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Gender, time-use, and energy expenditures in rural communities in India and Nepal

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ABSTRACT

Women's patterns of time-use, which proxy the work burdens associated with productive and reproductive activities, are an important determinant of nutrition and well-being in LMICs. However, there is a lack of empirical evidence on how patterns of time-use translate into patterns of physical activity and energy expenditure, particularly in rural areas where seasonal agricultural labour plays such an important role. We address this gap by integrating energy expenditure data derived from wearable tri-axial accelerometers with time-use data from conventional recall-based surveys. Using datasets from agricultural households in four rural communities in India and Nepal, our results show that there are significant gender differences in the patterns of time-use and energy expenditure. Men and women participate equally in productive work, however, women shoulder most of the additional reproductive work burdens in rural households at the expense of leisure opportunities. Our results provide insights into women's responses to opportunities for productive work and highlight the nature of trade-offs they face.

1. Introduction

Agricultural interventions that involve the adoption of new technology and practices for enhancing productivity are critical for improving nutrition and incomes in rural areas of low- and middle-income countries (LMICs) where most of the world's undernourished and poor households live (FAO et al., 2019). While these interventions offer the potential for enhancing productivity and household incomes, they can also fundamentally alter the patterns of time and physical effort devoted by men and women to productive and reproductive activities. Many of these interventions call for greater participation of women in agricultural work, contributing to the observed trend of "feminisation of agriculture"[1]. An increase in time and energy devoted to "productive" agricultural activities by women can negatively impact household nutritional status through the impact on reproductive tasks – childcare, feeding practices, acquisition and preparation of food influencing dietary choice. Physical exertion, often in high temperatures, required by increased participation in productive activities can adversely affect women's own health and nutrition, while impairing their ability to perform reproductive tasks (Headey & Masters, 2019).

The physical effort and energy requirements imposed on women through involvement in productive activities are an important element in understanding the nutrition and health impacts of agricultural interventions. Nutritional outcomes depend on the effects of interventions on food/energy intakes, as well as on energy expenditure. However, in the literature, gendered patterns of work allocation in households have been examined mainly through time-use reporting (Stevano et al., 2018). Time-use data, which are relatively easier to collect, are an imperfect proxy for the physical effort associated with productive and reproductive work, as they do not reflect the energy intensity of different activities. There is little empirical evidence on how patterns of time-use translate into patterns of physical activity and energy expenditure. This is because using conventional observational methods, the measurement of energy expen-

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[1] On trends and discussion of feminisation of agriculture in South Asia see Acharya et al. (1999); Grassi et al. (2015); Maletta (2008); World Bank (2008); and Zaidi and Farooq (2018).

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diture on different activities can be costly and intrusive in the context of free-living rural populations. Advances in accelerometry technology and the recent emergence of rugged wearable devices for monitoring physical activity have made it empirically easier to measure energy expenditure associated with rural livelihood activities.

This paper takes advantage of wearable accelerometry devices to generate reliable profiles of energy expenditure in rural agricultural households. We use an innovative approach that integrates reliable energy expenditure data derived from wearable tri-axial accelerometers with time-use data from conventional recall-based surveys. We generate profiles of time-use and energy expenditure for different classes of activities for men and women in agricultural households from two case studies in a SouthAsian context. The data derive from a study of 43 agricultural households in four rural communities in India and Nepal, across four phases of the agricultural season. The number of households covered in the countries is small and thus the external validity of our results is very limited. However, the small sample allowed us to collect an extremely rich dataset at the individual level which has more than 36,000 hours of energy expenditure and time-use data. We examine the gender differences in the patterns of time-use and energy expenditure and how they are influenced by individual and household characteristics, endowments, and seasons. We investigate how energy expenditure patterns respond to changes in time-use allocation for productive and reproductive work and for leisure by computing an elasticity measure – the elasticity of energy shares for an activity with respect to time shares.

Our results show that in our sample, men and women participate almost equally in productive activities which accounts for a dominant share of their time and energy expended. However, the reproductive domain remains predominantly feminised and women tend to compensate for heavier burdens of work by reducing the time for leisure and rest. While the allocation of time and energy to productive work varies markedly by season, reproductive work appears to be less elastic to seasonality. There are significant differences by gender in the effects of covariates – individual and household characteristics, endowments, and seasons – on time-use and energy expenditure profiles for productive and reproductive work. Our results highlight the constraints and trade-offs faced by women in rural households in LMICs when development interventions call for their greater participation in productive activities. They provide insights into why the response of women in agricultural households to opportunities of productive work and the nutritional outcomes of agricultural interventions may vary across households.

2. Previous literature

The effects of women's participation in agricultural activities on their nutrition and health has been explored in the literature mainly through the time-use dimension. A systematic review by Johnston et al. (2018) examined studies from developing countries focusing on the time-use pathways from agricultural work to nutritional effects. They find that while women devote a significant proportion of their time to agricultural activities, there is a range of nutritional effects for women, children and the household. These effects can be positive (Blau et al., 1996) or negative (Kumar, 1994; Paolisso et al., 2002; Pradeilles et al., 2019). Other studies (e.g. Bamji & Thimayamma, 2000) find no statistically significant effects of women's time in work on child nutritional outcomes. Johnston et al. (2018) identify several methodological and data issues that may account for the lack of a clear relationship between women's time burdens and nutritional outcomes. These include the poor quality of time-use data, the seasonality of time burdens and the simultaneous performance of care activities along with other activities that may not be reflected in time-use data. Similarly, a systematic review of women's agricultural work and nutrition in South Asia (Rao et al., 2019) incorporating insights from the LANSA[2] programme highlights the role of contextual factors – existing gender divisions of work and care based on prevalent socio-cultural norms, farming systems, seasonality, poverty and ethnic/caste identity – in determining the impacts of work on nutrition. An important factor explaining the lack of a clear relationship between women's time burdens and nutrition/health outcomes is that women's time-use does not capture the energy intensity of activities (Rao & Raju, 2020).

The literature exploring the impact of agricultural interventions has found only a weak link to nutritional improvements (Girard et al., 2012; Ruel & Alderman, 2013). This is particularly relevant for the South Asian context, where in the last two decades, substantial increases in agricultural productivity have not translated into widespread improvements in nutrition (Bird et al., 2019; Headey et al., 2012). The pathways through which the effects of agricultural development arise are not well understood (Headey, 2013; Johnston et al., 2018; Kadiyala et al., 2014) and efforts have been made to delineate the multiple pathways of impact. The pathway via work-related energy expenditures is being increasingly recognised as an important pathway for nutritional and health outcomes (Ruel & Alderman, 2013). However, empirical assessments of the energy expenditure pathway have not been attempted.

There is extensive evidence that high intensity agricultural work can deteriorate health through exhaustion, biological damage, and impairment to the immune system (Chiong-Javier, 2009; Habib et al., 2014; Pitt et al., 1989). The physical effort and energy expenditure associated with agricultural work represents an important pathway to women's own nutrition and health. However, this pathway has received limited attention in empirical research and in the design of agricultural interventions. Gillespie and Kadiyala (2012) found only a limited number of studies that relate employment in agriculture to nutrition and health outcomes. These studies have attempted to classify the energy costs of daily household and agricultural activities, to assess adaptations to seasonality, to assess the impact of activity and food intakes on neo-natal size and to look at differences in thinness/BMI according to occupational pattern and gender (Bains et al., 2002; Barker et al., 2006; Durnin et al., 1990; Griffiths & Bentley, 2001; Rao et al., 2009). Recent studies have also highlighted concerns that physical exertion, especially in high temperatures, could be harmful to women through weight loss, while also impairing a mother's ability to care for her children (Headey & Masters, 2019). Ruel et al. (2018) also acknowledge that the additional work burden placed on women through agricultural interventions can adversely affect their own health. Subasinghe et al. (2014) note the chronic energy deficiency of men and women in agricultural households in their study on South India, while Singh et al. (2012) find that women are pushed into negative energy balance during land preparation and harvesting. Nichols (2016) observes that women's food intake is the lowest during peak activity periods in agriculture as a result of fatigue, work and time pressures. She argues that agricultural interventions can create unsustainable work burdens for women, adversely affecting their nutrition and health.

The paucity of empirical studies along the energy expenditure dimension is mainly attributable to the difficulties in monitoring physical activity and measuring energy expenditure reliably in free

[2] Leveraging Agriculture for Nutrition in South Asia – programme funded by the Department for International Development, UK http://www.lansasouthasia.org/.

living populations in rural settings (Vaz et al., 2005; Zanello et al., 2017)[3]. However, new approaches to assessing workloads in farming households using wearable technologies are being increasingly explored in the literature e.g., Sathiyakumar et al. (2018) who examine the feasibility of using wearable technology to observe gender differences in workload in farming households in Indonesia and Srinivasan et al. (2020) who examine the impact of drudgery reduction on energy requirements for men and women in Indian and Ghanaian rural households. Time-use, which is more easily observable, remains the main indicator of work burdens used in empirical studies. However, time-use allocation may not be an accurate proxy for energy expended since it does not consider the intensity of activities (Higgins & Alderman, 1997). The work intensity of agricultural activities more than the time allocation may be relevant for nutritional and health outcomes (Floro, 1995; Palmer-Jones & Jackson, 1997; von Braun & Webb, 1989). This paper attempts to develop integrated time-use and energy expenditure profiles for men and women in our sample, while addressing important data gaps identified in the literature. These gaps relate to the lack of data on (1) time allocated to reproductive work and leisure alongside time devoted to productive work (2) gender differences in time-use and energy expenditure profiles (3) simultaneous performance of different activities and (4) socio-demographic characteristics of households and contextual factors (Johnston et al., 2018; Rao et al., 2019). We address the following questions:

(1) What are the gendered patterns of time-use and energy expenditure in agricultural households in LMIC settings?
(2) What are the correlations between time-use and energy expenditure patterns for productive and reproductive work for men and women across different phases of the agricultural season?

3. Data and methods

3.1. Study sites

This paper draws on data from a study conducted in Telangana state in India and Province No 3. (so named at the time of our survey work) in Nepal. In each country, two villages were selected, one representing a rain-fed agricultural system and one representing an irrigated agricultural system. We randomly selected a sample of 20 land owning households proportionally stratified by land size to represent small, medium, and large holders[4]. Among these, ten households were identified in each village and one economically active man and woman (generally husband and wife) from each household took part in the study. Data collection in India and Nepal took place between June through December 2018 and June 2017 through September 2018, respectively. Table A in the Appendix-1 provides the crop calendar for the major crops cultivated by respondents in India and Nepal.

In India, data collection took place in two adjacent villages, one irrigated and one rain-fed, in Jogulamba Gadwal district in the state of Telangana. Jogulamba Gadwal district is located in the state's southern agro-climatic zone where monsoon rainfall typically occurs from June to September. Forty percent of respondents were Muslim while 60% were Hindus of whom 58% belonged to Other Backward Castes, 8% to Scheduled castes, and 33% to other castes. Both villages have developed alongside all-weather and tarmac roads that provide reliable connection to the city of Gadwal, the district headquarters (average distance 8 km). Primary services within the radius of 2 km from the household include the village water pump, primary school and health posts, but the closest primary health center is located about 4.6 km from the households. In order to collect firewood, respondents had to walk on average 1.5 km to the nearest firewood collection area. The area's economy is agrarian with about 82% of the population engaged in agriculture of which 81% belong to the small and marginal category of farmers that rely on rain-fed farming systems and cultivate predominantly chilli and castor. These cash crops rely primarily on manual labour and are characterised by multiple harvests over an agricultural season. With none of the households owning mechanized agricultural equipment, additional labour requirement is fulfilled through hired or family labour (Table 2). Depending on rainfall patterns, land preparation starts in June, immediately followed by sowing. The harvest occurs during October and November.

In Nepal, data collection took place in two villages: Shaktikhor (irrigated system), situated in Chitwan district, a lowland region in southern Nepal, and Devbhumi Baluwa (rain-fed system), in Kabhrepalanchok District, an agro-ecological zone in the foothills of the Himalayas in central Nepal. However, the village of Devbhumi Baluwa is characterised by flat land, suitable for a variety of crops. All respondents were Hindus, and 77% belong to marginalized castes and 22% to upper castes. Both villages had adequate access to all weather roads (average distance < 1 km) and were located in the proximity of major market centers (average distance 5.8 km). Apart from primary schools (average distance 1.6 km from the household), all other primary services[5] and the firewood collection area were located farther away from the household (between 3 km and 4.3 km). Monsoon rainfall typically occurs during January and February and between June and October. The economy of both districts is largely agrarian with most of the population engaged in agriculture. The main crops produced in Shaktikhor include rice, maize and mustard. The major crops grown in Devbhumi include rice, maize and potato. Farmers in both villages also keep livestock, mainly cow, buffalo, goat and poultry. Farming practices in Nepal tend to be labour intensive and rising rural wages have increasingly put pressures on smallholder farmers (Takeshima et al., 2016). Due to high costs of hiring labour and low levels of farm mechanization in our sample (only 1 out of 20 farms owned a tractor), households rely on additional labour provided by family members, which is an established practice among small-holders in rural Nepal (figures on hired and family labour are provided in Table 2). Hiring of tractors and other mechanised tools is a common practice among better off farmers.

3.2. Data collection

Data collection comprised of three elements: a household questionnaire, accelerometer devices to collect data on physical activ-

[3] There is another strand of the literature which examines the energy expenditure and drudgery reduction associated with farm mechanisation particularly in the context of modernisation of agriculture and adoption of 'Green Revolution' technologies in South Asia. The focus of this literature was on demonstrating the efficacy and benefits of mechanisation on the physiology of work – using indicators for effort such as heart rate, energy expenditure, Total Cardiac Cost of work and Physiological Cost of work, e.g., Nag et al. (1980), Gite and Singh (1997), Nag and Nag (2004), Singh et al. (2007), Mohanty, Behera and Satpathy (2008), Kishtwaria and Rana (2012). These studies focus on drudgery reduction and typically do not draw links with potential nutritional impacts. Studies assessing agricultural households using wearable technologies are now emerging, Sathiyakumar et al. (2018), provide a review of recent studies that examine the workloads and drudgery of agricultural activities which rely mainly on heart rate monitors or direct observation.

[4] The classification of land endowments varies across countries based on local context. In India, based on the Agriculture Census (2010–11) the Ministry of Agriculture & Farmers Welfare defines smallholders (<2 ha), medium (2–4 ha), and large farmers (>5 ha). In Nepal, the High-Level Commission on Scientific Land Reform (2010) categorises 0.1–0.5 ha as small, 0.5–3 ha as medium and >3 ha as large.

[5] Primary services include health post (2.9 km), water pump (3.7 km) and primary healthcare facility (4.3 km).

ity, and a daily individual questionnaire on time-use. The study design and questionnaires were reviewed, and ethical approval granted by the University of Reading, Nepal Health Research Council, and the National Institute of Rural Development (India) before the start of the study.

Household questionnaire. The household questionnaire was administered to the head of the household at the start of the study and included questions on household composition, dwelling characteristics (used in construction of the wealth index), employment and labour force activities, land and agriculture, livestock, assets ownership, decision-making in the household, and access to infrastructure.

Accelerometer. To capture seasonality, the study was designed for the male and female respondent in each household to wear an accelerometer for four non-consecutive weeks. In each country, each week corresponded with a different phase of the agricultural cycle: land preparation, sowing and seeding, land maintenance (growing), and harvest. The participants were invited to wear the ActiGraph accelerometer model WGT3X-BT, a research-grade device approved by the U.S. Food and Drug Administration. The ActiGraph WGT3X-BT device is a tri-axial accelerometer that has been used extensively in research and provides the end user with raw data on movement along the three axes. Using validated algorithms (Santos-Lozano et al., 2013; Sasaki et al., 2011) the movement data is translated into energy expenditure (kilocalories). Movement data was sampled at 30 Hz and downloaded at the end of each week. Participants were invited to wear the accelerometer on an elastic belt around the waist at all times except during sleep at night or while bathing.

Individual questionnaire. While wearing the accelerometer, each respondent was interviewed daily for the full duration of the study (28 days). The daily questionnaire, administered by a trained enumerator, included questions to elicit sequential time allocation for different activities. Time allocation activities were recorded following the guidelines in Antonopoulos and Hirway (2010), (1-hour slots and free text to record the activity). During the interview, participants were invited to freely report on their daily activities without the aid of a pre-compiled list. This approach provided a granular picture of daily activities and the narrative nature of the interview helped participants to recall activities around routine parts of the day (sunrise, sunset, meals, religious activities). Activities were recorded as primary or secondary, where "primary" represented the activity that was the main objective of what the participant was doing at that time. "Secondary" reflected any other activity which the respondents were engaged in, but was not the main objective of their time-use (IFPRI, 2012). As part of the individual questionnaire, on the first day of week one (land preparation) and week three (growing), participants had their height and weight measured based on the guidelines recommended in Lohman et al. (1992)[6].

Given the study design, our results do not aim to provide generalizations beyond the communities we studied. However, the high intensity of data collection provides a robust identification of the livelihood patterns of time-use and energy expenditure within the sampled households.

More details of the study design can be found in Zanello et al. (2020). The full dataset is publicly available in UK Data Archive (Zanello et al., 2019).

[6] The BMI used in the analysis reflects the average of these two measurements.

3.3. Data analysis

Box 1 . Definitions of acronyms.

Basal Metabolic Rate (BMR) refers to the number of calories required to support basic physiological functions each day. Basal functions represent the calories needed to fuel the brain, heart, lungs, kidneys, nervous system, and everything else that happens automatically to keep bodies alive without conscious muscle activity. The BMR is a function of age, gender, body size and body composition.

Activity Energy Expenditure (AEE) represents the calories used to perform different forms of physical activities. AEE is a function of the intensity of activity and of body weight.

Total Energy Expenditure (TEE) is the sum of BMR and AEE.

Physical Activity Level (PAL) is the ratio of TEE to BMR and provides an index of the relative excess energy expended for physical activity. More simply, PAL is a measurement of the intensity of physical activity corrected for age, gender and body size. This feature makes PAL a suitable measure to compare the intensity of work across populations. Typical PAL values in free-living adults range from 1.40 to approximately 2.40.

3.3.1. Estimating energy expenditure

We used Actilife, the proprietary ActiGraph software, to export and analyse accelerometry data. Data were processed by compressing the 30 Hz raw format data to 3 second epochs in order to reduce the computational time without significant loss of accuracy (Chen & Bassett, 2005). Periods of 'non-wear' were detected and excluded from the analysis using the Choi algorithm (Choi et al., 2011). Days in which respondents did not wear the device for more than two hours (other than during night-time sleep hours when respondents were allowed to remove the devices) were also excluded. Using this threshold, we observe that compliance was higher in India than in Nepal, although in both cases compliance levels were significantly higher than in studies in Europe or the United States (Troiano et al., 2008). We observed more non-compliance in the first week of data collection. Compliance improved in the subsequent weeks as a result of prompts by enumerators during the daily survey and reinforced by local community facilitators. We do not find non-compliance associated with specific individuals. It appeared to occur randomly and from the time-use data it was seen to be mainly associated with participation in social or religious events (e.g., funerals, festivals) when respondents may have been unwilling to be seen wearing these devices.

The data were exported to an MS Excel dataset aggregated to one-hour intervals that included Activity Energy Expenditure (AEE), Basal Metabolic Rate (BMR) and Total Energy Expenditure (TEE). AEE is a measure of calories used to perform different types of activities. BMR refers to the calories needed to support basal physical functions that occur automatically without conscious muscle activity. This was computed based on the Harris–Benedict equation (Harris & Benedict, 1918) that estimates the BMR based on age, sex, height and weight of each individual. In turn, TEE is calculated as the sum of BMR and AEE[7]. Because of physiological

[7] TEE includes the Thermic Effect of Food, defined as the increase in basal metabolic rate after ingestion of a meal. TEF accounts for a small proportion of TEE (3–10%), and it is not captured by ActiGraph accelerometry devices. This represents one of the limitations of using said technology.

differences between men and women, Physical Activity Levels (PAL), a ratio between TEE and BMR, provide a measure of physical activity weighted by body size, allowing comparisons between gender and body types.

3.3.2. Capturing time-use and simultaneous work

The time-use questionnaire recorded data at 1-hour intervals during waking hours. In consultation with the field team and respondents, waking hours were set as 5 am to 10 pm in India (17 h) and 4 am to 10 pm in Nepal (18 h). The remaining time was considered night-time for sleep. The full sample included more than 36,000 hours of time-use and energy expenditure data associated with activities which were later coded into three categories – productive, reproductive, and leisure – for analysis (as shown in Table 1).

In the context of rural agricultural households in India and Nepal, *productive* activities are tasks undertaken for the production of goods and services, whether intended for exchange or for household consumption (subsistence) (Moser, 1989). *Productive* activities in this context may be undertaken for a payment (wages) or may reflect unpaid work. *Reproductive* activities include unpaid tasks carried out for the maintenance of the household unit, such as child-care; caring for the elderly, ill, disabled and other household members; caring for non-family members; and cooking, cleaning and collecting water and fuel (Moser, 1989). In this paper *leisure* is meant as a broad category that includes activities that reflect free time, as well as some activities positioned on a continuum of pure free time (resting and watching TV) and social and personal commitment (i.e. community events and meetings, medical care). We categorized 'travel time' based on the purpose of the activity.

Respondents were asked about activities performed simultaneously and asked to rank them as primary or secondary. Listing of secondary activities was relatively infrequent, around 25% of the hourly observations in India and 8% of the hourly observations in Nepal report secondary activities. In most cases, primary and secondary activities are of the same nature (e.g. both productive). Each hour recorded in an activity was assigned a weight. To reflect the prevalence of primary tasks, time spent on primary activities was given the weight of 0.6 on the hour interval; secondary activities, regardless of whether the activity fell in the same category (productive, reproductive, or leisure) as the primary activity, was given the weight of 0.4 on the time interval.[8] This allowed us to provide visibility to productive and reproductive activities that occur within the same hour, as well as account for the overlap between leisure and productive and reproductive work. If there was no secondary activity, the time spent on the primary activity was given the full weight (1.0).

The analytical allocation of energy expenditure to primary and secondary activities (where relevant) was done based on a weighting system. Weights were based on average energy intensity of these activities derived from instances where these were the only activities performed. For example, let us assume a case in which a female participant reported an agricultural activity (primary activity) and domestic activity (secondary activity) for a specific hour resulting in a total of 65 Kcals (AEE). We first compute the mean of the said agricultural activity and domestic activity for every female participant when reported without a secondary activity (e.g. 75 and 45 kcals, respectively). We then associate 40.6 Kcals for the agricultural activity (65 * (75/(75 + 45)) and 24.4 Kcals for the domestic activity (65* (45/(75 + 45)).

Table 1
Categories of reported activities in India and Nepal.

Productive work	Reproductive work	Leisure
• Crop production (activities in the field, e.g., seeding, ploughing, harvesting); and travelling • Livestock (e.g., looking after animals) • Marketing (e.g., selling products) • Off-farm work (e.g., processing, wage work) • Travelling for purposes pertinent to productive work	• Child and adult care • Getting services (e.g., going to the bank) • Household chores (e.g., cooking, cleaning, fetching water and firewood); • Travelling for purposes pertinent to reproductive work	• Individual Activities (e.g., eating; watching TV, reading, relaxing, medical and personal care) • Sleeping and resting during the day (excluding sleep at night) • Social activities (e.g., religious, social, and community events and meetings; survey completion) • Travelling for any of the purposes above

3.3.3. Modelling allocations of energy and time

In the literature, time-use data have been analysed with a range of models, from linear regressions (e.g. Frazis & Stewart, 2011) to fractional regressions (e.g. Cardoso et al., 2010), to Tobit models (e.g. Kooreman et al., 2000), or Cragg two-part models (e.g. Cawley & Liu, 2012). However, such estimation strategies do not consider that activities are substituted and therefore individuals face trade-offs between them. To acknowledge this, we use a Fractional Multinomial Logit (FML) model developed by Mullahy (2014) a multivariate generalization of the fractional logit model proposed by Papke and Wooldridge (1996). This approach allows us to jointly model the ratios of energy and time spent in different activities and to capture the potential trade-offs[9].

Following Mullahy (2014), let us consider our outcome of interest $y_{im} = \frac{t_{im}}{T}$, where $m = 1, \cdots, M$ (in our case m = 3, which corresponds to productive, reproductive, and leisure energy or time) and such as $y_{im} \in [0, 1]$ and $\sum_{m=1}^{M} y_{im} = 1$. Being x_i a set of exogenous covariates, two restrictions are in place i) $\mathrm{E}[y_{im}|x_i] \in (0, 1)$for all i; and ii) $\sum_{m=1}^{M} \mathrm{E}[y_{im}|x_i] = 1$ for all i such as the multinomial logit functional form using the normalization $\beta_1 = 0$ is

$$\mathrm{E}[y_{im}|\boldsymbol{x_i}] = \frac{\exp(\boldsymbol{x_i\beta_m})}{\sum_{m=1}^{M} \exp(\boldsymbol{x_i\beta_m})}, m = 1, \cdots, M = \mu_{im}(\boldsymbol{x})$$

The reduced form can then be interpreted as the demand of time (or energy) for individual activities. Given the functional form of the model does not allow modelling zeros, we inputted 2 min of activities for each activity that was not performed and subtracted that amount from sleeping time.

In our analysis we estimate the covariates of the share of AEE and time allocated to productive work, reproductive work, and leisure (e_p, e_r, e_l and t_p, t_r, t_l, respectively). Our econometric specifications are:

$$\begin{bmatrix} y_e^p = \beta_0 + \beta_1 SEASON \times SEX + \beta_2 IND + \beta_3 HH + \beta_4 CONTROLS + \varepsilon \\ y_e^r = \beta_0 + \beta_1 SEASON \times SEX + \beta_2 IND + \beta_3 HH + \beta_4 CONTROLS + \varepsilon \\ y_e^l = \beta_0 + \beta_1 SEASON \times SEX + \beta_2 IND + \beta_3 HH + \beta_4 CONTROLS + \varepsilon \end{bmatrix} \quad (1)$$

[8] It is not possible to determine the amount of time and sequencing of each primary and secondary activity. However, we assume that primary tasks prevail on secondary activities. While the weighting is arbitrary, we performed additional sensitivity tests with different weights (0.5–0.5 and 0.8–0.2). Results were not significantly different than the one presented

[9] While for each individual the time allocated in activities is relative to the fixed amount of time in a day (e.g. 24 h), the allocation of energy expenditure is *relative* to the total amount.

Table 2
Demographic and socio-economic characteristics.

	India		Nepal	
	Mean	SD	Mean	SD
Household composition				
Household size	4.30	(1.59)	4.65	(1.97)
Number of adult women (18–64 years old)	1.35	(0.49)	1.78	(0.90)
Number of adult men (18–64 years old)	1.45	(0.76)	1.65	(0.88)
Number of elderly household members (>64 years old)	0.10	(0.31)	0.13	(0.46)
Number of adolescents (13–17 years old)	0.35	(0.75)	0.48	(0.59)
Number of young children (0–5 years old)	0.40	(0.68)	0.39	(0.58)
Farm characteristics and labour availability				
Total land (in hectares)	4.05	(3.16)	1.52	(2.14)
Number of hired agricultural labourers	5.59	(3.20)	1.77	(1.91)
Number of family members in agricultural labour	4.64	(3.35)	5.22	(2.56)
Tropical Livestock Unit (TLU)	1.95	(2.48)	9.30	(5.32)
Household assets				
Asset Index†	0.00	(1.73)	0.00	(1.80)
Observations	20		23	

Note: †The Asset Index, a measure of wealth, is based on the ownership of a set of assets and built using a principal components analysis as described in Rutstein and Kiersten (2004). The range of the Index is [−3.59 | 4.02] and [−4.15 | 4.44] for India and Nepal, respectively.

$$\begin{cases} y_t^p = \beta_0 + \beta_1 SEASON \times SEX + \beta_2 IND + \beta_3 HH + \beta_4 CONTROLS + \varepsilon \\ y_t^r = \beta_0 + \beta_1 SEASON \times SEX + \beta_2 IND + \beta_3 HH + \beta_4 CONTROLS + \varepsilon \\ y_t^l = \beta_0 + \beta_1 SEASON \times SEX + \beta_2 IND + \beta_3 HH + \beta_4 CONTROLS + \varepsilon \end{cases} \quad (2)$$

where y_e captures the ratios of AEE allocated in a day in productive work ($y_e^p = \frac{e_p}{e_p+e_r+e_l}$), reproductive work ($y_e^r = \frac{e_r}{e_p+e_r+e_l}$), and leisure activities ($y_e^l = \frac{e_p}{e_p+e_r+e_l}$) and y_t represents the ratios of time allocated in a day in productive work, reproductive work and leisure activities ($y_t^p = \frac{t_p}{Z}, y_t^r = \frac{t_r}{Z}$ and $y_t^l = \frac{t_l}{Z}$ respectively, being the sum of t_p, t_r, t_l equals to Z minutes, 1020 min (17 h) and 1080 min (18 h) in India and Nepal respectively).

The focus of the analysis is on the vector **SEASON**, which contains the full factorial interaction between the four seasons (land preparation, seeding and sowing, land maintenance, and harvest) and gender (*SEX*). Individual characteristics are captured in the vector **IND**. This includes age of the participant (in years), literacy (dummy), and BMI as a measure of body size. For females, we included a dummy variable capturing whether the participant is pregnant or breastfeeding. Vector **HH** captures a series of household characteristics including household composition (number of adult males, adult females, elderly, adolescents, and children), agricultural activities (land endowment, livestock ownership, adoption of irrigation technologies), labour (hired and family labour), and a wealth index based on the ownership of a set of assets and built using a principal components analysis as described in Rutstein and Kiersten (2004). Finally, in vector **CONTROL** we control for the day of the week, sequential day of wearing the accelerometer, and the number of missing hours of wear.

We used the command FMLOGIT (Buis, 2008) in Stata to estimate each set of models at country level, first with the pooled sample of males and females, and then individual models split by sex. Estimation of marginal effects of covariates on energy and time shares for productive and reproductive work and leisure in both case studies can be found in Appendix-2. The models control for autocorrelation among the outcome variables, heteroskedasticity, and non-linearities. Standard errors throughout are clustered at individual level.

4. Results

The following section reports the results of our analysis which, given the sample of 43 households in India and Nepal, is not a representative of rural households in the two countries. Hence, we are not making any generalisations and inferences about country level differences from an examination of the sample households. However, for simplicity, we will refer to the two case studies as "India" and "Nepal" and to the respondents as "Indian" and "Nepali" households and individuals.

4.1. Demographic and socio-economic characteristics

Table 2 presents the demographic and socio-economic characteristics of the 43 participating households in India and Nepal[10].

With an average household size of 4–5 and larger number of adults than children, the agricultural households in the sample for both countries were closer to nuclear rather than extended family units. The average landholding size in Indian agricultural households (4.05 ha) was much larger than that of Nepali households. However, Nepali households reported owning more than four times as many Tropical Livestock Units[11] (TLUs) as Indian households. Both Indian and Nepali households had substantial participation of family members (including those not living in the household) in agricultural work, but Indian households engaged a larger number of hired agricultural workers.

4.2. Individual characteristics – anthropometry, physical activity and energy expenditure

Table 3 reports the individual characteristics of our respondents in both countries. The average age for men and women respondents was between 34.30 and 46 years and the average BMI was within the normal range (18.5–24.9) and in line with the latest results from the Demographic and Health Surveys (IIPS-India and ICF, 2017; Ministry of Health - Nepal et al., 2017)[12]. Literacy levels

[10] The study design included 20 households in each country. However, during the fourth week of data collection in Nepal, the community suffered from an outbreak of food poisoning, which affected some participating households. For this reason, the affected households were replaced with three additional households for the fourth week which corresponded with the harvest season.

[11] Tropical Livestock Units are livestock numbers converted to a common unit. Conversion factors are cattle = 0.7, sheep = 0.1, goats = 0.1, pigs = 0.2, chicken = 0.01 (Chilonda & Otte, 2006).

[12] One woman in India and two women in Nepal were breastfeeding over the course of the study. As mentioned earlier, pregnancy was an exclusion criterion for study participation, however, over the course of the study, one woman in India and one in Nepal became pregnant. They were not excluded from the study (but their BMI was excluded from the sample).

Table 3
Anthropometric and energy expenditure data of individual respondents in India and Nepal.

	India					Nepal				
	Men		Women			Men		Women		
	Mean	SD	Mean	SD	T-test	Mean	SD	Mean	SD	T-test
Individual characteristics										
Age (in years)	40.84	(12.58)	34.29	(9.78)		46.04	(9)	43.19	(7.92)	
Height (in cm)	163.02	(7.14)	150.3	(4.58)	***	164.8	(5.54)	151.33	(6.01)	***
Weight (in kg)	58.6	(8.92)	46.48	(5.87)	***	63.53	(11.37)	54.65	(10.55)	**
BMI (kg/m^2)	22.05	(3.21)	20.58	(2.46)		23.31	(3.31)	23.79	(3.88)	
Literacy (dummy)	0.3	(0.47)	0.05	(0.22)	*	0.65	(0.49)	0.39	(0.5)	*
Pregnant (dummy)	.	.	0.05	(0.22)		.	.	0.04	(0.21)	
Breastfeeding (dummy)	.	.	0.05	(0.22)		.	.	0.09	(0.29)	
Energy consumption										
AEE (kcal/d)	777.69	(365.49)	621.51	(202.19)		1086.32	(260.52)	917.55	(338.35)	
BMR	1405.71	(112.63)	1071.7	(86.84)	***	1440.09	(157.44)	1115.34	(149.43)	***
TEE (kcal/d)	2183.4	(424.12)	1693.21	(258.29)	***	2526.41	(360.65)	2032.89	(471.33)	***
PAL	1.55	(0.24)	1.58	(0.17)		1.75	(0.16)	1.81	(0.2)	
Compliance of accelerometer wear										
Number of days†	26.2	(2.12)	26.4	(2.14)		22.65	(7.68)	22.43	(7.25)	
Proportion of days excluded††	0.07	(0.26)	0.07	(0.26)		0.04	(0.20)	0.05	(0.22)	
Total number of days‡	524	(42.35)	528	(42.75)		521	(176.61)	516	(166.84)	
No. of households	20		20			23		23		

Notes: *** 0.1 percent significant, ** 1 percent significant, * 5 percent significant. BMI: Body Mass Index; AEE: Activity Energy Expenditure (kcal/d); BMR: Basal Metabolic Rate (computed based on the Harris-Benedict equation); TEE: Total Energy Expenditure (kcal/d); PAL: Physical Activity Level (TEE/BMR). †Average number of days with valid data (non-wearing time less than 2 h throughout the day) out of the four weeks (28 days) of the survey. ††Proportion of days excluded to the non-wear in excess of two hours ‡Total number of distinct day-level observations (individuals × days surveyed).

were low, particularly in India where only a third of men in the sample and less than 5% of the women could read and write. Literacy levels were higher overall in Nepal – 65% for men and 39% for women.

The physical activity parameters reported in Table 3 are Activity Energy Expenditure (AEE), Basal Metabolic Rate (BMR), Total Energy Expenditure (TEE) and the Physical Activity Level (PAL). The TEE for men exceeds that of women by 28% in India and 24% in Nepal. This partly reflects the higher BMR for men in relation to women, but AEE levels for men are also consistently higher than that of women. PAL greater than 1.5 in India and greater than 1.7 in Nepal would indicate that these households have light or moderately active lifestyles based on the classification suggested by the FAO (2001)[13]. In the aggregate (over all seasons), the PAL for women is greater than that of men in both countries, although the differences are not significant. The activities associated with rural livelihoods in Nepal appear to be more intense than in India. Table 4 reports the variation in energy expenditure patterns by gender and season.

Total energy expenditure is significantly higher for men than women in all seasons in both India and Nepal. In India, AEE for men does not significantly vary across seasons but it does for women. The highest energy expenditures for both men and women occur in Season 2 (seeding and sowing) followed by Season 3 (land preparation). In Nepal, AEE varies significantly across seasons for both men and women with the highest energy expenditures occurring in Season 2 (seeding and sowing). Women have a higher PAL than men in all seasons in both countries, except in Season 4 (harvest). However, the differences in PAL are significant only in Season 3 (land maintenance) when men's PAL appears to fall more than for women. When we compare all four seasons, the PAL for women is significantly higher than that of men only in Nepal.

[13] Physical activity level (PAL) of habitual tasks is defined in terms of three levels of physical activity: sedentary or light activity (1.40–1.69), active or moderately active (1.70–1.99) and vigorous and very vigorously active (2.00–2.40) (FAO et al., 2001).

4.3. Allocation of time and energy for livelihood activities

Table 5 presents the proportion of AEE and time allocated to productive, reproductive and leisure activities by gender in both study sites. The data provide a snapshot of gendered allocation of time and energy in productive and reproductive work in rural households. The data are weighted to reflect the simultaneity of primary and secondary activities.

In both case studies, women spend a larger proportion of their time and energy on work (productive and reproductive activities taken together) than men. The proportion of energy and time spent on productive and reproductive roles leaves women less time for leisure.

Productive work absorbs the bulk of women's (51–59%) and men's (61–62%) energy expenditure in both study sites. Although women devote a lower proportion of time to productive work than men, it accounts for over half of their total energy expenditure, highlighting the important role that they play in agricultural activities. Activities related to crop production are the largest subcategory, to which Indian and Nepali men and women devote the highest share of productive work time and energy, followed by animal husbandry. Men and women in Nepali households appear to devote a larger share of the energy and time to livestock activities, which may reflect the larger number of livestock units possessed by Nepali households. In India, animal husbandry appears to be a task performed predominantly by men, with women playing only a limited role.

In India, other productive work is related mainly to travelling and processing. In Nepal, off-farm activities are mainly undertaken by men while in India there is an equal participation of men and women in this domain. A small percentage of time and energy is allocated to marketing activities. Nepali households' livelihoods appear to involve very little travel for productive purposes.

There are large differences in the participation of men and women in reproductive activities in agricultural households in both countries. Women spend a much larger proportion of their time (17–19%) and energy (19–20%) on reproductive work compared to men. In India, participation by men in reproductive activities is very limited (accounting for <3% of time and energy). Nepali

Table 4
Energy expenditure by season and gender in India and Nepal.

	India					Nepal				
	Men		Women			Men		Women		
	Mean	SD	Mean	SD	T-test	Mean	SD	Mean	SD	T-test
AEE (kcal/d)	755	(450)	602	(298)	***	1061	(418)	876	(388)	***
Season 1	799	(499)	622	(310)	***	1032	(396)	857	(353)	***
Season 2	807	(479)	666	(326)	**	1226	(439)	955	(432)	***
Season 3	709	(415)	617	(288)	*	966	(392)	919	(408)	
Season 4	704	(395)	503	(240)	***	1010	(397)	755	(313)	***
Difference‡			***			***		***		
TEE (kcal/d)	2159	(498)	1674	(339)	***	2495	(478)	1982	(501)	***
Season 1	2207	(555)	1694	(352)	***	2480	(482)	1978	(480)	***
Season 2	2209	(522)	1735	(380)	***	2673	(482)	2075	(559)	***
Season 3	2101	(482)	1687	(330)	***	2414	(473)	2040	(534)	***
Season 4	2122	(419)	1580	(266)	***	2399	(417)	1808	(355)	***
Difference‡			***			***		***		
PAL	1.53	(0.31)	1.56	(0.26)		1.74	(0.29)	1.78	(0.27)	*
Season 1	1.56	(0.34)	1.58	(0.27)		1.71	(0.26)	1.75	(0.24)	
Season 2	1.57	(0.33)	1.61	(0.28)		1.85	(0.31)	1.83	(0.28)	
Season 3	1.51	(0.28)	1.57	(0.25)	*	1.66	(0.26)	1.80	(0.27)	***
Season 4	1.49	(0.27)	1.47	(0.22)		1.73	(0.29)	1.71	(0.28)	
Difference‡			***			***		***		
Observations	560		560			539		539		

Notes: ‡Intra-seasonal differences are captured with a one-way analysis of variance (Bonferroni multiple-comparison test). Agricultural seasons are numbered as 1 = land preparation, 2 = seeding and sowing, 3 = land maintenance, and 4 = harvesting. *** 0.1 percent significant, ** 1 percent significant, * 5 percent significant.

Table 5
Time-use and energy expenditure allocation for livelihood activities in India and Nepal.

	India				Nepal			
	Men		Women		Men		Women	
	AEE %	Time %	AEE %	Time %	AEE %	Time %	AEE %	Time %
Reproductive work (1)	***2.3***	***2.5***	***19.1***	***18.6***	***9.8***	***7.6***	***19.7***	***17.6***
Child/adult care	0.1	0.1	1.9	1.8	0.4	0.2	1.1	1.0
Getting services	0.3	0.4	0.1	0.1	0.2	0.1	0.1	0.1
Household chores	1.8	1.9	17.1	16.6	9.3	7.3	18.7	16.7
Travelling	0.1	0.2	0.0	0.1	0.0	0.0	0.0	0.0
Productive work (2)	***62.7***	***46.9***	***51.5***	***38.0***	***61.5***	***44.9***	***58.9***	***44.6***
Crop production	38.9	27.0	33.5	24.0	38.4	26.2	37.5	26.9
Livestock	8.1	6.3	1.6	1.1	12.3	9.7	17.5	13.9
Marketing	0.3	0.3	0.0	0.0	1.1	1.1	0.1	0.1
Off-farm	2.1	1.7	2.2	1.8	6.2	4.7	1.4	1.1
Processing	6.6	4.8	8.2	6.4	3.3	3.0	2.3	2.4
Travelling	6.8	7.0	6.0	4.7	0.3	0.2	0.1	0.2
All work (1) + (2)	***65***	***49.4***	***70.6***	***56.6***	***71.3***	***52.5***	***78.6***	***62.2***
Leisure (3)	***34.8***	***50.4***	***29.3***	***43.2***	***28.8***	***47.6***	***21.4***	***37.8***
Individual	13.8	17.6	13.4	15.9	11.8	11.6	7.6	8.5
Free time (resting)	9.5	11.1	10.1	10.5	9.3	17.6	7.1	13.5
Sleeping	0.6	9.2	0.4	9.1	0.3	7.0	0.1	6.1
Social	10.9	12.6	5.4	7.7	7.5	11.4	6.6	9.7

Notes: Energy and time refer to daytime activities (5 am to 10 pm in India and 4 am to 10 pm in Nepal) and include both weekdays and weekends. Data are weighted considering for simultaneity of primary and secondary activities.

men allocate a larger share of time (8%) and energy (10%) to reproductive work (mainly to household chores) compared to men in India. Household chores, such as the provision of food (cooking, collecting, and buying food), fuel and water collection and house cleaning, represent the bulk of time and energy devoted to reproductive work by women. The greater participation of men in reproductive work in Nepal is not on account of their higher participation in activities traditionally associated with women (e.g., child care, domestic chores etc) but on account of the time and energy they devote to what may be called 'house maintenance' activities – which include activities like fencing and upkeep of roofing. Childcare appears to represent a very small share of time and energy for women. This may be due to childcare being shared among other members of the household (or community) or the time devoted to childcare being under-reported on account of it being performed simultaneously with other primary or secondary activities.

4.4. Relationship between time-use and energy expenditure patterns

Fig. 1 shows the predicted patterns of time and energy expenditure proportions for productive work, reproductive work and leisure across season (1–4 on the horizontal axis of each graph) for men and women in India and Nepal. The proportions of time (in red) and energy expenditure (in blue) are predicted values from the multinomial logit model. Table 6 illustrates the energy share

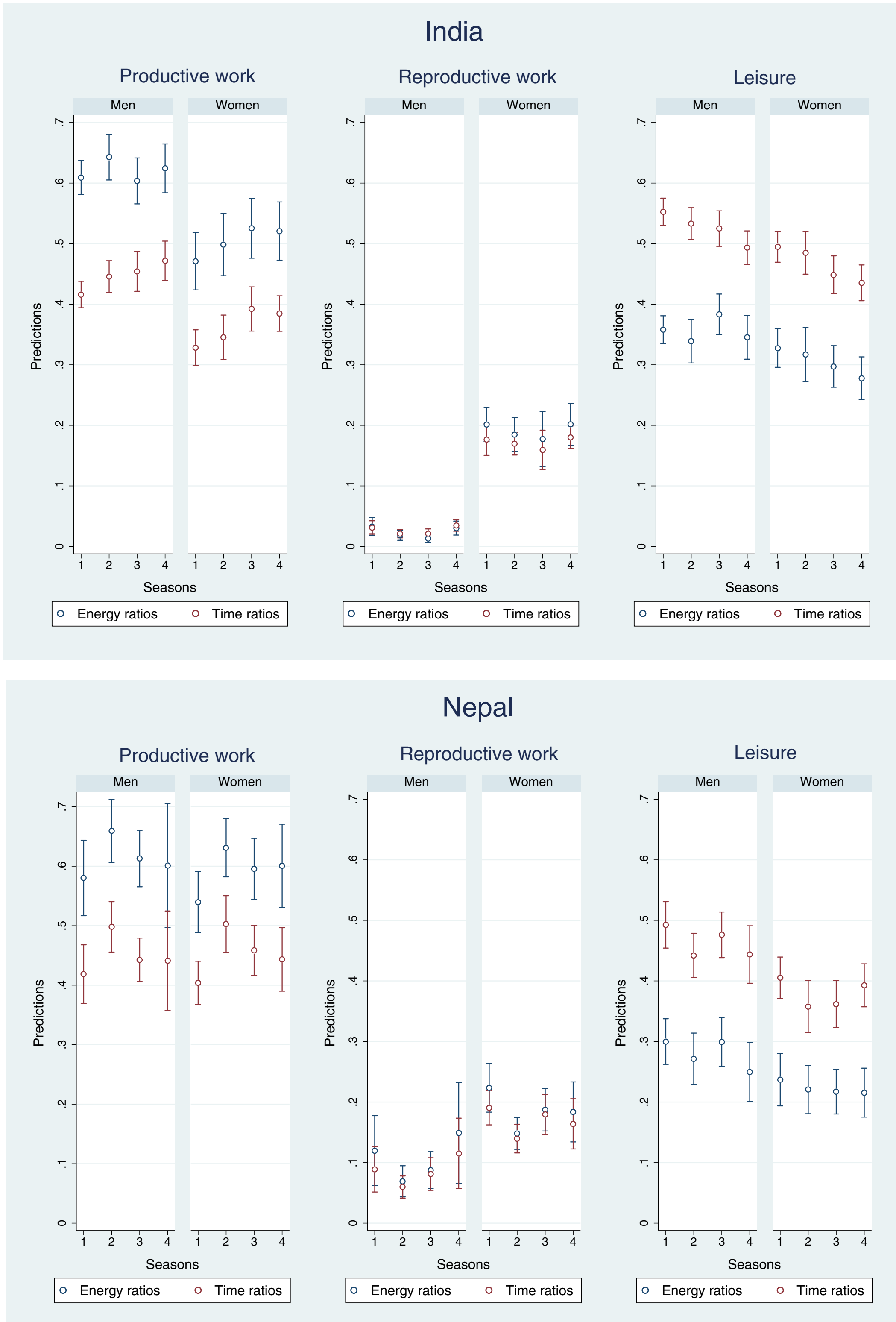

Fig. 1. Predicted energy and time ratios for men and women in India and in Nepal by type of activity, gender and season *Notes*: Agricultural seasons are numbered as 1 = land preparation, 2 = seeding and sowing, 3 = land maintenance, and 4 = harvesting. The bar plots show mean and 95% confidence intervals of time and energy shares, predicted from the fractional multinomial logit model.

elasticity with respect to time share (% change of energy expenditure share/% change of time share) of productive, reproductive and leisure across four seasons, in India and Nepal respectively. This elasticity (e_{et}) represents the responsiveness of energy expenditure to time calculated as the percentage change of energy expenditure share in response to a one percentage point change in time share. Elasticity indices greater than one indicate that energy expenditure shares respond more than proportionately to a change in time shares; indices equal to 1 indicate a proportional change of energy in response to time; indices lower than 1 indicate energy expenditure shares increase less than proportionately to a change in time shares.

Fig. 1 shows that for productive work, energy shares are larger than time shares for both men and women and the elasticities of energy shares with respect to time shares are significantly greater than one. For reproductive work, energy shares are closer to time shares, but are not significantly different from one. Expectedly, for leisure activities, energy shares are lower than time shares, with elasticities significantly less than one. These results show that time-use may not be a reliable indicator of work burdens, especially for productive work. Increased time allotted to productive work may demand a more than proportional increase in the share of energy devoted to productive work. For the range of activities observed in the case study, time-use may be a good indicator only for reproductive activities. Similarly, time-use may understate the energy demands associated with productive activities and overstate that for leisure.

The energy and time shares of productive activities vary across different phases of the agricultural cycle. Indian men appear to allocate a larger share of energy to productive activities during seeding and sowing than in other seasons. However, the most energy intensive activities are performed during land preparation (followed closely by seeding and sowing) as seen from the elasticity value. Women allocate larger shares of energy and time in productive work during land maintenance and harvest, but the most energy intensive activities take place during seeding and sowing. Similar patterns are seen in Nepal, where women and men allocate a larger proportion of energy (and time) to productive tasks in the seeding and sowing season and the most energy intensive work takes place during harvest. Compared to productive activities, reproductive activities exhibit much smaller seasonal variation in energy and time shares. This suggests that seasonal increased energy and time requirements in productive tasks are likely to be met through reduction in time devoted to leisure, with reproductive duties remaining unchanged. Finally, to complement the above discussion, we report on the marginal effects of covariates on energy and time shares for the three classes of activities in both case studies in Appendix-2.

5. Discussion and directions for future research

The profiles of energy and time-use developed in this paper show that, in rural agricultural households in the two case studies, both men and women participate almost equally in several elements of productive work, including crop production and livestock maintenance. Productive work accounts for the dominant share of energy expended by both men and women, while reproductive work accounts for the smallest share. This supports a more nuanced analysis of gender roles in rural livelihoods, avoiding the stereotype of productive work being chiefly the domain of men (Doss et al., 2018).

The evidence on the role of women in agricultural activities in our sample is also consistent with the observed trends on the feminisation of agriculture in South Asia, in the context of male migratory patterns (FAO et al., 2011). In line with other studies in the literature (Ferro-Luzzi & Martino, 1996; Yamauchi et al., 2001), we find that livelihood activities in agricultural households are mostly of light or moderate intensity. However, women have a higher PAL than men in both countries[14]. Higher PAL for women appears to result from longer hour spent in habitual light/moderate intensity tasks as opposed to short bursts of intense physical activity (Kashiwazaki et al., 1995; Lawrence et al., 1985; Panter-Brick, 1996). As argued by Panter-Brick (2003) "the nature of subsistence labour in these communities demands endurance over time rather than intensive effort per unit of time" (p. 503). Agricultural interventions aimed at increasing productivity that call for increased participation by women can place large demands on women's time and energy over and above their existing substantial contribution to productive work. Our analysis also shows that productive work in agricultural households calls for a larger share of energy than time. Increased energy demands associated with intensification of women's work in agriculture is likely to be an important pathway to nutritional and health impacts for women.

The reproductive domain remains predominantly a feminised sphere among selected Indian and Nepali households. In both case studies, women compensate for the heavier burden of work (productive and reproductive) by reducing leisure. There are noticeable differences in the contribution of men to reproductive work in the field sites, suggesting that the gender division of reproductive work is influenced by contextual factors. Women's reproductive work is central to the subsistence and functioning of the household, but rarely is acknowledged as "real work" (Rao, 2012). This raises concerns about women's time being viewed as limitless (Doss et al., 2018). Approaches to increasing women's participation in the cash-earning productive sector are often based on the assumptions that there are no trade-offs between income generation and the gender allocation of labour (Jackson & Palmer-Jones, 1998). Our results show there are real trade-offs made by women when income generation results in an increase in time and energy spent on productive tasks with potentially detrimental effects on leisure and reproductive tasks (Ruel & Alderman, 2013). Hence, ignoring these trade-offs has clear implications for the wellbeing of women and those they care for (Rao & Raju, 2020).

In our case studies, gendered allocations of time and energy to productive and reproductive work and leisure are associated with covariates on individual and household characteristics, endowments and seasonality effects[15]. Size of landholding, availability of irrigation and household assets generally appear to be associated with increased energy and time shares devoted to productive work by both men and women. As the land and livelihood relationship can take a "myriad of permutations" (Pritchard et al., 2017), we explore the gender differences in the influence of these factors (e.g., irrigation appears to be associated with time and energy allocation only of men) that may reflect the type of agricultural activities undertaken by men and women. Our results also suggest that in selected rural agricultural households, the energy and time devoted to productive work may be constrained by the availability of land and other assets, i.e., specific cultivation systems, availability of land and assets elicits a larger productive effort. We also recognise that, alongside gender relations, the allocation of time and energy to productive work is shaped by contextual and socio-economic factors. These were outside the scope of the present study and represent one of its limitations. Hence, future research on gendered patterns of rural livelihood activities will benefit from the adoption of mixed-methods approaches that integrate physical activity and time-use data with qualitative and contextual information about the nature of work (productive and reproductive) and its differentiations based on social hierarchies.

Our analysis suggests that the association between covariates of household composition differ between men and women. The presence of adult men and women, the elderly, adolescents and children is associated with increased demands for care, while also

[14] We do note that in our study the PAL for women is not significantly different from that of men.

[15] See Appendix-2 for a discussion of marginal effects of covariates on energy and times shares for each class of activity in India and Nepal.

Table 6
Elasticities of energy shares with respect to time shares in India and Nepal.

	Men				Women			
India	Land preparation	Seeding & sowing	Land maintenance	Harvest	Land Preparation	Seeding & sowing	Land maintenance	Harvest
Productive	1.468***	1.446***	1.350***	1.344***	1.435***	1.452***	1.356***	1.372***
Reproductive	1.054	0.879	0.637	0.886	1.144	1.097	1.135	1.132
Leisure	0.645***	0.632***	0.712***	0.679***	0.660***	0.644***	0.640***	0.617***
	Men				Women			
Nepal	Land preparation	Seeding & sowing	Land maintenance	Harvest	Land Preparation	Seeding & sowing	Land maintenance	Harvest
Productive	1.382***	1.327***	1.387***	1.371**	1.336***	1.267***	1.303***	1.357***
Reproductive	1.337	1.156	1.071	1.290	1.173	1.077	1.046	1.121
Leisure	0.614***	0.611***	0.629***	0.556***	0.584***	0.594***	0.593***	0.546***

Notes: Significance levels computed simulating 500,000 ratios from the original predicted distributions. *** denotes statistical significance at 1% level, ** at 5% level and * at 10% level.

providing avenues for sharing of productive or reproductive work. In line with previous studies (Rajkarnikar & Ramnarain, 2019; Ruwanpura, 2006), our paper emphasises that the influence of household composition may arise from the netting out of these opposing effects. The importance of intrahousehold labour dynamics along lines of gender and age, can be further examined by including the work contributions of other household members in time-use surveys and physical activity estimations. Seasonality exercises substantial pressures on productive work, at the expense of leisure. However, reproductive work appears to be less elastic to seasonality suggesting that additional seasonal productive work undertaken by women is compensated at the expense of leisure time. Similar dynamics are observed also by recent studies on the seasonal implications of gendered allocation of work in rural livelihoods in India (Rao & Raju, 2020). In conclusion, our data suggest that ownership of productive assets, household composition and agricultural seasons appear to be key factors influencing the energy and time allocations of selected rural households in India and Nepal.

6. Conclusions

The analysis of rural livelihoods has mainly relied on time-use as an indicator of the work burdens associated with livelihood activities. This study highlights the need to explicitly consider the energy expenditure dimension associated with different livelihood activities to better understand nutritional and health outcomes. Empirical measurement of the energy expenditure dimension provides visibility to the "invisible" work undertaken by women in both the productive and reproductive spheres and the nature of trade-offs that they face when called upon to increase their participation in productive work through agricultural interventions aimed at enhancing productivity.

The design of agricultural interventions needs to be cognisant of the energy and time demands that they impose on rural households. Facilitating greater participation of women in productive activities in agricultural households and increasing their productivity may call for provision of complementary services that mitigate the energy and time trade-offs. Reducing women's daily workload -- for example, by providing tap water or reducing the daily trek for firewood -- could free up time and energy which could be more productively used in farming and childcare. Improving child health and nutrition could also reduce the care burdens that women face. But these interventions are hardly ever evaluated in terms of their impact on women's agricultural productivity (Doss, 2018). These interventions should go alongside the provision of services that alleviate women's reproductive burden, such as childcare support and increasing women's available time to engage in formal and better paid economic activities (Johnston et al., 2018). Separate consideration of time and energy demands is a useful way to anticipate and plan for (and to certain extent avoid) unintended negative nutritional and health consequences of productivity-enhancing agricultural interventions. A richer picture of time-use and energy expenditure in rural agricultural households can ultimately improve the design and targeting of nutrition-sensitive agricultural interventions.

CRediT authorship contribution statement

Fiorella Picchioni: Investigation, Conceptualization, Methodology, Software, Formal analysis, Writing - original draft, Writing - review & editing. **Giacomo Zanello:** Supervision, Project administration, Investigation, Conceptualization, Methodology, Software, Formal analysis, Writing - original draft, Writing - review & editing. **C.S. Srinivasan:** Conceptualization, Methodology, Writing - original draft, Writing - review & editing. **Amanda J. Wyatt:** Conceptualization, Writing - original draft, Writing - review & editing. **Patrick Webb:** Conceptualization, Writing - review & editing.

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Conflict of interest

The author(s) declare(s) that there is no conflict of interest regarding the publication of this article.

APPENDIX-1

Table A. Crop calendars for study sites in India and in Nepal (major food crops reported)

India	J	F	M	A	M	J	J	A	S	O	N	D
Castor							Land preparation	Seeding/sowing	Land maintenance	Land maintenance	Harvesting	Harvesting
Chili							Land preparation	Seeding/sowing	Land maintenance	Land maintenance	Harvesting	Harvesting

Nepal	J	F	M	A	M	J	J	A	S	O	N	D
Maize (Chitwan)			Land preparation	Seeding/sowing	Land maintenance			Harvesting				
Maize (Baluwa)			Land preparation		Seeding/sowing	Land maintenance		Harvesting				
Mustard		Harvesting	Harvesting							Land preparation	Seeding/sowing	Land maintenance
Rice					Land preparation	Land preparation	Seeding/sowing	Land maintenance		Harvesting		
Potato	Land maintenance	Harvesting									Land preparation	Seeding/sowing

Land preparation	(orange)
Seeding/sowing	(brown)
Land maintenance	(green)
Harvesting	(yellow)

APPENDIX-2

Covariates of Energy and Time Shares

The full estimation results of the fractional multinomial logit models described in Section 3.3.3 with energy shares and time shares as the dependent variables are available in the Electronic Supplementary Material (Table 1 and 2). To examine the influence of covariates on time and energy shares we present the marginal effects of the covariates on time and energy shares, separately for men and women in the Indian and Nepali households in Table B and Table C. The marginal effects convey the influence of a one-unit change in the covariates on the energy and time shares. Table B and C also present the ratios of the marginal effects on energy and time shares, which show whether the covariates are associated with a larger effect on energy shares or time shares. Note that the marginal effects derived for any covariate from a fractional multinomial logit model sum to zero – they can thus be interpreted as the energy/time trade-offs between productive work, reproductive work and leisure associated with the covariate. The discussion is focussed on the significant marginal effects.

Productive work

As seen from the discussion in Section 4.4, time allocation alone may not be a reliable indicator of the work burdens associated with productive work. We, therefore, examine the influence of the covariates on both energy and time shares for productive work. In the Indian case study, larger size of agricultural landholding is associated with increases in both the energy and time shares devoted to productive work. The ratio of the marginal effects (1.4) suggests that landholding size has a stronger association energy shares than time shares. This is not surprising, as, during data collection, the Indian households were engaged in the cultivation of castor and chillies which rely heavily on manual work. Having irrigated agriculture is associated with an increase in the energy share of men for productive work but has no significant association with time shares. Ownership of livestock units is associated with reduced time shares devoted to productive work by men and reduced energy and time shares for women. The presence of adult women and the elderly in the household is associated with reduced time and energy shares for men for productive work, but only reduced time shares for women. The presence of a larger number of children and adolescents in the household is associated with increases in the time share of productive work for men while only the number of adolescents has a similar association with energy shares. Seasonality is associated with increases in the time share of productive activities in the land maintenance and harvest seasons for both men and women.

In Nepal, unlike in India, size of landholding, irrigation, asset index and TLUs do not have significant associations with energy or time shares for men. As in the case of India, the influence of landholding on productive labour in Nepal is probably shaped by cultivation practices. Nepali households cultivated crops (rice, maize, potato and mustard) where the use of mechanised tools is feasible. Hiring of tractors was a common practice among better-off households with larger landholdings. Women in wealthier households devote a larger share of time and energy to productive work, while larger land size is associated with reduced time shares. For men, the use of hired labour in agricultural work in the household is associated with reduced energy and time shares for productive work, while the engagement of family labour in agriculture is associated with increased energy and time shares. Literacy has a significant association with reduced energy and time shares for productive work for women, with a stronger association with energy than time shares. A higher BMI is associated with higher energy shares devoted to productive work for both men and women, but with increased time share only for men. This finding provides a direct link between adult male and female nutritional status and higher energy put into productive agricultural labour – a better nourished adult may enjoy higher productivity, which in turn supports improved diets via own production or income to spend on food.

For women, the presence of adolescents in the household is associated with increased energy and time shares of productive work, while a larger number of children is associated with reduced energy and time shares for productive work. The seeding/sowing season is associated with increased time and energy shares for both men and women, whereas the land maintenance season is associated with increased time and energy shares only for women.

Table B
Marginal effects of covariates on energy and time shares for productive and reproductive work and leisure in India.

	Men			Women		
	Energy (E) shares	Time (T) shares	Ratios (E/T)	Energy (E) shares	Time (T) shares	Ratios (E/T)
Productive Work						
Seeding/sowing	0.030	0.028	1.045	0.035	0.019	1.873
Land maintenance	−0.002	0.036*	−0.056	0.064	0.067**	0.944
Harvest	0.025	0.058**	0.437	0.059	0.058***	1.030
Age	−0.001	−0.002	0.683	−0.006	0.003	−1.903
Age square	0.000**	0.000	4.880	0.000	0.000	−0.683
Literacy	0.007	0.048	0.151	0.014	0.015	0.896
BMI	0.004	0.001	2.890	0.000	0.006	0.040
Irrigated system	0.088**	0.035	2.494	0.009	0.023	0.389
Log total land size	0.084***	0.059***	1.431***	0.068***	0.051***	1.339***
Asset Index	0.018	0.027**	0.671	0.019	0.015	1.249
TLU	−0.017	−0.025***	0.671	−0.020**	−0.020***	0.998**
No. of adult women	−0.143**	−0.144***	0.994**	−0.057	−0.085*	0.672
No of adult men	−0.033	−0.032	1.023	0.019	0.012	1.543
No. of elderly	−0.151***	−0.145***	1.042***	−0.031	−0.086***	0.359
No of adolescents	0.033*	0.035**	0.949*	0.012	0.020*	0.581
No of children	0.05	0.057*	0.864	−0.041*	−0.023	1.797
Hired Labour	−0.004	−0.004	0.928	0.007	0.004	1.958
Family Labour	0.002	0.003	0.766	−0.013	−0.008	1.633
Reproductive Work						
Seeding/sowing	−0.014	−0.01	1.465	−0.014	−0.005	2.698
Land maintenance	−0.018**	−0.009	1.912	−0.021	−0.017	1.213
Harvest	−0.004	0.002	−2.696	0.003	0.006	0.554
Age	0.000	0.000	−46.362	−0.013	−0.017*	0.748
Age square	−0.000***	−0.000***	1.104**	0.000	0.000*	0.767
Literacy	−0.022*	−0.02	1.116	0.012	−0.002	−6.479
BMI	0.002**	0.001*	1.607*	0.001	−0.004	−0.331
Irrigated system	−0.003	−0.006	0.597	0.027	−0.001	−50.538
Log total land size	−0.014***	−0.011***	1.276***	−0.019	−0.013	1.424
Asset Index	−0.005	−0.008**	0.649	−0.007	−0.008	0.855
TLU	0.006**	0.007***	0.841**	0.003	0.004	0.767
No. of adult women	0.034**	0.030**	1.155**	0.042	0.057*	0.746
No of adult men	0.009*	0.004	2.479	−0.038	−0.032*	1.198
No. of elderly	0.025***	0.026***	0.958***	−0.077**	−0.036*	2.119*
No of adolescents	−0.006**	−0.003	2.046	0.027	0.017	1.593
No of children	−0.023**	−0.016*	1.408*	0.029	0.022	1.327
Hired Labour	0.000	−0.001	2.710	0.003	−0.003	−0.995
Family Labour	−0.001	0.000	0.143	−0.014***	−0.006**	2.201**
Leisure						
Seeding/sowing	−0.015	−0.019	0.826	−0.021	−0.013	1.545
Land maintenance	0.02	−0.026	−0.758	−0.043*	−0.050**	0.850*
Harvest	−0.021	−0.059***	0.357	−0.063**	−0.063***	0.987**
Age	0.002	0.002	0.773	0.019	0.014	1.348
Age square	−0.000*	0.000	114.469	0.000	0.000	1.435
Literacy	0.015	−0.028	−0.531	−0.025	−0.013	1.899
BMI	−0.006	−0.002	2.343	−0.002	−0.002	1.029
Irrigated system	−0.085**	−0.03	2.861	−0.036	−0.023	1.570
Log total land size	−0.070***	−0.048***	1.468***	−0.049***	−0.037***	1.309**
Asset Index	−0.013	−0.019*	0.680	−0.012	−0.007	1.711
TLU	0.011	0.018**	0.604	0.017***	0.017***	1.053***
No. of adult women	0.109**	0.114***	0.952**	0.015	0.028	0.525
No of adult men	0.024	0.029	0.842	0.019	0.02	0.981
No. of elderly	0.126***	0.119***	1.060***	0.108**	0.122***	0.878**
No of adolescents	−0.027	−0.032**	0.845	−0.038**	−0.037**	1.037*
No of children	−0.027	−0.041	0.647	0.013	0.001	9.411
Hired Labour	0.005	0.004	1.003	0.006	0.002	2.589
Family Labour	−0.002	−0.002	1.085	0.009	0.011	0.860

Note: Fractional Multinomial Logit model. Robust standard errors clustered at individual level. Significance levels of ratios (E/T) computed simulating 10,000 ratios from the original predicted distributions. *** denotes statistical significance at 1% level, ** at 5% level and * at 10% level. Coefficients reported in Table 1 (Electronic Supplementary Materials).

Reproductive work

As discussed in the previous section, for the range of activities observed in the case studies, time-shares are reliable proxies for work burdens. Therefore, we can focus on the influence of covariates on time shares for reproductive activities. The contribution of men to reproductive activities is small in both India and Nepal, so it is more useful to examine the influence of covariates on the time-shares of reproductive work for women. In India, the presence of adult women in the household is weakly associated with an increase of time that they allocate for reproductive work, while the presence of adult men and the elderly is associated with reduced time for women in reproductive activities. Engagement of family labour in agricultural activities has a significant negative association with time devoted to reproductive activities by women. Seasonality has no significant association with the time allocated to reproductive activities.

In Nepal, larger landholding size is associated with increased time allocated for reproductive work by women. Greater engage-

Table C
Marginal effects of covariates on energy and time shares for productive and reproductive work and leisure in Nepal.

	Men			Women		
	Energy (E) shares	Time (T) shares	Ratios (E/T)	Energy (E) shares	Time (T) shares	Ratios (E/T)
Productive Work						
Seeding/sowing	0.095***	0.090***	1.045***	0.109***	0.104***	1.040***
Land maintenance	0.037	0.026	1.437	0.061*	0.055**	1.105*
Harvest	0.046	0.035	1.315	0.070	0.045	1.564
Age	0.057**	0.026	2.189	−0.025	−0.018	1.428
Age square	−0.001**	−0.000	2.330	0.000	0.000	1.393
Literacy	−0.034	−0.011	3.098	−0.141***	−0.106**	1.331**
BMI	0.018***	0.015***	1.144***	0.017***	0.007	2.522
Irrigated system	0.080	0.051	1.577	0.026	0.034	0.779
Log total land size	0.024	0.027	0.875	−0.026**	−0.016	1.679
Asset Index	−0.007	−0.001	5.013	0.015*	0.014*	1.091
TLU	0.003	0.003	0.952	0.003	−0.003	−0.743
No. of adult women	0.029*	0.018	1.656	−0.010	0.002	−6.227
No of adult men	−0.034	−0.035**	0.974	0.034*	0.009	3.698
No. of elderly	0.028	0.026	1.066	0.021	0.019	1.116
No of adolescents	−0.039	−0.070**	0.559	0.071***	0.046***	1.539***
No of children	−0.002	−0.020	0.111	−0.090***	−0.072***	1.253***
Hired Labour	−0.004**	−0.002**	1.652**	−0.001	−0.001	0.773
Family Labour	0.004*	0.003**	1.201*	0.001	0.002	0.440
Reproductive Work						
Seeding/sowing	−0.048*	−0.028	1.695	−0.073***	−0.047***	1.543***
Land maintenance	−0.031	−0.008	3.705	−0.036	−0.009	4.002
Harvest	0.018	0.019	0.944	−0.046	−0.034	1.373
Age	0.010	0.012	0.873	0.010	0.002	6.424
Age square	−0.000	−0.000	0.930	−0.000	−0.000	4.219
Literacy	0.013	0.010	1.360	0.041*	0.009	4.546
BMI	−0.002	−0.000	12.764	−0.005***	−0.003	1.909
Irrigated system	0.024	0.031	0.781	0.011	0.019	0.578
Log total land size	0.006	0.005	1.106	0.044***	0.038***	1.164***
Asset Index	0.007	0.008**	0.888	−0.008*	−0.002	3.486
TLU	−0.001	−0.001	0.763	−0.006***	−0.006***	0.890***
No. of adult women	−0.027*	−0.014	1.943	0.022***	0.022***	0.988***
No of adult men	0.014	0.000	57.550	−0.050***	−0.045***	1.115***
No. of elderly	−0.037	−0.024	1.582	0.015***	0.009*	1.736*
No of adolescents	0.033*	0.022*	1.503	−0.036***	−0.032***	1.133***
No of children	−0.006	−0.014	0.396	0.037***	0.011	3.335
Hired Labour	0.002	0.002*	1.324	0.000	−0.000	−1.828
Family Labour	0.000	0.000	0.565	0.002***	0.002***	0.995***
Leisure						
Seeding/sowing	−0.047*	−0.062**	0.749*	−0.035	−0.057**	0.621
Land maintenance	−0.007	−0.018	0.382	−0.025	−0.046**	0.544
Harvest	−0.064*	−0.054*	1.187	−0.024	−0.012	2.123
Age	−0.067***	−0.038**	1.776**	0.015	0.016	0.949
Age square	0.001***	0.000**	1.779**	−0.000	−0.000	0.952
Literacy	0.021	0.001	15.137	0.100***	0.097**	1.032**
BMI	−0.015***	−0.015***	1.014***	−0.012***	−0.004	2.936
Irrigated system	−0.104***	−0.081***	1.275***	−0.037	−0.053	0.705
Log total land size	−0.029**	−0.032**	0.911*	−0.017	−0.022*	0.793
Asset Index	−0.000	−0.006	0.010	−0.007	−0.012*	0.638
TLU	−0.002	−0.002	1.022	0.003	0.010***	0.301
No. of adult women	−0.002	−0.003	0.492	−0.012	−0.024	0.496
No of adult men	0.021**	0.035***	0.590**	0.017	0.036**	0.466
No. of elderly	0.009	−0.003	−3.655	−0.036*	−0.027*	1.317
No of adolescents	0.006	0.048*	0.127	−0.035*	−0.014	2.470
No of children	0.008	0.035**	0.230	0.053**	0.061**	0.877*
Hired Labour	0.002*	0.001	2.523	0.000	0.001	0.389
Family Labour	−0.004***	−0.003***	1.135***	−0.002***	−0.003***	0.701**

Note: Fractional Multinomial Logit model. Robust standard errors clustered at individual level. Significance levels of ratios (E/T) computed simulating 10,000 ratios from the original predicted distributions. *** denotes statistical significance at 1% level, ** at 5% level and * at 10% level. Coefficients reported in Table 2 (Electronic Supplementary Materials).

ment of family labour in agriculture is associated with increased time allocated for reproductive activities by women, while the ownership of livestock units has a negative association. In terms of household composition, the presence of more adult women and a larger number of elderlies is associated with increased time devoted by women to reproductive activities, while the presence of the adult men and adolescents has the opposite association. Association of seasonality with time shares is visible in Nepal with the seeding/sowing season associated with reduced time allocated for reproductive activities by women.

Leisure

Leisure activities are not energy intensive (elasticity of energy shares with respect to time shares < 1), so again we can focus on the influence of covariates on time shares. In India, larger landholding is reduced with reduced leisure for both men and women, while the ownership of livestock units is associated with increased leisure time. The Asset Index has positive association with leisure, but is significant only for men. In relation to household composition, the presence of the elderly in households is associated with increased time-shares for leisure, while the presence of adolescents has negative association with leisure. The presence of adult women in the household has a significant association with increased leisure time for men, but has no significant association for women. In terms of seasonality, the harvest season has a association with leisure time for men, whereas for women both the land maintenance and harvest seasons are associated with a negative impact on leisure.

In Nepal, as in India, larger landholding is associated with reduced leisure for both men and women, while irrigation systems have a negative association only for men. Ownership of livestock is associated with increased leisure for women, while women in wealthier households have less time for leisure. The utilisation of family labour for agriculture has a significant negative association with leisure for both men and women. A higher BMI is associated with a lower time share for leisure, but is significant only for men[16]. The presence of adult men and a larger number of children in the household is associated with increased leisure time for both men and women. The presence of the elderly, however, has a negative association with leisure time only for women, while the presence of adolescents is associated with increased leisure time for men. Seasonality influences on leisure are also seen in Nepal –the seeding/sowing and harvest seasons are associated with reduced leisure for men and the seeding/sowing and land maintenance seasons are associated with reduced leisure for women.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.worlddev.2020.105137.

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[16] With 78% and 22% of men in our sample normal weight and overweight BMI (respectively), higher BMI indicates better nutrition status and higher productive potential.

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