Sharing work and food within the household: Intra-couple time allocation effects on nutritional outcomes in rural Telangana, India

Afeni, O., Zanello, G., and Srinivasan, C. S.

Feminist Economist – In press

Abstract

In the context of the ongoing rural transformation in many countries, women's opportunities for economic participation are expanding. However, there is a limited understanding of how policy interventions can support rural households to adapt to the increasing opportunity cost of women's time in household activities. This paper presents empirical evidence on the relationship between couple interdependencies in time use and nutritional outcomes in rural Telangana, India. We used innovative datasets that combined accelerometer-based physical activity data, time use, food intake, and socio-demographic data – within the Actor-Partner Interdependence Model (APIM) framework. We find that differences in time allocation patterns between spouses in a household affect individual nutritional outcomes; when the male spouse allocates more time to economic activities, it tends to reduce the adequacy of the female spouse's energy intake, and conversely, when the female spouse allocates more time to domestic activities, it tends to reduce the male spouse's energy intake adequacy.

Keywords: Intra-couple time allocation; nutritional outcomes; physical activity; actor-partner interdependence model; Telangana, India.

JEL codes : J22, Q12, D13

1 Introduction

Malnutrition continues to be a development challenge in many low- and middle-income countries (LMICs), where around 185 million people cannot afford sufficient daily energy intake at an average cost of $0.79 (FAO et al., 2020). In the past decades, many agricultural and development interventions aimed at enhancing, diversifying, and substituting livelihood means have targeted women based on the central role that they play in ensuring household nutrition (FAO, 2011; Fiorella et al., 2016; Haddad et al., 1997). Even though interventions targeted at women can lead to greater participation in economic activities, increased productivity, and higher household incomes, it is not certain that nutritional outcomes will improve. This disconnect may arise because women in male-headed households still lack the capacity to influence household decision-making regarding the allocation of increased income and the use of their own time. (Kadiyala et al., 2014).

Building on the intrahousehold resource allocation literature, this paper presents empirical evidence on spousal interdependencies in time use and nutritional outcomes by investigating own and partner effects[1] of intrahousehold work division on nutritional outcomes among rural households in rural Telangana, India. We hypothesize that the time allocation of male and female spouses and the interdependencies between both individuals are consequential for nutritional outcomes. Inequity in intrahousehold work division has been linked to malnutrition, as women disproportionately bear household domestic work (including child-care) in addition to economic labour (Gillespie et al., 2012). Recent debates have suggested that sharing domestic responsibilities with men will reduce the burden borne by women and potentially improve women's well-being (Asadullah & Kambhampati, 2021; Madzorera &

[1] Own effects capture intra-individual outcomes (e.g., the effect of women's time use in a specific activity on their own nutritional outcome) while partner effects, interpersonal outcomes (e.g., the effect of women's time use in a specific activity on the spouse's nutritional outcome).

Fawzi, 2020; Rao & S. Raju, 2020), yet successful policy action to redefine men's household role will require understanding the well-being outcomes for both women and men.

Two are the major motivations for this paper. First, there is a research gap in the assessment of an individuals' partner effects, despite the extensive literature on household behaviour[2]. We assess partner effects in this study based on the premise that within households, couples share work and they also share food, especially in rural agricultural contexts where production and consumption decisions are interwoven (C. R. Doss & Quisumbing, 2020; Folbre, 1986; Singh et al., 1986). Even when couples adopt separate economic production spheres, it can be expected that they share some production and consumption between them. Second, there is thin evidence on how spouses in rural agricultural households in LMICs are adapting to rural transformation. Agriculture remains a major contributing sector to the rural economy in terms of employment and income, as increases in agricultural labour productivity and mechanization of farm activities are leading rural households to diversify into the rural non-farm sector (IFAD, 2016). Rural non-farm employment participation, including the time allocated to such activities is dominated by men (Binswanger-Mkhize, 2013; IFAD, 2016), but there are more opportunities for women to participate in economic activities outside of the home as a result of better education, changing socio-cultural norms and improvements in rural-urban transportation linkages (Binswanger-Mkhize, 2013; Ohlan, 2016). This form of rural transformation increases women's opportunity cost of time spent on food preparation

[2] A large body of literature looked at intrahousehold dynamics to understand the paradigms of household behaviour (see Fafchamps and Quisumbing (2007) for a review). The economic theory of household behaviour proposed by the unitary model aggregates utility of household members (Becker, 1981). Collective models contrarily posit independence in individual preferences and in the process of decision making. They argue that intrahousehold allocation is guided by bargaining even when couples cooperate (Apps & Rees, 1997; Chiappori, 1992; Lundberg & Pollak, 1993; McElroy & Horney, 1981). The drawback to the collective approach is when bargaining for food and other goods like healthcare and leisure is bounded by cultural norms, the approach produces outcomes akin to the unitary model (Agarwal, 1997; Duflo & Udry, 2004).

and care activities. The ensuing time reallocation can have implications for household nutritional outcomes (Da Corta & Venkateshwarlu, 1999).

Our analysis adopts the Actor Partner Interdependence Model (APIM) framework to capture partner and own effects. APIM is a model of interdependency between individuals (e.g. women and men) in a dyadic relationship (e.g. wife and husband). It postulates that own and partner's characteristics simultaneously influence the outcomes of both individuals (Cook & Kenny, 2005). The analysis allows to capture the effects of one person's characteristics on own outcomes and on the other person's outcome (partner effect). In studying bidirectional effects on two individuals, APIM presents a straightforward transition from economic theories which have either considered households as unified in their interests and preferences or treated individuals as independent decision-making units. The identification of women's and men's time use and their implications on their own and partner's nutritional outcomes is the contribution of this paper to the intrahousehold allocation literature. We examine the following research question: Among couples in farming households in rural Telangana (India), how does the distribution of time spent on economic, domestic, and leisure activities impact not only their own nutritional outcomes but also those of their partners?

2 Literature review

This literature review explores time allocation and nutritional outcomes in rural agricultural settings, first distilling evidence on the effects of women's time allocation on own nutritional outcomes and then focussing on the effects of intrahousehold time allocation on the nutritional outcomes of other family member(s).

2.1 Women's time allocation and nutritional outcomes

As a result of the ongoing rural transformations, there has been an increase in the number of women active in agriculture, including in the time women allocate to agricultural activities across all regions in LMICs – a trend known as "feminization of agriculture"(Asadullah & Kambhampati, 2021; FAO, 2011). Data collected from the rural areas of Telangana in India shows that women now spend on average, an additional two hours per day in agricultural activities than men and perform male-associated tasks such as land clearing, irrigation and plant protection on the farm (Padmaja et al., 2019). Conversely, male time commitment to farm work is on a downward trend due to the mechanization of male-dominated tasks and the result of male out-migration from rural areas (Padmaja et al., 2019). These changes in male and female time allocation are expected to have consequences for nutritional outcomes, yet empirical evidence is still very limited.

Women's time use tends to have a strong effect on their own well-being outcomes, however, the direction of the effect is not univocal (Ghosh & Bharati, 2005; Johnston et al., 2018; Ruel et al., 2018). Komatsu et al., (2018) found that women's agricultural time use is associated with a reduction in the consumption of diverse diets among women in Mozambique. They reported better nutritional outcomes among individuals in poor farming households. Other studies reported a negative association between agricultural time use and nutritional outcomes as well. The limited available evidence on this topic suggests that the ability of women to translate agricultural time allocation into desirable nutritional outcomes is mediated by diverse factors. Ghosh & Bharati (2005) found that the effect of agricultural time allocation on body mass index is mediated by socio-demographic factors, although women in paid agricultural work experienced better nutrition than unpaid working women. Also examining the differentiating effects of paid and unpaid work on household nutrition among women in five Indian states, Sangwan & Kumar (2021) found that women in paid farm work have better nutrition compared with peers in non-paid work – as a result of the increase in bargaining power emanating from women's labour force participation. Further, the effects of time use on the nutritional wellbeing of women and men vary across agricultural seasons as the energy demand of work is highest during land maintenance and harvest seasons (Picchioni et al., 2020; Rao & S. Raju, 2020; Srinivasan et al., 2020). This seasonality effect is intensified among individuals in non-mechanized farming households (Daum et al., 2019; Komatsu et al., 2019) and the landless (Vemireddy & Pingali, 2021). In their review, Johnston et al., (2018) concluded that increased time allocated to agriculture, and the resulting nutritional outcomes will depend on how different individuals in an agricultural household respond to the changes in time use.

In addition to women's time allocation to agricultural activities, women (and girls) disproportionately perform more than three-quarters of household domestic and care work (Jacques Charmes, 2019). However, the evidence linking participation in domestic work and wellbeing in rural areas is very sparse. Often, time use in domestic activity is explained in the context of trade-offs with agricultural and childcare activities, but not how it directly relates to wellbeing. Desai & Jain (1994) argue that domestic work reduces women's available time to both childcare and economic activities; to the extent that domestic work can be a greater obstacle than childcare to female labour force participation. A multi-country study across Asia and Africa on women's time use and dietary diversity found that time spent cooking is positively associated with women's dietary diversity in Bangladesh and Cambodia, while time committed to domestic work is positively associated with diverse diets among women in Cambodia, in Ghana (poorer households), and in Nepal (Komatsu et al., 2018). The authors suggest that the positive association between domestic/care tasks and more diverse diets could be a result of "staying close to the pot". Studying the time allocation to leisure activities and nutritional outcomes, Seymour et al., (2019) investigated the association of women's time poverty and household nutrition in Bangladesh and found that women's time poverty (defined as allocating less than 50 per cent of median time on leisure and self-care related activities) is not significant in its association with household nutritional outcomes. Indeed, time-poor women have relatively better nutritional outcomes.

The paradox seen in this strand of literature is that although female agricultural economic time use suggests better nutritional outcomes through the increase in and control of incomes, benefits can be outweighed by increasing time spent in strenuous physical activities leading to greater energy expenditure (Nichols, 2016) and sociocultural norms entrenched in intrahousehold negotiations can limit a woman's use of her monetary and time resources (Agarwal, 1997; Bittman et al., 2003). However, Sangwan & Kumar (2021) and van den Bold et al., (2021) finds no deleterious effects resulting from increasing agricultural time on nutritional status. Their conclusions may be due to the small additional time spent in agriculture following the interventions reported in their studies. Moreover, women may regard improvements in household food security and income as beneficial even though such involves trade-offs to their own well-being (Kabeer, 2001).

Reviews undertaken by FAO et al., (2020) and Johnston et al., (2018) show that the information about men's time use is often less researched. Despite the significant focus on women's time use and nutritional outcomes, women more than men continue to be malnourished in rural areas of LMICs where most people depend on agriculture for their livelihoods.

2.2 Intrahousehold time allocation and nutritional externalities

Intrahousehold externalities affect individual wellbeing (Basu, Narayan, & Ravallion, 2001) but there are few pieces of empirical evidence assessing the relationship between men's time allocation and women's nutritional outcomes and vice versa. Fleary & Joseph (2022) using APIM to analyse data from the United States show interdependencies in health literacy, time use and dietary behaviours between parents and adolescents. In the development literature, intrahousehold externalities are largely streamlined to maternal time use and its consequences on women's caring responsibilities for children's nutrition (Fadare et al., 2019; Ruel & Alderman, 2013). Such focus on maternal time use and child nutrition is based on the established linkages between the wellbeing of mother and child. However, in the face of deprivation, gendered pay gaps and ownership of assets, the maintenance of adequate nutrition among the poor and the very poor may lie in interdependencies between men and women within the household (Rao et al., 2017). Such interdependent view has largely been ignored, and women tend to have been targeted individually.

3 Study area and data collection

3.1 Study area

The secondary data used for analysis were collected in Jogulamba Gadwal District, south of Telangana State in India. The district has 20 per cent scheduled castes, 1.5 per cent scheduled tribes[3] and more than three-quarters of its 609,990-population scattered in 255 rural villages. About 60 per cent of its total land area is cultivated for food and cash crops, often on small and marginal plots. Due to a substantial increase in the amount of monsoon rainfall and the adoption of irrigation facilities in recent years, the semi-arid climate is increasingly turning favourable to agricultural production (Government of Telangana, 2019).

Figure 1 here

[3] "Schedule" refers to schedules in the Indian constitution identifying socially and economically deprived/marginalized caste groups and tribal (indigenous) groups as being entitled to affirmative actions in education, employment and development programs (Lelah Dushkin, 1967).

State government reports show a gradual decline in poverty in these areas; between 2014 and 2020, per capita annual income (adjusted for inflation) rose more than 10 per cent to 69,113 Rupees, equivalent to USD 1,100[4]. Rural income growth has been driven by agricultural production expansion and participation in the Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) social welfare program. Data show that about 20 per cent of the Jogulamba district population participates in MGNREGA and despite the mixed impacts[5] of the MGNREGA on agriculture in the area, agriculture and allied (crops, livestock, fisheries, forestry) sector contribution to the overall product output rose to 21 per cent in 2021 (Government of Telangana, 2021). The growth can be attributed, in part, to other government interventions in the form of inputs support, land redistribution, irrigation, and insurance schemes.

Despite per-capita income increased in the study area over the last decade, malnutrition within the population has remained high, especially among women. Figures from the Indian National Family Health Survey show that 22 per cent of women and 17 per cent of men are underweight (BMI $< 18.5 kg/m^2$) in rural Telangana in 2019-2020[6]; this is a decline from 29 per cent among women and 25 per cent among men in 2015-2016. The current prevalence of anaemia among women is 58 per cent, up from 57 per cent in 2015-2016 (Christopher et al., 2021; Ministry of Health and Family Welfare; Government of India, 2020). In comparison to the other States in India, the high malnutrition rate is linked to the large number of scheduled castes and scheduled tribes in Telangana.

[4] 1 USD averaged 62.78 Indian Rupees in 2014 (Reserve Bank of India, 2020).
[5] The MGNREGA has led to an increase in agricultural wages and a subsequent tightening of the agricultural labour market. In some instances, this agricultural labour shortage has been linked to shrinking farm plots in places where mechanization of farm work is elusive (Reddy et al., 2014).
[6] Data was collected prior to the COVID-19 pandemic.

Further, the patterns of time use in this region show rural men and women commit over eight hours to work-related activities daily (Government of India, 2020). There are however substantial gender disparities albeit to a lesser degree compared to the rest of India: 55.7 per cent of rural Telangana women participate in paid work, a figure three times the national average (Government of India, 2020). Using data from the Time Use Survey-2019, Figure 2 shows the allocation of time among males and females living in rural areas of Telangana state. Compared to men, women allocate on average 225 minutes more per day to care, domestic and volunteer work, 158 minutes less to employment and production of goods for own use and tend to spend on average 29 minutes more in work-related activities daily than men – the time they seem to reallocate from socializing, self-care, and maintenance activities.

Figure 2 here

3.2 Data collection

3.2.1 Survey

The secondary dataset used in this paper is described in Zanello et al., (2020). Twenty households were randomly selected after the households in the area had been stratified by their ownership of irrigation infrastructure and the size of their landholdings[7]. In each household, an economically active man and woman, aged between 16-64 years old took part in the study. All households were employed primarily in crop production; eighteen households cultivated their own land and two were sharecroppers. They cultivated predominantly rice, cotton, yam, chillies, and groundnuts. Respondents were visited daily for four non-consecutive weeks during June – November 2018, corresponding to each of the four

[7] Data were collected in two communities – one using rainfed agriculture and one using irrigation infrastructure. The stratification of the sample households by landholding size control for differences in socio-economic characteristics across the two agricultural systems.

agricultural seasons of land preparation, sowing, land maintenance, and harvest when Kharif[8] crops are cultivated.

At the beginning of the fieldwork, individuals self-reported information on their own health, and anthropometric measurements of height and weight were taken. All the questionnaires administered to respondents were translated into Telugu, the local language. The survey was carried out by enumerators living in the same district and who spoke the local language. Information on household characteristics was collected from the household head. In addition, individual food intake data were collected daily based on a 24-hour recall throughout the four weeks (Gibson & Ferguson, 2008). During the daily visits, enumerators also collected time use information at one hour-intervals based on 24-hour recall.

3.2.2 Accelerometers

In addition to questionnaires administered daily, respondents were invited to wear an accelerometer device throughout the length of the data collection. Accelerometers are portable motion sensor devices used in the collection of objective physical activity data in free-living populations (Troiano et al., 2014; Zanello et al., 2019). Raw 30Hz[9] movement data were collected using research-grade, tri-axial Actigraph GT3X+ accelerometers worn on the waist by respondents during awake hours of 5 am – 11 pm. The movement data collected from accelerometers were converted into energy expenditure (in kilocalories) using validated algorithms (Freedson et al., 1998). Time use data collected using questionnaires were matched with energy expenditure data derived from accelerometers to determine activity-specific energy expenditure (Zanello et al., 2019).

[8] In India, kharif crops are monsoon crops such as rice, maize, sugarcane, groundnut planted in July and harvested around October. Rabi crops are winter crops such as wheat, barley, carrot, chickpea planted in November and harvested around April and May.

[9] 1Hz (Hertz) is one cycle per second.

While accelerometers provide an effective tool to capture energy expenditure in a free-living population, they are not without limitations. Most importantly, as they capture movements, they do not capture the additional effort involved in carrying weight or activities performed while stationary (Lee & Shiroma, 2014). These limitations are particularly relevant for activities typically categorized as domestic or caregiving, potentially leading to a greater underestimation of energy expenditure in women compared to men (Shiroma et al., 2016). A common challenge in physical activity research using accelerometers, especially in studies among free-living populations, is participants not wearing the devices consistently (Troiano et al., 2014). However, in our study, compliance with wearing the accelerometer was high. A full day accelerometer wear rate was between 94-97% among the respondents. No sample attrition was recorded during the four weeks of data collection.

The unique dataset used in this study therefore combines information on individual and household sociodemographic characteristics, and individual data on food intake, time use, and physical activity.

4 Empirical Methods

4.1 Independent variables

The main independent variables used in this study were time use variables measured as the number of minutes allocated to each of economic, domestic and leisure activities (Moser, 1989). Every recorded activity in the hourly time use data was identified as either the primary or secondary activity to ensure that typical secondary activities such as leisure and childcare are also considered (Ironmonger, 2005). In cases where no secondary activities were recorded, a weight of 1 was assigned to the hourly observation. A weight of 0.6 was assigned to primary and weight of 0.4 was assigned to secondary activity, where respondents reported they carried out simultaneous activities (Picchioni et al., 2020). We aggregate each of economic, domestic and leisure time use data from hourly to day-level. Economic time use includes time spent in agricultural activities such as crop and livestock production, forest produce collection and related travel. Non-agricultural economic activities are salaried employment, non-farm wage employment in construction and public work schemes, business, petty trading, and professional development training. Domestic and care provision time use include household maintenance and chores, food management, caring for children, elderly, sick and disabled. Leisure time use includes time allocated to socializing and personal care.

4.2 Dependent variables

A set of three dependent variables are used in the analysis to capture the association between time allocation and own and partner's calorie intake adequacy: Physical Activity Level (PAL), Total Individual Energy Intake (EI), and Calorie Adequacy Ratio (CAR). We examine the associations of time allocation with PAL, EI and CAR outcomes.

4.2.1 Physical Activity Level (PAL)

Physical Activity Level (PAL) is a measure of the intensity of physical activity over a day (or other time period). To calculate individual PAL, raw 60-second epoch length physical activity data collected from accelerometers were converted to Activity Energy Expenditure (AEE) in kilocalories using a validated algorithm (Freedson et al., 1998). PAL is the ratio of Total Energy Expenditure (TEE) to Basal Metabolic Rate (BMR), where TEE is the sum of BMR (energy required to maintain vital physiological processes in the body) and AEE[10]. We compute the BMR using the Harris-Benedict equation (Harris & Benedict, 1918). We use

[10] TEE is the sum of BMR, AEE, and Thermal Effect of Feeding (TEF). TEF is energy required for metabolism, but TEF data is not available for this study. However, we assume the effect of this limitation to be minimal, since TEF accounts for only about 5-10 per cent of TEE (FAO, 2001).

PAL as the outcome variable instead of AEE because PAL controls for individual anthropometric differences, allowing for comparisons across different age, gender, and BMI groups. PAL values of 1.40-1.69 reflects sedentary or light activities, 1.70-1.99 moderate activity and >2.00 indicates vigorous activity in free-living population. PAL has been used to model energy expenditure among free-living populations (Friedman et al., 2021; Picchioni et al., 2020; Srinivasan et al., 2020).

4.2.2 Total Individual Energy Intake (EI)

Total Individual Energy Intake (EI) is the total dietary energy reportedly consumed by individual respondents in the last 24 hours. It captures the calorie (kcal) equivalent of food and beverages per-adult day energy consumption (FAO, 2003). We use individual's food intake data recorded through a 24-hour recall to compute the caloric values. The Indian Food Composition tables were used to determine the calorie content of local recipes (Bowen et al., 2011). The United States' National Nutrient Database for Standard Reference was used for calorie conversion of ultra-processed foods (U.S. Department of Agriculture, 2019). However, while EI captures caloric availability, the nutritional components of the food, and the quality of diets cannot be ascertained.

4.2.3 Calorie Adequacy Ratio (CAR)

We use Calorie Adequacy Ratio (CAR) as a measure of nutritional outcomes. CAR is a metric of energy balance which quantifies the overall dietary energy adequacy of an individual based on the ratio of energy intake to energy expenditure (Randolph et al., 1991). We compute CAR as the ratio of energy intake (EI) relative to total energy expenditure (TEE). An individual whose CAR is equal to 1 is classified as energy balanced, a CAR below 1 is classified as being energy deficient, and a CAR value above 1 indicates that the individual is in energy surplus for a given day (FAO, 2001). The CAR as an indicator of nutritional outcomes allows to measure individual energy intake adequacy. However, its focus on calories prevents measuring the adequacy of the other nutrients necessary for a diverse diet. A person with a CAR equal or above 1 may be deficient in essential nutrients. The description of all dependent and independent variables used in the analysis (including intermediate variables) is presented in Table 1.

Table 1 here

4.3 Empirical strategy

4.3.1 The Actor-Partner Interdependence Model (APIM)

The Actor-Partner Interdependence Model (APIM) explains dyadic relationships by incorporating the concept of non-independence between two linked individuals with the statistical methods to test such interdependence (Cook & Kenny, 2005). The APIM postulates that own (actor), and partner's characteristics simultaneously influence the outcomes of both individuals. This methodological approach assumes correlations in the characteristics and outcomes of individuals within the same unit (for example, household). Conventional statistical procedures assume independent observations but ignoring nonindependence of observations between linked individuals will likely lead to biased statistical estimates (Cook & Kenny, 2005). Non-independence in the observations of two linked persons may arise as a result of *common fate*, *mutual influence* and *partner effects* (Kenny & Cook, 1999). APIM focuses on modelling the interdependence between two individuals through partner effects. Partner effects measure the bi-directional influence of one person on the other member of the dyad. This contrasts intrahousehold behaviour theories that posits that individual outcomes are determined either by individual preferences or by altruism (Fafchamps & Quisumbing, 2007). APIM approach has been used to study dyadic relationships, for example, in the analysis of health behaviors in parent-adolescent dyads (Fleary & Joseph, 2022), work division, communication, and couples' relationship satisfaction (Carlson et al., 2020). APIM is used in this study to predict the influence that time allocation of spouses has on own and partner's PAL, EI, and CAR outcomes. The household is treated as the unit of analysis.

Figure 3 here

Figure 3: Path depiction of the APIM model (Adapted from Kenny et al., 2006)

Notes: X_m = independent variable of the male, X_f = independent variable of the female, Y_m = outcome variable of the male, Y_f = outcome variable of the female, β_m = male own (actor) effects, ρ_m = male partner effects, β_f = female own (actor) effects, ρ_f = female partner effects, E_1 and E_2 = error term.

We assess own (intrapersonal) and partner (interpersonal) effects of time use on dependent variables of PAL, EI and CAR using the APIM for dyadic data depicted in Figure 4 (Cook & Kenny, 2005). To treat individuals as nested within a dyad, we use the gender of each respondent as the distinguishing variable within couples – and to capture role-specificity of individuals. This differentiation allows for estimating the main components of the APIM: own effects - β_m, β_f and partner effects - ρ_m, ρ_f; by using the main independent variables - X_m, X_f; and the dependent variables - Y_m and Y_f. Own effects (β_m, β_f) capture the association between own independent variables and dependent variables ($X_{m;}$ and Y_m; X_f and Y_f for male and female respectively), while partner effects (ρ_m, ρ_f) capture the association between own independent variables and partner's dependent variable (Xm and Y_f; X_f and Y_m). E_1 and E_2 control for the correlation within couples. Interdependency between couple occurs when the partner effects ρ_m, ρ_f are significantly associated with the dependent variables (Kenny et al., 2006).

In the APIM model, to estimate own (β_m, β_f) and partner (ρ_m, ρ_f) effects of the time use variables on the dependent variables of PAL, EI and CAR, we arrange the dyadic data in a pairwise structure as shown in Table 2[11]. Each row of data includes the household identifier, the gender of the individual, the outcome variable for the individual and the characteristic(s) of the individual. Additionally, the last two columns of Table-2 include the individual characteristics and partner characteristics each multiplied by a dummy variable Z which is equal to 0 for "own" and equal to 1 for "partner". Arranging the data in this way yields equations where the outcome for each individual is a function of the individual's characteristics and the partner's characteristics.

Table 2 here

4.3.2 Own and partner effects - couple composition, context, and the endogeneity of time use variables.

Ordinary least squares, structural equation modelling and multilevel modelling can be used in the analysis of the APIM. We apply a multilevel model (MLM) to analyse the APIM framework. This allows for the simultaneous estimation of hierarchies in the nested data- two individuals (level-1) nested in a household (level-2) – whilst accounting for the inherent nonindependence within each couple. To obtain the actor and partner effects by male and female gender, the random two-intercepts model for MLM using the restricted maximum likelihood method (Kenny et al., 2006; Rabe-Hesketh & Skrondal, 2012; Raudenbush et al., 1995) estimates fifteen separate panel equations with separate observations for each day of the

[11] For simplicity, the illustration in Table-2 includes only one characteristic (explanatory variable) for each individual. The analysis can be extended to cases where there are several characteristics associated with each individual (e.g., time spent in different types of activities).

form $Y_{ijt} \epsilon$ {PAL_{ijt}, EI_{ijt}, CAR_{ijt}, $CAR_{ijt} > 1$, $CAR_{ijt} < 1$} and k = {Economic, Domestic and Leisure time uses}:

$$Y_{ijt} = \alpha_m^k \delta_i + \alpha_f^k (1- \delta_i) + \beta_m^k X_{mjt}^k \delta_i + \beta_f^k X_{fjt}^k (1- \delta_i) +$$

$$\rho_m^k X_{mjt}^k (1- \delta_i) + \rho_f^k X_{fjt}^k \delta_i + \theta_j^k \overline{X}_j^k + \boldsymbol{\omega}^{\mathbf{k}}\mathbf{I}_j + \boldsymbol{\sigma}^{\mathbf{k}} \mathbf{H}_j + \gamma^{\mathbf{k}}\mathbf{C}_t + \boldsymbol{\tau}^{\mathbf{k}}\mathbf{Z}_s + \varepsilon_{ijt}^k \quad (1)$$

where i is the person (subscript m = male, f = female), j is household and t is day of the week; male α_m and female α_f intercepts; δ_i indicates that the person is male, female is $(1- \delta_i)$; $X_{mjt}^k \delta_i$ is the time spent in activities type k by the male in the jth household in t^h period (day); $X_{fjt}^k (1- \delta_i)$ is the time spent in activities type k by the female in the jth household in t^h period (day); $X_{mjt}^k (1- \delta_i)$ is the time spent in activities type k by the male partner in the jth household in t^h period (day); $X_{fjt}^k \delta_i$ is the time spent in activities type k by the female partner in the jth household in t^h period (day); $\overline{X}_j^k$ is the mean of couple time use; I_j is a vector of couple-mean centred variables of age and literacy[12], H_j is vector of household socio-demographic characteristics such as irrigation system, size of cultivated land, household composition and assets index, and controls such as accelerometer wear, self-reported health, caste; C_t is day dummies; Z is seasonal (land preparation, sowing, land maintenance, and harvest) dummies; and the error term is $\varepsilon_{ijt} = \zeta_j + \mu_{ij}$ where ζ_j is household component, and individual-specific component μ_{ij}

The composition of groups, their contexts and the endogeneity of variables are likely sources of bias in multilevel analysis of APIM. For instance in our analysis, if higher couple literacy is associated with higher CAR for household j, comparing own and partner effects among couples is confounded by higher estimates among more literate couples (Bingenheimer &

[12] Couple mean centering of age and literacy was obtained by subtracting the household mean from individual observation.

Raudenbush, 2004; Rabe-Hesketh & Skrondal, 2012). This confounding by average household level characteristics is referred to as compositional effects (Duncan et al., 1998). We address compositional effects by including couple-mean centred variables of age and literacy in equation 1 (Rabe-Hesketh & Skrondal, 2012).

In addition to bias that may be introduced by compositional effects, individual's patterns of time use is known to correlate with unobserved household-level characteristics such as sociocultural norms, resulting in level-2 endogeneity (Kevane & Wydick, 2001). We used the Mundlak or "including-the-group-means approach" to address level-2 endogeneity of the time use variables (Mundlak, 1978). This was done by including the means of couple time use variables in equation 1. The Mundlak approach results in own and partner time use effects that captures pure within-couple variation, which is unaffected by level-2 endogeneity.

Further, to ascertain the exogeneity of the within-couple time use estimates, we conduct post regression tests of equal between and within time use effects (Rabe-Hesketh & Skrondal, 2012). Results show that the within-couple effects are uncorrelated with the between couple time use effects. However, the Mundlak approach can produce biased estimates due to other omitted variables, and the effects of time-invariant variables may not be consistent, as the within and between effects are estimated separately in equation 1 (Hanchane & Mostafa, 2012). This limitation is addressed by the instrumental variable or Hausman-Taylor (HT) approach (Hausman & Taylor, 1981). The HT approach can consistently estimate models with endogenous time-invariant variables and time-variant variables, to produce estimates which are uncorrelated with the residuals. In equation 2, household-level (level 2) factors not captured in the model could have influenced differently, the patterns of time use of females and males (level 1). The HT method first estimates individual-level effects of the time-varying variables. This estimation produces residuals which are then regressed on time-invariant variables. Regressing the residuals on the exogenous variables produces between-household effects, which are uncorrelated with the time-varying individual-level variables. The produced between-household effects act as instrumental variables (Rabe-Hesketh & Skrondal, 2012). As such, using the HT approach requires independent variables to be classified into four kinds as: exogenous time-varying variables, endogenous time-varying variables, exogenous time-constant variables, and endogenous time-constant variables. These are presented in Table 3.

Table 3 here

In addition to this criterion, the number of exogenous time-varying variables must be equal or higher than the number of the endogenous time-constant variables. Both conditions are satisfied in equation 2, where we estimated nine[13] separate regression models where each outcome variable PAL, EI and CAR depend on each set of economic, domestic and leisure activities of the form $Y_{2ijt} \in \{PAL_{ijt}, EI_{ijt}, CAR_{ijt}\}$ and k = {Economic, Domestic and Leisure}:

$$Y_{2ijt} = (\beta_{2i} + \zeta_j) + \beta^k_{2m} X^{k,\,end}_{mjt}\, \delta_i + \beta^k_{2f} X^{k,\,end}_{fjt}\, (1-\delta_i) + \rho^k_{2m} X^{k,\,end}_{mjt}\, (1-\delta_i) + \rho^k_{2f} X^{k,\,end}_{fjt}\, \delta_i + \pi^k_{ij} P^k_{ijt} + \boldsymbol{\omega}^k_2 \mathbf{I}_j + \boldsymbol{\tau}^k_2 \mathbf{Z}_s + \boldsymbol{\gamma}^k_2 \mathbf{C}_t + \varepsilon^k_{ijt} \qquad (2)$$

where i is the person (subscript m = male, f = female), j is household and t is on day t; superscript *end* indicates endogenous variables; subscript 2 here distinguishes equation 1 from equation 2; $(\beta_{2i} + \zeta_j)$ is the intercept; δ_i indicates that the person is male = 1, female = $(1-\delta_i)$; $X^{k,\,end}_{mjt}$ is the time spent in activities type k by the male in the jth household in t^h period (day); $X^{k,\,end}_{fjt}$ is the time spent in activities type k by the female in the jth household in t^h period

[13] CAR>1 and CAR<1 was dropped as dependent variables in equation 2 because of the largely insignificant effects produced in equation 1.

(day); $X_{mjt}^{k,\ end}(1-\delta_i)$ is the time spent in activities type k by the male partner in the jth household in t^h period (day); $X_{fjt}^{k,\ end}\ \delta_i$ is the time spent in activities type k by the female partner in the jth household in t^h period (day); P_{ijt}^{k} is a vector of gender and literacy; I_j is a vector of household socio-demographic characteristics such as irrigation system, size of cultivated land, vector of household composition and assets index, and controls such as accelerometer wear, self-reported health, caste; Z is seasonal (land preparation, sowing, land maintenance, and harvest) dummies; C_t is daily dummies; error term = ε_{ijt}. Own and partner time use variables were designated as related to components in the random intercept ($\beta_{2i} + \zeta_j$) in equation 2. The regression analysis was carried out using the "xthtaylor" command in Stata software (Castellano et al., 2014; Hausman & Taylor, 1981; StataCorp, 2013). The other form of endogeneity in MLM is the level-1 endogeneity of level-1 covariates. For instance, individual preference for certain activities may influence the amount of time spent on such activity. However, level-1 endogeneity in MLM is not directly testable (Rabe-Hesketh & Skrondal, 2012). Post-regression estimates of the own and partner effects of each time use category were computed as the percentage change in dependent variable divided by the percentage change in the independent variable for equations 1 and 2.

5 Results

5.1 Descriptive statistics

Table 4 presents descriptive statistics of household-level characteristics. On average, households in our sample cultivate around 10 acres of land, which is greater than the 3 acres district average (Government of Telangana, 2021). There is however variability in the sample with 35 per cent being smallholders, 35 per cent medium and 30 per cent large farmers based on classification of landholding by the Indian Ministry of Agriculture and Farmers Welfare[14]. The average household size of 4.3 is slightly below the Indian national average of 4.6 people (UNDESA, 2019), with the number of males slightly higher than the number of females. The respondents belonged to the backward caste, while one household identifies as belonging to the scheduled caste.

Table 4 here

Descriptive statistics of individual-level characteristics are reported in Table 5. An average PAL value of 1.55[15] suggests that men and women spend a significant amount of time engaged in light and moderate-intensity activities. There are indications of calorie deficits among survey participants. Energy intakes for males and females are below the Indian recommended daily dietary allowance (RDA) of 2,730 and 2,230 kcal for moderately active people (National Institute of Nutrition, 2011). On average, men have a higher energy intake than women (158 kcals/day more). However, relative to their energy expenditure needs, men also have higher energy shortfalls compared to women. This translates to 978,82 kcals and 636,87 kcals calorie deficits for males and females respectively. Using CAR values, about 57 per cent of male respondents have an average daily CAR value below 1, while about 86 per cent of female respondents have an average daily CAR value below 1. The CAR values indicate more women than men are experiencing undernutrition.

Table 5 here

On average, males were older than females, with mean ages of around 40 years and a significant difference of 5.5 years. In terms of literacy, defined as the ability to read and write,

[14] Smallholders < 4.94 acres, medium 4.94-9.88 acres and large farmers >12.35 acres.
[15] PAL values are classified as sedentary or light (1.40-1.69), active or moderately active (1.70-1.99), and vigorous (2.00-2.40) in free-living populations (FAO, 2001).

a substantial gap was observed: 30% of males were literate, compared to only 5% of females, marking a significant difference of 25 percentage points. When it came to daily activities, males spent significantly less time on domestic and care activities, averaging 27 minutes per day, while females spent considerably more time, averaging 206 minutes per day. Conversely, males engaged more in economic activities, averaging 516 minutes per day, compared to females, who averaged 420 minutes per day. Men also spend on average 72 minutes more per day than women in leisure activities. Similar unequal pattern of intrahousehold work division have been reported in developed countries (Bittman et al., 2003).

5.2 Own and partner effects

As explained in Section 4.3.2, we run fifteen separate regressions such that own and partners' time spent in economic, domestic and care and leisure activity were regressed on the outcome variables of PAL, EI, CAR, CAR<1 and CAR$>=1$. Table 5 reports an overview of own and partner effects elasticities computed post-MLM analysis of the Mundlak approach in Equation 1. The own and partner elasticities were computed as the percentage change in the dependent variable relative to the percentage change in independent variable (that is, time use) in minutes. The time use coefficients can be interpreted as the effect on the dependent variable, of a one minute change in the time devoted to an activity category. Full regression tables are reported in Appendix B. The effect sizes in Table 6 are expressed in percentages.

Table 6 here

5.2.1 Physical Activity Level (PAL)

The highest PAL effect is observed in the time allocated to economic activities, followed by domestic and care activities. Conversely, the smallest PAL effect is noted in leisure activities, for both females and males. A one percent increase in the time allocated to economic work leads to a ten percent and eight percent increase in own PAL for males and females, respectively. Male economic time use is associated with a two percent reduction in female PAL. This suggests that male economic time use has a positive partner effect by reducing the female PAL. Regarding domestic and care activity, a negative association is observed between time spent on domestic and care work and PAL for both males and females. Although very small, male domestic and care time use has a positive partner effect on female PAL, while female domestic and care time use has no significant partner effect on male PAL. Furthermore, given that men spend considerably less time on domestic and care activities, the equal PAL effect size observed for domestic and care activity among males and females is notable. This may be attributed to men engaging in short duration but more energy-intensive activities, in contrast to women performing longer duration but less energy-intensive tasks. Leisure time use is inversely related to PAL, with a more pronounced effect among women than men. A one percent increase in the time allocated to leisure is associated with a five percent reduction in PAL for females and a four percent reduction for males. Additionally, a one percent increase in male leisure time use increases female PAL by one percent.

5.2.2 Total Individual Energy Intake (EI)

No significant effects on energy intake were observed for males across all three activity categories. Female energy intake appears to increase by six percent with each one percent increase in time spent on economic activities. These patterns of intrahousehold food allocation indicate that time spent in economic activities is a significant, but not the only, determinant of intrahousehold food distribution. The significant partner effects observed in domestic and care time use confirm couple interdependence in this category and in terms of energy intake. We also observe contrasting partner effects on energy intake; male time spent in economic activity is correlated with a decrease in the quantity of food calories consumed by his spouse, whereas female time spent in economic work is positively associated with the energy intake of males. Given that the coefficient estimate for male partner economic time use (-0.07) is lower than that for female partner economic time use (0.06), the effects of female time spent in economic work on the couple's energy adequacy is large enough to offset the reduced calorie intake due to male partner effects. In other words, females and their spouses benefit more when the females spend time in economic work. This finding is consistent with studies indicating that women's participation in economic work improves not only their nutritional outcomes but also those of other household members (Ruel et al., 2018).

We also observe that female energy intake declines with increasing time allocated to domestic and care activity, in contrast to the increasing effect observed with time spent in economic work. This finding contradicts the positive nutritional outcomes associated with domestic and care work reported in a previous multicountry study (Komatsu et al., 2018). The male partner EI effects of domestic and care activity indicate an increase in female EI as men engage in domestic and care activities. This pathway is further validated by the EI effects observed in economic activities, where male participation in economic activities is seen to negatively influence female EI. For both females and males, there is no statistically significant relationship between EI and leisure time use.

5.2.3 Calorie Adequacy Ratio (CAR)

Results show that a one per cent increase in male economic time use leads to a nine per cent decrease in CAR, with no corresponding significant relationship observed for females. This contradicts the observations from Section 5.2.2, where female economic time use significantly predicted EI but not CAR, in contrast to the findings for men. Such an outcome underscores the importance of accounting for energy requirements in nutrition assessments. Regarding partner effects, we note a decrease in female CAR with an increase in male economic time use: a one per cent increase in male economic activity participation results in a five per cent decrease in female CAR.

The effect of female domestic and care time use on female CAR mirrors that of male economic activities on male CAR. Similar to the observations for EI, female domestic and care time use reduces female CAR, while economic activities tend to reduce male CAR. In addition to own effects, female domestic and care time use is also negatively associated with the CAR of their spouses. Our results reveal no significant effects of male domestic and care time use on CAR, neither in their own nor in partner effects.

The association between leisure time use and CAR shows that for every one per cent time spent in leisure, female CAR increases by five per cent. Corresponding own male effects are not significant, and there are no partner effects of leisure on CAR for both males and females.

We decompose CAR into energy sufficient (CAR≥1) and energy deficient (CAR<1) groups to provide additional insights on intra-couple time allocation by their energy adequacy status. Calorie adequacy tends to decrease with increasing own domestic and care time use among energy-deficient females. Among females with a calorie adequacy ratio greater than 1, CAR appears to increase with male partner domestic and care time use. There are no significant effects observed in the relationship between mean couple time use ans CAR among the calorie- deficient and sufficient groups.

Table 7 here

5.3 Robustness checks

To assess the robustness of regression results to the different estimation methods of the MLM, we compare magnitudes and significance values between coefficient estimates of the restricted maximum likelihood (REML) and full information maximum likelihood (FIML) for all models. Estimates are similar and our conclusions hold for both REML and FIML parameter estimation methods. However, our preferred approach is the REML methods, as it is more suitable with estimations of small sample sizes compared to the FIML (Peugh, 2010). The regression tables and post regression elasticities tables of the FIML are presented in Appendices C1 – C4. Equation 2 regression results are presented in Table 7. Post-regression elasticity estimates of the Hausman-Taylor estimator are quite like the Mundlak approach already described in subsections 5.2.1, 5.2.2 and 5.2.3, except for the insignificant female partner domestic and care time use effect on CAR in the Mundlak approach and the insignificant male partner leisure time use on PAL in the Hausman-Taylor approach.

6 Discussion and conclusion

While time use patterns of women have been hypothesized to be responsible for the persistence of malnutrition among women; previous empirical studies have mainly examined the effects of women's time use allocations on children's nutrition. We contribute to the literature on time allocation and nutritional externalities by looking at own and partner effects of intra-couple time allocation on nutritional outcomes among households in Jogulamba district in rural Telangana, India. Women tend to spend more time in domestic and care activities in addition to economic activities, while men predominantly allocate more time to economic activities.

The main finding of our analysis is that interdependencies between men and women in households have an important influence on nutritional outcomes. Nutritional outcomes for individuals are not determined by their own characteristics and endowments alone but also by their spouses' characteristics and endowments. Specifically, increase in economic time allocation by males, and an increase in domestic and care time allocation by females tend to diminish both their own and their partners' food intake and caloric adequacy. Increasing time spent in economic work is linked to improved nutrition for females, whereas for males, nutritional improvements are associated with engaging in less physically intensive tasks, such as domestic and care work. Partner effects reveal a negative link between female caloric adequacy and increase in male economic time use, and a similar negative association exists between male caloric adequacy and increase in female domestic and care time use. We see that the greater participation of females in economic activities is rewarded with better nutritional improvements relative to when males participate in economic activities, which suggests that opportunities for women to participate in economic activities has the potential to lead to improved nutritional outcomes in rural households.

Our analysis, incorporating both physical activity level and energy intake, highlights levels of physical activity play an important role in caloric (in-) adequacy outcomes. This result underscores the significance of considering physical activity information in individual nutrition (energy requirement) assessments in rural areas of LMICs.

6.1 Implications of study findings for development interventions

The understanding that resources managed by women often lead to better household nutritional outcomes than when those same resources are controlled by men has been a foundational premise for many development and agricultural interventions. This approach is predicated on the belief that women, when empowered with resources, are more likely to allocate them in ways that enhance the nutritional well-being of their households. This concept has been influential in shaping strategies that specifically target women with the aim of achieving improved nutrition across households (Ruel et al., 2018). This paper underscores the contribution of female economic work to securing own nutrition and that of other members in line with existing literature.

Our findings reinforce the critical role that female economic participation plays in securing not only their own nutritional well-being but also that of other household members. This aligns with existing literature which finds positive impact of women's economic activity on household nutrition (Kabeer, 2001; Quisumbing & Maluccio, 2003). By engaging in economic work, women contribute significantly to household's resources, which in turn can be leveraged to improve the nutritional status of the entire family. However, our findings suggest that women's empowerment programmes focusing solely on increasing women's productive assets may not guarantee improvements in nutritional or other outcomes, as these outcomes also depend on personal and partner time allocations. To enhance nutritional outcomes, women should no longer be regarded as the *sole proprietor* of household nutrition. Development interventions should extend beyond improving autonomy for women, as current evidence indicates that women in rural LMICs are already experiencing burdens in terms of time and energy expenditure. Intrinsically, the trade-offs to nutrition resulting from women's empowerment or those occurring through the process of rural transformation can be minimized by encouraging cooperation between spouses, especially regarding intra-household sharing of domestic work. Indeed, changes in the norms surrounding intra-household work division – supporting a gender-equal distribution of economic and domestic work – are necessary to alleviate nutritional insecurity among both women and men. However, as spousal cooperation tends to vary across socio-demographic contexts, it is important to understand these contexts to tailor policy interventions aimed at advancing women’s empowerment(Kabeer, 2010; Lecoutere & Wuyts, 2020; Ragasa et al., 2019; Spark et al., 2021).

Regarding whether increasing women's economic labour will not be detrimental to women's health, growing evidence from the feminisation of agriculture literature reveals that increasing female employment opportunities, especially in the agricultural sector, has not always led to female empowerment. This is due to social norms and gender-intensified constraints such as lack of productive assets, lower pay, and higher unpaid work burdens among women relative to men (Asadullah & Kambhampati, 2021; Da Corta & Venkateshwarlu, 1999; Supriya Garikipati, 2006). Policymakers concerned about female empowerment should address these constraints and ensure that increases in female economic work are accompanied by a reduction in their domestic and care work burdens. The way in which work and food are shared between spouses will likely embody "unequal interdependence", where women bear higher labour burdens relative to men (Kabeer, 2001). Yet, paid economic work constitutes the beginning of "the breaking of traditional social norms" for some women, especially in countries like India where female agricultural employment alone accounts for 58 per cent of the 17 per cent total female labour force participation (Banerjee, 1997; ILO, 2022).

6.2 Limitations and further research

The innovative methodology used to collect and triangulate multiple data streams is not without shortcomings. The sample size cannot be considered representative of the country where the data was collected but rather an exemplary case study. Our empirical analysis is supported by simulation studies that have proven that fixed-effects estimates (unlike variance components) and standard errors of the multilevel analysis are not necessarily biased as a result of sample size limitation (Bell et al., 2014; Huang, 2018; Peugh, 2010). Nevertheless, weak significance values should be interpreted with caution. Also, due to statistical software limitations, we have not examined heterogeneities across households through cross-level effects of household characteristics or seasonality that may mediate the level of spousal interdependency observed in this study. For instance, whether individual characteristics, type of work, or income levels moderate own and partner effects.

Further, household composition has been shown in earlier literature to determine the division of domestic work within couples with small children (Lundberg, 1988). Indeed, households in our sample are composed of more than the two individuals that were sampled. Even if we had no data for the other household members, we controlled in our analysis for the presence of other members by including household size in the vector of household characteristics as well as included a vector of seasonality to control for seasonal changes in time allocation.

Food intake data are known to be subjected to under-reporting due to social desirability and recall bias, particularly in terms of food consumed outside the home. Under-reporting bias in our study may be larger for men than women concerning calories derived from alcohol consumption and food consumed outside the home. Also, cultural aspects of intrahousehold food sharing such as the order of food servings and the tendency to allocate more nutritious meals to males – are not explicitly considered in this study due to data limitations. Given the focus of this paper on calories, the indicators of nutritional outcomes are not comprehensive to understand the nutrient adequacy and healthiness of diets. These are aspects that future work may seek to improve upon.

Information from human participants

All personal information that would allow the identification of any person or person(s) described in the article has been removed. The data used is contained in Zanello et al., (2020).

References

Agarwal, B. (1997). 'Bargaining' and Gender Relations: Within and Beyond the Household. *Feminist Economics*, *3*(1), 1–51. https://doi.org/10.1080/135457097338799

Alesina, A., Guiliano, P., & Nunn, N. (2013). On the origins of gender roles: Women and the plough. *The Quarterly Journal of Economics*, *128*(2). https://doi.org/10.1093/qje/qjt005

Apps, P. F., & Rees, R. (1997). Collective Labor Supply and Household Production. *Journal of Political Economy*, *105*(1), 178–190. https://doi.org/10.1086/262070

Asadullah, M. N., & Kambhampati, U. (2021). Feminization of farming, food security and female empowerment. *Global Food Security*, *29*(100532). https://doi.org/10.1016/j.gfs.2021.100532

Banerjee, N. (1997). How real is the Bogey of Feminization? *Indian Journal of Labour Economics*, *40*(3), 427–438. https://aud.ac.in/uploads/1/admission/admissions2016/Reading%201%20How%20Real%20is%20the%20bogey%20of%20feminisation.pdf

Becker, G. S. (1981). Altruism in the Family and Selfishness in the Market Place. *Economica*, *48*(189), 1. https://doi.org/10.2307/2552939

Bell, B. A., Morgan, G. B., Schoeneberger, J. A., Kromrey, J. D., & Ferron, J. M. (2014). How low can you go?: An investigation of the influence of sample size and model complexity on point and interval estimates in two-level linear models. *Methodology*, *10*(1), 1–11. https://doi.org/10.1027/1614-2241/a000062

Bingenheimer, J. B., & Raudenbush, S. W. (2004). Statistical and substantive inferences in public health: Issues in the application of multilevel models. *Annual Review of Public Health*, *25*, 53–77. https://doi.org/10.1146/annurev.publhealth.25.050503.153925

Binswanger-Mkhize, H. P. (2013). The Stunted Structural Transformation of the Indian Economy: Agriculture, Manufacturing and the Rural Non-Farm Sector. *Economic And Political Weekly*, *48*(26/27), 5–13. https://www.jstor.org/stable/23527235

Bittman, M., England, P., Folbre, N., Sayer, L., & Matheson, G. (2003). When Does Gender Trump Money? Bargaining and Time in Household Work. *American Journal of Sociology*, *109*(1), 186–214. https://doi.org/10.1086/378341

Bowen, L., Ebrahim, S., de Stavola, B., Ness, A., Kinra, S., Bharathi, A. V., Prabhakaran, D., & Reddy, K. S. (2011). Dietary intake and rural-urban migration in India: A cross-sectional study. *PloS One*, *6*(6), 1–8. https://doi.org/10.1371/journal.pone.0014822

Carlson, D. L., Miller, A. J., & Rudd, S. (2020). Division of Housework, Communication, and Couples' Relationship Satisfaction. *Socius: Sociological Research for a Dynamic World*, *6*, 1–17. https://doi.org/10.1177/2378023120924805

Castellano, K. E., Rabe-Hesketh, S., & Skrondal, A. (2014). Composition, context, and endogeneity in school and teacher comparisons. *Journal of Educational and Behavioral Statistics*, *39*(5), 333–367. https://doi.org/10.3102/1076998614547576

Chiappori, P.-A. (1992). Collective Labor Supply and Welfare. *Journal of Political Economy*, *100*(3), 437–467. http://www.jstor.com/stable/2138727

Christopher, A., Scott, S., Singh, S. K., Menon, P., & Nguyen, P. H. (2021). *State Nutrition Profile Telangana. POSHAN* (Data Note 54; Vol. 3, Issue 54). International Food Policy Research Institute, New Delhi. http://poshan.ifpri.info/

Cook, W. L., & Kenny, D. A. (2005). The actor-partner interdependence model: A model of bidirectional effects in developmental studies. *International Journal of Behavioral Development*, *29*(2), 101–109. https://doi.org/10.1080/01650250444000405

Da Corta, L., & Venkateshwarlu, D. (1999). Unfree relations and the feminisation of agricultural labour in Andhra Pradesh, 1970-95. *Journal of Peasant Studies*, *26*(2–3). https://doi.org/10.1080/03066159908438705

Daum, T., Capezzone, F., & Birner, R. (2019). *The Forgotten Agriculture-Nutrition Link: Estimating the Energy Requirements of Different Farming Technologies in Rural Zambia With Time-Use Data* (Discussion Paper 182). Center for Development Research, Bonn. https://ssrn.com/abstract=3435998

Desai, S., & Jain, D. (1994). Maternal Employment and Changes in Family Dynamics: The Social Context of Women's Work in Rural South India. *Population and Development Review*, *20*(1), 115–136. https://doi.org/10.2307/2137632

Doss, C., Malapit, H., & Comstock, A. (2020). *Methods for measuring women's empowerment* [PIM synthesis brief]. CGIAR. https://doi.org/10.2499/p15738coll2.134044

Doss, C. R., & Quisumbing, A. R. (2020). Understanding rural household behavior: Beyond Boserup and Becker. *Agricultural Economics*, *51*(1), 47–58. https://doi.org/10.1111/agec.12540

Duflo, E., & Udry, C. (2004). *Intrahousehold Resource Allocation in Cote d'Ivoire: Social Norms, Separate Accounts and Consumption Choices* (NBER Working Paper Series 10498). National Bureau of Economic Research. https://ssrn.com/abstract=552103

Dufour, D. L., & Piperata, B. A. (2008). Energy expenditure among farmers in developing countries: What do we know? *American Journal of Human Biology*, *20*(3), 249–258. https://doi.org/10.1002/ajhb.20764

Duncan, C., Jones, K., & Moon, G. (1998). Context, Composition and Heterogeneity: Using Multilevel Models in Health Research. *Social Science and Medicine*, *46*(1), 97–117. https://doi.org/10.1016/s0277-9536(97)00148-2

Fadare, O., Amare, M., Mavrotas, G., Akerele, D., & Ogunniyi, A. (2019). Mother's nutrition-related knowledge and child nutrition outcomes: Empirical evidence from Nigeria. *PloS One*, *14*(2). https://doi.org/10.1371/journal.pone.0212775

Fafchamps, M., & Quisumbing, A. R. (2007). Household Formation and Marriage Markets in Rural Areas. *Handbook of Development Economics*, *4*, 3187–3247. https://doi.org/10.1016/S1573-4471(07)04051-X

FAO. (2001). *Human energy requirements* (Food and Nutrition Technical Report Series 1; Report of a Joint WHO/UNU/FAO Expert Consultation, pp. 20–50). Food and Agricultural Organization, Rome. https://www.fao.org/3/y5686e/y5686e.pdf

FAO. (2003). Food energy—Methods of Analysis and Conversion Factors. In *Chapter 3: Calculation of the Energy Content of Foods- Energy Conversion Factors*. Food and Agricultural Organization, Rome. https://www.fao.org/3/y5022e/y5022e04.htm

FAO. (2011). *The State of Food and Agriculture—2010- 2011. Women in Agriculture—Closing the Gender Gap for Development* (pp. 7–22). Food and Agricultural Organization, Rome. https://www.fao.org/3/i2050e/i2050e.pdf

FAO, IFAD, UNICEF, WFP, & WHO. (2020). *The State of Food Security and Nutrition in the World 2020. Transforming Food Systems for Affordable Healthy Diets*. Food and Agricultural Organization, Rome. https://doi.org/10.1109/JSTARS.2014.2300145

Filmer, D., & Pritchett, L. (2001). Estimating Wealth Effects without Expenditure Data-or Tears: An Application to Educational Enrollments in States of India. *Demography*, *38*(1), 115–132. https://doi.org/10.1353/dem.2001.0003

Fiorella, K. J., Chen, R. L., Milner, E. M., & Fernald, L. C. H. (2016). Agricultural interventions for improved nutrition: A review of livelihood and environmental dimensions. *Global Food Security*, *8*, 39–47. https://doi.org/10.1016/j.gfs.2016.03.003

Fleary, S. A., & Joseph, P. L. (2022). Health literacy and health behaviors in parent-adolescent dyads: An actor-partner interdependence model approach. *Psychology & Health*. https://doi.org/10.1080/088700446.2022.2117809

Folbre, N. (1986). Cleaning House: New perspectives on economic development. *Journal of Development Economics*, *22*, 5–40. https://doi.org/10.3920/978-90-8686-716-5

Freedson, P. S., Melanson, E., & Sirard, J. (1998). Calibration of the Computer Science and Applications, Inc. Accelerometer. *Medicine & Science in Sports & Exercise*, *30*, 777–781. https://doi.org/10.1097/00005768-199805000-00021

Friedman, J., Gaddis, I., Kilic, T., Antonio, M., Palacios-Lopez, A., & Zezza, A. (2021). *The Distribution of Effort Physical Activity, Gender Roles, and Bargaining Power in an Agrarian Setting* (Working Paper 9634). The World Bank. http://hdl.handle.net/10986/35481

Ghosh, R., & Bharati, P. (2005). Effect of working patterns on women's health in two ethnic groups in a peri-urban area of Kolkata City, India. *Ecology of Food and Nutrition*, *44*(3), 189–206. https://doi.org/10.1080/03670240590953016

Gibson, R. S., & Ferguson, E. L. (2008). An interactive 24-hour recall for assessing the adequacy of iron and zinc intakes in developing countries. In *HarvestPlus Technical Monograph 8* (pp. 1–160).

Gillespie, S., Harris, J., & Kadiyala, S. (2012). *The Agriculture-Nutrition Disconnect in India What Do We Know?* (Discussion Paper 1187; pp. 1–56). IFPRI, Washington, D.C. http://www.ifpri.org/publication/agriculture-nutrition-disconnect-india

Government of India. (2020). *Time Use in India-2019* (p. 263). National Statistical Office, Ministry of Statistics & Programme Implementation, New Delhi. http://mospi.nic.in/sites/default/files/publication_reports/Report_TUS_2019_0.pdf

Government of Telangana. (2019). *Telangana Socio-Economic Outlook 2019*. Planning Department, Government of Telangana, Hyderabad, India. https://www.telangana.gov.in/PDFDocuments

Government of Telangana. (2021). *Telangana Socio Economic Outlook 2021*. Planning Department, Government of Telangana, Hyderabad, India. https://www.telangana.gov.in/PDFDocuments

Haddad, L., Hoddinott, J., & Alderman, H. (1997). Intrahousehold Resource Allocation in Developing Countries: Methods, Models, and Policy. *IFPRI Food Policy Statement*, *24*. https://doi.org/10.1016/s0306-9192(98)00011-6

Hanchane, S., & Mostafa, T. (2012). Solving endogeneity problems in multilevel estimation: An example using education production functions. *Journal of Applied Statistics*, *39*(5), 1101–1114. https://doi.org/10.1080/02664763.2011.638705

Harris, J. A., & Benedict, F. G. (1918). A Biometric Study of Human Basal Metabolism. *Proceedings of the National Academy of Sciences*, *4*(12), 370–373. https://doi.org/10.1073/pnas.4.12.370

Hausman, J. A., & Taylor, W. E. (1981). Panel Data and Unobservable Individual Effects. *Econometrica*, *49*(6), 1377–1398. https://doi.org/10.2307/1911406

Huang, F. L. (2018). Using Cluster Bootstrapping to Analyze Nested Data With a Few Clusters. *Educational and Psychological Measurement*, *78*(2), 297–318. https://doi.org/10.1177/0013164416678980

IFAD. (2016). *Rural Development Report 2016*. International Fund for Agricultural Development, Rome. https://www.ifad.org/documents/38714170/39155702/Rural+development+report+2016.pdf/347402dd-a37f-41b7-9990-aa745dc113b9

ILO. (2022). *International Labour Organization*. ILOSTAT-Employment Data. https://ilostat.ilo.org/

Ironmonger, D. (2005). There are only 24 Hours in a Day! Solving the problematic of simultaneous time. *Comparing Time*, *The 25th LATUR Conference on Time Use Research*(November). https://www.researchgate.net/profile/D-Ironmonger/publication/267420848

Jackson, C., & Palmer-Jones, R. (1998). *Work Intensity, Gender and Well-being* (Discussion Paper 96). United Nation Research Institute for Social Development, Geneva. http://www.unrisd.org/80256B3C005BCCF9/%28httpPublications%29/B0B8B39DC2859F6080256B67005B7017?OpenDocument

Jacques Charmes. (2019). *The Unpaid Care Work and the Labour Market. An analysis of time use data based on the latest World Compilation of Time-use Surveys*. International Labour Organization, Geneva. https://www.ilo.org/wcmsp5/groups/public/---dgreports/---gender/documents/publication/wcms_732791.pdf

Johnston, D., Stevano, S., Malapit, H. J., Hull, E., & Kadiyala, S. (2018). Review: Time Use as an Explanation for the Agri-Nutrition Disconnect: Evidence from Rural Areas in Low and Middle-Income Countries. *Food Policy*, *76*, 8–18. https://doi.org/10.1016/j.foodpol.2017.12.011

Kabeer, N. (2001). Conflicts over credit: Re-evaluating the empowerment potential of loans to women in rural Bangladesh. *World Development*, *29*(1), 63–84. https://doi.org/10.1016/S0305-750X(00)00081-4

Kabeer, N. (2010). Women's Empowerment, Development Interventions and the Management of Information Flows. *IDS Bulletin*, *41*(6), 105–113. https://doi.org/10.1111/j.1759-5436.2010.00188.x

Kadiyala, S., Harris, J., Headey, D., Yosef, S., & Gillespie, S. (2014). Agriculture and nutrition in India: Mapping evidence to pathways. *Annals of the New York Academy of Sciences*, *1331*(1), 43–56. https://doi.org/10.1111/nyas.12477

Kenny, D. A., & Cook, W. (1999). Partner effects in relationship research: Conceptual issues, analytic difficulties, and illustrations. *Personal Relationships*, *6*(4), 433–448. https://doi.org/10.1111/j.1475-6811.1999.tb00202.x

Kenny, D. A., Kashy, D. A., & Cook, W. L. (2006). *Dyadic Data Analysis*. The Guilford Press.

Kevane, M., & Wydick, B. (2001). Social norms and the time allocation of women's labor in Burkina Faso. *Review of Development Economics*, *5*(1), 119–129. https://doi.org/10.1111/1467-9361.00111

Komatsu, H., Malapit, H., & Balagamwala, M. (2019). Gender effects of agricultural cropping work and nutrition status in Tanzania. *PloS One*, *14*(9), 1–17. https://doi.org/10.1371/journal.pone.0222090

Komatsu, H., Malapit, H. J. L., & Theis, S. (2015). *How Does Women' s Time in Reproductive Work and Agriculture Affect Maternal and Child Nutrition?* (Discussion Paper 01486). International Food Policy Research Institute, Washington, D.C. http://ssrn.com/abstract=2741272

Komatsu, H., Malapit, H. J. L., & Theis, S. (2018). Does women's time in domestic work and agriculture affect women's and children's dietary diversity? Evidence from Bangladesh, Nepal, Cambodia, Ghana, and Mozambique. *Food Policy*, *79*, 256–270. https://doi.org/10.1016/j.foodpol.2018.07.002

Lecoutere, E., & Wuyts, E. (2020). Confronting the Wall of Patriarchy: Does Participatory Intrahousehold Decision Making Empower Women in Agricultural Households? *Journal of Development Studies*, *00*(00), 1–24. https://doi.org/10.1080/00220388.2020.1849620

Lee, I.-M., & Shiroma, E. J. (2014). Using Accelerometers to Measure Physical Activity in LargeScale Epidemiologic Studies: Issues and Challenges. *Br J Sports Med*, *48*(3), 197–201. https://doi.org/10.1136/bjsports-2013-093154

Lelah Dushkin. (1967). Scheduled Caste Policy in India: History, Problems, Prospects. *Asian Survey*, *7*(9), 626–636. https://www.jstor.org/stable/2642619

Lundberg, S. (1988). Labor Supply of Husbands and Wives: A Simultaneous Equations Approach. *The Review of Economics and Statistics*, *70*(2), 224–235. http://www.jstor.com/stable/1928306

Lundberg, S., & Pollak, R. A. (1993). Separate Spheres Bargaining and the Marriage Market. *Journal of Political Economy*, *101*(6), 988–1010. http://www.jstor.com/stable/2138569

Madzorera, I., & Fawzi, W. (2020). Women empowerment is central to addressing the double burden of malnutrition. *EClinicalMedicine*, *20*, 100286. https://doi.org/10.1016/j.eclinm.2020.100286

McElroy, M. B. ., & Horney, M. J. (1981). Nash-Bargained Household Decisions: Toward a Generalization of the Theory of Demand. *International Economic Review*, *22*(2), 333–349. http://www.jstor.com/stable/2526280

Ministry of Health and Family Welfare; Government of India. (2020). *National Family Health Survey—5: State Fact Sheet* (State Fact Sheet Telangana, pp. 1–7). International institute for population studies, New Delhi. http://rchiips.org/nfhs/factsheet_NFHS-5.shtml

Moser, C. O. N. (1989). Gender planning in the third world: Meeting practical and strategic gender needs. *World Development*, *17*(11), 1799–1825. https://doi.org/10.1016/0305-750X(89)90201-5

Mundlak, Y. (1978). On the Pooling of Time Series and Cross Section Data. *Econometrica*, *46*(1), 69–85. https://www.jstor.org/stable/1913646

National Institute of Nutrition. (2011). *Dietary Guidelines for Indians* (Vol. 3, Issue 1, p. 139) [A manual]. https://www.nin.res.in/downloads/DietaryGuidelinesforNINwebsite.pdf

Nichols, C. E. (2016). Time Ni Hota Hai: Time poverty and food security in the Kumaon hills, India. *Gender, Place and Culture*, *23*(10), 1404–1419. https://doi.org/10.1080/0966369X.2016.1160871

Ohlan, R. (2016). Rural Transformation in India in the Decade of Miraculous Economic Growth. *Journal of Land and Rural Studies*, *4*(2), 1–18. https://doi.org/10.1177/2321024916640110

Padmaja, R., Pramanik, S., Pingali, P., Bantilan, C., & Kavitha, K. (2019). Understanding nutritional outcomes through gendered analysis of time-use patterns in semi-arid India. *Global Food Security*, *23*, 49–63. https://doi.org/10.1016/j.gfs.2019.04.001

Peugh, J. L. (2010). A practical guide to multilevel modeling. *Journal of School Psychology*, *48*(1), 85–112. https://doi.org/10.1016/j.jsp.2009.09.002

Picchioni, F., Zanello, G., Srinivasan, C. S., Wyatt, A. J., & Webb, P. (2020). Gender, time-use, and energy expenditures in rural communities in India and Nepal. *World Development*, *136*, 105137. https://doi.org/10.1016/j.worlddev.2020.105137

Quisumbing, A. R., & Maluccio, J. A. (2003). Resources at marriage and intrahousehold allocation: Evidence from Bangladesh, Ethiopia, Indonesia, and South Africa. *Oxford Bulletin of Economics and Statistics*, *65*(3), 283–327. https://doi.org/10.1111/1468-0084.t01-1-00052

Rabe-Hesketh, S., & Skrondal, A. (2012). *Multilevel and Longitudinal Modeling Using Stata Volume I: Continuous Responses* (Third Edition). StataCorp LP, Texas. https://doi.org/10.1198/tas.2006.s56

Ragasa, C., Aberman, N. L., & Alvarez Mingote, C. (2019). Does providing agricultural and nutrition information to both men and women improve household food security? Evidence from Malawi. *Global Food Security*, *20*(2018), 45–59. https://doi.org/10.1016/j.gfs.2018.12.007

Randolph, S., Ely, R. D., Allen, L. H., Chavez, A., & Pelto, G. H. (1991). The assessment of caloric adequacy. *Food & Nutrition Bulletin*, *13*(1), 3–6. https://doi.org/10.1177/156482659101300124

Rao, N., Pradhan, M., & Roy, D. (2017). *Gender justice and food security in India: A Review* (Discussion Paper 01600). International Food Policy Research Institute, Washington, DC. http://cdm15738.contentdm.oclc.org/cdm/ref/collection/p15738coll2/id/131054

Rao, N. & S. Raju. (2020). Gendered Time, Seasonality, and Nutrition: Insights from Two Indian Districts. *Feminist Economics*, *26*(2), 95–125. https://doi.org/10.1080/13545701.2019.1632470

Raudenbush, S. W., Brennan, R. T., & Barnett, R. C. (1995). A Multivariate Hierarchical Model for Studying Psychological Change Within Married Couples. *Journal of Family Psychology*, *9*(2), 161–174. https://doi.org/10.1037/0893-3200.9.2.161

Reddy, D. N., Reddy, A. A., & Bantilan, M. C. S. (2014). The impact of Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) on rural labor markets and agriculture. *India Review*, *13*(3), 251–273. https://doi.org/10.1080/14736489.2014.937271

Reserve Bank of India. (2022). *Reference Rate*. https://m.rbi.org.in/scripts/ReferenceRateArchive.aspx

Ruel, M. T., & Alderman, H. (2013). Nutrition-sensitive interventions and programmes: How can they help to accelerate progress in improving maternal and child nutrition? *The Lancet*, *382*(9891), 536–551. https://doi.org/10.1016/S0140-6736(13)60843-0

Ruel, M. T., Quisumbing, A. R., & Balagamwala, M. (2018). Nutrition-sensitive agriculture: What have we learned so far? *Global Food Security*, *17*, 128–153. https://doi.org/10.1016/j.gfs.2018.01.002

Sangwan, N., & Kumar, S. (2021). Labor force participation of rural women and the household's nutrition: Panel data evidence from SAT India. *Food Policy*, *102*, 102117. https://doi.org/10.1016/j.foodpol.2021.102117

Seymour, G., Masuda, Y. J., Williams, J., & Schneider, K. (2019). Household and child nutrition outcomes among the time and income poor in rural Bangladesh. *Global Food Security*, *20*, 82–92. https://doi.org/10.1016/j.gfs.2019.01.004

Shiroma, E., Schepps, M., Harezlak, J., Chen, K., Mathews, C., Koster, A., Caserotti, P., Glynn, N., & Harris, T. (2016). Daily physical activity patterns from hip- and wrist-worn accelerometers.

Physiological Measurement, *37*(10), 1852–1861. https://doi.org/10.1088/0967-3334/37/10/1852

Singh, I., Squire, L., & Strauss, J. (1986). A survey of agricultural household models: Recent findings and policy implications. *World Bank Economic Review*, *1*(1), 149–179. https://doi.org/10.1093/wber/1.1.149

Spark, C., Sharp, T. L. M., & Koczberski, G. (2021). Relationality and Economic Empowerment: The Role of Men in Supporting and Undermining Women's Pathways. *Journal of Development Studies*, *57*(7), 1138–1153. https://doi.org/10.1080/00220388.2020.1850697

Srinivasan, C. S., Zanello, G., Nkegbe, P., Cherukuri, R., Picchioni, F., Gowdru, N., & Webb, P. (2020). Drudgery reduction, physical activity and energy requirements in rural livelihoods. *Economics and Human Biology*, *37*, 100846. https://doi.org/10.1016/j.ehb.2019.100846

StataCorp. (2013). *Stata: Release 11. Longitudinal-data/Panel-data Reference Manual*.

Supriya Garikipati. (2006). Feminization of Agricultural Labor and Women's Domestic Status: Evidence from Labor households in India. *SSRN*. http://dx.doi.org/10.2139/ssrn.951199

The National Commission for Backward Classes Act, 27, Government of India (1993). https://legislative.gov.in/sites/default/files/A1993-27.pdf

Troiano, R., McClain, J. J., Brychta, R. J., & Chen, K. Y. (2014). Evolution of accelerometer methods for physical activity research. *British Journal of Sports Medicine*, *48*(13), 1019–1023. http://dx.doi.org/10.1136/bjsports-2014-093546

UNDESA. (2019). *India Household Size and Composition 2019* [Database on Household Size and Composition]. United Nations Department of Economic and Social Affairs, Population Division. https://population.un.org/Household/index.html#/countries/356

U.S. Department of Agriculture. (2019). *Nutrient Profile Data*. FoodData Central. http://fdc.nal.usda.gov/

van den Bold, M., Bliznashka, L., Ramani, G., Olney, D., Quisumbing, A., Pedehombga, A., & Ouedraogo, M. (2021). Nutrition-sensitive agriculture programme impacts on time use and associations with nutrition outcomes. *Maternal and Child Nutrition*, *17*(2), 1–16. https://doi.org/10.1111/mcn.13104

Vemireddy, V., & Pingali, P. L. (2021). Seasonal time trade-offs and nutrition outcomes for women in agriculture: Evidence from rural India. *Food Policy*, *101*(102074). https://doi.org/10.1016/j.foodpol.2021.102074

Zanello, G., Srinivasan, C. S., & Nkegbe, P. (2017). Piloting the use of accelerometry devices to capture energy expenditure in agricultural and rural livelihoods: Protocols and findings from northern Ghana. *Development Engineering*, *2*, 114–131. https://doi.org/10.1016/j.deveng.2017.10.001

Zanello, G., Srinivasan, C. S., Picchioni, F., Webb, P., Nkegbe, P., Cherukuri, R., & Neupane, S. (2020). Physical activity, time use, and food intakes of rural households in Ghana, India and Nepal. *Scientific Data*, *7*(71), 1–10. https://doi.org/https//doi.org/10.1038/s41597-020-0414-x

Zanello, G., Srinivasan, C. S., Picchioni, F., Webb, P., Nkegbe, P., Cherukuri, R., Neupane, S., Ustarz, Y., Gowdru, N., Neupane, S., & Wyatt, A. J. (2019). *Using Accelerometers in Low-and Middle-Income Countries: A Field Manual for Practitioners* (p. 28). University of Reading. https://immana.lcirah.ac.uk/sites/default/files/Manual_Web_March19.pdf