types of malnutrition issues are co-existing at the same time – thus, India is facing the triple-burden of malnutrition.

It is well recognized that the regional disparities in intake of calories as well as improvement in the determinants of nutrition are still a common feature. Whether disparities in income growth, governance structure and the associated factors affect nutrition across geographical space requires further probe.

Understanding regional variability in developmental outcomes is critical as larger units of analysis mask much of the variations within them. While the relevant political, administrative, social, and agro-ecological unit of analysis for choosing the unit of analysis is debatable and often depended upon data availability, more disaggregated geographic units provide us with more clarity (Kim, Mohanty, and Subramanian 2016). The poverty and inequality literature for India has devoted some attention to it. Kim, Mohanty, and Subramanian (2016) and Mohanty et al. (2016) show how local contexts matter, despite state boundaries being critical to overall development outcomes(Kim, Mohanty, and Subramanian 2016; Mohanty et al. 2016). Sub-national state units remain their importance in explaining much of the welfare outcomes as they are the most important geographical scale from the perspective of politics and administration. Regional clusters of poor and higher development outcomes are also a feature of district level variability. Studies have also shown clear spatial pattern and clustering in mortality rates across Indian districts (C. Kumar, Singh, and Rai 2012; Singh et al. 2011; Gupta, Ladusingh, and Borkotoky 2016; Ram et al. 2013).

Trends of a nutritional transition are being reflected in India. There has been a gradual shift in the consumption patterns with changes in demography, urbanization access to processed food and "westernization" of diets(Landy 2009; Shetty 2002; Pingali 2006). With growth income, households must diversify into other sources of calories e.g., milk products, meat, edible oils, and sugar (Gaiha et al. 2012). As a result, there has been an increase in dietary diversity, but a decline in the intake of overall calorie and protein, across the income distribution (Shankar et al. 2017). This has led to overall welfare gains across the income distribution (Li 2009). The government policy, however, continues to support production and consumption of staple grains, like rice and wheat, which has led to a disconnect between the supply and demand of food products (Pingali 2015). These shifts in diets and improvements in epidemiological environment have also been associated with the emerging issues of micro-nutrient deficiency and over nutrition. Rising evidences of obesity and non-communicable diseases leading to the triple-burden of malnutrition pose a serious problem to public health (Meenakshi 2016). Over nutrition has been thought of as something which is associated with more sedentary lifestyles because of increase in urbanization and higher incomes (Kulkarni, Kulkarni, and Gaiha 2013). However, Meenakshi (2016) argues that obesity is not only an urban phenomenon. She finds that the prevalence of overweight women in rural areas is higher than the percentage of thin women in the relatively richer states of Tamil Nadu, Kerala, Punjab and Himachal Pradesh.

2. Data and Measures

2.1. Data

We use data from the latest National Family Health Survey (NFHS) data for the year 2015-16. This survey is the fourth one in a series of cross-section surveys on population health and demography, being conducted under the supervision of Ministry of Health and Family Welfare (MoHFW), Government of India. This survey for the year 2015-16 contains a sample of approximately 568,200 households which comprised to total sample of 625,014 women, 93,065 men and 265,653 children (less than 5 years of age). NFHS surveys capture some of the most critical indicators on population, health and nutrition. The 2015-16 survey covers all the 640 districts in the country as per the latest census. For this time, the NFHS samples are also representative at the district level, which is being used in this paper. We use the district level aggregates from these surveys, provided by MoHFW as "District Fact Sheets" as the unit level data is not yet available for public use. We supplement this with the district level aggregated from decennial national census information on demographic and other socio-economic indicators. We use the 2011 census, which is the closest to the year in which NFHS has been carried out. We compile the district level data with average rainfall from 2001-2011 and average temperatures from 2001-2011 for each district. For the climate variables, we merge the data from AidGeo climate data. To account for topology of a given region as that can play a very important role, we classify the districts based on agro-ecological zones[2].

2.2. Measures

Outcome variables: Indicators for nutritional outcomes

The three standard anthropometric indicators used to measure child malnutrition are "height-for- age" representing stunting, "weight-for-height" is a marker of wasting, and "weight-for-age" symbolizes wasting. Child stunting is a sign of chronic undernutrition because it quantifies growth potential. It has been the commonly used metric for child nutrition in the literature is a cumulative indicator of nutritional deprivation from mother's womb onwards and is independent of immediate circumstances (Deaton and Drèze 2009), since height does not change much in the short term. Wasting captures acute undernutrition since it measures weight loss. It is, however, considered a short-term nutritional status, since weight of children fluctuate across the year. Underweight is a more comprehensive measure as it captures the combination of both wasting and stunting among children. In addition to these measures of child nutrition, we also include the prevalence of obesity (measured through body mass index (BMI)) and high blood pressure among women as indicators of over-nutrition and non-communicable diseases.

Structural determinants of nutritional indicators

We use the conceptual framework which was used by Smith and Haddad 2000 (Smith and Haddad 2000) and adapted from the UNICEF, 1990 framework - to identify the variables that can explain the spatial variation of nutritional outcomes at a district level. Figure A1 presents the classifications of the underlying factors: immediate, underlying and structural (Smith and Haddad 2000). Even though this conceptual framework was designed for child nutritional outcomes- we believe that these factors are represent determinants of women's nutrition. Dietary intake and health status are the immediate and direct ones, which are influenced by the underlying factors such as maternal nutrition, antenatal care, mother's age at conception, nutrient intake, child feeding practices, and mother care practices in addition to the public health environment. The indirect determinants of nutrition are the status of women in the society - such as women's education and agency, access to safe water and sanitation facilities and economic status of the households. The underlying structural factors- termed as the "basic determinants" include - the environment, technology and people- which translate onto the socio-cultural environment, political and economic structures of an economy.

[2] We classify this based on book chapter from (Mishra and Harriss-White 2015)

Most studies that analyze the underlying factors have focused on the immediate and underlying determinants (Menon et al. 2018). However, for a sub-national district level analysis, the structural factors play the most crucial role, and the current literature does not provide any evidence in this direction (Khan and Mohanty 2018). In this study, we are interested in the role of agricultural productivity in explaining the heterogeneity in nutritional outcomes. As reflected in the figure, the underlying and immediate determinates are affected by the structural drivers of malnutrition: per-capita national income, political environment and technological and natural resources to reducing malnutrition. Since in this analysis at macro level (district level), we use structural factors to explain variation in malnutrition across districts. As outlined in the conceptual framework, resources and technology form the fulcrum of the structural factors- which influence the structural transformation process. Agricultural productivity growth is dependent on the pace of technology adoption and increased use of agricultural inputs such as water and fertilizer. Furthermore, the state of technology provisioning and the institutional capability of the administrative units within an economy gets reflected in the provisioning of agricultural technology and infrastructure development- which in turn fuels agricultural productivity growth. Irrigation is a critical technology for agricultural productivity. There is enough evidence to show that improving the state of irrigation infrastructure has led to marked improvements in productivity (Jin et al. 2012; P. Kumar and Mittal 2006). We believe that irrigation not only reflects the state of agricultural technology and productivity but it also reflects the functioning of the administration at the local levels. Particularly, for an Indian context, where still a significant portion of agricultural production is rainfed – irrigation becomes a crucial technology. For these reasons, we include percentage of land irrigated in a district as *to reflect agriculture productivity* -suggesting better technology and greater input use.

We use the poverty headcount ratio to capture the overall wealth effect. Poverty levels are highly correlated with income levels and can lead to higher purchases of inputs of nutrition such as food, water, sanitation, and health. Improved incomes at a macro level can also influence the infrastructure and services at the district level. The indirect determinants are likely to be correlated with income levels at both individual levels and a macro level. Low levels of infrastructure, lack of education services may be correlated with the district level poverty level.

We do not include any of the intermediate determinants in our analysis as they are correlated with the poverty headcount ratio at the district level. Table A1 in the appendix shows the correlation matrix between the intermediate determinants such as the percentage of households receiving improved sanitation, electricity access, percentage women receiving antenatal care, children receiving health checkup after birth and women's education. Here we notice that all these intermediated determinants are highly correlated with structural variables such as poverty and urbanization.

Furthermore, we use the rate of urbanization as a proxy for infrastructural growth at the district level. Urbanization is correlated with increased non-farm opportunities, growing infrastructure such as roads, access to markets, etc. As societies go through a structural transformation process, urbanization captures the changing energy requirements, dietary habits, and lifestyle which proximate causes of obesity are. Nutrition transition is faster for those residing in urban areas or the periphery of it. Increasing rural-urban connectivity and increase in labor mobility has changed food environments, which has had a direct bearing on food choices, even in the rural areas (Hawkes, Harris, and Gillespie 2017).

Environmental factors are also structural can influence nutritional outcomes in a significant manner. To control for environmental factors, we use average temperatures/ rainfall variables and the agro-ecological zone classification within the Indian subcontinent. There are fifteen agricultural regions based on agro-climatic features, particularly soil type, climate including temperature and rainfall and its variation and water resources availability as under. These are: Western Himalayan division, Eastern Himalayan division, Lower Gangetic plain region, Middle Gangetic plain region, Upper Gangetic plain region, Trans-Gangetic plain region, Eastern plateau and hill region, Central plateau and hill region, Western plateau and hill region, Southern plateau and hill region, East coast plain and hill region, West coast plain and hill region, Gujarat plain and hill region, Western plain and hill region and Island region.

3. Methods

3.1. Assessing spatial autocorrelation

In this paper, we use various spatial analysis techniques to analyze the data- descriptive statistics, univariate LISA maps, Moran's I statistic and spatial regression models. As a first step, to identify clustering of the malnutrition variables, we first divide each of the district level variables- stunting, wasting, underweight, and obesity into quantiles and plot the data spatially after assigning each district to a geo-coded polygon. This way we can identify if there are any clustering patterns or not.

Spatial analysis assumes that values of an entity, in this case a district (*d*)- are dependent on other regions. That is, there is spatial autocorrelation within entities as nutritional outcomes in one region may impact other regions as well. To detect spatial autocorrelation, we use the Moran's I statistic- a global index of spatial autocorrelation: it reflects the overall degree of similarity between spatially close observations in a given study area (Stevens et al. 2008). The null hypothesis assumes no global spatial autocorrelation and the expected value of *I* is:

$$E(I) = -\frac{1}{N-1}$$

Where, if $I > E(I)$, it indicates positive spatial autocorrelation and negative autocorrelation if I is less than the expected value. We calculate the Moran's I for all the outcome variables as well as independent variables. If the Moran's *I* statistic takes the value 1, then it reflects perfect autocorrelation and 0 for no correlation. The univariate Moran's *I* scatter plot visualizes a spatial autocorrelation statistic as the slope of the regression line- where the original variable is plotted on the horizontal axis and a weighted average of the values of neighboring districts – called the spatial lag is plotted on the vertical axis. In this paper, we use these scatter plots to assess the level of autocorrelation and clustering.

The objective of the global Moran's *I* is to give an overall spatial autocorrelation, but it stops short when it comes to the location of the clusters. We do this by plotting the bivariate Local Indicators of Spatial Association (LISA) maps – which provide a measure of association for each spatial unit and identifies the type of correlation. The LISA maps categorize the spatial clusters into four groups as follows: categories with positive correlation, where the values of the neighboring districts are similar to the concerned district (high-high and low-low), and categories with negative correlation where the values of the neighboring districts are dissimilar to the concerned district (high-low and low-high). We map the associations of each of the nutrition variables with – percentage land irrigated, poverty headcount ratios and the rate of urbanization variables. To conduct this analysis, we use a very user-friendly software for spatial data analysis- GeoDa (Anselin, Syabri, and Kho 2006) and STATA (Pisati 2012).

3.2. Spatial Regression Analysis

In a simple linear regression framework, coefficient on the determinants of nutrition is estimated using an ordinary least squares (OLS) framework as expressed in equation (1), where Y_i is the outcome of interest and *X* is a vector of covariates.

$$Y_i = \alpha_i + \beta_i X_i + \varepsilon_i \tag{1}$$

In the case of spatial dependency or clustering among the outcome variables, the standard OLS assumption of the independence of error terms may not hold. In that case, the values observed at a region, say i, depends upon the values of its neighboring region, say j, and vice-versa. Hence, a system of equation needs to estimated. There are two variants of the spatial regression – spatial lag models and the spatial error model. Spatial lag models are very similar to the time series autoregressive models, where the current outcome depends upon the outcome in the previous time. The spatial lag models replace the element of time with space, in which the dependent variable Y_i is a function of weighted average of outcome Y, in its neighborhood. As we can see in equation (2), the weights are calculated based upon a spatial lag parameter, ρ, and spatial weight matrix, W_i. the error term, ε_i, is assumed to be independent and identically distributed. The coefficient β_i, is estimated here by controlling for the spatial dependency in outcome variables only.

$$Y_i = \rho_i W_i Y_i + \beta_i X_i + \varepsilon_i \tag{2}$$

In spatial error models, spatial dependence enters the model through the error *term,* ε_i, as represented in the equation (3a-3b). Here, λ_i is the spatial autoregressive parameter and W_i is the spatial weight parameter, based upon the geographic distance among the geographical units. In the case of spatial error models, β_i is estimated not only controlling for the spatial dependency in the outcome variables, but among the covariates as well.

$$Y_i = \alpha_i + \beta_i X_i + \varepsilon_i \tag{3a}$$

$$\varepsilon_i = \lambda_i W_i \varepsilon_i + \nu_i \tag{3b}$$

4. Results

4.1. Descriptive statistics

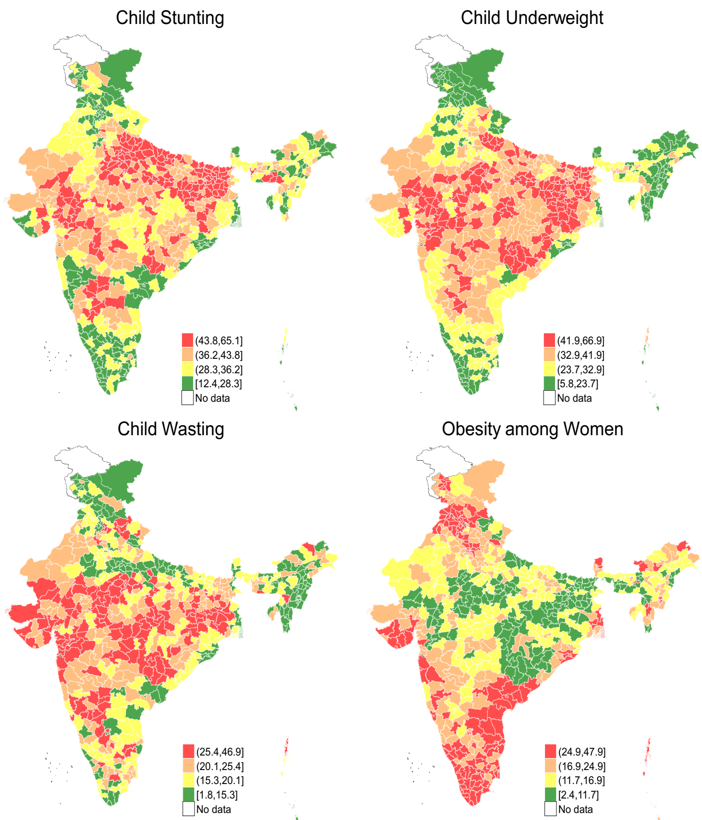
We first investigate the spatial patterns of stunting, wasting, underweight and obesity across districts of India. Figure 1 shows the maps for each of these variables. The districts are classified by quintile distribution of the variable where the highest number means high prevalence of each of the outcome variables. Visually, there is evidence of spatial clustering as suggested by these graphs for each of the outcome variables. For instance, high levels of stunting are highly clustered around the states of Uttar Pradesh and Bihar which lie in the upper/middle Gangetic plains of India. On the other hand, high rates of obesity can be visually seen in the high-income states of Tamil Nadu, Andhra Pradesh, Punjab and along the coastal regions. The prevalence of underweight and wasting reflects a similar spatial pattern as the stunting. Parts of Maharashtra and Gujarat seem to be reflecting a trend of triple burden of malnutrition. As shown in table 1, the average prevalence is highest for stunting followed by underweight and wasting. The variance for each of these variables is high suggesting that there is a lot of variation across districts.

Table 2 shows the distribution of 620 districts across the categories for each of the outcome variables. At the district level, the number of children who are wasted are less compared to underweight children and are highest for stunted children. There are almost an equal number of districts below/above the mean which is again reflective of the high variance. There is significant variation in the proportion of irrigated land across districts. The average lies around 50 percent across district but the range lies between no irrigation to almost 98 percent irrigation across districts.

4.2. Spatial autocorrelation

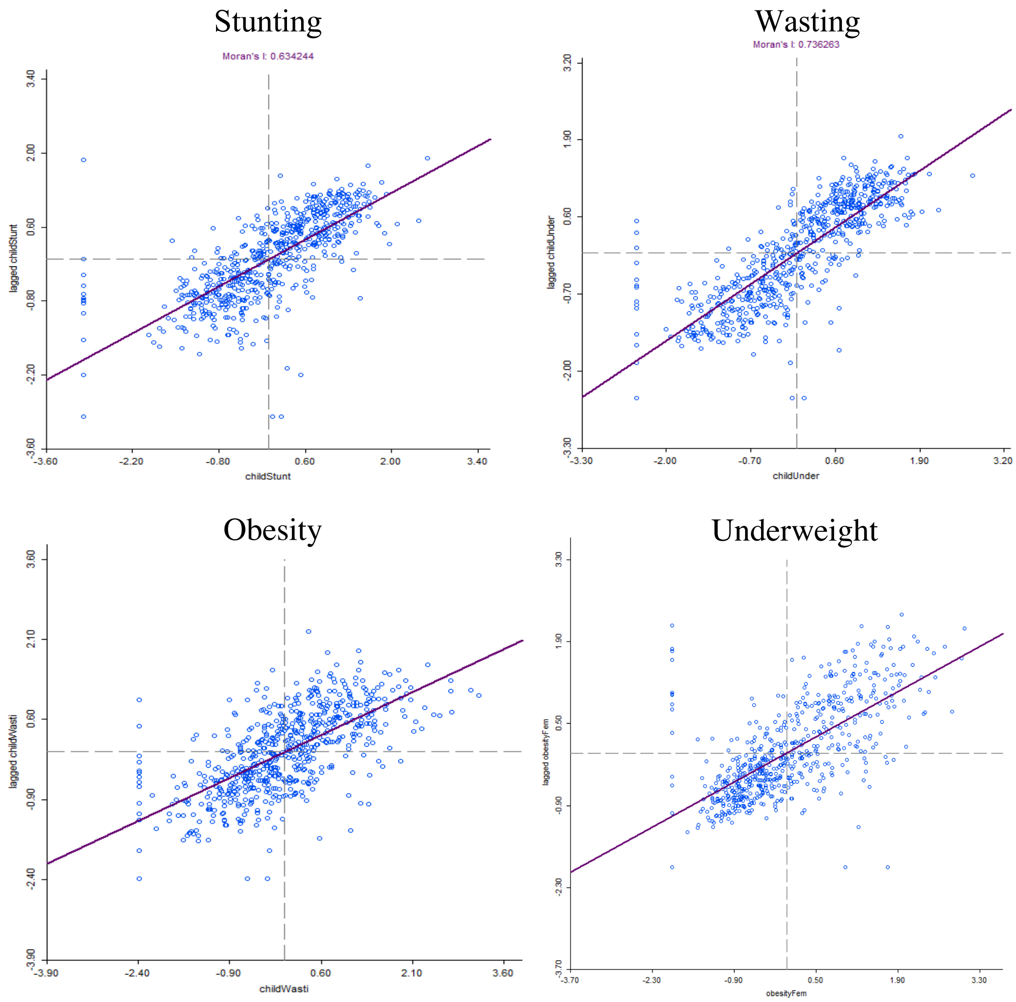
To investigate the claim of spatial clustering in malnutrition indicators, we calculate the Moran's *I* univariate and bivariate statistic. Table 3 and Figure 2, represent the extant of spatial autocorrelation among stunting, wasting, underweight and obesity among women across districts. Table 3 present the results from multivariate regression analysis. As represented graphically and numerically, there is very high prevalence of spatial autocorrelation. If the Moran statistic takes the value 1, then it reflects perfect autocorrelation and 0 for no correlation. This measures the spatial autocorrelation and it shows the degree of similarity in spatially close regions within a study area.

Figure 1: Nutritional outcomes across districts of India



The Moran *I* statistic is highest for undernutrition at 0.74, followed by 0.65 for stunting. The value for obesity are also high at 0.55 suggesting a strong spatial clustering of the values. In terms of the independent variables, the district level poverty head count ratio reflects a high value of 0.61 and percentage of irrigated land is also spatially auto correlated with a value of 0.42.

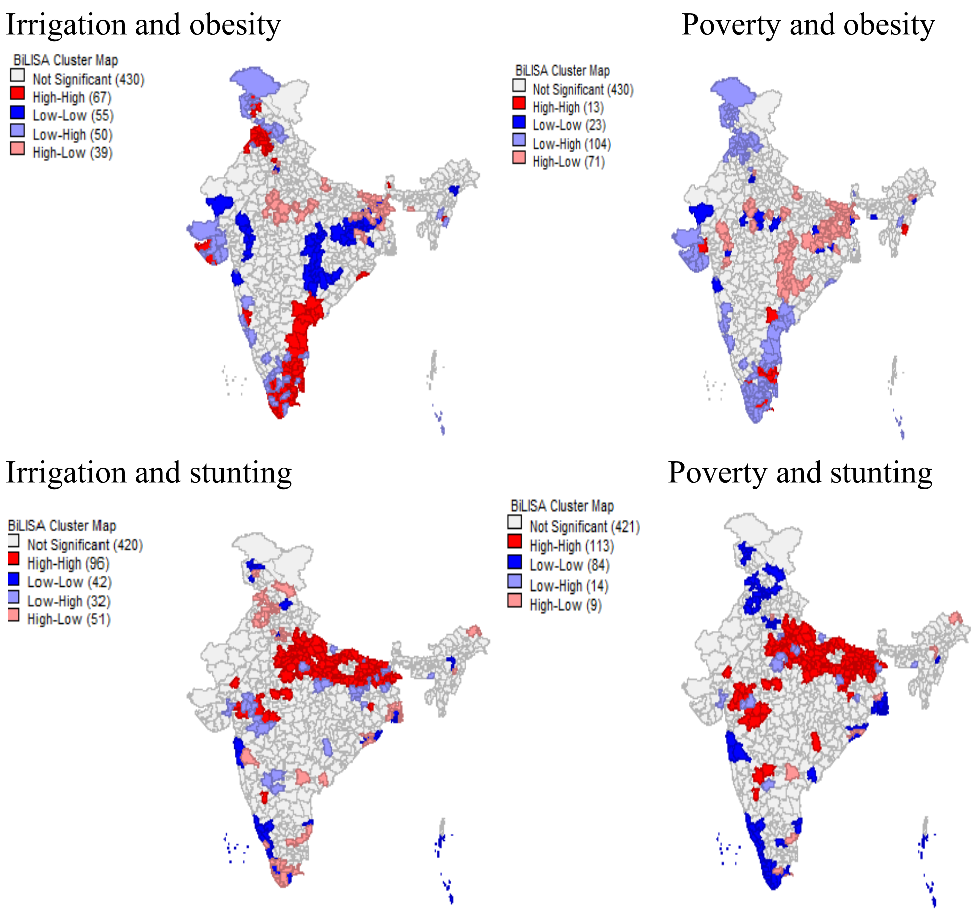
Figure 2: Global spatial autocorrelation using Univariate Moran's *I* statistic



To understand the clustering of two variables together, we calculated the bivariate Moran's *I* statistic for each of the malnutrition indicators with irrigation and the poverty head count ration for each district. The bivariate values show that spatial autocorrelation of stunting and underweight with the poverty head count ration were about 0.51 and about -0.40 with obesity among women and poverty, reflecting that higher income areas have a higher prevalence of obesity. We map these using Local Indicator Spatial Autocorrelation (LISA) maps to reflect the clustering. These maps show that about 11 percent of districts reflect high percentage of irrigated land and high obesity prevalence (Tamil Nadu, Odisha, Andhra Pradesh, Himachal Pradesh, Punjab and parts of Gujarat) and about 16 percent have high irrigation and high stunting (Uttar Pradesh, Bihar and Madhya Pradesh).

With respect to poverty, we see that Gujarat, Tamil Nadu, Andhra Pradesh, Karnataka and Punjab reflect low levels of poverty but higher prevalence of Obesity among women. Whereas, with respect to stunting, Uttar Pradesh, Bihar and parts of Madhya Pradesh have high rates of poverty and stunting.

Figure 3: Local Indicator Spatial Autocorrelation (LISA) maps to detect spatial clusters



In all the specifications, we find that irrigation is significant in explaining stunting, underweight and obesity prevalence. We find that an increase in the percentage of irrigated land leads to a decrease in stunting and underweight prevalence, but increases obesity among women.

4.3. Spatial Regression models

While highlighting the complexity of triple- burden problem these results show agricultural productivity is correlated with nutritional outcomes at an aggregate level. The associations suggest that a 1 percentage increase in the proportion of area under irrigation within a district reduces prevalence of stunting by 4 percent, underweight prevalence by 3 percent and increases prevalence of obesity by about 4 percent among women. Increase in the poverty headcount ratio decreases the prevalence of obesity but is positively associated with both stunting and underweight variables. More urbanization associates with low levels of stunting but high levels of obesity. We control for the agro-ecological zone clusters, we control for climatic and topographical differences to explain the variation among malnutrition indicators. After we adjust for the agro-ecological areas, irrigation doesn't explain wasting anymore. In terms of magnitude, poverty explains a major part of the prevalence of malnutrition. These results are robust to all specifications. The graphical analysis suggests a clear spatial clustering of the outcome variables. To test the presence of this pattern, we test for spatial auto-correlation using Moran test after OLS and we find that all these models reject the null hypothesis that the errors are independent and identically distributed. This confirms that are errors are spatially auto-correlated. This suggests that malnutrition among children as well as women is clustered spatially within certain districts in India and is not uniformly distributed.

To control for spatial auto-correlation in our estimation we estimate spatial autoregressive models (SEM). We consider both the spatial lag (Table 5) as well as the spatial error models (Table 6) for testing the robustness of the coefficients. The OLS models assume that the dependent variables are not correlated to each other, but that is violated as the spatial analysis suggests the presence of auto-correlation, where one districts malnutrition prevalence is correlated with nearby districts. To overcome this issue, we run a spatial lag model where the lagged value of the variable for the neighboring district is also included as an independent variable in the regression model- thus, accounting for the spatial dependence. As shown in table 5, the lagged terms are significant for all models except wasting. Therefore, the coefficients of poverty, irrigation and urbanization are after controlling for the lagged values. These models too confirm the association of agricultural productivity and poverty with stunting, underweight and obesity prevalence. In comparison to the OLS results, the SEM models have slightly lower coefficients, but the strength of the relationship remains the same. For stunting and underweight, results suggest that an increase in poverty, decrease in urbanization and a decrease in irrigation increases these outcomes. While, for obesity we see opposite patterns. Rising poverty leads to an increase in wasting results too. These results are in line with the OLS model, bust are adjusted for the spatial autocorrelation. The magnitudes are still the highest for poverty, followed by irrigation.

The lag coefficients are significant in both the SEM models suggesting that outcome variables in one district are correlated with that of neighboring districts. The errors are significant only in the case of stunting and wasting. This suggests that any district specific shock to the omitted variables within these models will not only affect the district, but is also likely to affect the neighboring districts. However, the results suggest that this might not be true in the case of obesity and underweight models. These results suggest that after accounting for the spatial dependencies, rising incomes, agricultural productivity and higher rates of urbanization are associated with lower stunting, underweight and higher prevalence of obesity among women. These results confirm the structural transformation and the associated nutrition transformation.

5. Discussion and Conclusion

Malnutrition, especially among children and women in the reproductive age group, puts massive development and welfare objectives because of its long-term implication for human capital. Addressing malnutrition in its multiple dimensions, hence, remains an imperious challenge across the world and among nations. The importance of this issue is highlighted in the sustainable development goals, and many countries are working towards reducing malnutrition. However, the problem is complex and is multidimensional. Despite reductions in the prevalence of stunting over time in India, large intra and inter-district variations exist. Coupled with undernutrition, there are signs of overnutrition in the better off states such as Tamil Nadu, Kerala, Karnataka, and Punjab. Some districts are grappling with both undernutrition as well as obesity simultaneously. These patterns across districts are concerning and require an immediate understanding of the factors that are associated with this phenomenon.

Agricultural productivity is imperative for giving impetus to the process of economic development and well-being. It is imperative for the structural transformation process to take place. In economies that are heavily dependent on agriculture, reductions in levels of malnutrition go together with improvements in well-being through increasing agricultural productivity. Our results suggest that agricultural productivity is negatively associated with the prevalence of stunting, underweight but positively associated with obesity among women. This paradox reflects the complex challenges associated with the structural transformation process which govern the stages of economic development. Reduction in poverty and increase the levels of urbanization across districts reduce child undernutrition but increase obesity. Our results also show malnutrition is spatially clustered and it is important to note that while designing the policies.

Our study has several unique strengths. Previous studies have looked at the intermediate determinants such as women's education, access to healthcare, sanitation etc. Given the inter-regional variations and multi-dimensionality of the problem, we think structural factors such as agricultural productivity is significant. Our study addresses this gap by exploring the links between agriculture, poverty, and nutrition. Since most of the outcomes are spatially clustered, child/women level analysis may ignore the spatial dimension. These regions lie in different agro-ecological zones, experience different climatic effects and undergo a different process of economic development. Accounting for these differences is imperative for an equitable, sustained and directed policy interventions. By merging different data sources and using the latest national data on health (NFHS 4), we account for climatic, agro-ecological and clustering in our analysis. Our findings contribute timely for directed interventions by the government of India for fulfilling their commitments towards achieving the SDG's.

Our findings have significant policy implications. First, we provide the first evidence on the growing concern of obesity among women. So far, the attention of policymakers has centered on undernutrition on children, but rising levels of obesity in relatively prosperous and literate regions adds a dimension of complexity in the current challenge and needs immediate attention. Second, agricultural productivity plays a key role and is associated with malnutrition, negatively with undernutrition and positively with obesity. Importance must be given to the stage of structural transformation process so that improvements are not mitigated by other malnutrition challenges.

Effective policies to tackle this complex interplay between economic development and malnutrition are required. Third, we show that there is significant inter-region variation in the outcomes and the policy changes need to be made at the district-level/disaggregated level. Agricultural productivity and poverty reduction vary based on the level of human capital, industrial capital, and other endowments. The strategies and policy options would thus, be region specific, based on resource endowments and the type of malnutrition problem.

TABLES

Table 1: Descriptive statistics of outcome and control variables
(District level, India)

	N	Mean	SD	Min	Max
Stunting	620	36.15	9.89	12.40	65.10
Wasting	620	20.71	7.69	1.80	46.90
Underweight	620	32.92	11.73	5.80	66.90
Obesity (Women)	620	18.41	8.65	2.40	45.50
Proportion of irrigated land	620	52.66	19.85	3.66	98.38
Urbanization	620	24.45	17.75	0.00	99.75
Poverty head count ratio	605	34.26	18.65	0.31	94.97
Population (log)	620	14.05	1.06	8.99	16.22
Average temperature during 2001-10	620	24.21	4.74	-2.70	29.38
Average rainfall during 2001-10	620	365.94	402.34	0.00	5036.10

Table 2: Distribution of outcome variables (out of 620 districts)

Stunting		Wasting		Underweight		Obesity	
43.8-65.1	156	25.4,46.9	158	41.9-66.9	158	24.9-47.9	143
36.2-43.8	165	20.1,25.4	151	32.9-41.9	158	16.9-24.9	159
28.3-36.2	148	15.3,20.1	152	23.7-32.9	152	11.7-16.9	158
12.4-28.3	151	1.8,15.3	159	5.8-23.7	152	2.4-11.7	160

Table 3: Moran I statistic (Univariate) (out of 620 districts)

Variable	Moran I Statistic - Univariate
Child Stunting	0.634
Child Wasting	0.736
Child underweight	0.535
Obesity (Female)	0.555

I. OLS

Table 4: Results from OLS showing the relationship between stunting, underweight, wasting, obesity with irrigation (Controls + agro-climatic zones+ climate)

	(1) Stunting b/se	(2) Wasting b/se	(3) Underweight b/se	(4) Obesity(Women) b/se
Proportion of irrigated land	-0.04*	-0.02	-0.04*	0.04**
	(0.02)	(0.02)	(0.02)	(0.01)
Urbanization	-0.09***	0.01	-0.05**	0.17***
	(0.02)	(0.02)	(0.02)	(0.01)
Poverty head count ratio	0.13***	0.08***	0.16***	-0.08***
	(0.02)	(0.02)	(0.02)	(0.01)
Population (log)	0.22	-0.87+	-0.46	0.89*
	(0.54)	(0.51)	(0.55)	(0.35)
Average temperature during 2001-10	0.18+	0.01	0.24*	0.04
	(0.10)	(0.09)	(0.10)	(0.07)
Agro-Climatic zones*	YES	YES	YES	YES
Constant	27.79***	32.13***	32.80***	2.06
	(7.07)	(6.64)	(7.15)	(4.62)
Adj. R-Square	0.64	0.46	0.73	0.80
N	605.00	605.00	605.00	605.00

* There are fifteen agricultural regions based on agro climatic features, particularly soil type, climate including temperature and rainfall and its variation and water resources availability as under: *Western Himalayan division, Eastern Himalayan division , Lower Gangetic plain region , Middle Gangetic plain region, Upper Gangetic plain region, Trans-Gangetic plain region, Eastern plateau and hill region, Central plateau and hill region, Western plateau and hill region , Southern plateau and hill region, East coast plain and hill region, West coast plain and hill region, Gujarat plain and hill region, Western plain and hill region and Island region*

II. Spatial lag model

Table 5: Results from Spatial lag model showing the relationship between stunting, underweight, wasting, obesity with irrigation (Controls + agro-climatic zones+ climate)

	(1) Stunting b/se	(2) Wasting b/se	(3) Underweight b/se	(4) Obesity (Women) b/se
Proportion of irrigated land	-0.03*	-0.02	-0.03+	0.03**
	(0.01)	(0.02)	(0.01)	(0.01)
Urbanization	-0.08***	-0.01	-0.08***	0.17***
	(0.01)	(0.02)	(0.02)	(0.01)
Poverty head count ratio	0.09***	0.05**	0.11***	-0.06***
	(0.02)	(0.02)	(0.02)	(0.01)
Population (log)	0.48	-0.15	0.67+	0.31
	(0.35)	(0.36)	(0.36)	(0.24)
Average temperature during 2001-10	0.01	-0.03	0.09	-0.01
	(0.08)	(0.08)	(0.08)	(0.05)
Agro-Ecological Zones*	YES	YES	YES	YES
Constant	9.17+	11.82*	4.47	-2.68
	(4.82)	(5.28)	(4.64)	(3.22)
Stunting	0.60***			
	(0.07)			
Wasted		0.62***		
		(0.11)		
Underweight			0.58***	
			(0.06)	
Obesity (Women)				0.60***
				(0.05)
N	605.00	605.00	605.00	605.00

* There are fifteen agricultural regions based on agro climatic features, particularly soil type, climate including temperature and rainfall and its variation and water resources availability as under: *Western Himalayan division, Eastern Himalayan division , Lower Gangetic plain region , Middle Gangetic plain region, Upper Gangetic plain region, Trans-Gangetic plain region, Eastern plateau and hill region, Central plateau and hill region, Western plateau and hill region , Southern plateau and hill region, East coast plain and hill region, West coast plain and hill region, Gujarat plain and hill region, Western plain and hill region and Island region*

III. Spatial Error Model

Table 6: Results from Spatial error model showing the relationship between stunting, underweight, wasting, obesity with irrigation (Controls + agro-climatic zones+ Climate)

	(1) Stunting b/se	(2) Wasting b/se	(3) Underweight b/se	(4) Obesity(Women) b/se
Proportion of irrigated land	-0.03*	-0.02	-0.03^{+}	0.03**
	(0.01)	(0.01)	(0.01)	(0.01)
Urbanization	-0.08***	-0.01	-0.07***	0.17***
	(0.01)	(0.01)	(0.01)	(0.01)
Poverty head count ratio	0.08***	0.04**	0.11***	-0.06***
	(0.02)	(0.02)	(0.02)	(0.01)
Population (log)	0.45	-0.11	0.63^{+}	0.35
	(0.33)	(0.32)	(0.36)	(0.24)
Average temperature during 2001-10	0.01	-0.02	0.09	-0.00
	(0.07)	(0.07)	(0.08)	(0.06)
Agro-Ecological Zones*	YES	YES	YES	YES
Constant	7.16	7.86^{+}	4.18	-3.94
	(4.38)	(4.37)	(4.66)	(3.23)
Stunting	0.67***			
	(0.06)			
e. Stunting	-0.35***			
	(0.10)			
Wasted		0.76***		
		(0.09)		
e. Wasted		-0.48***		
		(0.13)		
Underweight			0.61***	
			(0.06)	
e. Underweight			-0.04	
			(0.10)	
Obesity(Women)				0.65***
				(0.05)
e. Obesity(Women)				-0.03
				(0.09)
N	605.00	605.00	605.00	605.00

* There are fifteen agricultural regions based on agro climatic features, particularly soil type, climate including temperature and rainfall and its variation and water resources availability as under: *Western Himalayan division, Eastern Himalayan division , Lower Gangetic plain region , Middle Gangetic plain region, Upper Gangetic plain region, Trans-Gangetic plain region, Eastern plateau and hill region, Central plateau and hill region, Western plateau and hill region , Southern plateau and hill region, East coast plain and hill region, West coast plain and hill region, Gujarat plain and hill region, Western plain and hill region and Island region*

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APPENDIX

Chapter two

A21: Domains included in each of the sub-indicators in A-WEAI and WEAI_S

No.	Domain (Original WEAI)	**A-WEAI**	**Inclusions/Exclusions for this study**	**Weights**
1	Input in production decisions	Included	Included	1/5
	Relative autonomy	Not included	Not included	0
2	Ownership of assets	Included	Included	1/10
	Purchase/Sale of assets	Not included	Not Included	0
	Decisions on credit	Included	included	1/10
3	Control over income	Included	Included	1/5
4	Group membership	Included	Included	1/5
	Speaking in public	Not included	Not included	0
5	Workload	Included	Included	1/5
	Leisure	Not included	Not Included	0

A22: Test of differences across years in sub-indicators (WEAI_S)

	2014mean	2016mean	Difference	(p-value)
Input	0.66	0.62	0.04	0.09
ownership	0.06	0.23	-0.17	0
Credit Decisions	0.69	0.46	0.23	0
Income control	0.92	0.84	0.07	0
Group membership	0.46	0.34	0.12	0
Workload	0.61	0.49	0.12	0
Leisure	0.97	0.88	0.08	0
Empowerment	0.68	0.68	0	0.82

A23: Categorization of women's change in empowerment

Categories	Freq.	Percent	Cum.
Decrease in empowerment	375	42.42	42.42
No change in empowerment	135	15.27	57.69
Increase in empowerment	374	42.31	100.00
	Total	884	100.00

A24: Different specifications of the relationship between change in empowerment and change in nutritional outcomes

	Calories (Kcal)	Calories (Kcal)	Calories (Kcal)
Change in women's empowerment	-446.8* (162.1)	-446.8** (159.1)	-442.7** (158.4)
Income from livestock sale and produce (Rs.)	0.493 (3.865)	0.493 (4.710)	0.452 (4.702)
Woman's agricultural wage income (Rs.)	-5.261 (10.64)	-5.261 (8.442)	-5.337 (8.441)
Woman's non-farm income (Rs.)	1.630 (3.103)	1.630 (3.633)	1.573 (3.628)
Income from sale of cash crops (Rs.)	-0.0197 (0.758)	-0.0197 (0.689)	-0.0362 (0.692)
Income from sale of cereal crops (Rs.)	3.051^{+} (1.713)	3.051 (2.019)	3.043 (2.020)
Production diversity of non-staples	182.7** (50.77)	182.7** (63.44)	183.1** (63.53)
Square of Empowerment			267.5 (476.8)
Constant	-19.42 (54.02)	-19.42 (49.92)	-38.48 (60.66)
Observations	883	883	883
Adjusted R^2	0.016	0.016	0.016

A25: Relationship between change in empowerment using sub-indicators and change in nutritional outcomes

	Change in share of consumption of F&V in total consumption	Change in share of consumption of F&V in total consumption	Change in share of consumption of F&V in total consumption	Change in share of consumption of F&V in total consumption	Change in share of consumption of F&V in total consumption	Change in share of consumption of F&V in total consumption
Input in decision making						
No change	0.0341* (0.0137)					
Increase	0.0469** (0.0169)					
Ownership of assets						
No change		0.126*** (0.0352)				
Increase		0.0983** (0.0373)				
Decisions on credit						
No change			-0.0255 (0.0176)			
Increase			-0.00340 (0.0266)			
Control over income						
No change				-0.00324 (0.0173)		
Increase				0.0227 (0.0250)		
Group membership						
No change					-0.0156 (0.0160)	

Increase					0.0288 (0.0211)	
Leisure						
No change						0.0577** (0.0176)
Increase						0.0609 (0.0372)
Income from livestock sale and produce (Rs.)	-0.000278 (0.000519)	-0.00135+ (0.000688)	-0.000190 (0.000848)	-0.000256 (0.000611)	0.000119 (0.000626)	-0.000407 (0.000517)
Woman's agricultural wage income (Rs.)	0.00459*** (0.00138)	0.00475** (0.00181)	0.00350 (0.00243)	0.00386* (0.00160)	0.00388* (0.00175)	0.00487*** (0.00138)
Woman's non-farm income (Rs.)	-0.000634 (0.000567)	-0.000668 (0.000744)	-0.000681 (0.000832)	-0.000915+ (0.000544)	0.0000623 (0.000944)	-0.000731 (0.000565)
Income from sale of cash crops (Rs.)	-0.0000666 (0.000084)	-0.0000247 (0.000101)	-0.00000135 (0.00009)	-0.0000370 (0.000080)	-0.0000856 (0.000102)	-0.0000836 (0.000084)
Income from sale of cereal crops (Rs.)	-0.000145 (0.000245)	-0.000364 (0.000281)	-0.000143 (0.000313)	-0.000223 (0.00025)	0.000181 (0.000302)	-0.000105 (0.000245)
Production diversity of non-staples	-0.0274*** (0.00774)	-0.0192* (0.00934)	-0.00642 (0.0106)	-0.0271** (0.00839)	-0.0321** (0.00988)	-0.0282*** (0.00774)
Constant	0.0108 (0.0118)	-0.0525 (0.0341)	0.0583*** (0.0146)	0.0506** (0.0163)	0.0418** (0.0134)	-0.0129 (0.0170)
Observations	881	421	316	542	497	879
Adjusted R^2	0.033	0.048	-0.009	0.023	0.028	0.035

A26: Adequacy requirements for AWEAI and WEAI_S and their associated weights

Sub-indicators	AWEAI	WEAI_S (Our analysis)	Weights
Input in production decisions	*Has some input or feels can make decision at least two activities* Food crop farming Cash crop farming Livestock raising Fisheries	*Same as the A-WEAI*	**1/5**
Ownership of assets	*Adequate if self/joint owns at least two small assets or if households owns one large asset* Agricultural land, large livestock, small livestock, fishing equipment, farm equipment (mechanized /non-mechanized), non-farm business equipment, house, large consumer durables, small consumer durables, cell phones, non- agricultural land, means of transportation	*Adequate if self/joint ownership of* agriculture land owned by women	**1/10**
Decisions on credit	*Adequate if self/joint makes decisions regarding credit and has at least one credit* NGO, formal lender, informal lender, friends and relatives, group-based MFI, informal group-based	*Same as the A-WEAI*	**1/10**
Control over income	*Adequate if there is at least one domain in which individual has some input or feels can make decisions regarding wage employment and minor household expenditures.* Food crop farming, cash crop farming, livestock raising, non-	*Adequate if there is at least one domain in which individual has input in controlling income:* Income from sale of crops Income from sale of livestock Income from collection of forest produce Income from ag- daily labor	**1/5**

	farm activities, wage and salary employment, minor and major household expenditures fishing		
Group membership	*Adequate if a woman is a member of at least one group* Agricultural/livestock/fisheries producer groups, water users group, forest users group, credit or microfinance group, mutual help/insurance group, Trade and business association group, civic group, other group	*Adequate if a women is a member of at least one group:* Agricultural/livestock/fisheries producer groups, water users' group, forest users group, credit or microfinance group (SHG).	**1/5**
Workload	Adequate if time spent in primary activities is less than 10.5 hours	Included only the time spent on agriculture-based activities.	**1/10**
Leisure	Adequate if women are satisfied with the time that they get for leisure	Same as AWEAI	**1/10**

Chapter 3

Figure A31: Conceptual framework: Determinants of children's nutritional status.

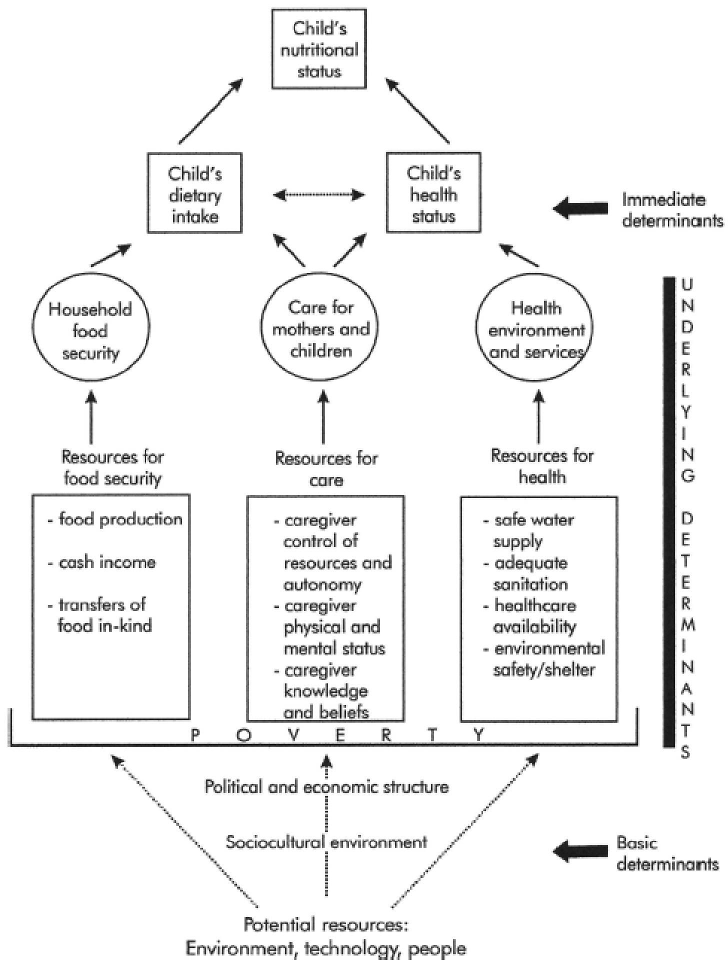

Table A32: Correlation matrix of variables

	1	2	3	4	5	6	7	8	9	10	11
1. **Irrigation**	1										
2. **Urbanization**	0.1	1									
3. **Poverty**	-0.09	-0.34	1								
4. **Average temperature**	0.14	0.13	0.24	1							
5. **Average rainfall**	-0.1	0.21	-0.27	0.1	1						
6. **Total open Defecation**	-0.04	-0.55	0.58	0.3	-0.29	1					
7. **At least 4 antenatal care visits**	-0.1	0.4	-0.42	0	0.37	-0.43	1				
8. **Checkup within 2 days of birth**	0.08	0.23	-0.18	0.19	0.21	-0.15	0.53	1			
9. **Females with > 10 yrs. of school**	0.15	0.52	-0.56	-0.1	0.31	-0.62	0.52	0.39	1		
10. **% of hhs. with improved sanitation**	0.01	0.49	-0.66	-0.23	0.3	-0.87	0.45	0.21	0.68	1	
11. **% of hhs. with electricity**	-0.13	0.45	-0.54	-0.14	0.24	-0.5	0.63	0.3	0.5	0.61	1

Table A33: Results from OLS showing the relationship between stunting, underweight, wasting, obesity with irrigation (Specification 1) (N=602)

	(1)	(2)	(3)	(4)
	Stunting	Wasted	Underweight	Obesity (Women)
	b/se	b/se	b/s	b/s
Proportion of irrigated land	-0.07***	-0.06***	-0.08***	0.08***
	(0.02)	(0.02)	(0.02)	(0.02)
Constant	39.60***	23.71***	*	*
	(1.02)	(0.91)	(1.0	(0.83)
Adj. R-Square	0.55	0.41	0.6	0.6

Table A34: Results from OLS showing the relationship between stunting, underweight, wasting, obesity with irrigation (Specification 2) (N=602)

	(1) Stunting b/se	(2) Wasted b/se	(3) Underweight b/se	(4) Obesity(Wome b/s
Proportion of irrigated land	-0.04*	-0.04*	-0.05**	0.05***
	(0.02)	(0.02)	(0.02)	(0.01)
urbanization	-0.09***	0.01	-0.05**	0.17***
	(0.02)	(0.02)	(0.02)	(0.01)
Poverty head ratio	0.15***	0.10***	0.19***	-0.10***
	(0.02)	(0.02)	(0.02)	(0.01)
Population (log)	0.57	-1.12*	-0.27	1.25***
	(0.51)	(0.48)	(0.52)	(0.34)
Constant	27.62***	34.88***	34.39***	-2.39
	(6.91)	(6.55)	(7.06)	(4.63)
Adj. R-Square	0.6	0.42	0.71	0.7

Table A35: Results from OLS showing the relationship between stunting, underweight, wasting, obesity with irrigation (Specification 3: Controls + agro-climatic zones) (N=602)

	(1) Stunting	(2) Wasted	(3) Underweight	(4) Obesity (Women)
	b/se	b/se	b/s	b/s
Proportion of irrigated land	-0.04*	-0.02	-0.04*	0.04**
	(0.02)	(0.02)	(0.02)	(0.01)
Urbanization	-0.09***	0.01	-0.06**	0.17***
	(0.02)	(0.02)	(0.02)	(0.01)
Poverty head count	0.14***	0.08***	0.16***	-0.08***
	(0.02)	(0.02)	(0.02)	(0.01)
Population (log)	0.55	-0.86+	-0.02	0.98**
	(0.51)	(0.48)	(0.52)	(0.33)
Agro-ecological zone dummies	Yes	Yes	Yes	Yes
Constant	27.52***	32.12***	32.45***	1.99

Table A: Results from OLS showing the relationship between stunting, underweight, wasting, obesity with irrigation (Specification 4: Controls + agro-climatic zones+ rainfall) (N=602)

	(1) Stunting	(2) Wasted	(3) Underweight	(4) Obesity (Women)
	b/se	b/se	b/se	b/se
Proportion of irrigated land	-0.04*	-0.02	-0.04*	0.04**
	(0.02)	(0.02)	(0.02)	(0.01)
Urbanization	-0.09***	0.01	-0.06**	0.17***
	(0.02)	(0.02)	(0.02)	(0.01)
Poverty head count ratio	0.13***	0.08***	0.16***	-0.08***
	(0.02)	(0.02)	(0.02)	(0.01)
Population (log)	0.55	-0.95*	-0.07	0.91**
	(0.51)	(0.48)	(0.51)	(0.33)
Percentage change in rain between and 2000s	-0.06	0.02	-0.05	0.06**
	(0.04)	(0.03)	(0.04)	(0.02)
Agro-ecological zone dummies	Yes	Yes	Yes	Yes
Constant	27.45***	33.53***	33.11***	3.17
	(7.10)	(6.63)	(7.18)	(4.61)
Adj. R-Square	0.63	0.46	0.73	0.80