You eat what you work - livelihood strategies and nutrition in the rural-urban interface

by Anjali Purushotham and Linda Steinhübel

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Abstract

To understand how rural transformation affects smallholder welfare, it is important to understand the links between household livelihood strategies and nutrition. As cities all over the world grow, an increasing number of smallholders find themselves in the interface between rural and urban areas where they are confronted with trade-offs in decision making regarding production (agricultural operations vs. off-farm employment) and consumption (own produced vs. purchased food from different markets). In such contexts, we are particularly interested in the full composite effect of different employment choices on household nutrition—an aspect often neglected in the literature. To do so, we propose a conceptual framework that considers agricultural production for own consumption, income-generating agricultural operations and off-farm employment, and the role of market access in explaining household nutrition. Then, we use primary socio-economic survey data from the rural-urban interface of Bangalore, a megacity in southern India, to test the interactions displayed in the conceptual framework. We apply a multivariate regression for household-level nutrient adequacy ratios (HNARs) of three macronutrients (calories, protein, and fat) and three micronutrients (vitamin A, iron, and zinc). Our results show that the mix of different agricultural operations and off-farm employment are important to explain households' nutritional status. Furthermore, our results imply that the relationship between income generated through agriculture and off-farm employment and nutrition is non-linear, with a threshold, beyond which further increase in

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income associated with overnutrition. Also, we find that undernutrition is most prevalent in socio-economically disadvantaged households.

Keywords: livelihood strategies, nutrition transition, nutrient adequacy ratio, multivariate regression, rural-urban interface.

1. Introduction

Rural livelihoods are changing in many low- and middle-income countries (LMICs) around the world. Urbanization, improved infrastructure, and access to new technologies are just some of the factors changing the way smallholder households earn a living and shape their lives (Schneider & Woodcock, 2008; Vandercasteelen et al., 2018). Literature shows that once provided with better market access, smallholder households are likely to diversify their livelihood strategies and that there are trade-offs in household decision-making regarding the allocation of labor into the farm and/or off-farm sectors (Diao et al., 2019; Steinhübel & Cramon-Taubadel, 2020). This can mean a shift from labor-intensive subsistence agriculture to commercialized agricultural operations (Pingali, 2007a; Damania et al., 2017; Vandercasteelen et al., 2018) and/or an increased share of household labor allocated into off-farm employment (Haggblade et al., 2010; Fafchamps & Shilpi, 2003; Deichmann et al., 2009).

Of developmental relevance is the question of how these changes in employment affect the living standards and food security of smallholder households. Several studies have analyzed the effects of commercialized agriculture and off-farm employment on household income and living standards, generally finding a positive association (Haggblade et al., 2010; Imai et al., 2015; Ogutu & Qaim, 2019; Pfeiffer et al., 2009). The patterns often become complex when it comes to their effect on household food security and nutrition.

The existing literature on the link between smallholder employment and food security can generally be divided into two strands. The first addresses the role of agricultural operations on household food security. The second strand is concerned with the effects of off-farm employment.

Regarding agricultural operations, some studies emphasize increased on-farm production diversity as a means to increase dietary diversity (Ecker, 2018; Jones et al., 2014). However, this link mainly applies to subsistence farmers and becomes weaker when households shift to commercialized agricultural operations (Muthini et al., 2020; Pingali & Sunder, 2017; Sibhatu et al., 2015; Sibhatu & Qaim, 2018). In many cases, households' market participation reduces the role of on-farm production diversity in increasing their dietary diversity (Pingali & Sunder, 2017; Sibhatu et al., 2015). While some studies show that agricultural commercialization improves household nutrition (Ntakyo & van den Berg, 2019; Cazzuffi et al., 2020), the recent evidence suggests a weaker relationship between the two (Carletto et al., 2017; Radchenko & Corral, 2018).

As for the effect of off-farm employment, it increases households' expenditure on diversified diet and leads to improved nutrition security (Babatunde & Qaim, 2010; Owusu et al., 2011; Rahman & Mishra, 2019; D'Souza et al., 2020). However, the forces of urbanization, globalization, access to modern food outlets, and lifestyle change increase the intake of sugar, salt, oil, snacks, and sweetened beverages (Cockx et al., 2018; Pingali, 2007b; Pingali & Khwaja, 2004; Popkin, 1999). Furthermore, participation in off-farm activities increases the opportunity cost of cooking food at home and the consumption of convenience foods away from home (Kennedy & Reardon, 1994; Regmi & Dyck, 2001). The resulting increase in the intake of energy-dense food items together with changes in work effort due to the shift in occupation patterns has lead to multiple forms of malnutrition in many LMICs (Popkin et al., 2020; Meenakshi, 2016).[3] Thus, it is important to understand how different employment choices of households and the resulting income generation are linked to their nutrition from the perspective of malnutrition.

We argue that solely focusing on either the effects of agricultural operations or the effects of off-farm employment is not sufficient to understand the full effect of households' employment choices on their nutritional status. Particularly when households engage in several livelihood strategies at the same time, the net effect of interacting changes in production, income, and consumption decisions can be highly complex. Thus, different employment choices and their combinations, depending on the access to labor, agricultural, and food markets, affect household nutrition in different ways. We visualize this literature gap in Fig. 1. Based on recent findings in the literature (Diao et al., 2019; Steinhübel & Cramon-Taubadel, 2020), we argue that most smallholder households will fall in one of the four white

[3] Until recently malutrition was synonymous with undernutrition/hunger. However, two other forms – overnutrition and micronutrient deficiency – have been included ((Development Initiatives, 2017)). In many cases multiple burdens of manutrition co-exists at individual-, household-, community-, and country-level and they are termed as double burden of malnutrition (co-existence of under- and overnutrition) and triple burden of malnutrition (co-existence of undernutrition, overnutrition, and micronutrient deficiency).

boxes (Fig. 1) when aligning them according to their (i) agricultural operations and (ii) off-farm employment decisions. This means that households' livelihood depends on a composite of agricultural operations and off-farm employment. However, for studies in the first strand of literature discussed before, boxes (a) and (b) are normally the points of departure. Authors are interested in what happens when farmers move from the box (a) to box (b) not paying much attention to off-farm employment. Studies in the second strand of literature rather place their households in boxes (d) and (e) in Fig. 1 analyzing implications of off-farm employment and lifestyle changes on nutrition disregarding remaining agricultural operations of the household.

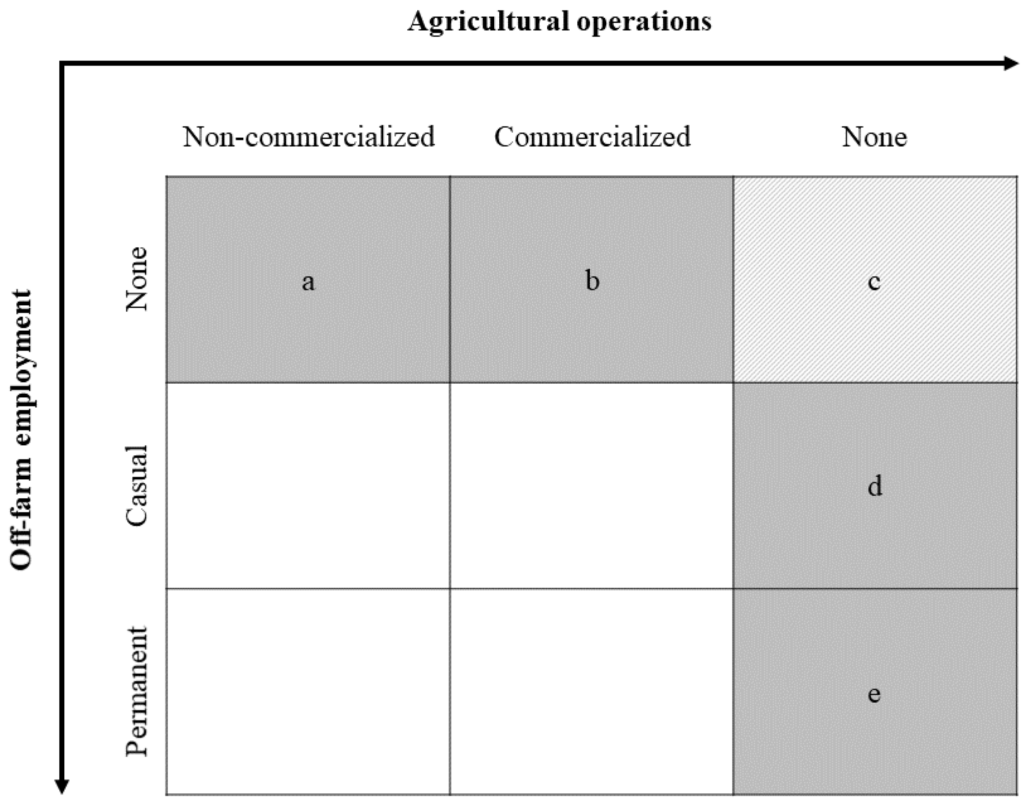


Figure 1. Dimensions of household employment choices – agricultural operations vs. off-farm employment

Note: For consistency, we chose the categories in the two dimensions based on the indicators used later in the empirical analysis. Other specifications are possible as well (e.g. skilled vs. unskilled off-farm employment). Households in box (c) are a special case neither employed in the farm nor the off-farm sector.

Thus, we aim to contribute to the literature by explicitly investigating the effect of interactions between smallholders' agricultural operations and off-farm employment choices on their nutritional status. To this end, we propose a framework that considers the full composite of household employment choices—farm and off-farm—and their joint effects on nutrition. We pay special attention to possible effects of access to both, (i) agricultural and labor markets (production and income side) and (ii) food markets (consumption side). We then use primary socio-economic survey data from 941 households in the rural-urban interface of the mega-city of Bangalore in southern India to empirically investigate the pathways illustrated in the conceptual framework. Bangalore region shows exactly the development characteristic representative of many parts of India and other LMICs: a relative decline of the importance of income from the agricultural sector (Chand et al., 2017; Chand et al., 2015; Pingali, 2007a) and a growing casual labor and off-farm sector (Jatav & Sen, 2013; Chandrashekar & Mehrotra, 2016). These transitions in economic activities are driven by the large urban center as well as the growth of small towns and peri-urban areas (Himanshu et al., 2011; Li & Rama, 2015; Pingali et al., 2019; Chatterjee et al., 2015). This makes the rural-urban interface of Bangalore particularly useful for our analysis of the interactions among household employment choices and their effect on nutrition. By using HNARs for three macronutrients (calories, protein, and fat) and three micronutrients (vitamin A, iron, and zinc), we can investigate the households' nutrient consumption level in a nuanced way.

A multivariate regression framework is the center of our statistical analysis with the HNARs as dependent variables. We group households based on their occupational choices regarding agricultural operations and off-farm employment. Agricultural operations include non-commercialized agriculture, commercialized agriculture, and no agriculture; whereas, off-farm employment is divided into permanent, casual, or no employment in the off-farm sector of at least one adult household member (>16 years of age). Allowing for interaction between these two employments dimensions, we obtain a detailed insight into the association of employment choices within a household and its (average) nutrient consumption. Furthermore, we include the distance to Bangalore and the closest small town in our analysis as proxies for market access.

Our results show that the composite effect of agricultural operations and off-farm employment is important in explaining household nutrition. Of particular importance is the combination of commercialized agricultural operations and permanent off-farm employment. Households with such a mix of employment choices display an excess consumption of nutrients. We see a further increase in such excess consumption among households with the aforementioned combination of employment choices that are located closer to the town. This suggests that an increase in income due to households' participation in more than one employment and proximity to urban markets increase the burden of overnutrition. Furthermore, the results indicate that undernutrition is still prevalent among the socio-economically disadvantaged households in this setting of the rural-urban interface.

The remainder of the paper is structured as follows. We set up a conceptual framework to illustrate possible pathways between livelihood strategies and nutrition in section 2. In section 3, we describe our study area, data set, variable definitions, and statistical analysis employed. In section 4, we descriptively elaborate on our sample characteristics and discuss the results. In the final section, we summarize our findings and derive policy implications.

2. Conceptual Framework

Several studies show that many smallholder farm households in LMICs rely on some form of off-farm income to supplement their livelihood (Chandrashekar & Mehrotra, 2016; Steinhübel & Cramon-Taubadel, 2020). Thus, the livelihood of these smallholder households should be understood as a composite of different employment choices (commercialized and non-commercialized agricultural operations, any kind of off-farm employment). The share of the respective employment dimension in households' livelihood portfolio will be significantly influenced by their access to agricultural input and output markets as well as to access to labor markets (Vandercasteelen et al., 2018; Fafchamps & Shilpi, 2003). Similarly, the diet consumed by households will be affected by their access to food markets (Pingali, 2007b; Reardon et al., 2003). This means households' location has a significant influence on production, income, and household diets, as well as pathways connecting them.

A recent framework presented by Muthini et al. (2020) investigates the interdependencies between market access, farm production diversity, and nutrition. We add to this concept by adding the element of off-farm employment and by differentiating between the market access regarding production and consumption decisions. We indicate this by the two gray boxes in Fig.2 and disregard for the moment that anything but market access influences households' employment or diet choices. Hence, a households' employment choices, i.e. the share of labor attributed to agricultural operations (non-commercialized or commercialized) and off-farm employment are influenced by its access to agricultural (input and output) and labor markets (upper gray box). Transportation costs generally decrease for households located closer to any type of market. Thus, Vandercasteelen et al. (2018) and Damania et al. (2017), argue that with proximity to agricultural markets net input prices decrease and net output prices increase, leading to a higher rate of commercialized agriculture closer to markets and cities. On the other hand, Deichmann et al. (2009) and Fafchamps & Shilpi (2003) show that once access to (urban) off-farm markets increases, smallholder households are likely to take up this opportunity and remove some labor force from their agricultural operations. Thus, households often face trade-offs when assigning labor into agricultural operations and/or off-farm employment resulting in potentially complex patterns of employment choices in peri-urban areas (Steinhübel & Cramon-Taubadel, 2020). Therefore, we visualize households' employment choices as a continuum between agricultural operations and off-farm employment in Fig. 2 assuming that most smallholder households are located somewhere between the two extremes.

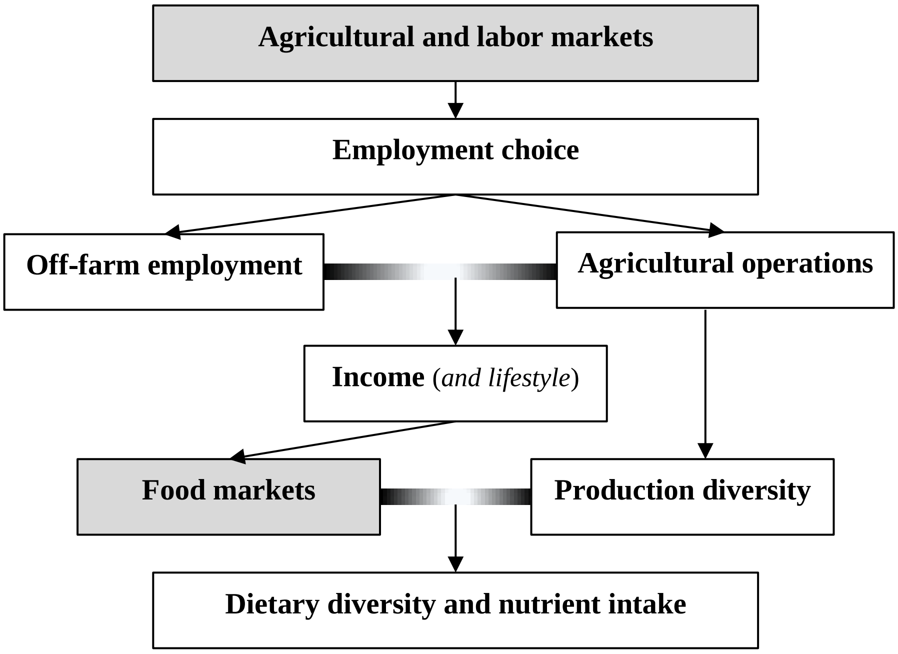


Figure 2. Household employment choice, nutrition, and access to markets

Employment choices are linked to household nutrition mainly through two pathways. The first is the subsistence pathway, where the households consume the food crops produced on their farm. The second pathway is income, where households use income generated through agricultural commercialization and off-farm employment to purchase food items from the market. The respective share of either type of economic activity—on-farm production and income generation—will determine how much of households' diet relies on food markets. This is where the access to food markets (second gray box)—which does not have to coincide with access to agricultural and labor markets—comes into play. Note that income-generating employment choices are likely connected to lifestyle changes (e.g. health awareness or opportunity costs of cooking) as well. Thus, next to pure access to food markets, the income pathway to nutrition also relies on the choice made in the market (i.e. which food items are purchased). Households' dietary patterns and nutrient consumption are, therefore, determined by the (subsistence) production diversity as well as the assortment of food markets and outlets available to a household.

3. Materials and methods

3.1. Study area and survey design

With a population of 9.6 million (Directorate of Census Operations Karnataka, 2011), Bangalore is the fifth most urban agglomeration in India and the city is expanding continuously. Bangalore and several satellite towns, located within a 40-kilometer distance, provide many opportunities for employment in the formal and/or informal off-farm sector. Several highways connecting the urban centers lead to a rise in urbanization patterns in the entire region (Directorate of Census Operations Karnataka, 2011). Nevertheless, agriculture still prevails as a major livelihood strategy for people living in the peripheries and small towns around Bangalore (Directorate of Census Operations Karnataka, 2011). Improved infrastructure and expanding agricultural markets help farmers to intensify their production systems (cultivating crops and rearing dairy cows) beyond just subsistence. Several domestic supermarkets in Bangalore have established collection centers in nearby villages and small towns to procure fresh food products and make them available to urban and peri-urban consumers (Vishnu & Kumar, 2019). Also, such marketing arrangements provide a higher price to the farmers than the price received at the traditional markets and, thus, serve as an incentive for farmers to produce crops for sale.

While undernutrition persists, overweight/obesity and anemia (which is a result of micronutrient deficiency) are rising health concerns in both the Bangalore urban and rural districts (NFHS - 4, 2015-16). This indicates that diet-related health problems in Bangalore are shifting from the burden of undernutrition to overnutrition. One of the mainly attributed factors for this is the transition in the type of diet consumed by the people. Pingali & Khwaja (2004) conceptualize two stages of diet transition associated with economic growth in India. The first stage is characterized by the income-induced shift from the consumption of a few traditional staples (such as rice and wheat) to a diversified diet, leading to improved diet quality. In the second stage, the influence of urbanization and globalization results in excess consumption of sugar, salt, sodium, saturated fat, etc., which is associated with the incidence of overnutrition. Pingali & Khwaja (2004) also highlight that urbanization can have a significant effect on the speed of the shift from the first to the second stage of dietary transition due to the improved access and affordability (rising income levels) of diverse diets. In the Bangalore area, this can be observed in a variety of food outlets, ranging from mom & pop stores to hypermarkets to fast food centers. A recent study by Mittal & Vollmer (2020) shows the double burden of malnutrition crisis in the rural-urban interface of Bangalore.

In this setting, a socio-economic survey of 1275 households provides the basis for our empirical analysis. Our study area comprises two research transects that cut through the rural-urban interface of Bangalore city, as shown in Fig. 3. The first transect extends towards the northern part of Bangalore and the second transect extends towards the southwest part of Bangalore.

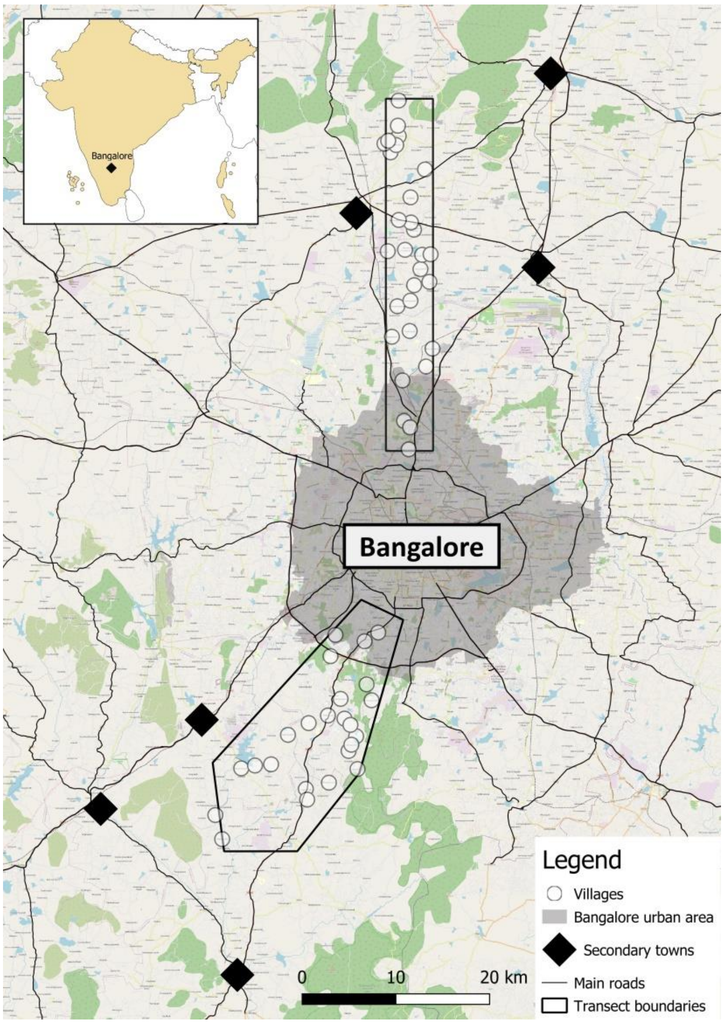


Figure 3. Study area, research transects, and sample villages

By applying a two-stage stratified random sampling technique, we ensured that the selected households provide a good representation of urbanization patterns in the area. In the first stage, all villages in each transect were divided into three strata (urban, peri-urban, and rural) using the "Survey

Stratification Index (SSI)" constructed by Hoffmann et al. (2017). Then, 10 villages were randomly selected from each stratum, yielding 61 villages in total. In the second stage, the households were randomly selected in each sample village again proportional to their size using a village household list maintained by the publicly run village kinder gardens. All sampled households were interviewed between December 2016 and May 2017 using a comprehensive questionnaire covering socio-demographic, economic, and agricultural information. The respective caregiver of the family was also interviewed to collect the information on food consumption data for the past 14-days of the interview.

Though the survey comprises 1275 households, we were not able to interview caregivers of 152 households. Thus, data on livelihood strategies and food consumption is only available for 1123 households. Furthermore, we did not consider households from eight villages in which none of the sample households reported agricultural production. Agriculture is no longer possible in these villages, which have been integrated into Bangalore as urban wards. Hence, we consider 1004 households from 53 villages in which circumstances allow a choice between agricultural operations and off-farm employment.[4] After dropping the observable outliers of nutrition variables and missing observations of covariates, our empirical analysis is based on a sub-sample of 941 households.

3.2. Measurement of nutrition

Household food security is a multidimensional concept and is determined by several factors such as availability, access, and utilization of adequate and appropriate food (Barrett, 2010). As a consequence, measurement is not straightforward and several indicators have been developed. The nutrient adequacy ratio (NAR) and the mean adequacy ratio (MAR) are commonly employed to evaluate nutrient adequacy of diet consumed (Arimond et al., 2010) and validate simple measures of nutrition such as dietary diversity (Steyn et al., 2006; Torheim et al., 2003). However, since NAR and MAR require individual-level dietary recall (commonly 24-hour), data collection is costlier and more time-consuming than the collection of household-level food consumption data for a specific recall period. The adult male equivalent (AME) method is commonly used in the literature to work with

[4] We also performed the analysis (section 3.5) with the full data set as a robustness check. If at all, the effects presented in section 4.2 turn out stronger. The results are available on request.

household-level data (Babatunde & Qaim, 2010; Ntakyo & van den Berg, 2019). However, recent studies show that it is only a rough proxy of the individual nutrient intake (Coates et al., 2017; Sununtnasuk & Fiedler, 2017; Weisell & Dop, 2012). Connecting both approaches, Schneider & Masters (2019) extend the concept of individual-level NAR and MAR and introduce Household-level NAR and Household MAR to advance the nutrition-related analysis potential using household-level food consumption data.

Since we expect to observe different dimensions of malnutrition in our dataset, MARs are not useful in our case because they are not informative about the under/overconsumption of an individual nutrient. When households experience dietary transition, they tend to consume excess quantities of macronutrients such as calories and fat, and lower amounts of important micronutrients (Pingali, 2007b; Popkin, 1999). Even if they consume recommended quantities of calories there might be too few proteins and important micronutrients consumed (Caulfield et al., 2006). Therefore, we consider HNARs of individual nutrients as dependent variables in our analysis. HNARs are calculated using the 14-day recall household-level food consumption data from our sample. HNARs are calculated for three macronutrients (calories (c), protein (p), and fat (f)) and three micronutrients (vitamin A (v), iron (i), and zinc (z)). We followed the standard approach used in the construction of individual-level NAR to calculate subsequent HNAR measures (INDEX Project, 2018). To calculate the HNAR of nutrient k for household j, we divided the total amount of consumed nutrient k by its recommended dietary allowance (RDA).

$$HNAR_{k,j} = \frac{\text{Amount of nutrient } k \textit{ consumed} \text{ by household } j}{\text{Recommended dietary allowance for nutrient } k \text{ for household } j} = \frac{q_{k,j}}{RDA_{k,j}} \quad (1)$$

where $k = (c, p, f, v, i, z)$.

The quantities $q_{k,j}$ are calculated based on reported quantities of food items consumed for a 14-day recall period in the survey. Nutrient conversion factors for India, summarized in the Indian Food Composition Tables (IFCT) (Longvah et al., 2017), are used to convert the quantities of raw food items into their consumption values for each nutrient k in household j, i.e. $q_{k,j}$. The RDA is commonly given for each individual and it differs by their age, gender, and physical activity level. The

RDA for household j is estimated by using demographic information (age and gender) of each household member older than six months to define how much of each nutrient k every household member should ideally consume. We did not have a detailed account of the type of physical activities conducted by each member of our sample households and therefore we considered a moderate level of work for all adult household members.[5] The standardized dietary guidelines recommended by the Indian Council of Medical Research (ICMR) are used to calculate the RDAs for each household member. Then summing up individual RDAs of all household members provided us with an RDA estimate for the household, i.e. $RDA_{k,j}$.

Table 1 presents the mean and median values for the HNARs of all six nutrients (distributions are all somewhat skewed with flatter tails to the right). It shows that households on average exceed the consumption of recommended quantities for all these nutrients except vitamin A. Fat scores by far the highest mean and median values; on average households consume 1.6 times more fat than recommended. The average consumption of calories, protein, iron, and zinc come closer to the recommended quantities with the average household (median) overconsuming these nutrients by between 1 and 33 percent. Average vitamin A consumption falls under recommended levels; the average household in our sample only consumes around 60 percent of recommended quantities of vitamin A. These summary statistics and the differences in HNARs highlight the importance of analyzing nutrients separately. Also, observing HNARs much larger (e.g. fats) and smaller (e.g. Vitamin A) than 1 implies that multiple dimensions of malnutrition might pose issues in our study area. Therefore, HNARs of macro- and micronutrients seem to be a suitable proxy to analyze dynamics around nutrition in the rural-urban interface of Bangalore.

Table 1. Summary statistics of HNARs of sample households

HNAR for	Obs.	Mean	St. Dev.	Median
Calories	941	1.396	0.565	1.275
Protein	941	1.432	0.613	1.329

[5] Physical activity factor is considered in the RDA of only male and female individuals of 18 years and above, therefore we consider the physical activity factor only for these household members.

Fat	941	2.628	1.431	2.278
Vitamin A	941	0.717	0.431	0.615
Iron	941	1.108	0.535	1.013
Zinc	941	1.373	0.593	1.276

3.3. Measurement of livelihood diversification and market access

Following our conceptual framework in section 2, the employment choices of the households should play an important role in determining what they eat and, thus, their nutritional consumption. Common classifications in previous studies on employment choices are, for example, formal vs. informal, casual vs. full-time off-farm employment (D'Souza et al., 2020), or commercialized vs. non-commercialized agriculture (Sibhatu et al., 2015; Cazzuffi et al., 2020). Accordingly, we classify our sample households depending on the primary occupation of all household members older than 16 into different categories of agricultural operations and off-farm employment. Agricultural operations relevant in our study area are non-commercialized agriculture, commercialized agriculture (defined as at least one crop sold in 2016), and no agricultural operations at all. These categories are hereafter referred to as non-commercialized, commercialized, and no agriculture households, respectively. Note that these categories are exclusively built on crop management systems. Especially dairy production is common in our study area, with about 54 percent of our households owning dairy cows (Table A.1). We consider this aspect with a separate dummy variable in the subsequent analysis. No agriculture households account for about 40 percent of the sample; whereas another 40 percent of households pursue commercialized and the rest non-commercialized agricultural production (Table 2). Off-farm employment is classified into three categories – permanent, casual, and no off-farm employment. In almost two-thirds (62 percent) of all households in our sample, at least one household member works in permanent off-farm employment. Around 30 percent of households do not have any member working in the off-farm employment, i.e. these are pure agricultural households (Table 2). About 7 percent of households receive income from casual off-farm employment.

Table 2. Cross-table

	Agricultural operations			
	Non-commercialized	Commercialized	No agriculture	TOTAL
Off-farm employment				
No off-farm	98	146	50	294
Permanent	96	199	288	583
Casual	4	26	34	64
TOTAL	198	371	372	941

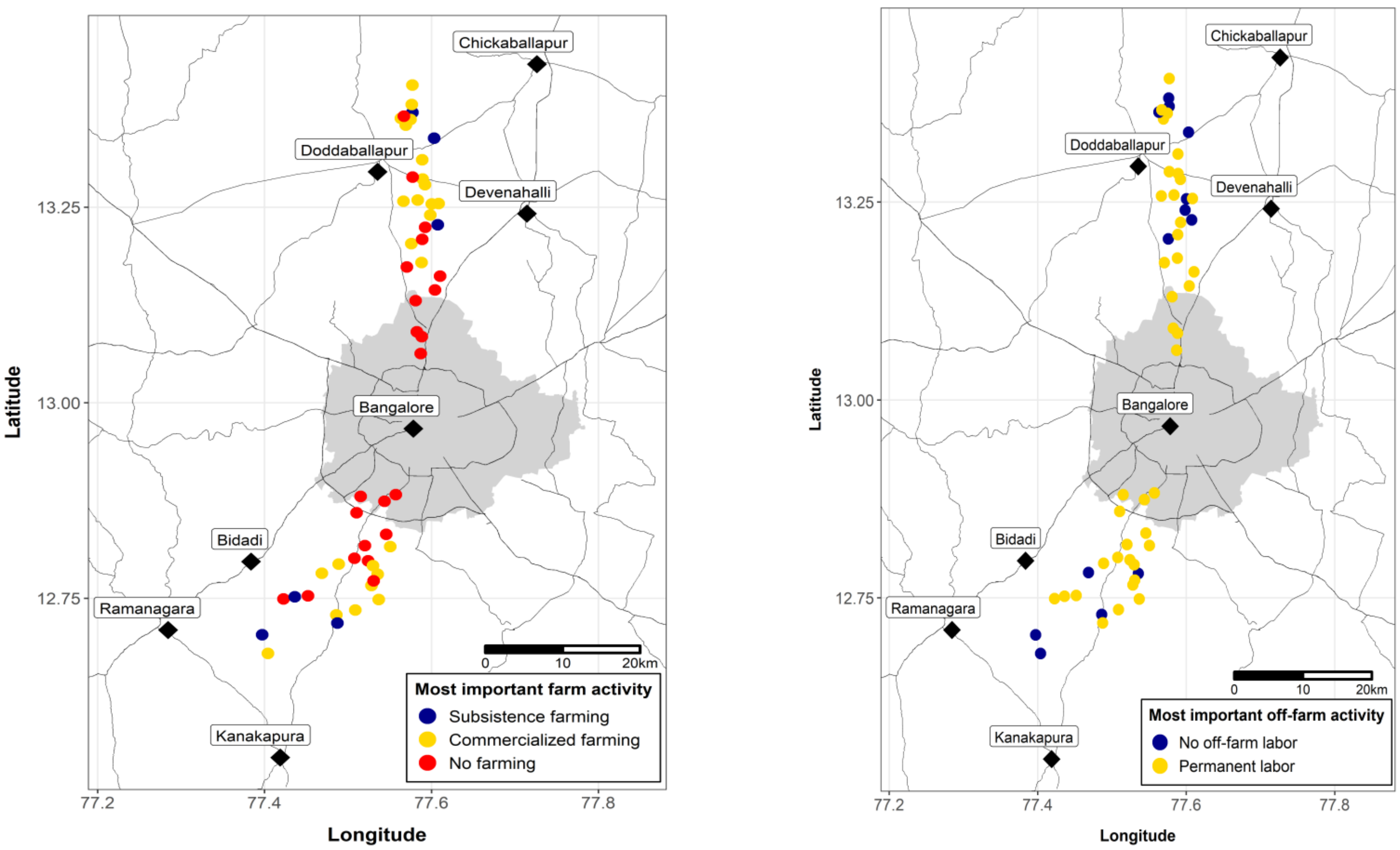
Table 2 also presents a cross-tabulation of agricultural operations and off-farm employment. It shows that households with permanent off-farm employment with no agricultural operations are most common (288 households) followed by composite households with permanent off-farm employment and commercialized agriculture (199 households), and commercialized agricultural households with no off-farm employment (146 households). Exclusive non-commercialized agriculture and non-commercialized agriculture combined with permanent off-farm employment each score about 100 households. This implies that we observe a diverse set of different employment choices by households in the rural-urban interface of Bangalore.

Furthermore, when mapping the most common agricultural operations and off-farm employment by village (Fig. 4 (a) and (b)), we can see spatial clusters in both employment choices. Permanent off-farm employment appears to be more frequent closer to Bangalore city in both transects (Fig. 4(b)) and agricultural operations seem to be less attractive close to the city. Commercialized agricultural operations are the most common in villages in the center and outer areas of both transect (Fig. 4(a)). Non-commercialized agriculture is only dominant in some villages in the outmost areas of the transects. This observation hints at a spatial gradient radiating from the urban center of Bangalore. This observation coincides with the conceptual framework in section 2 (first gray box in Fig. 2), where we argue that the gradient/trade-off between on-farm production and income generation depends on access to off-farm labor markets (e.g. permanent off-farm employment) or agricultural markets (e.g. commercialized agriculture).

Considering that access to food markets might affect nutrient consumption (second gray box in Fig. 2), we include the distance to Bangalore and distance to the closest town (including Bangalore) as variables measuring market access in our regression analysis.

1.1. Control variables

Besides the variables on employment choices and market access, we include household socio-economic characteristics as control variables (Table A.1). This includes the number of household members, the caste of the household, age, gender, literacy of the household head, and the number of durable assets owned by the household. Furthermore, we include variables directly related to food consumption such as the type of ration card owned by the household, the household member typically purchasing food items, and whether the household follows a vegetarian diet. The public distribution system (PDS) established in 1945 has a long tradition in India and aims at achieving food security by providing subsidized access to basic food items (e.g. rice, wheat, sugar, and oil) distributed in government-run shops. By now almost every household has one of two types of ration cards, namely either an above poverty line (APL) or below poverty line (BPL) (NITI Aayog, 2016). In our sample, BPL is the most common (85.3 percent) and only 9.5 percent of the sampled households do not have any ration card. The person buying groceries in the market might also affect household nutritional consumption; a female household member might prioritize the nutritional relevance of food items over its price and convenience more than a male household member (Turrell, 1997). Almost 60 percent of the sampled households report that an adult male is primarily responsible for grocery shopping; whereas in 22.7 percent of households it is a female and in 5.2 percent of households any member is responsible for grocery shopping. Some households in India follow strict vegetarian diets for cultural/religious reasons; such families do not consume any type of meat, fish, and eggs, which is likely to influence their nutritional consumption. In our sample, about 10 percent of households are vegetarians.



(a) (b)

Figure 4. (a) Most important agricultural operations in the village; (b) Most important off-farm employment in the village

1.2. Statistical analysis

We apply a multivariate model framework to investigate factors influencing the adequacy of household nutrient consumption, i.e. HNAR. Hereby, HNARs for calories, proteins, and fats ($k = (c, p, f)$) represent different measures for macronutrient consumption (Y_{macro}) and HNARs for vitamin A, iron, and zinc ($k = (v, i, z)$) for micronutrient consumption (Y_{micro}), respectively. Applying multivariate regressions with a joint estimator allows us to estimate the effects of covariates on the different HNARs simultaneously and we cannot only evaluate the effects of covariates on the consumption of individual nutrients but consumption of overall macro- and micronutrients. To meet model requirements of multivariate normal distributions, we log-transformed all HNARs and estimated the following model specifications with predictor η:

$$ln(Y_{macro}) = \eta_{macro} + \varepsilon_{macro} \Leftrightarrow Y_{macro} = e^{\eta_{macro}+\varepsilon_{macro}} \quad (1)$$

$$ln(Y_{micro}) = \eta_{micro} + \varepsilon_{micro} \Leftrightarrow Y_{micro} = e^{\eta_{micro}+\varepsilon_{micro}} \quad (2)$$

With

$$\eta_k = \beta_{0,k} + \gamma_k I + \gamma_k^{\times} I^{\times} + \beta_{Dist,k} D + \beta_{Dist,k}^{\times} D^{\times} + \gamma_k^{\times\times}(I^{\times} \times D) + \beta_{control} X_{control} \quad (3)$$

Here, Y_{macro} and Y_{micro} are matrices of HNARs-vectors of macro- and micronutrients k, respectively. The stochastic error terms, ε, are assumed to be $\varepsilon \sim (0_k, \Sigma)$ with Σ being the variance-covariance matrix. The predictor η contains a constant $\beta_{0,k}$ and parameters γ, β_{Dist}, and $\beta_{control}$ representing fixed effects of variables in matrices I, D, and $X_{control}$. Matrix I contains the vectors of categorical variables for different types of agricultural operations and off-farm employment ($I = (i_{agriculture}, i_{off-farm})'$) and matrix D two vectors of distances to Bangalore and the closest towns to village centers ($D = (x_{dist\_Bangalore}, x_{dist\_Town})'$). The control variables presented in section 3.4 are included in $X_{control}$.

Another key element of our analysis is the interaction terms, $I^{\times} = (i_{agriculture} \times i_{off-farm})$ to capture the effects of different combinations of agricultural operations and off-farm employment on HNARs. Furthermore, we want to understand how households' location and the resulting access to markets affect their nutrition consumption. Therefore, we also consider the effects of interaction terms $D^{\times} = (x_{dist\_Bangalore} \times x_{dist\_Towns})$ to obtain a more flexible measure of households' locations in the rural-urban interface. Finally, we allow for interaction between $I^{\times}$ and either of the distance measures, $(I^{\times} \times D) = (i_{agriculture} \times i_{off-farm} \times x_{dist\_Bangalore/Towns})$.[6] An introduction to multivariate regression models and more information on inference can be found in Anderson (1984).

2. Results and Discussion

2.1. Descriptive analysis

In Tables 3 and 4, we present the means of all six log-transformed HNARs grouped by different agricultural operations and off-farm employment. Tests for overall mean differences and t-test to evaluate differences between particular groups give a first idea of interactions between the employment choice and HNARs. A mean value larger than 0 ($ln(1) = 0$), implies an above RDA consumption for the respective nutrient (compare Table 1).

For agricultural operations (Table 3), we find significant mean differences in three out of the six nutrients, namely calorie, iron, and zinc. Households with non-commercialized agriculture appear to have significantly higher HNARs for these three nutrients than the households with no agriculture. Note that the difference for iron HNAR crosses the adequacy recommendation with no agriculture households having lower (<0 mean values) and non-commercialized households having higher (>0 mean values) than the RDA for iron. A similar pattern is observed for the difference between no agriculture households and households with commercialized agriculture, though the magnitude of the differences is not as big as for non-commercialized and no agriculture households. Out of the remaining nutrients, only HNAR for vitamin A does not show any significant differences between the different farm activities. For protein and fat, non-commercialized households have significantly higher HNAR than no agriculture households and commercialized households.

[6] Including interaction effects with all four variables did not add any more information to the model and inference becomes increasingly complex. Thus, we only consider either distance in the interaction term.

The same exercise with off-farm employment shows significant mean differences for all nutrients (Table 4). The pattern of significant differences between individual groups is more homogenous than in Table 3; households with no off-farm employment have significantly higher HNARs for all nutrients than households with at least one member working in permanent off-farm employment. Again, the difference in HNAR for iron crosses zero (>0 mean values). For HNAR of calories, we also observe a significant difference between households with casual and households without any off-farm employment.

Table 3. Average HNARs for all the six nutrients by agricultural operations

	Mean differences	**t-tests**					
		Non-commercialized	$\overleftrightarrow{a}$	Commercialized	$\overleftrightarrow{b}$	No agriculture	$\overleftrightarrow{c}$
Ln(HNARs)							
Calories	**	0.285		0.240	*	0.195	***
Protein		0.325	*	0.266		0.247	**
Fat		0.891	*	0.802		0.817	*
Vitamin A		-0.531		-0.529		-0.456	
Iron	***	0.067		0.028	***	-0.092	***
Zinc	***	0.288		0.251	***	0.169	***

Note: ***p<0.01, **p<0.05, *p<0.1. $\overleftrightarrow{a}$ – difference between non-commercialized and commercialized agriculture; $\overleftrightarrow{b}$ – difference between commercialized and no agriculture; $\overleftrightarrow{c}$ – difference between no agriculture and non-commercialized agriculture.

Table 4. Average HNARs for all the six nutrients by off-farm employment

	Mean differences	**t-tests**					
		No off-farm	$\overleftrightarrow{a}$	Permanent	$\overleftrightarrow{b}$	Casual	$\overleftrightarrow{c}$
Ln(HNARs)							
Calories	***	0.336	***	0.176		0.255	*
Protein	***	0.357	***	0.225		0.294	
Fat	***	0.917	***	0.781		0.829	
Vitamin A	*	-0.454	**	-0.533		-0.422	
Iron	***	0.079	***	-0.061		0.029	
Zinc	***	0.320	***	0.175		0.269	

Note: ***p<0.01, **p<0.05, *p<0.1. $\overleftrightarrow{a}$ – difference between no off-farm and permanent off-farm employment; $\overleftrightarrow{b}$ – difference between permanent and casual off-farm employment; $\overleftrightarrow{c}$ – difference between casual and no off-farm employment.

2.2. Multivariate regression

A table that depicts all of the possible interaction effects for all macro- and micronutrients in our model (equation (3)) would be very complex. To ease interpretation, we present the results for the interaction terms in cross-tables and only display statistically significant estimates. The two important aspects of our conceptual framework (section 2) – the full composite effect of employment choices and market access on HNARs – are presented in Table 5 and Table 6, respectively. Full estimation results can be found in Table A.2 and Table A.3. Because the dependent variables are log-transformed, the coefficients are given in percentage changes. Note that the reference groups for the estimated effects of agricultural operations and off-farm employment are non-commercialized agriculture and no off-farm employment, respectively (gray column and row in Tables 5 and 6). Hence, the estimated effects have to be understood relative to the mean HNARs of these reference groups. In section 4.1 (Tables 3 and 4), we show that these groups have the highest average HNARs for calories, proteins, fats, iron, and zinc; whereas, they have the lowest HNAR for vitamin A. We chose these reference groups because we consider non-commercialized agriculture to be the traditional livelihood strategy of smallholder households.

Table 5. Cross-table – (Interaction) effects of different employment choices as percentage change on HNARs (based on parameter estimates $\boldsymbol{\gamma_k}$ and $\boldsymbol{\gamma_k^{\times}}$ in equation (3))

	No interaction		Agricultural operations				
			Non-Commercialized	Commercialized		No agriculture	
	Macro	Micro		Macro	Micro	Macro	Micro
Off-farm employment							
No interaction	*Not applicable*			C: - P: -27.8* F: -30.7*	V: - I: -36.6** Z: -34.0**	-	-
No off-farm							
Permanent	-	-		C: -	V: -	-	-

				P: 50.2’ F: -	I: 94.9** Z: 59.9*		
Casual	C: - P: - F: -83.8*	-		C: - P: - F: 722.6**	-	C: - P: - F: 313’	-

Note: ***p<0.01, **p<0.05, *p<0.1. ’ indicates significance levels with 0.1<p-values>2.0. - indicates that coefficients are not statistically significant. HNARs: C=Calories, P=Proteins, F=Fats, V=Vitamin A, I=Iron, Z=Zinc.

Compared with a non-commercialized agricultural household, a household with commercialized agriculture but no off-farm employment consumes 28 to 37 percent lower levels of proteins, fats, iron, and zinc. Considering the above-RDA HNARs for these nutrients, it appears that households that generate their income through commercialized agriculture display less excess nutrient consumption than non-commercialized agricultural households. This might be associated with an initially positive income effect, which exhibits a shift away from the consumption of energy-dense staples to a diversified diet (Ntakyo & van den Berg, 2019; Cazzuffi et al., 2020; Pingali & Khwaja, 2004). However, if we look at households that obtain income from both commercialized agriculture and permanent off-farm employment, we see a different picture. These households consume between 22 (-27.8+50.2=22.4) and 59 (-36.6+94.9) percent more macro- and micronutrients. This might be explained by a larger share of food purchased in markets when the share of household labor assigned to income-generating agricultural operations and off-farm employment increases. Furthermore, if some household members work outside the farm, they might bring changes in lifestyle and food preferences. Though some forms of lifestyle changes are beneficial if they lead to healthy eating practices (Popkin, 1999), in the case of Bangalore it seems that the effect of off-farm employment rather contributes to unhealthy eating patterns and overnutrition. This shows that considering the full composite effect (main and interaction effect) of different income-generating employment choices is important for household nutrition. Previous studies that considered only either the agricultural operations or off-farm employment dimension might, thus, provide partial evidence on the relationship between livelihood strategies and nutrition (Sibhatu et al., 2015; Carletto et al., 2017; Rahman & Mishra, 2019).

We also find some interesting results for the fat consumption of households pursuing casual off-farm employment. If a non-commercialized household adds casual off-farm employment to its livelihood portfolio, its fat consumption reduces by over 83 percent compared with a household with no off-farm employment. Nonetheless, when a household engages in both commercialized agriculture and casual off-farm employment, the fat consumption is almost 640 percent higher. Note, however, that this estimate is based on only a very small group of observations (Table 2).

In Figure 3, we showed that employment choices seem to be clustered in space and depend on access to agricultural and labor markets. In Fig. A.1 and Fig. A.2, we present simple graphs plotting HNARs against distance to Bangalore and the closest town, respectively. It appears that there are slight gradients; these relationships are, however, not statistically significant in the regression analysis (Table 6).

Table 6. Cross-table – (Interaction) effects of different employment choices and distance to closest town as percentage changes on HNARs (based on parameter estimates $\boldsymbol{\gamma_k^{\times\times}}$ equation (3))

	Distance to closest town			Agricultural operations			
			Non-Commercialized	Commercialized		Non-farm	
	Macro	Micro		Macro	Micro	Macro	Micro
Off-farm employment							
Distance to closest town	-	-		C: - P: 2.7’ F: -	V: - I: 3.2’ Z: 3.0*	-	-
No off-farm							
Permanent	-	-		C: - P: -3.3’ F: -3.9’	V: -4.1’ I: -5.1* Z: -3.5’	-	-
Casual	C: - P: - F: 16.9*	-		C: -8.8’ P: - F: -16.4*	-	-	-

Note: ***p<0.01, **p<0.05, *p<0.1. ’ indicates significance levels with 0.1<p-values>2.0. - indicates that coefficients are not statistically significant. HNARs: C=Calories, P=Proteins, F=Fats, V=Vitamin A, I=Iron, Z=Zinc.

Interestingly, it is the same agricultural operations and off-farm employment, and their interactions that have significant effects on HANRs in Table 5 show significant associations with market access (i.e., distance to the closest town). A smallholder household with commercialized agriculture but no off-farm employment consumes around 3 percent more macro- and micronutrients with every kilometer away from the closest town. Thus, the negative effect we see for commercialized agricultural operation in Table 5 depends on where a household is located. That is, the households with commercialized agricultural display an increased excess consumption of nutrients if they are located far away from urban centers and food markets. Again, similar to the observation in Table 5, the effect changes for the households receiving income from commercialized agriculture and permanent off-farm employment. That is, households with this combination of income-generating employment choices exhibit less overnutrition if they are located further away from the closest town.

It appears that there are distinct differences in nutrient consumption levels of households pursuing income-generating agricultural operations and off-farm employment, and their combinations, at least in our study area. Non-commercialized households that switch to a commercialized agricultural operation seem to improve their nutritional status by consuming less excess nutrients. However, if these households are located further away from an urban center they display an increase in excess consumption of nutrients. It might be that these households in the hinterland are stuck in traditional dietary patterns consisting of staple foods than the ones that are closer to a town and, thus, display excess consumption of nutrients (likely similar to non-commercialized households). In contrast, households with commercialized agriculture and permanent off-farm employment seem to have completely different consumption patterns. Households with this combination of employment choices consume excess nutrients, thus, more likely to be prone to overnutrition. Furthermore, this association weakens for households in the hinterlands than the ones closer to a town. This may be due to an unhealthy lifestyle or a larger share of income to be spent in food markets to buy energy-dense food items among households located closer to a town. A similar pattern for obesity prevalence in India is shown by Aiyar et al. (2021). Thus, our results show that a simple linear relationship between income generated by different employment choices and nutrition is unlikely. Rather there seems to be a threshold, until which income generated by employment choices supports improvement in nutrition (by consuming less excess nutrients), and beyond which additional income contributes to further overconsumption of macro- and micronutrients.

Table 7. Effects of control variables as percentage changes on HNARs

Variables	**Percentage change in HNARs**					
	Macronutrients			**Micronutrients**		
	Calories	**Protein**	**Fat**	**Vitamin A**	**Iron**	**Zinc**
Dairy production	7.8**	6.2*	12.8**	2.7	8.8**	8.3**
(Dummy – Yes)	(0.028)	(0.088)	(0.007)	(0.573)	(0.036)	(0.025)
Number of household	-6.2***	-6.0***	-6.6***	-8.2***	-7.7***	-6.9***
members	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)	(<0.001)
Gender of household head	-3.8	-1.7	-5.1	-7.5	-4.2	-3.4
(Dummy – Female)	(0.249)	(0.631)	(0.233)	(0.102)	(0.278)	(0.327)
Age (years)	0.0	-0.2**	0.0	-0.1	0.1	-0.1
	(0.930)	(0.030)	(0.779)	(0.635)	(0.340)	(0.645)
Literacy of household	-1.8	-1.3	0.2	2.1	-1.8	-2.1
head (Dummy -Yes)	(0.572)	(0.694)	(0.965)	(0.648)	(0.638)	(0.528)
Caste (ref. General)						
SC&ST	-5.3	-4.7	-7.7*	-4.3	-4.4	-4.4
	(0.101)	(0.161)	(0.066)	(0.350)	(0.248)	(0.199)
OBC	-0.6	-1.6	-1.1	-1.9	-1.3	-2.4
	(0.845)	(0.616)	(0.798)	(0.669)	(0.730)	(0.463)
Ration card (ref. None)						
APL	4.5	1.9	5.6	2.9	0.4	3.6
	(0.535)	(0.802)	(0.560)	(0.777)	(0.965)	(0.639)
BPL	3.4	1.5	-3.2	-10.9*	3.0	5.4
	(0.464)	(0.758)	(0.588)	(0.076)	(0.584)	(0.271)
Asset index (count)	1.9**	2.7**	4.9***	5.1***	2.2**	2.2**
	(0.034)	(0.004)	(<0.001)	(<0.001)	(0.034)	(0.017)
Main grocery shopper (ref. Adult female)						
Adult male	3.7	3.6	4.0	2.5	7.1*	3.8
	(0.296)	(0.323)	(0.386)	(0.612)	(0.092)	(0.304)
Others	2.7	2.7	0.7	-4.8	4.6	2.8
	(0.532)	(0.540)	(0.897)	(0.405)	(0.367)	(0.525)
Vegetarian diet	8.4*	1.7	8.0	11.1*	5.8	4.9
(Dummy – Yes)	(0.077)	(0.715)	(0.195)	(0.099)	(0.289)	(0.310)
Transect	-2.9	-4.7	-6.7*	-7.7*	0.8	-3.2
(Dummy – South)	(0.359)	(0.144)	(0.093)	(0.071)	(0.829)	(0.318)

Intercept	107.3**	138.2**	180.4**	30.9	48.3	110.3**
	(0.011)	(0.004)	(0.006)	(0.503)	(0.239)	(0.013)

Note: ***p<0.01, **p<0.05, *p<0.1. p-values in parentheses.

One important exception in our study is vitamin A, which, on average, is under-consumed and does not show any statistically significant interaction with employment choices (Tables 5 and 6). Vitamin A shows some individual patterns in the estimation results for the control variables (Table 7). For example, dairy production significantly increases the HNARs of both macro- and micronutrients, except vitamin A. Besides, vitamin A is the only nutrient that yields an almost statistically significant and negative effect for female lead households. Also, BPL ration card holders consume significantly less vitamin A. Since these are both common signs of low wealth, we can conclude that the only form of undernutrition in our sample prevails mainly in socio-economically disadvantaged households. The only positive effect on vitamin A consumption is reported for a vegetarian diet.

Next to vitamin-A-specific effects, households with more members have statistically significant lower HNARs for all the six nutrients implying that household size reduces the individual nutrient uptake. The same holds for the number of assets a household owns, which increases HNARs for all six nutrients. Assets are generally considered as wealth indicators. Since the largest positive effect of assets (5.1 percent) is observed for vitamin A, this fits our previous findings that socio-economic characteristics of the household play a significant role in vitamin A undernutrition.

3. Conclusion

We analyze how different employment choices of smallholder households affect their food security. We are particularly interested in how the different combinations between household agricultural operations and off-farm employment are associated with nutrition, an aspect that has so far been neglected in the literature. Especially, when urbanization and improved market access enable households to engage in more than one form of employment, it is not just different types of employment chosen but also their combinations that affect their nutrition. Therefore, we present a conceptual framework describing the pathways between household employment choice and nutrition while accounting for the composite effect of different agricultural operations and off-farm employment, and the market access on the production and consumption side. In our empirical analysis, we use the HNARs of three macronutrients (calorie, protein, and fat) and three micronutrients (vitamin A, iron, and zinc) to explore these interactions between employment choices and household nutrition in the rural-urban interface of Bangalore. For all nutrients, except for vitamin A, we find that the average HNARs are above the recommended levels of consumption. Such high HNARs for macronutrients (especially for calories and fat) show the onset of dietary transition among our sample households and suggest the existence of multiple forms of malnutrition.

There are three main results of our regression analysis. First, a mix of income-generating agricultural operations and off-farm employment in households' livelihood portfolio is associated with changes in HNARs, and, second, this association depends on the distance to the closest town. Relative to non-commercialized agriculture, households with commercialized agriculture but no off-farm employment display an improvement in their nutritional status by consuming less excess nutrients. Furthermore, we can see an increase in the excess nutrient consumption if these commercialized households are located in the hinterlands than the households with similar employment choices but located closer to a town. Proximity to an urban center improves market access on both the production and consumption side, which might lead to a shift away from energy-dense staples to a diversified diet and thus, less excess nutrient consumption (Pingali & Sunder, 2017; Pingali, 2007b). In contrast, if households earn income from commercialized agriculture and permanent off-farm employment, the outcome is the overconsumption of nutrients. This effect, again, is less prominent among households in the hinterlands than the ones with a similar livelihood portfolio located closer to a town. Thus, we find a distinct difference between nutrition patterns among different employment choices. Factors driving these differences are probably the share of income generated from agricultural commercialization and off-farm employment relative to own agricultural production, and access to food outlets but also lifestyle changes due to urban proximity and off-farm opportunities. Besides, the relationship between income generated from employment choices and nutrition appears to be non-linear. This means we have a positive nutritional outcome up to a certain threshold and beyond which there is an onset of overnutrition.

Third, vitamin A, a seriously lacking nutrient in the diet of our average sample households is not significantly influenced by different livelihood strategies and market access. However, there are signs that vitamin A undernutrition is associated with household socio-economic characteristics (such as asset index, type of ration card, and female household head). Thus, socio-economically disadvantaged households suffer most from this deficiency. Besides, a vegetarian diet improves vitamin A consumption.

These results not only fill an important gap in the literature but are also relevant for policymakers. We show that agricultural operations and off-farm employment, when considered as a single dimension show less excess nutrient consumption, however, combinations between them are mainly associated with excess consumption of nutrients. Thus, initiatives targeting the food systems to prevent emerging health issues such as overweight and/or non-communicable diseases should consider the full livelihood portfolio of a household. Especially, households active in commercialized agriculture and with members engaged in off-farm employment are vulnerable to overconsumption of nutrients. Strengthening market access on the production and consumption side is one of the commonly advocated policy measures to improve nutrition in smallholder households. Such policies have to account for the negative health effects that pose in terms of access to unhealthy dietary patterns, especially, in those areas facing multiple burdens of malnutrition. We also show that the undernutrition of vitamin A in our study is rather linked to socio-economic factors and not to employment choices. Thus, to fight severe undernutrition it is important to support disadvantaged families (e.g. female-headed households or families or families under the poverty line).

The framework we propose in the study can be further applied in regions experiencing malnutrition as well as urbanization and rural transformation. Future research can aim to derive causal effects using panel data and relevant methods. One possible extension would be to differentiate between skilled and unskilled laborers to further explore the relevance of lifestyle changes associated with off-farm employment and (over) nutrition. Furthermore, it is also worth exploring the role of dairy farming (for own consumption and selling in the market) in household nutrition. Since our nutrition indicators are estimated at the household level, we can draw no conclusions about the intra-household distribution of nutrients, especially the nutrient intake by vulnerable household members such as children and women. Therefore, another extension would be to use individual intake data to apply this conceptual framework.

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Appendix:

Table A.1. Summary statistics of sample households

Variables		Obs.	Mean	St. Dev.	Median
Distance to Bangalore	From village centers to Bangalore city center in kilometers	941	27.546	9.793	26.795
Distance to closest town	From village centers to the center of closest town (incl. Bangalore) in kilometers; see Fig. 2	941	11.479	3.414	11.031
Controls					
Dairy production	Dummy variable; 1=household is active in dairy production	941	0.538		
Household members	Number of household members (count)	941	4.624	2.113	4
Gender of the household head	Dummy variable; 1=male household head	941	0.777		
Age	Age of household head in years	941	47.083	13.664	45
Literacy of household head	Dummy variable; 1=household head can read	941	0.665		
Caste	***General***	941	0.470		
	SC&ST		0.269		
	OBC		0.261		
Ration card	Factor variable; Ration card held by the household	941			
	None		0.095		
	APL		0.052		
	BPL		0.853		
Asset index	Number of durable assets owned by the household (count)	941	5.750	1.698	6
Main grocery shopper	Factor variable; Household member normally purchasing food items in the market	941			
	Female		0.227		
	Male		0.595		
	Others		0.178		
Vegetarian diet	Dummy variable; 1=household follows a vegetarian diet	941	0.097		
Transect	Dummy variable; 1=Southern transect	941	0.454		

Table A.2. Association between employment choices and HNARs of macronutrients – multivariate regression results

	% change in HNARs		
Variables	**Calories**	**Protein**	**Fat**
Agricultural operations (ref. non-commercialized)			
Commercialized	**-27.8** (0.092)	**-30.7** (0.070)	-26.4 (0.225)
No agriculture	17.6 (0.589)	13.8 (0.680)	38.8 (0.404)
Off-farm employment (ref. no off-farm)			
Permanent	-15.5 (0.433)	-20.0 (0.319)	-23.6 (0.337)
Casual	-54.0 (0.274)	-28.0 (0.657)	**-83.8** (0.050)
Agricultural operations × Off-farm employment			
Commercialized × Permanent	33.8 (0.265)	***50.2*** (0.136)	52.8 (0.215)
Commercialized × Casual	160.1 (0.207)	66.9 (0.517)	**722.6** (0.033)
No agriculture × Permanent	-26.8 (0.365)	-17.6 (0.589)	-24.8 (0.526)
No agriculture × Casual	72.2 (0.485)	11.5 (0.894)	***313.0*** (0.164)
Distance to Bangalore (km)	-0.5 (0.511)	-0.6 (0.396)	0.3 (0.712)
Distance to closest town (DCT) (km)	-0.9 (0.676)	-1.2 (0.607)	1.8 (0.528)
Distance to Bangalore × Distance to closest town	0.0 (0.938)	0.0 (0.754)	***-0.1*** (0.191)
Agricultural operations × Distance to closest town			
Commercialized × Distance to closest town	*2.4* (0.158)	*2.7* (0.134)	2.0 (0.363)
No agriculture × Distance to closest town	-1.9 (0.453)	-1.9 (0.470)	-3.0 (0.350)
Off-farm employment × Distance to closest town			
Permanent × Distance to closest town	0.6 (0.748)	1.1 (0.577)	1.8 (0.459)
Casual × Distance to closest town	7.8 (0.260)	3.9 (0.580)	**16.9** (0.073)
Agricultural operations × Off-farm employment × Distance to closest town			
Commercialized × Permanent × Distance to closest town	-2.4 (0.273)	***-3.3*** (0.152)	***-3.9*** (0.179)
Commercialized × Casual × Distance to closest town	***-8.8*** (0.191)	-5.2 (0.469)	**-16.4** (0.051)
No agriculture × Permanent × Distance to closest town	2.4 (0.414)	1.8 (0.549)	1.8 (0.631)
No agriculture × Casual × Distance to closest town	-5.8 (0.408)	-2.0 (0.787)	-11.3 (0.205)

Note: p-values in parentheses. Bold coefficients indicate significance levels with p-values<0.1. Bold and italic coefficients indicate significance levels with 0.1≤ p-values>0.2.

Table A.3. Association between employment choices and HNARs of micronutrients – multivariate regression results

Variables	% change in HNARs		
	Vitamin A	**Iron**	**Zinc**
Agricultural operations (ref. non-commercialized)			
Commercialized	-21.8 (0.368)	**-36.6** (0.045)	**-34.0** (0.040)
No agriculture	36.4 (0.463)	12.9 (0.731)	4.4 (0.890)
Off-farm employment (ref. no off-farm)			
Permanent	-19.3 (0.479)	***-27.9*** (0.195)	-23.9 (0.224)
Casual	65.9 (0.613)	-56.8 (0.314)	-44.7 (0.425)
Agricultural operations × Off-farm employment			
Commercialized × Permanent	54.9 (0.235)	**94.9** (0.030)	**59.9** (0.086)
Commercialized × Casual	-3.9 (0.970)	***221.2*** (0.202)	102.2 (0.374)
No agriculture × Permanent	-28.5 (0.489)	-16.2 (0.662)	-12.5 (0.771)
No agriculture × Casual	-46.4 (0.570)	59.8 (0.608)	37.9 (0.693)
Distance to Bangalore (km)	***-1.6*** (0.113)	**-0.4** (00652)	-0.4 (0.616)
Distance to closest town (DCT) (km)	-1.2 (0.690)	-1.0 (0.684)	-1.3 (0.551)
Distance to Bangalore × Distance to closest town	0.1 (0.562)	0.0 (0.782)	0.0 (0.834)
Agricultural operations × Distance to closest town			
Commercialized × Distance to closest town	2.3 (0.335)	***3.2*** (0.106)	**3.0** (0.089)
No agriculture × Distance to closest town	-2.0 (0.561)	-2.2 (0.458)	-1.3 (0.627)
Off-farm employment × Distance to closest town			
Permanent × Distance to closest town	1.7 (0.520)	2.3 (0.299)	1.5 (0.428)
Casual × Distance to closest town	-0.8 (0.928)	7.6 (0.351)	6.8 (0.344)
Agricultural operations × Off-farm employment × Distance to closest town			
Commercialized × Permanent × Distance to closest town	***-4.1*** (0.184)	**-5.1** (0.048)	***-3.5*** (0.126)
Commercialized × Casual × Distance to closest town	-2.1 (0.830)	-8.7 (0.272)	-6.9 (0.334)
No agriculture × Permanent × Distance to closest town	1.5 (0.707)	1.3 (0.695)	1.2 (0.690)
No agriculture × Casual × Distance to closest town	1.3 (0.896)	-4.0 (0.631)	-4.3 (0.559)

Note: p-values in parentheses. Bold coefficients indicate significance levels with p-values<0.1. Bold and italic coefficients indicate significance levels with 0.1≤ p-values>0.2.

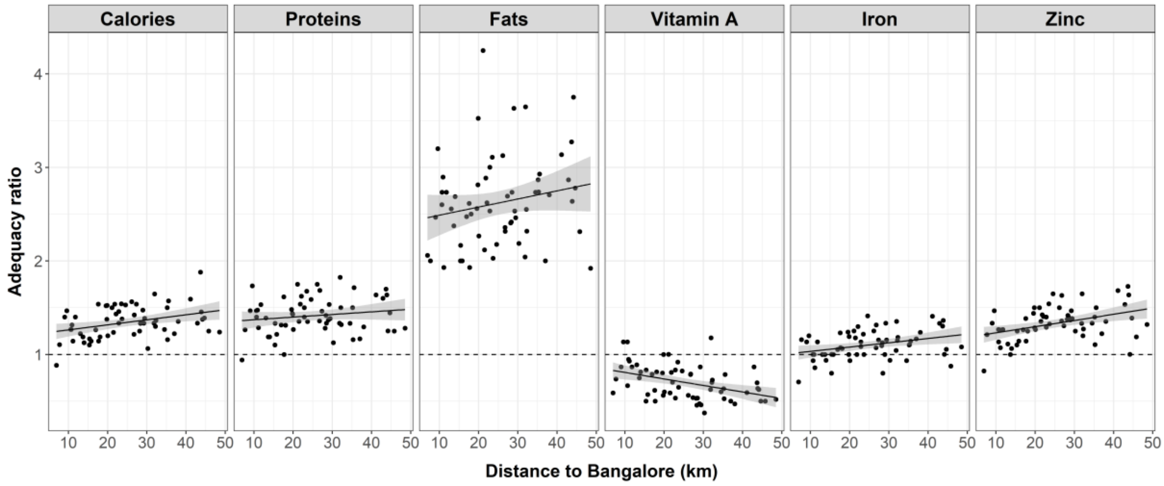

Figure A.1. Association between village HNARs and distance to Bangalore (gray areas represent 90 % confidence intervals for the trend lines)

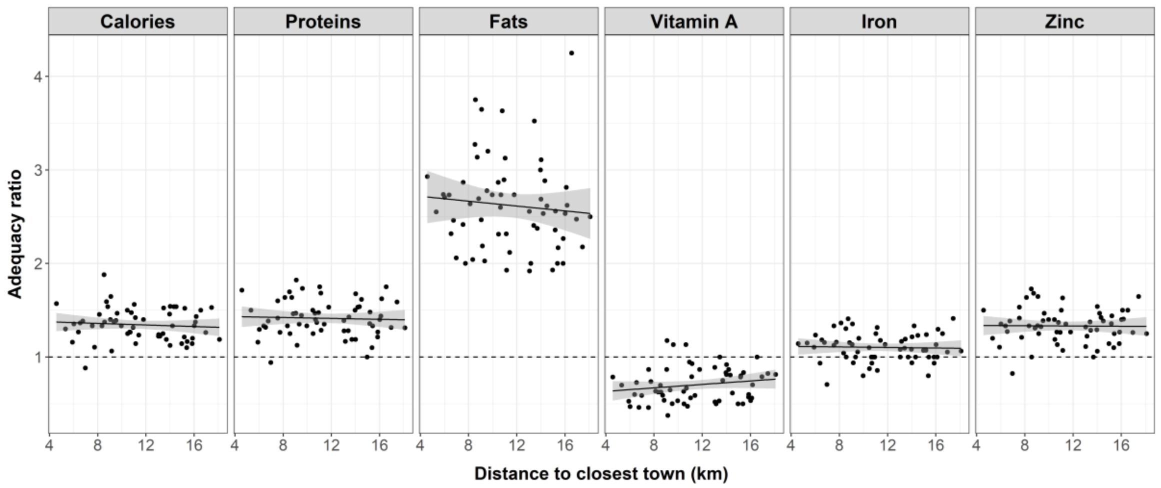

Figure A.2. Association between village HNARs and distance to the closest town (gray areas represent 90 % confidence intervals for the trend lines)