Energy Research & Social Science 118 (2024) 103780

Contents lists available at ScienceDirect

Energy Research & Social Science

journal homepage: www.elsevier.com/locate/erss

Original research article

Women's decision-making power, cooking fuel adoption and appliance ownership: Evidence from Rwanda, Nepal and Honduras☆

Svenja Flechtner [a,*], Ulli Lich [a,b], Setu Pelz [c]

[a] University of Siegen, Germany
[b] Reiner Lemoine Institute, Germany
[c] International Institute for Applied Systems Analysis (IIASA), Austria

ARTICLE INFO

Dataset link: https://github.com/svenjafl/cooking_devices_gender

Keywords:
Energy choices
Cooking fuels
Household appliances
Gender
Women's agency
Women's decision-making power
Honduras
Nepal
Rwanda
Multi-Tier Framework

ABSTRACT

Universal energy access underpins progress towards achieving many of the Sustainable Development Goals (SDGs), including gender equality (SDG 5). Yet this link is conditioned by a range of contextual factors that warrant careful consideration in designing measures that guide intervention. In this article, we examine the relationship between women's decision-making power and household energy choices in Honduras, Nepal and Rwanda. Analysing household and individual data from the World Bank's Multi-Tier Framework Surveys, we develop a measure to proxy women's decision-making power within a household and assess how this correlates with cooking fuel choices and appliance ownership. We find that Honduran and Nepalese households are up to 20 and 30 percentage points more likely to use clean cooking fuels when women in the household also experience high levels of decision-making power, but find no such associations in Rwanda. In terms of household appliances, we observe mixed results. In Honduras and Nepal, we find evidence that households with higher women's decision-making power also own a range of household appliance more often, but there is no general pattern across countries as to which appliances this concerns. In Rwanda, households with higher women's decision-making power own leisure-related devices less often. These descriptive findings highlight patterns of gender- and context-specific preferences over household energy usage relevant to the measurement of energy access and the development of context-aware energy access improvement interventions.

1. Introduction

The alleviation of energy poverty (SDG 7) is considered an important enabler of the other Sustainable Development Goals and central to development efforts more generally [1,2]. Literature at the nexus of energy poverty and international development discusses several paths by which improvements in energy access can lead to improvements in gender equality (SDG 5). For example, increasing access to electric household devices may free up time for women, who predominantly perform household chores [2–4]. The use of electric cooking stoves may save the time that mostly women and girls otherwise use for the collection of firewood [e.g. 5]. Electric cooking stoves may also improve women's and families' health by reducing indoor air pollution, as air pollution due to traditional cooking stoves causes eye and respiratory symptoms and is responsible for 3.8 billion premature deaths globally [6,7]. Other technologies such as refrigeration play a key role in preserving perishable foods and ensure certain medications remain cool and safe [8], which may reduce the workload of girls and women and improve their nutritional and medical provision [see also 2]. Girls who are involved in household chores during day-times may be able to use evening hours for educational activities thanks to electric light [9]. The list could go on.

At the same time, a branch of the literature indicates that women may not necessarily experience the same level of benefits from electricity access as men do. In some cases, gender equality may even decline as a result of gaining electricity access. One possible explanation for the unequal distribution of benefits from electrification lies in gendered hierarchies of decision-making within households. When men have larger decision-making power than women in a given household, they can shape the household's energy and appliance choices in ways that prioritise their own needs and preferences while disregarding those of women household members. In households where men's and women's energy needs and preferences differ due to a gendered organisation of work, gendered hierarchies in decision-making power can lead to choice patterns that significantly disadvantage women [10,11]. In other

☆ **Replication:** A replication package is available at https://github.com/svenjafl/cooking\protect\T1\textunderscoredevices\protect\T1\textunderscoregender.

* Corresponding author.
E-mail address: svenja.flechtner@uni-siegen.de (S. Flechtner).

https://doi.org/10.1016/j.erss.2024.103780
Received 3 July 2023; Received in revised form 5 September 2024; Accepted 28 September 2024
Available online 7 October 2024
2214-6296/© 2024 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

words, patriarchal norms in decision-making and household task organisation can contribute to women having less access to energy services and favour male-biased choices in appliance purchases, with lower priority given to devices that benefit women and their activities [4,12]. For example, several studies have documented reluctance among men who do not cook themselves to purchase healthier but more expensive cooking fuels [11,13–16]. In this context, Moniruzzaman and Day [11] speak of "multi-faceted energy injustice" that many women, especially those living in poverty, suffer.

To facilitate the implementation of context-aware electrification projects, it is essential to understand potential modifiers to the purported positive effects of household energy poverty alleviation on women's lives and on gender equality more generally [17,18]. A large number of studies has investigated households' choices over cooking technologies, cooking-related energy needs and related preferences of men and women. Choices over other household appliances have been investigated less extensively: we still have a rather limited understanding of gendered energy preferences and needs over technologies that facilitate household chores such as laundry, food provisioning or cleaning, as well as over technologies related to leisure and relaxation [19].

To deepen the understanding of potential gender disparities in energy uses and priorities, this study examines women's decision-making power in the household and households' choices over cooking fuels and household appliances. We capture women's decision-making power by an index comprising information on women's autonomy and mobility in the household, women's employment and educational levels — hence a range of characteristics that we think provide a good reflection of the degree to which women can participate in decisions around energy usage of their household. Using survey data from Honduras, Nepal and Rwanda, collected by the World Bank under the 'Multi-Tier Framework for Energy Access' initiative (MTF), we investigate whether there are differences in choices over various household appliances and cooking fuels between households with low or high women's decision-making power. By comparing representative data from three countries in three different world regions with widely differing gender norms, distributions and levels of women's decision-making power, economic backgrounds, and patterns of electricity use, we are able to investigate whether any universal patterns emerge across heterogeneous settings.

Regarding the utilisation of clean cooking fuels, we observe that households with higher women's decision-making power in Honduras and Nepal use clean cooking fuels considerably more often than comparable households with lower women's decision-making power. We estimate that the predicted probability of using clean cooking fuels increases from 41 percent at the lowest level of women's decision-making power to 61 percent at the highest level in Honduras, controlling for household wealth and education, and from 16.5 to 46 percent in Nepal. No such association is evident in Rwanda, where we investigate the use of improved versus traditional cookstoves, since hardly any households use clean cooking fuels. In terms of household appliances, we find evidence that households where women experience relatively higher decision-making power have made different choices and own various relevant household appliances more often than households where women have less say, especially in Honduras and Nepal. However, there is a high degree of heterogeneity in terms of which devices specifically this concerns. Appliances that households with high women's decision-making power own more often are not limited to appliances that improve the efficiency of household chores. We conclude that the use, meaning and priority given to different devices differs from context to context and cannot be generalised across heterogeneous settings — but they also differ according to women's decision-making power in the household, and hence are worthwhile being investigated and considered in electrification projects on a context-specific basis if women are to benefit equally from energy access.

Our study contributes to a body of research that has delved into energy choices and preferences of men and women in different contexts. Through the use of comparable survey data and measurement instruments across three distinct countries, we demonstrate that the relationship between women's roles in households and households' choices concerning cooking fuels and household appliances is not universally consistent. Significantly, our findings suggest that while men and women may have differing preferences, these differences are not a universal rule and not inherent or essential to their sex, as also argued by Listo [20]. Instead, they are related to local needs, gender roles and norms, underscoring that gender roles and hierarchies, as well as socio-economic contexts, vary across locations. This variation is not surprising considering that gender, understood here as a socio-cultural construct distinct from biological sex, refers to the roles, behaviours, and expectations societies attribute to individuals. These behaviours and expectations differ across cultural, historical, and political contexts, as highlighted by Butler [21]. While we cannot distinguish between sex and gender in our empirical analysis due to data limitations of the MTF, the interpretation of our results is nevertheless guided by an understanding of gender roles and identities that puts their social construction at centre stage.

The remainder of the paper is organised as follows. Section 2 discusses related literature. Section 3 presents our dataset and descriptive statistics and Section 4 explains our empirical approach. Section 5 shows and discusses the estimation results, before Section 6 concludes.

2. Intra-household decision-making power and energy usage: literature

The literature on the determinants of energy choices has identified a range of socioeconomic determinants such as the household's economic situation [18,22–25], urban or rural locality [24], the educational background of household members [24,26–28], household size [24,26], access to markets [29] and the presence of roads [26]. Social dynamics such as imitation [30] as well as the presence of livestock [31] have also been considered. Insofar as effects of gendered decision-making on the uptake of household technologies are concerned, a range of studies has analysed effects on choices over cookstoves and cooking fuels, whereas choices over other appliances have been less intensively studied [11,32]. Overall, there is mounting evidence indicating that in male-dominated households, choices over appliances and cooking technologies are biased towards what commonly counts as male preferences, whereas the opposite happens in women-dominated households [10,33]. In many societies, gender roles occasion a tendency whereby women are assigned to the private or domestic sphere while men are associated more strongly with the public sphere. This translates into gendered divisions of labour where women take care of the household, which in turn may cause divergences in preferences concerning the choice of household appliances [34]. When gendered hierarchies in decision-making power on the household level coincide with gendered preferences, choices may systematically disadvantage women [10,33,35,36]. Lights or fans might not be placed in the kitchen where women could benefit from them more [10]; men might be willing to purchase batteries to listen to the radio, but refuse to buy solar cookers or other household devices that women may benefit from [37]; or men may deny the health risks arising from traditional cooking methods to discard the purchase of alternative technologies [11], for example.

In the following sections, we separately review empirical evidence with respect to cooking fuel and stove choices (Section 2.1) and to household appliances more broadly (Section 2.2).

2.1. Cooking fuel and stove choices

There is evidence that the use of different energy sources is tied with gender norms across the globe in diverse ways [19]. Asibey et al. [23] analysed gender differences in energy use in Ghana's rural non-farm economy and found that women-owned businesses rather used solid fuels, while men-owned businesses rather operated on electricity. These choices seemed to be driven by gender norms: for example, a

man indicated that it was below his dignity as a man to light a fire with solid fuel in public [23]. In a case study in Himachal Pradesh in India, Parikh [38] provides another vital illustration of how different cooking fuels clearly fall into men's (kerosene, LPG) or women's responsibilities (dung cakes, agriculture residues), preventing women from becoming engaged with cleaner and superior fuels. Vyas et al. [39] provided evidence of a strong influence of patriarchal norms on cooking fuel choices in Northern India. Their mixed-method research analysed reasons behind low adoption of LPG and found that women were culturally encouraged to preserve resources like gas for the use of others, and to collect firewood instead. Low valuation of women's work and time contributed further to low uptake of LPG for gendered activities such as cooking. However, there also seems to be a lot of variation across space. Chandrasekaran et al. [40] used household survey data from the Multi-Tier Framework to study the relationship between a multi-dimensional women's empowerment index and the use of clean cookstoves and cooking fuels. The associations found were positive in Ethiopia, Nepal, Myanmar and Zambia, negative in Rwanda and statistically insignificant in Cambodia and Sao Tome and Principe. These results point into a similar direction as our analysis using the same data in that situations seem to differ significantly across countries.

In terms of preferences, several studies have found a stronger preference for improved cookstoves among women than among men. However, women's preferences seem to be closely intertwined with their bargaining position in the household. Alem et al. [13] elicited spouses' willingness to pay for improved cooking stoves in a field experiment in Ethiopia. Women expressed higher preferences for improved stoves, on average. However, women with low decision-making power expressed the same willingness to pay as their husbands, anticipating that their husbands' preferences would determine their access to this technology. In gender-disaggregated focus group discussions with mixed-gender couples in Kenya, Ochieng et al. [36] also found that men's willingness to buy cleaner cook-stoves was lower compared to that of women, even though men were aware of the problems associated with traditional cookstoves. The authors suspect that even women with own income sources would be inhibited from buying improved stoves due to their lower decision-making power. Results from a field experiment conducted in Bangladesh point into a similar direction [35]. The author investigated men's and women's choices over the purchase of healthier cooking stoves, finding that households where women were more empowered had either a higher chance of women choosing a cleaner stove for themselves or a lower chance of refusal of women's choices by their husband. Studying the case of Pakistan, Yasmin and Grundmann [41] found that women's decision-making power over the adoption of new cooking technologies increased with education, age, employment and women's ownership of land.

It should be noted that not all women unanimously prefer cleaner cooking technologies. Nuño Martínez et al. [42] analysed the demand for subsidised LPG cylinders in Peru and found that practical considerations prevented women from their adoption: women found it difficult to take care of other chores while cooking with LPG, and perceived the food to taste differently. Khandelwal et al. [43] found that women in India preferred traditional cookstoves because they attached cultural and spiritual value to their use and were able to produce and repair these stoves autonomously. Malakar and Day [44] illustrate that women's preferences over cooking fuels may also change with their acquaintance and personal experiences. They found that women in Northern India who utilised firewood perceived this technology as beneficial to their well-being in various aspects, whereas they did not expect such benefits from LPG use. However, women who had switched to LPG from firewood acknowledged that LPG had enhanced their well-being. With experience, women seemed to change and adjust their subjective assessment.

2.2. Choices over household appliances

Not only cooking, but household chores more broadly are predominantly carried out by women in most societies [4,34]. Hence women may benefit more directly from the purchase of electric devices that facilitate household chores. Some studies have investigated if different appliances – for housework, but also for entertainment – are desired, purchased, owned, or used predominantly by men or women. Winther et al. [12] asked households in India, Kenya and Nepal about such patterns and found gendered attributions of some appliances that varied by context. For example, irons had a feminine connotation in Kenya, but a male connotation in India. Some household devices such as sewing machines or rice cookers were considered female appliances, while radios, fans and refrigerators were mostly owned and used by men. Decisions about the location of light within the household were mostly made by men in India and Nepal, but jointly in Kenya. Overall, results varied strongly by context.

Rosenberg et al. [10] enquired if men and women in households in India used different appliances with different intensities. They found that TVs, non-kitchen fans and mobile phones were predominantly used by men and kitchen-related devices by women. Overall, men used more appliances. Women-led households owned more lights in the kitchen area. Muza and Debnath [17] used survey data from Rwanda to analyse non-income drivers of appliance uptake. They found that 21.6 percent of women-headed households versus 93.9 percent of male-headed households owned mobile phones, and only 7.5 percent versus 42.7 percent owned radios — controlling for household income. Male-headed households also owned more freezers, TVs, fans, laundry machines and computers. In a study in India by Dhanaraj et al. [3], households with higher levels of women's education more often owned fridges, which were more strongly desired by women because they reduced their work burden. It should be noted though that not all studies find different patterns of ownership of, or desire for, household appliances. Combining household survey data, interviews with households and experts and observation of cooking practices in rural Ethiopia, Wassie and Adaramola [45] found that men and women made similar choices about the use of kerosene, solar energy or biogas.

3. Data and descriptive statistics

This study uses data from the Multi-Tier Framework Global Survey (MTF), a survey that provides information about energy access and usage within households in a variety of Global South countries. In this study, we use data from one Latin American (Honduras), one Asian (Nepal) and one African (Rwanda) country. These countries differ in many aspects, among them not only gender norms but also levels of economic development and climatic conditions, which motivates our selection. Certainly, the prevalence of certain cooking fuels and household appliances will depend on these and other factors. For instance, some devices might be largely unaffordable for large parts of the population in a country with low income levels, or unnecessary for climatic regions (such as fans or fridges in cold regions). However, we are not interested in comparing levels of prevalence across households in different countries or regions *per se*. Rather, we enquire if women's decision-making power makes a relative difference, given a household's income level and location, and whether any universal patterns emerge across heterogeneous country contexts. The MTF survey provides nationally representative data from the years 2016 (Rwanda) and 2017 (Honduras, Nepal).[1]

[1] The MTF Survey oversamples some population groups. All country samples contain a 50–50 distribution of grid versus non-grid users and a 50–50 distribution of urban versus rural users. We use sampling weights throughout to make the analysis representative of the underlying national populations [46].

Table 1
Summary statistics: energy access, usage, and appliance ownership.

	Honduras	Nepal	Rwanda
Cooking-related energy use (percentages)			
Prevalence of clean cooking fuels	53.2	31.6	0.5
Cook stoves used (Rwanda only)			
Clean fuel stoves			0.5
Improved biomass stove			29.9
Three-stone stoves			53.2
Traditional stoves			16.4
Household appliance ownership (percentages)			
The household owns			
blender	n/a	6.9	n/a
fan	52.0	46.1	0.1
fridge	61.6	14.0	2.5
iron	44.8	16.7	7.5
kettle	n/a	4.6	1.9
microwave	28.6	n/a	n/a
PC	13.9	7.1	2.3
radio	48.8	18.9	40.4
rice cooker	n/a	14.3	n/a
TV	73.7	52.8	11.6
washing machine	13.0	n/a	n/a
water pump	n/a	9.3	n/a
Access to energy services			
Access to grid (% of households)	84.0	71.7	23.6
Years of grid access: mean (std. dev)	11.3 (10.4)	9.5 (7.2)	5.1 (5.2)
# observations	1,541	3,700	1,354
Hours of daily grid service: mean (std. dev)	23.3 (2.9)	21.5 (3.0)	21.3 (4.3)
# observations	2,217	4,043	1,428
Access to mini grid (% of households)	0.0	12.0	0.4
Years of mini grid access: mean (std. dev)	2.0 (0.0)	2.5 (0.6)	2.1 (0.5)
# observations	2,813	1,953	8
Hours of daily mini grid service: mean (std. dev.)	24.0 (0.0)	14.4 (4.5)	19.2 (6.0)
# observations	1	814	8
Access to solar home system (% of households)	4.9	24.2	4.9
Years of solar home system: mean (std. dev)	3.0 (3.0)	4.1 (3.0)	1.5 (1.0)
# observations	188	1,933	101
Hours of daily solar energy: mean (std. dev.)	8.9 (7.0)	10.4 (7.1)	8.6 (7.5)
# observations	194	1,854	100
# of observations (if not indicated otherwise)	2,815	6,000	3,295

Reported shares include sample weights and hence reflect population, not sample properties. # of observations in access to energy services panel indicate on which number of observations in the sample summary statistics are based. Reduced # of obs. for type of cook stove in Rwanda: 3,209.

The MTF provides information on household structures, the household's economic situation and socio-economic background, access to energy services, cooking stoves and fuels used, household appliances owned or desired, and women's positioning in the household. Table 1 provides summary statistics of key variables reflecting households' access to energy services, cooking-related energy use and the ownership of household appliances. The following paragraphs summarise key characteristics and provide information on two indices that we build to represent the household's economic situation and women's decision-making power in the household.

Types of cooking fuel and cookstoves used. In Nepal, less than one third use clean cooking fuels (primarily LPG cooking gas, but also biogas; electric and solar cookers are very uncommon), while the majority relies on biomass (mainly wood, but also dung, crop residue and others) [47]. In Honduras, more than half of all households already rely on clean cooking fuels.[2] In Rwanda, in contrast, virtually all households cook with biomass. Therefore, we investigate the type of stoves used instead. More than half of Rwandan households use a three stone stove (a pot balanced on three stones over an open fire), and about 16 percent a traditional stove (locally-produced stoves made from mud, metal, rockets or similar materials). Both these types of stoves produce high emissions, negatively affect indoor air quality and are associated with health problems such as eye and respiratory symptoms. 30 percent use improved biomass stoves (a variety of stoves using newer technologies, built out of metal or stone and tiles), which are still not clean and do not necessarily meet emission or efficiency standards, but produce lower levels of emissions [50]. Hence even though we are unable to analyse if women might prefer the use of clean cooking fuels, we are able to analyse relevant gender differences in cooking-related energy choices.

Ownership of electrical appliances. We investigate a broad variety of household devices, including fans, fridges, irons, microwaves, personal computers (PCs), rice cookers, televisions (TVs), washing machines and water pumps. Table 1 reports the prevalence of these devices by country. From the set of household devices enquired by the MTF, we selected these devices because we think that they either facilitate household chores or can be used for leisure and relaxation. Some devices, such as microwaves (investigated in Honduras but neither Nepal nor Rwanda), were only enquired in the survey of one or two countries and hence could not be included for the others. In some cases, there was too little within-country variation, such as in the case of fans in Rwanda (0.1 percent ownership rate). Some devices, such as blenders or kettles, had to be excluded altogether because of low prevalence in all countries. Finally, we excluded some devices with unclear implications for the present analysis. For example, the MTF enquires the number of light bulbs, but not their location. As discussed

[2] In the MTF's country report, their share is only 34 percent, while firewood is the dominant cooking fuel [48]. This discrepancy with published data has been documented before [49].

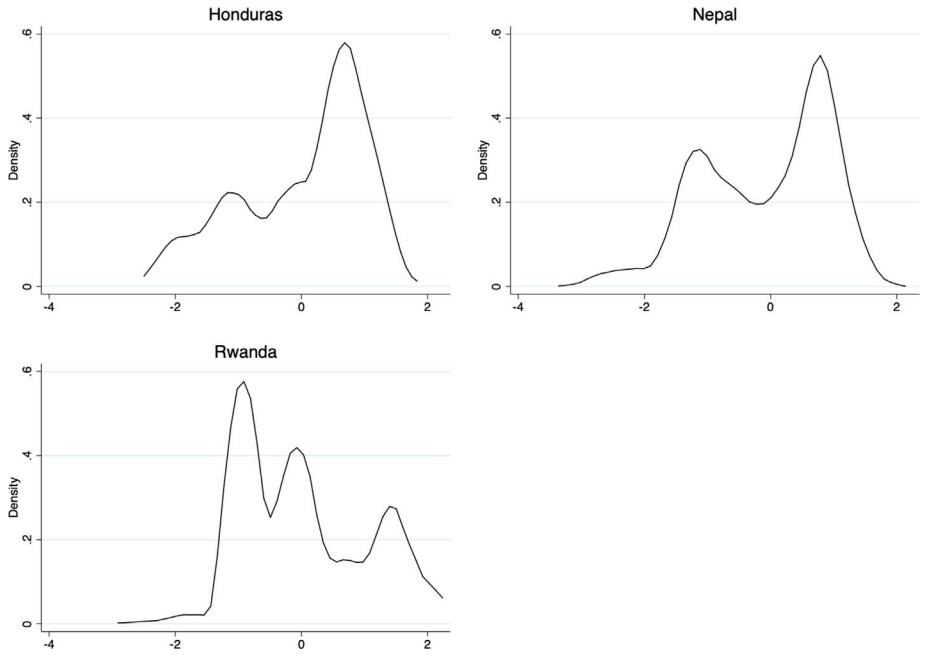

Fig. 1. Women's decision-making power index in the household, by country.

previously, it makes a differences for gender benefits whether light bulbs illuminate men's or women's activity spaces [10].

Ownership of devices varies considerably across our three countries under study. In Honduras – the device-richest country overall–, almost 75 percent own a TV, more than 60 percent own a fridge, and about half own radios, fans, and irons, respectively. Microwaves are present in about 30 percent, PCs and washing machines only in 14 percent of the households. In Nepal, too, TVs are the most frequently owned device, but only 53 percent of households indicate owning one. Device ownership is lower overall: 46 percent own a fan, and between 14 to 20 percent own a fridge, a rice cooker, an iron, or a radio, respectively. Ownership rates of PCs and water pumps are below ten percent. Rwanda, finally, has markedly lower levels of device ownership. The most frequent device is a radio, owned by about 40 percent. Only about 12 percent own a TV, 7.5 percent an iron, and around 2.5 percent PCs and fridges.

Women's decision-making power in the household. To measure women's decision-making power in a household, a variety of approaches have been used and tested, many of them related to theoretical concepts such as agency [see e.g. 51].[3] Following Chandrasekaran et al. [40], who worked with data from the Multi-Tier Framework, we use the following variables to construct an index of women's positioning and decision-making power in the household: the gender of the household head, the highest level of formal education obtained by a female household member, the share of adult women (over 15 years old) among all household members, the share of women over 15 years who pursue employed work, and three indicators of women's independent mobility. These indicators enquire if women can go to the market, visit friends and leave the village by themselves or rather only accompanied by others or their husband, respectively. While broader information on, for instance, women's participation in financial or major purchasing decisions in the household and the equal opportunity to express opinions would clearly be desirable, we think that the variables available in the MTF and included in our index provide a good reflection of women's decision-making power in the household. Women can arguably contribute more to a household's decisions when the household head is a woman, when women represent a larger share of its members and when a larger share of women contribute to the household's income. A higher formal educational qualification is often associated with both higher reputation and standing as well as knowledge to contribute to decisions. Finally, measures of autonomous mobility reflect women's independence, which is arguably tied to their ability to contribute to decision-making. Jayachandran et al. [52] even argue that questions about women being allowed by other household members to perform certain activities, such as going to the market or to visit others, by themselves are among the most meaningful indicators of women's agency. They used different survey questions on a sample of respondents to compare which questions best identified women with high decision-making power. Among the questions with the highest predictive power were whether women needed permission from other household members to buy clothing for themselves, if they were allowed to buy things in the market without asking their partner or if their opinion was heard when the household was about to purchase expensive goods.

For each country, we build an index based on the seven variables mentioned using principal component analysis.[4] Because many of the included variables are binary, our PCA is based on a correlation matrix using tetrachoric correlations. The factor explains 39 percent of the observed variation in Honduras, 36.7 percent in Nepal and 46.5 percent in Rwanda. Expectedly, a female household head, higher levels of female education, the shares of adult women and of employed women, and autonomous mobility all load positively on the indicator, which we thus interpret as reflecting women's decision-making power.[5] Fig. 1 shows the distribution of the index, which was standardised to have a mean of zero and a standard deviation of 1, in each country. We cannot compare indices across countries, but observing the relative

[3] Yasmin and Grundmann [41] analysed the educational and employment status as well as the age of women to measure their decision-making power. Others have used income shares and individual asset ownership [13] as well as education, age and income earnings [18]. Vyas et al. [39] constructed indices including information about whether a women is allowed to go by herself to the market, to a health facility, and out of the village, or if women participate in decisions about how their husband's earnings are used.

[4] Appendix B provides detailed information on the index and the included variables.

[5] An exception is female education in Rwanda, where higher levels load negatively on the retained factor, but with very small coefficients.

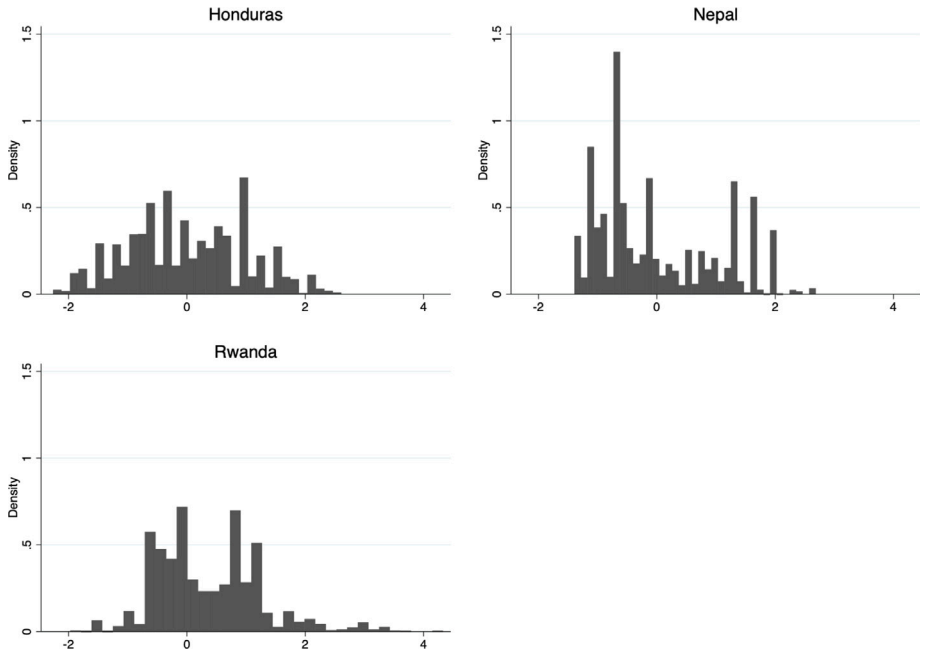

Fig. 2. Wealth index, by country.

distribution within each country we can state that the share of women with relatively high decision-making power is largest in Honduras, followed by Nepal where we observe a larger group with relatively high and a smaller group with relative low decision-making power. In Rwanda, the majority of women experience rather low decision-making power.

Because of the manifold ways in which the latent construct of women's decision-making power have been measured in the literature, and because we lose observations due to missing responses to some of the variables included in our index (most often, female education and mobility items), we also use the gender of the household head as an alternative indicator of women's decision-making power for robustness. We assume that women's decision-making power is higher, all else equal, in households with a woman as the household head. This is the case in 26.5 percent of all households in Honduras, in 19.7 percent in Nepal and in 25.1 percent in Rwanda. Figure A1 in the appendix compares the scores of the women's decision-making index of households with male and female heads and shows that, expectedly, women's decision-making power is higher in households with a female head. Differences are particularly pronounced in Rwanda.

Wealth index. To capture the economic situation of households, we build a wealth index using the rich information that is provided in the MTF Survey. The index combines information on size, material and facilities of the household's home and vehicles present in the household.[6] The index is built using principal component analysis on the basis of polychoric correlation matrices, as most variables are on an ordinal scale. Fig. 2 shows the wealth distribution by country. The index was standardised to have a mean of zero and a standard deviation of 1. While scores as such are not comparable across countries, within-country distributions can be compared to some extent. Wealth distribution is skewed to the left in Nepal, where the larger part of the population lives under relatively poor conditions. In Honduras, wealth is rather normally distributed over the middle of the distribution, but also slightly skewed to the left. In Rwanda, we observe a rather strong middle-range with two poles, and few very poor and very rich households.

[6] The precise variables that enter the index for each country differ slightly, as we excluded variables with insufficient variation. This was the case, for example, with home ownership in Nepal (only 25 out of 5,972 households indicated not owning the house they lived in). Appendix A provides detailed information about the construction of the index and the included variables.

4. Empirical approach

This section lays down our empirical approach to analyse households' choices over cooking fuels and household appliances in light of women's decision-making power in the household. For cooking-related energy choices and the cases of Honduras and Nepal, our outcome variable is a binary that indicates if household i uses solid or clean cooking fuel cf:

$$cf_i = \begin{cases} 1 \text{ if the household's choice of energy is clean fuel/ an improved cookstove} \\ 0 \text{ if the household's choice of energy is solid fuel/ a traditional cookstove} \end{cases}, \tag{1}$$

where solid fuels comprise, for example, charcoal or wood, and clean fuels mean predominantly LPG. In the case of Rwanda, where less than 1 percent of the sample uses clean cooking fuels, our outcome variable indicates instead whether households use a traditional or an improved cookstove.

In the estimations analysing appliance ownership, the outcome variable is also binary and indicates whether household i owns the household appliance of interest ha_j or not:

$$ha_{i,j} = \begin{cases} 1 \text{ if the household owns household appliance } j \\ 0 \text{ if the household does not own household appliance } j \end{cases}, \tag{2}$$

where $j = 1, \ldots, J$ denotes the set of the different household appliances we investigate.

To analyse the probability that a household uses clean cooking fuel (Honduras, Nepal) or an improved cookstove (Rwanda), we estimate a logistic model separately for each country:

$$\text{logit}(\pi_i) = log(\frac{pr}{1-pr}) = \beta + \gamma \text{ women's decision-making power} + \vartheta X, \tag{3}$$

Table 2
Use of clean cooking fuel — Honduras and Nepal.

Dependent variable: use of clean cooking fuel (1=yes)								
	Honduras (1–4)				Nepal (5–8)			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Women's decision-making power index	1.313***	1.269***			1.460***	1.367***		
	(0.0829)	(0.105)			(0.107)	(0.118)		
Female HH head			1.550***	1.170			1.266*	1.145
			(0.242)	(0.211)			(0.161)	(0.196)
Male education: primary	0.231***	0.216**	0.313**	0.318**	0.739	0.758	0.664**	0.680
	(0.129)	(0.137)	(0.155)	(0.182)	(0.151)	(0.207)	(0.135)	(0.179)
Male education: secondary	0.326*	0.453	0.623	0.484	1.103	1.104	1.050	1.050
	(0.258)	(0.207)	(0.312)	(0.274)	(0.189)	(0.258)	(0.187)	(0.248)
Male education: post-secondary	0.557	0.408	0.753	1.753	1.638**	2.335***	1.699**	2.265**
	(0.349)	(0.304)	(0.433)	(0.415)	(0.365)	(0.709)	(0.393)	(0.739)
Wealth index	2.753***	1.534***	2.855***	1.549***	3.898***	2.519***	3.694***	2.455***
	(0.276)	(0.176)	(0.297)	(0.176)	(0.344)	(0.303)	(0.329)	(0.303)
Constant	0.672***		1.959		0.420***	0.596**	0.426***	0.615**
	(1.673)		(0.957)		(0.0798)	(0.124)	(0.0856)	(0.136)
Model	logit	cond. logit	logit	cond. logit	logit	logit	logit	logit
Fixed effects	no	village	no	village	no	village	no	village
# obs.	2,422	1,784	2,497	1,858	5,603	3,170	5,649	3,194
log likelihood	−747476.6	−381110.1	−777544	−398373	−2237334	−1487322	−2312382	−1520813
AIC	1 494 965	762 230.2	1 555 100	796 755.9	4 474 680	2 974 655	4 624 776	3041635
BIC	1 495 000	762 257.6	1 555 135	796 783.6	4 474 720	2 974 685	4 624 816	3041666

Table reports odds ratios. Standard errors are clustered at primary sampling unit (Honduras: 266 villages; Nepal: 400 villages) and shown in parentheses. Male education indicates the highest educational level obtained by a male household member. The reference category is "none". *** p<0.01, ** p<0.05, * p<0.1. All specifications include sample weights. Sample size is reduced when units at the level of the fixed effect predict the outcome perfectly, i.e. when all respondents within a unit showed the same outcome. These villages were dropped.

where $pr = Pr(cf = 1)$. We estimate the same model for household appliances, with $pr = Pr(ha = 1)$. In all estimations, γ is our coefficient of interest and X is a vector of control variables.

Our explanatory variable of interest is women's decision-making power in the household. As mentioned in the previous section, we primarily measure women's decision-making power using the index presented in Section 3, but also run estimations using the household head's gender as an alternative indicator for robustness. Our basic set of control variables comprises the households' economic situation (by means of the wealth index from Section 3) and the highest educational levels obtained by a male household members. As to the former, the economic situation may have an important influence on the choice of cooking fuel [18,22–24]. As to the latter, we expect that higher educational levels may come along with awareness and information about the benefits of clean cooking fuels [24,26–28]. We wish to distinguish such effects from effects of women's decision-making in the household.

To control for unobserved locality-related effects, we include fixed effects at the village level. Among other unobserved local characteristics, this allows us to account for climatic conditions that vary at the sub-national level. For example, the demand for devices such as fridges or fans will certainly vary comparing the mountainous and subtropical areas of Nepal. When gender norms and levels of women's decision-making power also vary across these regions, we may falsely attribute households' choices to women's decision-making power. Introducing village fixed effects, we specifically enquire if women's decision-making power makes a difference comparing across households from the same village, facing the same local contexts. In logit models, introducing dummy variables to account for fixed effects may lead to biased estimators due to the incidental parameters problem [53,54]. Therefore, we also estimate a conditional logistic model where the data are grouped and the likelihood is calculated relative to each group, that is, as a conditional likelihood:

$$Pr(y_{it} = 1|\mathbf{x}_{it}) = F(\alpha_i + \mathbf{x}_{it}\beta), \tag{4}$$

where F denotes the cumulative logistic distribution

$$F(z) = \frac{exp(z)}{1 + exp(z)}. \tag{5}$$

y is our outcome of interest, $i = 1, 2, \ldots, n$ denotes the fixed effects unit, and $t = 1, 2, \ldots, T_i$ are the households in these units.[7]

Standard errors are clustered at the village level, which is the primary sampling unit of the MTF Survey, following Abadie et al. [55].

5. Results

5.1. Choices over clean cooking fuels

Tables 2 and 3 summarise our estimation results. Note that we report odds ratios, not coefficients. For Honduras and Nepal (Table 2), the dependent variable is a binary indicating whether the household uses clean cooking fuel or not. In Honduras, households with higher women's decision-making power have a higher probability of using clean cooking fuel, controlling for the economic situation of the household and the highest educational level obtained by a male household member (estimation 1). The result persists with fixed effects at the village level, which however reduce our estimation sample considerably because villages without variation in the outcome variable are dropped from the estimation (estimation 2). In terms of magnitude, the average marginal effect (AME) of the women's decision-making power index on the probability of using clean cooking fuel is 0.05, indicating that a one-unit increase on the index increases the probability of using clean cooking fuel by five percentage points. Fig. 3 illustrates the predicted probability of using clean cooking fuels along the distribution of the women's decision-making power index.

Households with a female head have a higher probability of using clean cooking fuel (estimation 3): their odds of using clean cooking fuel are 55 percent higher than those of male-headed households. The average predicted probability of using clean cooking fuels is 62 percent for female-headed and 51.3 percent for male-headed households, at the mean of covariates. However, this effect does not persist with village fixed effects (estimation 4). In other words, households with a female head are no more likely to use clean cooking fuels than male-headed

[7] In conditional logits, sample weights apply to the group as a whole, not individual observations. Since our sampling weights come from the village level, we can only estimate the conditional logit using villages as groups.

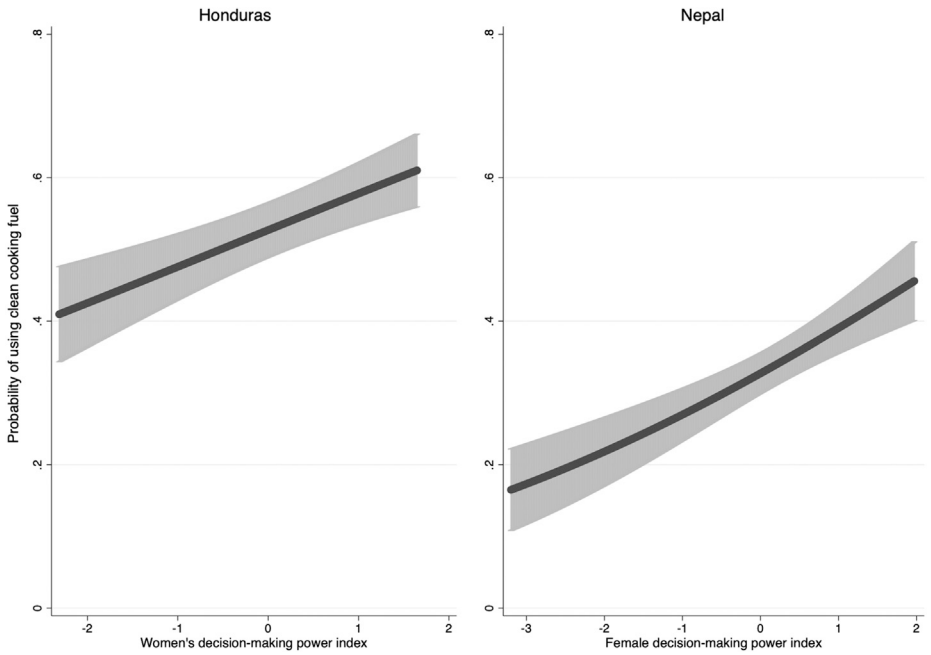

Fig. 3. Predictive margins: clean cooking fuel and women's decision-making power index.
Notes: Predictive Margins with 95% Confidence Interval. Based on estimation (1) for Honduras and (5) for Nepal from Table 2.

households controlling for the economic and educational background and for unobserved village characteristics. We cannot exclude the possibility that this result is driven by the reduction in sample size, which is unfortunately unavoidable when village membership predicts the outcome perfectly.

In Nepal, households with higher female decision-making power use clean cooking fuel more often (estimations 5 and 6), too. The probability of using clean cooking fuel increases by 6 percentage points with a one-unit increase of women's decision-making power — an AME slightly higher than in Honduras. Fig. 3 shows the predicted probability of using clean cooking fuels at different levels of women's decision-making power. As in Honduras, we also observe that female-headed households use clean cooking fuels more often, but this finding is statistically significant only at the 10 percent level (estimation 3) and disappears with village fixed effects (estimation 4).[8] The average predicted probability of using clean cooking fuels based on specification (7) is 32.9 percent for female-headed and 27.9 percent for male-headed households, at the mean of covariates.

Note that in the estimation sample, we lose 300 to 400 observations from the original sample of 2,815 observations in Honduras and of 6,000 observations in Nepal — occasionally due to missing values in variables entering the decision-making power index, but mostly because of missing information about male education, a control variable. Because the highest educational level obtained by a male household member seems theoretically, statistically and substantively important (see discussion section), we prefer not to exclude it from the estimation just for the sake of fewer lost observations. One might be worried about selection bias arising from the possibility that information about male education is not missing at random. For robustness, we repeated all estimations without this control variable and hence the nearly full sample (not reported) and find that neither estimated odds ratios nor predicted probabilities and predictive margins change. Hence we are confident that our results are not biased by selection due to missing values, and that point estimates are more accurate when controlling for male education.

For Rwanda, the dependent variable is a binary indicating whether the household uses a clean or improved cookstove (as opposed to traditional or three-stone stoves) (Table 3). We neither find statistically significant results for the women's decision-making power index nor for the household head's gender. We lose about 120 observations due to missing values, again predominantly due to missing information on male education, but results are robust when the variable is dropped.

5.2. Appliance choices

Next, we study whether women's decision-making power is related with choices over appliances. As above, we investigate if households with higher scores on the women's decision-making power index, as well as households with a female head, own various devices more or less frequently. Our analysis makes no causal claims, but nevertheless we need to consider potential confounders since we want to learn something about the role of women's decision-making power given a number of household characteristics. We control for economic wealth, the highest educational level obtained by a male household member, as well as the availability of electricity (hours of electricity service from grid service and from solar home systems). Whether a household disposes of electric energy 24 h a day or not may impact their device purchase: one can easily use a TV without constant service, but not a fridge, for example. We note that grid connection may well be endogenous to women's decision-making power: if a woman has a preference for household appliances that require electricity service, she may push for that service first. Controlling for the availability of electricity, we may control away this potential effect of women's decision-making power on household appliance choice, which could operate at least partly through grid connection or the presence of solar home systems. We therefore also test estimations without these controls.

Table 4 summarises estimation results including controls for electricity access. The table reports average marginal effects (women's decision-making power index) and changes in predicted probability (female household head) in case the underlying estimations found a

[8] Note that in the case of Nepal, we cannot use conditional logit estimations for the estimation with village fixed effects because the sample weights are not provided at this level, which would however be required. Instead, we recur to the less preferable use of dummy variables and note that results should be treated with caution.

Table 3
Use of clean or improved cookstoves — Rwanda.

Dependent variable: use of clean or improved cookstove (1=yes)				
	(1)	(2)	(3)	(4)
Women's decision-making power index	0.994	0.971		
	(0.0788)	(0.0862)		
Female HH head			1.298	1.254
			(0.244)	(0.251)
Male education: primary	1.023	0.990	1.180	1.128
	(0.269)	(0.315)	(0.314)	(0.373)
Male education: secondary	1.563	1.483	1.796**	1.652
	(0.450)	(0.491)	(0.493)	(0.548)
Male education: post-secondary	2.587***	1.820	2.989***	2.108
	(0.895)	(0.908)	(1.145)	(1.075)
Wealth index	2.319***	1.700***	2.379***	1.732***
	(0.208)	(0.226)	(0.217)	(0.229)
Constant	0.466***		0.388***	
	(0.106)		(0.103)	
Model	logit	cond. logit	logit	cond. logit
Fixed effects	no	village	no	village
# obs.	2,985	2,391	3,083	2,489
log likelihood	−1245160	−643795.2	−1284953	−666552.6
AIC	2 490 333	1 287 600	2 569 919	1333115
BIC	2 490 369	1 287 629	2 569 955	1333144

Table reports odds ratios. Standard errors are clustered at primary sampling unit (465 villages) and shown in parentheses. Male education indicates the highest educational level obtained by a male household member. The reference category is "none". *** p<0.01, ** p<0.05, * p<0.1. All specifications include sample weights. Sample size is reduced when units at the level of the fixed effect predict the outcome perfectly, i.e. when all respondents within a unit showed the same outcome. These villages were dropped.

Table 4
Household appliances and women's decision-making power: overview of results.

Women's decision-making power index Average marginal effect in % points			
	Honduras	Nepal	Rwanda
Fan	+3.2/+2.1	ns	n/a
Fridge	−3.6[1]	+3.3[2]	+0.5[2,3]
Iron	+3.4/+0.9	+3.4[2]	ns
Microwave	+2.4[2]	n/a	n/a
PC	ns	+2.5[2]	n/a
Radio	ns	+2.9[2]	−3.3/−4.7
Rice cooker	n/a	+1.8[2]	n/a
TV	ns	+2.1[2]	−1.2/−6.8
Washing machine	ns	n/a	n/a
Water pump	n/a	+2.1[2]	n/a
Female household head Change in predicted probability in % points			
	Honduras	Nepal	Rwanda
Fan	ns	−11.9[2]	n/a
Fridge	ns	ns	ns
Iron	ns	ns	+0.3[2,3]
Microwave	ns	n/a	n/a
PC	ns	ns	n/a
Radio	ns	ns	−17.6/−21.0
Rice cooker	n/a	ns	n/a
TV	−13.9[1]	ns	ns
Washing machine	ns	n/a	n/a
Water pump	n/a	−1.8[2]	n/a

Numbers indicate the AME of a one-unit increase in the women's decision-making power index (upper panel) and the change in the predicted probability of owning a device comparing female- to male-headed households (positive changes imply a larger probability in female-headed households; lower panel). The table only reports estimated effects when the coefficient of the index or of the household gender were statistically significant in the underlying estimations. Unless otherwise indicated, we report results from the estimation without and with fixed effects.[1] = result is based on estimation with fixed effects at the village level.[2] = result is based on the estimation without fixed effects at the village level.[3] = statistically significant at 10% level only. ns = no statistically significant association; n/a = not applicable because not investigated. Full estimation tables are reported in appendix C.

statistically significant association. Full result tables are reported in Appendix C.

Overall, our findings are very heterogeneous across devices, countries, and indicators of women's decision-making power. In Honduras, we find that households that score higher on the women's decision-making power index own fans, irons and microwaves more frequently than households that score lower, controlling for wealth levels, male educational background and availability of electricity. In contrast, ownership of fridges is less prevalent at higher levels of women's decision-making power — a counterintuitive finding for which we have no immediate explanation. The pattern is very different when we compare households by the gender of their household head: the only statistically significant association that we find is that households with a female head own TVs less frequently, controlling for our set of covariates. The predicted probability of owning a TV is 63.1 percent for male-headed and 49.2 percent for female-headed households, hence a difference of 13.9 percentage points.

In Nepal, households with higher women's decision-making power own fridges, irons, PCs, radios, rice cookers, TVs and water pump – hence all devices that we investigate except fans – more frequently than comparable households with lower scores. In contrast, households with a female household head have lower probabilities of owning a fan and a water pump. The predicted probability of owning these devices is 44.8 and 4.9 percent in male-headed households and 32.9 and 3.1 percent in female-headed households, respectively, at the mean of covariates.

In Rwanda, we observe associations of women's decision-making power with device ownership less frequently, and most often with negative signs. Households that score higher own radios and TVs less frequently than comparable households with lower women's decision-making power. The probability of owning a fridge is slightly higher, but the difference is of small magnitude and hardly statistically significant at conventional thresholds. Households with a female household head own radios considerably less often: their predicted probability is around 27 to 28 percent, versus 45 to 50 percent for male-headed households. Women-led households have a slightly higher probability of owning an iron, but again this result is hardly statistically significant.

Estimations are largely robust to the inclusion or exclusion of the control variables for grid service and solar home systems.[9] In Honduras, the only change in results we observe is a now positive association of

[9] Estimation tables are not reported but available from the authors or through the replication package.

the women's decision-making power index with TV ownership, with an AME of 2.2 percentage points (with controls: statistically insignificant). In Nepal, the only change we observe is a positive and statistically significant association of a female household head with the presence of a rice-cooker. The predicted probability is 14 percent for male-headed and 18 percent for female-headed households. In Rwanda, the only change we observe is a statistically significant (albeit only at the 10% level), negative association of a female household head with TV ownership. The predicted probability is 2.7 percent for women-led and 4.3 percent for men-led households. These findings could imply that women in Honduras who wish to own a TV and women in Nepal who wish to own a rice-cooker use their decision-making power to improve their household's electricity access. Reversely, women in Rwanda who fancy TV ownership less than men could stand up for electricity access less than they otherwise would. Otherwise, all of our findings are robust, and signs and magnitude of estimated odds ratios remain qualitatively unaltered. One may have suspected that the cases of statistically insignificant findings could be cases where the impact of women on households' choices was mediated through the households' energy choices, which our analysis would have concealed. However, this seems not to be the case, except maybe in the three cases mentioned. And even if this was the case, two more devices would be added to the list of devices that households with higher decision-making power own more (Honduras, Nepal) or less (Rwanda) frequently, hence reinforcing or main results.

5.3. Discussion

Our analysis of households' choices about cooking fuels and household appliances suggests that the relationship between households' choices and women's decision-making power is heterogeneous across choices and settings. Overall, we find strong evidence that households with high and low women's decision-making power make different choices in Honduras and Nepal, where households with higher women's decision-making power are more likely to use clean cooking fuels as well as a range of household appliances. In Rwanda, we find no association for cookstoves, and households with higher decision-making power of women are less likely to own radios and TVs, but hardly likely to own any devices more often. This could be related with the fact that according to our index, fewer women in Rwanda experience relatively high decision-making power in their household as compared to women in Honduras and Nepal, as well as to lower rates of appliance ownership in general. However, this cannot explain, for instance, why women-led households – who account for one quarter of Rwandan households – are not more likely than men-led households to use improved cookstoves.

It is interesting that we observe no consistent gendered patterns of device ownership across countries. For example, households with higher womens decision-making power in Honduras own fans more frequently while households in Nepal do not, even though ownership rates in general are not too different (52 versus 46.1 percent, see Table 1). In contrast, households with higher womens decision-making power own fridges less frequently in Honduras, but more frequently in Nepal. Radios are more prevalent in Nepal but less prevalent in Rwanda when womens decision-making power is higher, while no association exists in Honduras. We think that two lessons can be drawn from these results. First, on many instances, households where women experience relatively higher decision-making power have made different choices and own various relevant household appliances more often than households where women have less say. Even though this finding does not point to specific appliances that women may generally favour, we think this is a noteworthy result. Second, while some of the devices that these households own more often can be argued to benefit the efficiency of household chores – such as rice cookers or irons –, we also found higher ownership rates of leisure- and relaxation-related devices (fans in Honduras, PCs and radios in Nepal). On the other hand, radios and TVs were less frequently owned in Rwanda. This suggests that the use, meaning and priority given to the various devices differs from context to context.

Another interesting observation is that estimations using the women's decision-making power index and estimations using the gender of the household head yield mostly different results for the household appliances. Remember that the household head's gender is part of the index. We chose it as a simple alternative measure and proxy for women's decision making power, assuming that women's decision-making power can be expected to be higher in women-led than in male-led households. While results for the cooking fuels and cookstoves are largely congruent, results for the appliances differ most of the time. The index is positively related with households' ownership of fans, irons and microwaves in Honduras, while simply having a female household head is not. The same happens in Nepal, where the index is positively associated with households' ownership of fridges, irons, PCs, radios, rice cookers, TVs and water pumps, while a female household head is not. To the contrary, women-led households are *less* likely to own a water pump (and fans). In Rwanda, results coincide in the case of radios, but do not overlap otherwise.

One possible explanation for these divergences in results is that the household head's gender alone is not a good proxy for women's decision-making power in the sense that women in households with a male head experience as little or as much decision-making power as women in a household with a woman in the lead. However, this is not very plausible. Figures A1 and A2 in the appendix compare the decision-making power index in households with male and female household heads. Even when the household head's gender itself is excluded from the index for the sake of this comparison (figure A2), women-led households obtain clearly higher values on the index, perhaps most markedly in Rwanda. This suggests that the household head's gender is not a bad proxy. However, another explanation is that the simple distinction by household head does not do sufficient justice to the variation of women's decision-making power especially in male-led households. Figure A2 suggests that most women-led households have a high degree of women's decision-making power, whereas the situation varies much more in male-led households. In other words, some women in male-led households have as much decision-making power as women in women-led households, but some also have much less. It seems that the index is able to capture this variety more appropriately than a simple binary indicator. We therefore think that our results using the index are more telling and that the many instances, especially in Honduras and Nepal, where households with a higher decision-making power of women own many devices more frequently are trustworthy even though they are not replicated in the estimations using the household head's gender.

As a final remark related to the complex dynamics underlying households' technology choices, we note that the level of male education in the household – which we include as control variable – is statistically and substantively important in many estimations. While we acknowledge that it is often ill-advised to interpret coefficients of control variables [56], in this case we think that the other included variables – the decision-making index, the wealth index, and partly the electricity access – are adequate controls if one were interested in the relationship of male education and households' choices. A higher level of education among male household members is in many cases associated with a higher prevalence of clean cooking fuel or household appliances, often going into the same direction as higher decision-making power of women. One interpretation could be that our wealth index does not capture the economic situation well, and so male education captures some of this variance instead. However, if this was the case, this should happen throughout our estimations, which is not the case: male education seems to increase the probability of clean cooking fuels in Honduras and Nepal, but not in Rwanda, and of selected household appliances only. Some of this could be related to men's own interests: for example, the higher prevalence of PCs and

irons in households with higher levels of male education in Honduras, Nepal, and Rwanda could reflect that men in these households are employed in white-collar jobs more often. However, this cannot explain, for example, why these households also own rice-cookers (Nepal) or microwaves (Honduras) more often. While we do not want to delve into speculative interpretations around single devices, we think that our results suggest that gender-sensitive analyses merit to embrace both men and women, rather than equating gender analysis with women only. Also, we think future research should delve into the role of male education for women's decision-making power and gender equality in the household in the context of energy choices.

With this evidence that households' choices around cooking technologies and household appliances systematically differ with women's decision-making power across three different countries, it becomes evident that the MTF – as the only data source available to enquire households about both a wide range of technology choices and women's positioning in the household – has the potential to advance the understanding of energy needs on a global scale. But our findings also suggest that a yet more gender-focused survey design could help to understand complex socio-technological choices even better. For example, our measurement of women's decision-making power is not as nuanced as one would ideally desire (see discussion in Section 3). A thoroughly curated basic set of gender-specific questions to illuminate how energy access impacts women and their daily lives, augmented by country-specific measures selected together with local gender experts, could improve the empirical assessment of women's decision-making power (see also Kooijman et al. [19]). Such an approach could also allow to illuminate men's role in gender equality, rather than focusing mainly on women. It would certainly also be helpful to expand the MTF framework in such a way that it goes beyond the common approach of conducting one survey interview mainly with the household head, and rather interview various people per household about their energy needs, uses and perspectives. Such an approach could shed light on potential hidden uses of appliances and ensure a more gender-balanced representation of needs, preferences, usages and household bargaining dynamics in energy data [3,11,19,57].

6. Conclusion

This paper analysed households' choices over cooking fuels or cookstoves and household appliances in light of women's decision-making power. We sought to understand if households in three different countries – Honduras, Nepal and Rwanda – made different choices, depending on whether women's decision-making power is rather high or low. We compared choices made between households with low and high scores on an index of women's decision-making power, as well as between male-headed and female-headed households.

Our results confirm previous studies in that our findings differ starkly across Honduras, Nepal and Rwanda. While Honduran and Nepalese households with higher decision-making power of women seem to value clean cooking fuels more, no such evidence was found for Rwanda. We estimate that the predicted probability of using clean cooking fuels increases from 41 percent at the lowest level of women's decision-making power to 61 percent at the highest level in Honduras, controlling for household wealth and education, and from 16.5 to 46 percent in Nepal. With respect to household appliances, our evidence is very mixed. In terms of household appliances, we find evidence that households where women experience relatively higher decision-making power make different choices and own relevant household appliances more often than households where women have less say, especially in Honduras and Nepal. However, there is a high degree of heterogeneity across countries and devices. While our results indicate that households make different choices depending on the degree of decision-making power of their female household members, the way in which choices differ seems context-specific.

Oftentimes, researchers (try to) compare results obtained from different country studies, and the comparison is limited by the extent to which data and research designs differ. Here, we study three countries with the same survey data and measurement instruments. The fact that our results vary substantially by country points to the importance of considering socio-economic and socio-cultural aspects and contexts in the analysis of electricity access and gender. Enhancing the Multi-Tier Framework survey to more deeply explore gender-specific energy needs could further refine our understanding of these dynamics. Our study suggests that men and women may, but need not, have differing preferences. If electrification projects are to benefit women and men equally, they should pay attention to the possibility that men's and women's energy needs differ, but not assume in which ways this happens: careful and context-specific analysis is required.

CRediT authorship contribution statement

Svenja Flechtner: Writing – review & editing, Writing – original draft, Visualization, Software, Methodology, Investigation. **Ulli Lich:** Writing – review & editing, Writing – original draft, Software, Methodology, Investigation, Data curation, Conceptualization. **Setu Pelz:** Writing – review & editing, Writing – original draft, Software, Methodology, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

A replication package with instructions is available at https://github.com/svenjafl/cooking_devices_gender.

Acknowledgments

This work was supported by the Reiner Lemoine Foundation, Berlin, Germany. We would like to express our gratitude to Clara Neyrand and the Reiner Lemoine Institute for organising the summer school during which the foundations for this paper were laid. We also thank Jan-Robin Kleiner and three anonymous reviewers for their helpful comments and suggestions.

Appendix A. Supplementary data

Supplementary material related to this article can be found online at https://doi.org/10.1016/j.erss.2024.103780.

References

[1] David L. McCollum, et al., Connecting the sustainable development goals by their energy inter-linkages, Environ. Res. Lett. 13 (3) (2018) 033006.
[2] Canh Phuc Nguyen, Thanh Dinh Su, Does energy poverty matter for gender inequality? Global evidence, Energy Sustain. Dev. 64 (1) (2021) 35–45.
[3] Sowmya Dhanaraj, Vidya Mahambare, Poonam Munjal, From income to household welfare: Lessons from refrigerator ownership in India, J. Quant. Econ. 16 (2) (2018) 573–588.
[4] Edwina Fingleton-Smith, The lights are on but no (men) are home. The effect of traditional gender roles on perceptions of energy in Kenya, Energy Res. Soc. Sci. 40 (2018) 211–219.
[5] M. Njenga, J.K. Gitau, R. Mendum, Women's work is never done: Lifting the gendered burden of firewood collection and household energy use in Kenya, Energy Res. Soc. Sci. 77 (1) (2021) 102071.
[6] Aba Obrumah Crentsil, Derek Asuman, Ama Pokuaa Fenny, Assessing the determinants and drivers of multidimensional energy poverty in Ghana, Energy Policy 133 (2019) 110884.
[7] Rebecca Pratiti, et al., Health effects of household air pollution related to biomass cook stoves in resource limited countries and its mitigation by improved cookstoves, Environ. Res. 186 (2020) 109574.

[8] Jennifer Richmond, Johannes Urpelainen, Electrification and appliance ownership over time: Evidence from rural India, Energy Policy 133 (2019) 110862.
[9] Tanja Winther, et al., in: Gender Endergy Research Programme (Ed.), Exploring Factors that Enhance and restrict Women's Empowerment through Electrification (EFEWEE): Scoping Study Report, 2016.
[10] Meital Rosenberg, et al., Evidence of gender inequality in energy use from a mixed-methods study in India, Nat. Sustain. 534 (2019) 320.
[11] Md Moniruzzaman, Rosie Day, Gendered energy poverty and energy justice in rural Bangladesh, Energy Policy 144 (1) (2020) 111554.
[12] Tanja Winther, et al., In the light of what we cannot see: Exploring the interconnections between gender and electricity access, Energy Res. Soc. Sci. 60 (2020) 101334.
[13] Yonas Alem, Sied Hassen, Gunnar Köhlin, Decision-making within the household: The role of division of labor and differences in preferences, J. Econ. Behav. Organ. 207 (1) (2023) 511–528.
[14] Jiajia Li, et al., Does gender inequality affect household green consumption behaviour in China? Energy Policy 135 (2019) 111071.
[15] Dil Bahadur Rahut, Bhagirath Behera, Akhter Ali, Factors determining household use of clean and renewable energy sources for lighting in Sub-Saharan Africa, Renew. Sustain. Energy Rev. 72 (2017) 661–672.
[16] Ariva Sugandi Permana, Norsiah Abd Aziz, Ho Chin Siong, Is mom energy efficient? A study of gender, household energy consumption and family decision making in Indonesia, Energy Res. Soc. Sci. 6 (7) (2015) 78–86.
[17] Olivia Muza, Ramit Debnath, Disruptive innovation for inclusive renewable policy in sub-Saharan Africa: A social shaping of technology analysis of appliance uptake in Rwanda, Renew. Energy 168 (2) (2021) 896–912.
[18] Johanna Choumert-Nkolo, Pascale Combes Motel, Leonard Le Roux, Stacking up the ladder: A panel data analysis of Tanzanian household energy choices, World Dev. 115 (2019) 222–235.
[19] Annemarije Kooijman, Joy Clancy, Jon Cloke, Extending energy access assessment: The added value of taking a gender perspective, Energy Res. Soc. Sci. 96 (1) (2023) 102923.
[20] Romy Listo, Gender myths in energy poverty literature: A critical discourse analysis, Energy Res. Soc. Sci. 38 (2018) 9–18.
[21] Judith Butler, Gender Trouble: Feminism and the Subversion of Identity, in: Routledge Classics, Routledge, New York and London, 2015.
[22] Michaël Aklin, Chao-yo Cheng, Johannes Urpelainen, Geography, community, household: Adoption of distributed solar power across India, Energy Sustain. Dev. 42 (2018) 54–63.
[23] Michael Osei Asibey, Kafui Afi Ocloo, Owusu Amponsah, Gender differences and productive use of energy fuel in Ghana's rural non-farm economy, Energy 215 (2021) 119068.
[24] Francis Mwaura, Okoboi Geoffrey, Ahaibwe Gemma, Determinants of household's choice of cooking energy in Uganda, 2014.
[25] Gunther Bensch, Michael Grimm, Jörg Peters, Why do households forego high returns from technology adoption? Evidence from improved cooking stoves in Burkina Faso, J. Econ. Behav. Organ. 116 (2015) 187–205.
[26] Yibeltal T. Wassie, Meley M. Rannestad, Muyiwa S. Adaramola, Determinants of household energy choices in rural sub-Saharan Africa: An example from southern Ethiopia, Energy 221 (1) (2021) 119785.
[27] Vanesa Castán Broto, Maria de Fátima S.R. Arthur, Louise Guibrunet, Energy profiles among urban elite households in Mozambique: Explaining the persistence of charcoal in urban areas, Energy Res. Soc. Sci. 65 (2020) 101478.
[28] Carlos F. Gould, Johannes Urpelainen, The role of education and attitudes in cooking fuel choice: Evidence from two states in India, Energy Sustain. Dev. 54 (2020) 36–50.
[29] Bishal Bharadwaj, et al., Context matters: Unpacking decision-making, external influences and spatial factors on clean cooking transitions in Nepal, Energy Res. Soc. Sci. 85 (5) (2022) 102408.
[30] Jacopo Bonan, et al., Social interaction and technology adoption: Experimental evidence from improved cookstoves in Mali, World Dev. 144 (2) (2021) 105467.
[31] Deepti Chatti, Cows, cookstoves, and climate change: A non-anthropocentric view of household energy use in the rural Indian Himalayas, Relations 6 (1) (2018).
[32] Dylan D. Furszyfer Del Rio, et al., Do we need better behaved cooks? Reviewing behavioural change strategies for improving the sustainability and effectiveness of cookstove programs, Energy Res. Soc. Sci. 70 (2020) 101788.
[33] Valérie Lechene, Krishna Pendakur, Alex Wolf, Ordinary least squares estimation of the intrahousehold distribution of expenditure, J. Polit. Econ. 130 (3) (2022) 681–731.
[34] Rihab Khalid, Maiss Razem, The nexus of gendered practices, energy, and space use: A comparative study of middleclass housing in Pakistan and Jordan, Energy Res. Soc. Sci. 83 (2) (2022) 102340.
[35] Grant Miller, A. Mushfiq Mobarak, Gender differences in preferences, intrahousehold externalities, and low demand for improved cookstoves, 2013, Nber Working Paper Series 18964.
[36] Caroline A. Ochieng, et al., The forgotten half: Men's influence over cookstove adoption decisions in Northern Kenya, Energy Res. Soc. Sci. 74 (5) (2021) 101913.
[37] Amita Makan, Power for women and men: towards a gendered approach to domestic energy policy and planning in South Africa, Third World Plan. Rev. 17 (2) (1995) 183–198.
[38] Jyoti Parikh, Hardships and health impacts on women due to traditional cooking fuels: A case study of Himachal Pradesh, India, Energy Policy 39 (12) (2011) 7587–7594.
[39] Sangita Vyas, Aashish Gupta, Nazar Khalid, Gender and LPG use after government intervention in rural north India, World Dev. 148 (1) (2021) 105682.
[40] Maya Chandrasekaran, et al., Gender empowerment and energy access: Evidence from seven countries, Environ. Res. Lett. 18 (4) (2023) 045003.
[41] Nazia Yasmin, Philipp Grundmann, Home-cooked energy transitions: Women empowerment and biogas-based cooking technology in Pakistan, Energy Policy (2019) 111074.
[42] Néstor Nuño Martínez, Daniel Mäusezahl, Stella Maria Hartinger, A cultural perspective on cooking patterns, energy transfer programmes and determinants of liquefied petroleum gas use in the Andean Peru, Energy Sustain. Dev. 57 (2020) 160–167.
[43] Meena Khandelwal, et al., Why have improved cook-stove initiatives in India failed? World Dev. 92 (2017) 13–27.
[44] Yuwan Malakar, Rosie Day, Differences in firewood users' and LPG users' perceived relationships between cooking fuels and women's multidimensional well-being in rural India, Nat. Energy 5 (2020) 125.
[45] Yibeltal T. Wassie, Muyiwa S. Adaramola, Socio-economic and environmental impacts of rural electrification with solar photovoltaic systems: Evidence from southern Ethiopia, Energy Sustain. Dev. 60 (7) (2021) 52–66.
[46] The World Bank, Rwanda: Multi-Tier Framework (MTF) Survey: Sampling strategy_MTF_Standard.docx, 2018.
[47] Alisha Pinto, et al., NEPAL. Beyond Connections. Energy Access Diagnostic Report Based on the Multi-Tier Framework, International Bank for Reconstruction and Development/ The World Bank, Washington D.C., 2019.
[48] Lucia Luzi, et al., HONDURAS. Beyond Connections. Energy Access Diagnostic Report Based on the Multi-Tier Framework, International Bank for Reconstruction and Development/ The World Bank, Washington D.C., 2020.
[49] Setu Pelz, Shonali Pachauri, Narasimha Rao, Application of an alternative framework for measuring progress towards SDG 7.1, Environ. Res. Lett. 16 (8) (2021) 084048.
[50] Bryan Bonsuk Koo, et al., Rwanda: Beyound connections: Energy access diagnostic report based on the multi-tier framework, 2018.
[51] Martha C. Nussbaum, Women and Human Development: The Capabilities Approach, Cambridge University Press, Cambridge/ New York, 2000.
[52] Seema Jayachandran, Monica Biradavolu, Jan Cooper, Using machine learning and qualitative interviews to develop a five-question women's agency index, 2021.
[53] Jerzy Neyman, Elizabeth L. Scott, Consistent estimates based on partially consistent observations, Econometrica (1948) 1–32.
[54] Gary Chamberlain, Analysis of covariance with qualitative data, Rev. Econ. Stud. 47 (1) (1980) 225–238.
[55] Alberto Abadie, et al., When should you adjust standard errors for clustering? Q. J. Econ. 138 (1) (2023) 1–35.
[56] Paul Hünermund, Beyers Louw, On the nuisance of control variables in causal regression analysis, in: Organizational Research Methods, SAGE Publications Sage CA, Los Angeles, CA, 2023, 10944281231219274.
[57] Saska Petrova, Neil Simcock, Gender and energy: Domestic inequities reconsidered, Soc. Cult. Geogr. 44 (2019) 1–19.