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Working Paper: Intra-household decisions on cookstove choices and impacts on the welfare of women and girls

The study aimed to examine the intra-household decision-making on stove choices in Ethiopia and understand whether the gender of the decision-maker affects the intended welfare gains for women and girls. The study shows that cookstove choices are associated more with the characteristics of the person who makes such decisions within the household than the characteristics of the head of the household. The study also documented the trade-offs in women's time use for collecting fuel, cooking, childcare, and schooling because of different choices and stacking of cook stoves.

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Intra-household decisions on cookstove choices and impacts on the welfare of women and girls

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Abstract

This study aimed to examine the intra-household decision-making on stove choice and understand whether the gender and other characteristics of the household member who decides on the type of cookstove used affect the intended welfare gains for women and girls. Using a nationally representative data set collected by the World Bank in 2018, factors associated with cookstove choices and the impact of the chosen cookstove type on women's time use were estimated using a generalized structural equation modelling. The findings show that cookstove choices are associated more with the characteristics of the person who makes such decisions within the household than the characteristics of the head of the household. When the person who decides on the types of stoves used in the house is female, literate, married, cooks frequently in the house, and is employed, they are more likely to choose manufactured and self-built stoves. Women and girls in households that use a combination of manufactured and self-built stoves spend less time on cooking and collection of fuel for home use and more time on childcare and paid work outside the house compared to women and girls in households that use only open fire tripod stoves. The stacking of manufactured, self-built, and open fire tripod stoves frees up women's and girls' time for schoolwork by reducing cooking time, though it increases time they spend on fuel collection.

Education and extension campaigns aimed at improving the adoption of improved cookstoves in rural Ethiopia would be more successful if they first identified who in the household makes the decision on cookstove choices and then focused their messaging to those persons, who are not always household heads. Cookstove program implementers will have a higher chance of convincing people to adopt self-built and manufactured stoves instead of open-fire stoves if their messaging focuses more on female members of households rather than male members, on those household members who cook frequently rather than those who cook only sometimes, and focus on educated rather than non-educated members of the household.

Key words: intra-household decision-making, women, time use, cookstove, stove stacking, welfare gains

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1. Introduction

Energy demand in Ethiopia continues to grow proportionally with increasing population (Benti et al., 2021) while the supply of modern energy services is not showing a commensurate growth. Despite the growing efforts to deploy alternative energy sources, Ethiopia remains the most biomass-dependent country in the globe (Mekonnen, 2020), with biomass accounting for 92 percent of energy consumption in the country (Gabisa and Gheewala, 2018). The commonly used biomass energy sources are wood (73%), agricultural residuals (13%), and animal dung (14%) (Gabisa and Gheewala, 2018). Woody biomass takes the largest share, and its use further exacerbates deforestation and forest degradation. According to FAO (2020), unsustainable use of fuelwood in Ethiopia has resulted in 73,000 hectares of forest loss yearly and has led to a severe shortage of biomass fuel for household consumption (Mekonnen, 2020).

In the household sector, cooking and baking are the principal biomass energy-consuming activities. The primary cooking fuel for more than 90 percent of the households in the country is solid biomass (Kooser, 2014; EDHS, 2016; Padam et al., 2018; Adane et al., 2020;). Most rural and peri-urban communities rely on the free collection of firewood, crop residuals, and cattle dung (Benti et al., 2021), where fuel gathering and cooking represent one of the most important activities in women's and girls' daily routine (Foley and van Buren, 1980; Clancy, Skutsch, and Batchelor, 2003; Köhlin et al., 2011; Jeuland et al., 2020). With increased forest exploitation, people face increasing scarcity of firewood (Bensch and Peters, 2015) and hence spend more time collecting fuelwood, worsening the burden on women and girls.

Existing household biomass utilization is widely inefficient and is characterized by the open fire tripod system, causing consumption of large volumes of fuel (Bluffstone et al., 2022), indoor air pollution, and greenhouse gas (GHG) emissions. Such externalities from inefficient utilization of fuel highlight the importance of improved biomass-based cooking solutions in the short-run (Padam et al., 2018) because other cleaner alternatives (such as LPG and electricity) are either unavailable, irregularly supplied, or unaffordable to use for cooking (Gebreegziabher et al., 2018). Improved biomass-based cooking technologies use still use the same fuel as the open fire tripod system but reduce the amount of fuel consumption and indoor air pollution (Guta, 2012; Brooks et al., 2016; Gebreegziabher, Van Kooten, and Van Soest, 2017; Gebreegziabher et al., 2018; Kedir, Bekele, and Feleke, 2019; Wassie and Adaramola, 2021). Improved stoves reduce the amount of time women spend on firewood collection, which in turn allows women to engage in other activities such as childcare, income generating activities, leisure, or helping children with their schooling (Barnes et al., 1994; Adrianzén, 2013; Beltramo et al., 2015; Jeuland et al., 2020; Jagoe et al., 2020). Therefore, it is important to examine the intra-household decision-making on stove choices and understand whether the gender of the decision-maker affects the intended welfare gains for women and girls.

Decision making on the type of cookstove used requires autonomy in the household, regardless of other factors. In a typical patriarchal society such as Ethiopia, most of the decisions are made by the head of the household (usually male). Decisions on cookstove choices however have immediate impacts on the time use of women and girls, who are largely responsible for domestic activities including cooking and fuel collection.

Empirical evidence on intra-household decision making on stove choices and welfare gains are limited in Ethiopia, and existing

studies primarily deal with benefits of cookstove adoption mostly in an experimental setting. For instance, the studies by Beyene et al. (2015), and Kedir, Bekele, and Feleke (2019) proved significant savings on fuel and GHG emissions from the adoption of improved biomass cookstove. Hassen and Köhlin (2017) assessed how quickly an improved cookstove is put in use after the technology is disseminated, and found that those who have high valuation for the attributes (features) of the stove start to use the stove quickly, while the time for starting to use the stove does not differ based on whether the household paid for the stove or got it for free. Beyene and Koch (2013) found that economic factors, such as product price, household income and household wealth, are important determinants of adoption behaviour for improved cookstoves. The impact of an improved cookstove (ICS) on cooking time, is subject to various factors such as types of cooking appliances, experience with the stove, and the type of fuel, among others. Gebreegziabher et al. (2018) showed, in an experimental setting, that improved biomass cookstoves require no more cooking time than the traditional three-stone tripods s, while Bluffstone et al. (2022) showed that slow cooking is a potentially significant stumbling block in promoting fuelwood-conserving cookstoves. However, Bluffstone et al. (2022) also showed that experiences with improved cookstoves have led to negligible differences between traditional and improved cookstoves in cooking times for *injera* baking in Ethiopia within a year of adopting the improved stoves. The effect of ICS is more pronounced on fuel consumption (Gebreegziabher, Van Kooten, and Van Soest, 2017), where it is shown to use about 22 to 31 percent less fuel compared to open fire tripods (Gebreegziabher et al., 2018). The time and fuel-saving incentives make women the primary beneficiaries of improved cooking technologies (Wassie and Adaramola, 2021).

This study contributes to the literature on cookstove choices and its impact on time use of women and girls in developing countries (e.g., (Ezzati, Mbinda, and Kammen, 2000; Krishnapriya et al., 2021)). The main objective of this paper is to answer two basic questions on intra-household decisions related to households' decision of cookstove types in Ethiopia: (1) who decides on the types of cookstoves that households use? and (2) what are the impacts of the different types of cookstoves on the amount of time women and girls spend on cooking, fuelwood collection, childcare, schooling, and paid work?

The rest of the paper is structured as follows. The next section presents a conceptual framework for the influences of gender-based decision-making on cookstove choices and time use. Section three discusses the methodology used in the study, highlighting the data source, descriptive analysis, and the empirical approach employed. The fourth section discusses the results. Concluding remarks are given in section five.

2. Conceptual framework

The huge dependence on raw biomass energy in developing countries, including Ethiopia, disproportionately affects the welfare of women and girls (Oparaocha and Dutta, 2011), who spend time collecting fuel and doing unpaid domestic work. According to a 2014 study across 22 African countries, women and girls spend an average of two hours each day just collecting fuel, where the authors reported 100 minutes a day for women and girls in Tigray region of Ethiopia (Kammila et al., 2014). Women collect fuel for lighting, cooking, and heating. More than half of the collected fuel is used for cooking purposes (Gebreegziabher et al., 2012). As the electrification rate is low in Ethiopia, using biomass in a more efficient way (through improved biomass stoves) could serve as an intermediate solution to ease women's burden within the household (Köhlin et al., 2011). Adopting an improved cooking system fosters such a transition (Gebreegziabher, Van Kooten, and Van Soest, 2017), though it requires an

informed decision.

The choice of cookstove type is affected by several factors. The socio-economic and demographic characteristics of decision-makers and their understanding about the stove's attributes are likely to be the most important drivers of such decisions, among other things. The way that the decision-maker contemplates specific features of the stove (such as smoke level, affordability, market supply, amount of fuel used, and convenience) plays an important role in deciding what type of stove to be used in the household (Takama, Tsephel, and Johnson, 2012). In addition, the decision maker's interest in the attributes of stoves affects decisions on cookstove adoption. For instance, in prior studies, cultural norms (Mohapatra and Simon, 2017), socioeconomic factors (income, wealth, price, education, information), institutional issues (market penetration), and lack of infrastructural facilities (Guta, 2012; Beyene and Koch, 2013; Alem, Hassen, and Köhlin, 2014; Mohapatra and Simon, 2017) were reported to have strong impact on decisions on the type of stoves households adopt. The decision made on a stove should, therefore, combine determinants that have personal (related to decision-maker behaviour, cooking habits, and experiences) and household contexts (such as the enabling environment and household characteristics) (Wilson and Dowlatabadi, 2007; Kowsari and Zerriffi, 2011).

As already noted, the decision on cookstove choice influences women's and girls' time use for different activities, particularly fuelwood collection, schoolwork, childcare, paid work, and cooking. The impact of the chosen stove on women's time use varies with the specific features of stoves (Takama et al., 2011). The stoves considered in this study are traditional open fire tripod stoves, self-built stoves, and manufactured stoves. The open fire tripod consumes large amounts of fuel, releases GHG emissions, and has low thermal efficiency. Self-built stoves are produced by the households themselves using locally available materials such as mud that have a similar feature to an open fire tripod, except its mud closure. The self-built stoves usually do not require cement or aluminium sheets like the manufactured stoves, and are unlikely to have an integrated chimney, but the mud/clay enclosure is expected to reduce firewood consumption and smoke. On the other hand, manufactured cookstoves (improved biomass stoves) are produced by a technically equipped entity and are designed to improve efficiency, cleanliness, and safety compared to open fire tripod and self-built stoves (Padam et al., 2018). All the three stove types consume biomass fuel; the difference lies in the volume of the fuel each stove type consumes. As widely presented in previous studies (such as Barnes et al., 1994; Beyene and Koch, 2013; Beyene et al., 2015; Gebreegziabher et al., 2018; Akter and Pratap, 2022), improved biomass cookstoves can significantly reduce fuel consumption. The reduced consumption lowers women's burden by reducing the frequency and time spent on fuel collection. Both self-built and open fire tripod stoves are similar, but the self-built stove is good in reducing direct fire exposure and probably has lower fuel consumption than the open fire tripod.

3. Methodology

3.1. Data and Descriptive Analysis

We use the data from World Bank's Multi-Tier Framework (MTF) Survey on household access to electricity and clean cooking in Ethiopia. The survey data was collected in 2018 and is nationally representative. The data was collected from both rural and urban areas across all regions of the country. The original MTF survey data consisted of 4317 households. However, this study uses only the 3453 households who responded to the questions on the type of cookstoves the household uses and who in the household made the decision to build or purchase the chosen cook stove.

Household Characteristics

Table 1 summarizes the characteristics of the households. As indicated in Table 1, on average, nearly 30 percent of the households are female headed in the overall sample, although the figure is much lower than this in rural areas and significantly higher in urban areas (11 percent vs 42 percent). There is also a visible difference in school attendance of household heads across the rural-urban divide, as 46 percent and 78 percent of household heads in the rural and urban areas, respectively, have attended schools.

Table 1: Household Characteristics by localities

	Rural		Urban		Total	
	Mean	SD	Mean	SD	Mean	SD
Household head is female=1	0.11	0.313	0.42	0.494	0.29	0.454
Household head age (in years)	43.42	12.893	45.56	15.709	44.66	14.622
Household ever attended school=1	0.46	0.499	0.78	0.416	0.64	0.479
Household head cooks every day=1	0.11	0.307	0.38	0.486	0.26	0.441
Share of male household heads who cook everyday	0.01	0.087	0.05	0.21	0.026	0.158
Household head cooks sometimes=1	0.03	0.157	0.09	0.292	0.07	0.247
Household head never cooks=1	0.87	0.337	0.53	0.500	0.67	0.470
Share of dependent members in the household	0.43	0.221	0.29	0.233	0.35	0.239
Share of female members in household	0.50	0.190	0.56	0.240	0.54	0.222
Any household member has bank account at formal institution=1	0.16	0.365	0.69	0.462	0.47	0.499
Any household member has bank account at informal institution=1	0.11	0.308	0.12	0.326	0.11	0.318
Household connected to the national grid=1	0.19	0.396	0.95	0.219	0.63	0.483
Household has an electric meter=1, if grid connected	0.44	0.497	0.71	0.454	0.68	0.468
Number of rooms in the house	2.03	0.915	2.18	1.321	2.12	1.169
Wall mainly made of wood and mud=1	0.82	0.381	0.73	0.445	0.77	0.422
Floor mainly made of mud/dung=1	0.92	0.276	0.30	0.456	0.56	0.497
Floor mainly made of cement screed=1	0.06	0.229	0.45	0.498	0.28	0.451
Number of Observation	1459=42%		1994=58%		3453	

Household heads in nearly 11 percent and 38 percent of the rural and urban households cook every day and most of these households are female headed as less than 1 and 5 precent of male heads in rural and urban areas, respectively, cook everyday compared to 90 and 84 precent of female heads who cook daily in rural and urban areas. On the other hand, the share of households where the head never cooks is relatively larger in the rural than the urban households (87 percent vs 53 percent).

In the overall sample, on average, nearly 35 percent of household members are dependent (aged bellow 15 or above 64). This share is higher in the rural households (43 percent) than in urban households (29 percent). However, the share of female members in the average household is slightly higher in urban than rural areas (56 percent vs 50 percent).

Access to financial institutions and infrastructure such as electricity and dwelling are among the factors that significantly differentiate households in the rural and urban settings. For instance, access to formal bank accounts is very limited in the rural areas compared to urban ones. In rural areas, only 16 percent of households indicated that at least one household member has a bank account in formal financial institutions while in the urban areas this figure increases to 69 percent of the households. Access to informal financial institutions such as credit associations and cooperatives is small in both areas (less than 12 percent).

Only 19 percent of the rural sample households are connected to the national grid. Among those connected to the national grid, nearly 44 percent have their own electric meter. Nearly 52 percent of those households with electric meter also reported that they share the electric meter with others. Contrary to the rural areas, urban households are well connected to the national grid. Almost 95 percent of the households in urban areas are connected to the national electric grid and among those connected, nearly 71 percent owned the electric meter. The results imply the widespread occurrence of electric meter sharing in Ethiopia.

Household Cookstove Choices

Most households use one or a combination of the common three cookstoves, namely open fire tripod stoves, self-built stoves, and manufactured stoves. Cookstoves such as electric stoves are not considered in the choice set as they are rarely used and collectively captured in the survey as “others”, an indication of the massive effort the country needs to engage in to increase the adoption of electric cookstoves and appliances.

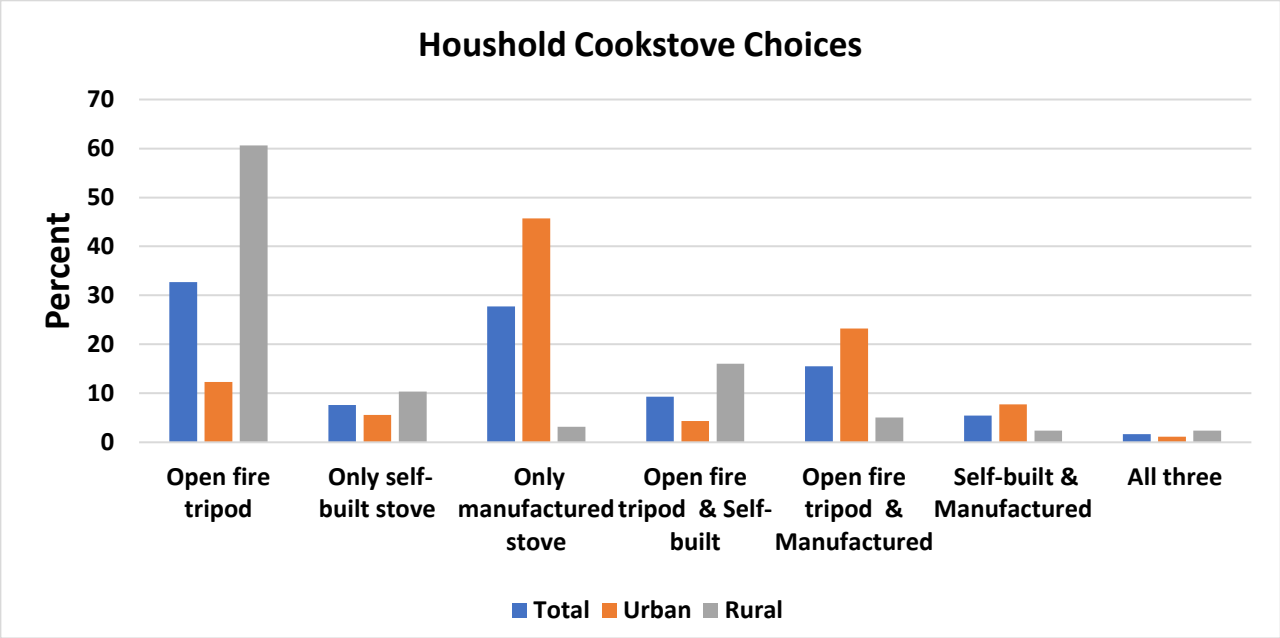

Figure 1: Households' Cookstove Choices and Stacking

Figure 1 shows cookstove choices of households. The three common cookstove choices in the rural areas are only the open fire tripod stoves (61 percent), a combination of open fire tripod stoves and self-built stoves (16 percent), and only self-built stoves (10 percent). The proportion of households that choose to use only manufactured stoves in rural areas is small (3 percent of households), while the share of rural households who use open fire tripod and manufactured stoves is 5 percent. Only 3 percent of rural households use all the three types of stoves. In the urban areas cookstove choices shift more towards the modern options: manufactured stoves alone (46 percent), manufactured and open fire tripod stoves (23 percent), manufactured and self-built stoves (8 percent), and open fire tripod stove alone (12 percent). Similar to rural areas, only two percent of households in urban areas choose all the three cookstoves together.

Who makes the decision to build or purchase stoves?

Who makes decisions in households on cookstove choices is an important factor in adopting technologies that could improve lifestyles, save time, and empower women so they engage better in more productive activities. Table 2 presents characteristics of individuals who decide on the type of cookstoves used in the sample households.

Table 2: Characteristics of household members who decide to build/purchase cookstoves

Variables	Rural		Urban		Total	
	Mean	SD	Mean	SD	Mean	SD
Female =1	0.88	0.32	0.84	0.37	0.86	0.35
Age (in year)	34.42	12.91	39.77	15.33	37.60	14.64
Attended school=1	0.30	0.46	0.75	0.43	0.56	0.50
Wage/self-employed=1	0.24	0.43	0.38	0.49	0.32	0.47
Unemployed=1	0.50	0.50	0.33	0.47	0.40	0.49
Cooks everyday=1	0.86	0.35	0.78	0.42	0.81	0.39
Never cooks =1	0.08	0.27	0.13	0.34	0.11	0.31
Number of observations	1872		2745		4617	

Results in Table 2 shows that most of the decision makers to build or purchase cookstoves in households were women (86 percent in the overall sample, 88 percent in rural areas, and 84 percent in urban areas). The results appear that women are empowered in deciding on cookstove choices. However, this might be because either these cookstove can be built by women themselves or are inexpensive enough to demand men's budget approval. The average age of a person in the household who decides to build or purchase a stove is between 34 and 39 years depending on the location of the household. The share of household members deciding on cookstove choices who have attended schools is 30 percent in rural areas and 75 percent in urban areas, who are wage or self-employed are 24 percent in rural areas and 38 percent in urban areas, who are unemployed are 50 percent in rural areas and 33 percent in urban areas.

The decision maker on cookstove choices is also more likely to cook every day in rural and urban households (86 percent and 78 percent). As majority of the decision makers are women and most likely to cook every day, time spent on cooking and cooking related activities are gender sensitive and would be higher for women and girls than men and boys.

Description and summary statistics for outcome variables

We looked at six main activities than women and girls often engage with and the time they spend on each activity in a typical day, in minutes. The activities are cooking, work for pay outside of home, schooling (studying or helping children with schooling), fuel collection (gathering, collecting, or purchasing fuels including travel time) for home use and for generating income through selling to the market, and childcare (caring, attending or playing with/for younger children). Table 3 shows average time households spend on the selected activities for those who use a stove type, without considering stove stacking. Summary that shows time use of households by different combinations of stoves is provided in the annex (Table A1).

Table 3: Summary of time use in minutes for various activities by stove choices

Activities in minutes per day	Manufactured Stove		Self-built stove		Stone/fire stove		Total	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Cooking (food, tea, boiling water)	99.89	92.05	110.96	88.88	101.95	92.02	102.79	91.54
Other time spent in cooking area	35.88	46.25	38.40	49.33	37.48	49.57	37.04	48.30
Working for pay outside of the house	115.70	209.71	57.85	161.89	43.52	140.75	73.31	176.57
Studying or helping with school	48.33	112.21	52.35	97.34	50.11	109.59	49.84	108.49
Gathering, collecting, or purchasing fuels including travel time for home use	27.00	55.20	53.36	66.03	56.45	69.20	44.78	65.16
Gathering, collecting, purchasing fuels (including travel time) to generate income	4.87	23.79	11.68	35.25	7.46	31.32	7.24	29.61
Caring, attending, or playing with/for younger children	95.47	209.50	101.74	199.65	91.99	182.72	95.06	196.23
Number of observations	1741		831		2045		4617	

As shown in Table 3, in the overall sample, amongst the activities listed, women and girls spend the most time per day on cooking, childcare, and working for pay outside of home (on average 103 minutes, 95 minutes, and 73 minutes on a typical day for the three activities, respectively). Women and girls in the households that choose manufactured cookstoves seem to spend relatively less time on cooking and more time on working for pay outside of home – which could partly be because more urban households use manufactured stoves than rural households, and urban households are less likely to rely on their own agriculture and more likely to rely on paid employment to provide for themselves. On the other hand, households who choose self-built stoves spend more time on cooking than households that chose open fire tripod stoves and manufactured stoves.

Attitudes of household heads on energy related statements

Households were asked of their opinions on energy use related issues. As Table 4 shows, about 85 percent of respondents stated that smoke from cooking fuels is a big health problem in their family, while a similar share of households reported that firewood is not convenient to use. About 89 percent of the household heads stated that cooking with firewood is harmful to a person's health in their families. Nearly 37 percent of household heads also disagree with the statement that says, "firewood is hard to find". On the decision power of men, about 67 and 69 percent of household heads in the total sample agreed on the statements "men usually make decisions on the distribution of family budget" and "men usually make decisions on purchasing of energy and energy-consuming devices", respectively. As shown in Table 2 above, while women have more role in deciding on the building or purchasing of cookstoves, men are the ones who make the decision when it is broadened to decisions on all energy and energy using devices.

Table 4: Attitude of household heads on energy related statements

Perception statements (N=3453)	Agrees	No opinion	Disagrees
Smoke from cooking fuels is a big- health problem in my family	85.35	3.21	11.44
Cooking with Firewood is not convenient	84.65	1.16	14.19
Cooking with charcoal is harmful	76.34	3.97	19.69
Cooking with firewood is harmful	89.02	1.85	9.12
Firewood is hard to find	63.16	1.8	35.04
Men usually decide on distribution of family budget	67.45	1.65	30.9
Men usually decide on purchasing of energy and energy-consuming devices	68.58	2.29	29.13

3.2 Empirical strategy

The empirical model specifies seven recursive structural equations for (1) the type of cookstoves (C) as function of the gender of the household head (G) and a vector of other explanatory variables (XC), (2) time spent by women and girls on collecting

fuelwood for home use (F) as a function of the type of cookstoves (C) and a vector of other explanatory variables (XF), (3) time spent by women and girls on collecting fuelwood for generating income by selling to markets (I) as a function of the type of cookstoves (C) and a vector of other explanatory variables (XI), (4) time spent by women and girls on cooking (K) as a function of the type of cookstoves (C) and a vector of other explanatory variables (XK), (5) time spent by women and girls on childcare (H) as a function of the type of cookstoves (C) and a vector of other explanatory variables (XH), (6) time spent by women and girls on schooling (S) as a function of the type of cookstoves (C) and a vector of other explanatory variables (XS), and (7) time spent by women and girls on paid work outside the house (W) as a function of the type of cookstoves (C) and a vector of other explanatory variables (XW). C takes a value of 1, 2, and 3 for traditional open fire tripod stoves, self-built stoves, and manufactured stoves, respectively. Due to fuel-stacking behaviour observed in 32 percent of the households in the overall sample (and in 26% in the rural sample), where households use more than one type of stove in the house, C takes additional three values representing the pairwise interactions of the three stoves and one additional value for households that use all three types of stoves. Hence, the cookstove equation in (1) is modelled with a multinomial logit specification where C takes seven different combinations of stove types. Equations (2) to (7) on the amount of time women and girls spend on fuelwood collection for home use, fuelwood collection for sale, cooking, childcare, schooling, and paid work are continuous variables, and hence all are specified with a Gaussian link.

Given the recursive nature of the seven equations and the non-linear nature of the cookstove equation, the seven equations are estimated simultaneously using a generalized structural equation modelling (GSEM) as shown in Rabe-Hesketh, Skrondal, and Pickles (2004). Evidently, the dependent variables from (2) to (7) are correlated with each other since they are all functions of the same variable C. Moreover, GSEM allows the statistical errors (white noises) between any two pairs of the equations to be correlated with each other. We have allowed all pairs of the error terms among the six equations of time uses of women and girls (F, I, K, C, S, and W) to be correlated to each other, since they are all constrained by the overall time endowments of the women and girls in the household. The traditional open fire tripod stoves are used as the base group in the model in a reference to which the effects of the other types of cookstoves are compared with.

In the structural equations discussed above, we controlled for five different types of control variables. The first set of control variables are related to the characteristics of the person who make the decision of what type of cook stove is used in the house. These characteristics of the person who makes the decision on the type of stoves in the house that we have good data for include gender, relationship to the head of the household head (i.e, household head, wife or spouse, or other family member), age, whether the person ever attended school, marital status, how frequently the person cooks food for the household (everyday, a few times a month, or never), whether the person is wage or self-employed, and whether the person is unemployed. These characteristics of the person who makes decisions on the type of cookstove used in the house are included only in the cookstove equation, but not in the time use equations, because they do not have additional information content once the type of cookstove chosen is included in the time use equations. Gender of the person who makes the decision on cookstove types is the focus of this paper during the interpretation of the results.

The second set of variables controls for different characteristics of the head of the household and the household in general. These characteristics include gender of the household head, marital status of the head of the household (married, never married,

divorced, or widowed), how frequently the household head cooks food for the household, household size, the share of female members in the household, and if anyone in the household has a bank account at a formal institution.

The third set of variables controls for the different attributes of the households' dwelling and its access to infrastructure. These attributes of the house include the material from which the walls, roof, and floors of the house are made of. The materials of the walls, roof, and floors of the house are used as proxies of wealth indicators.

The fourth set of variables controls for attitudes of the household head on a number of energy related statements, measured on a Likert scale of agree, no opinion, and disagree. These energy-related statements include "smoke from cooking fuels is a big health problem in my family", "cooking with firewood is not very convenient", "cooking with charcoal is harmful to a person's health", "cooking with firewood is harmful to a person's health", "firewood is hard to obtain", "men usually make decisions on the distribution of family budget", and "men usually make decision on purchasing of energy and energy-consuming devices".

The fifth set of variables controls for location effects, which is primarily captured by the indicator (dummy) variables for the district (*woreda*) the household is located.

4 Results and Discussion

This section presents findings of the econometric analysis. The generalized structural equation modelling resulted in quite a large set of coefficients since it has seven system of equations on cookstove types and six selected women's and girl's time use on fuel wood collection (for own use and sale), cooking, childcare, schooling, and paid work, with the cookstove equation having seven different combinations of the three cookstove types considered in this study. Thus, we present two sets of results – one on factors associated with cookstove choices and another set of results focusing on the impact of the chosen cookstove type on women's and girl's time use. Even in these two sets of results, we presented coefficients on selected variables, relegating the full set of results to the annex. The results are split only for the purpose of presentation and were estimated simultaneously with the error structures between the different time use equations allowed to have non-zero covariances and the cookstove decision recursively included in the time use equations.

Table 5 presents the factors associated with cookstove types used in the house with a focus on the characteristics of the person who makes the decision on the type of stove used in the house and on the characteristics of the head of the household. The results in Table 5 show that the decision on cookstove choices is associated more with the characteristics of the person who makes such decisions within the household than the characteristics of the head of the household, a result that calls for better understanding of intra-household decisions in the effort to promote improved types of cookstoves in Ethiopia.

When the person who makes the decision on the type of cookstove used in the house is a female member of the household relative to being a male, the household is more likely to stack open fire tripod and self-built cookstoves or to stack manufactured cookstoves either with a self-built or with open fire tripod stove, compared to using only an open fire tripod cookstove. The results indicate the importance of decision making by women on cookstove types to be used in the house to move away from

open fire tripod cookstoves or stack manufactured and self-built cookstoves on their open fire tripod cookstove. When the person who makes the decision on cookstove types is the head of the household relative to being the spouse of the head of the household, they are more likely to stack self-built and manufactured cookstoves compared to using only an open fire tripod cookstove. Similarly, when the person who makes the decision on cookstove types is the head of the household relative to being other members of the household (children, grandchildren, in-laws, or siblings of the head), they are more likely to stack self-built and manufactured cookstoves or to stack all the three types of stoves, compared to using only an open fire tripod cookstove.

When the person who makes the decision on cookstove types has ever attended school relative to never being to a school, they are more likely to use either only a self-built stove, or only a manufactured stove or stack a manufactured cookstove with a self-built stove or an open fire tripod stove, compared to using only a stone and fire cookstove. When the person who makes the decision on cookstove types is married relative to never being married, they are more likely to use either only manufactured stoves or stack an open fire tripod cookstove with a self-built stove, but less likely to stack all the three types of stoves, compared to using only an open fire tripod cookstove.

When the person who makes the decision on cookstove types is someone who cooks every day relative to being someone who cooks only sometimes, they are more likely to stack an open fire tripod cookstove with a self-built stove, compared to using only an open fire tripod cookstove. The result indicates the importance of decision making on the type of cookstove used in the house by the person who is primarily engaged with cooking to add self-built or manufactured cookstoves than just using open fire tripod cookstoves.

When the person who makes the decision on cookstove types is wage or self-employed, the household is more likely to use a self-built stove, compared to using only an open fire tripod stove. When the person making the decision on cookstove types is older, the household is more likely to use only manufactured cookstoves and less likely to stack an open fire tripod cookstove with a self-built cookstove, compared to using only an open fire tripod cookstove.

Female headed households are more likely to use an open fire tripod cookstove than a self-built cookstove or a stack of self-built and manufactured cookstoves. When the household head is never married relative to being married, he or she is more likely to use either a manufactured cookstove or a stack of open fire tripod cookstove with self-built cookstove, but less likely to use a stack of all three stoves, compared to using only an open fire tripod cookstove. When the household head is divorced relative to being married, they are more likely to stack all three types of stoves, compared to using only an open fire tripod cookstove. Families in larger household sizes are less likely to use only manufactured cookstoves or a stack of all the three types of stoves, compared to using only an open fire tripod cookstove. When the share of female members in the house is bigger, the household is less likely to use only manufactured cookstoves, compared to using only an open fire tripod cookstoves. When at least one person in the household has a bank account at a formal financial institution, the household is more likely to use a manufactured cookstove (either alone or stacked with either self-built or open fire tripod stove) or a stack of open fire tripod and self-built stove, compared to using only an open fire tripod cookstoves. The results on the association of cookstove choices with characteristics of the house, attitudes of the head of the household on different energy related statements, and location (district) dummies are presented in Table A2 in the appendix.

Table 5: Factors associated with the type of cookstove used in the house[1]

	Self-built	Manufactured	Open fire tripod & self-built	Open fire tripod and Manufactured	Self-built and manufactured	All three
The person who makes the decision on the type of stove used in the house is						
Female (vs male)	-0.14	-0.17	1.07*	0.71*	0.93*	0.43
	(0.60)	(0.44)	(0.55)	(0.43)	(0.53)	(0.86)
Spouse of the head (vs household head)	-0.72	-0.17	-0.18	-0.22	-1.09***	-1.23
	(0.49)	(0.35)	(0.45)	(0.34)	(0.42)	(0.79)
Another house member (vs household head)	-0.50	0.57	-0.21	-0.31	-0.97*	-3.71***
	(0.61)	(0.41)	(0.51)	(0.43)	(0.57)	(1.32)
Attended school (vs no schooling)	0.31*	0.68***	-0.14	0.59***	0.91***	-0.03
	(0.18)	(0.15)	(0.14)	(0.13)	(0.19)	(0.24)
Never married (vs married)	-0.26	-1.38***	-2.10***	-0.53	0.02	2.55**
	(0.68)	(0.52)	(0.66)	(0.51)	(0.62)	(1.25)
Divorced (vs married)	0.10	0.06	-0.54	0.02	1.15	-1.63
	(0.90)	(0.66)	(0.83)	(0.64)	(0.80)	(1.21)
Widowed (vs married)	0.30	0.72	-0.69	0.37	-0.83	1.22
	(0.69)	(0.54)	(0.67)	(0.51)	(0.62)	(1.10)
Cooks sometimes (vs frequently)	-0.14	-0.31	-1.16**	-0.47	0.13	-0.14
	(0.45)	(0.33)	(0.49)	(0.31)	(0.36)	(0.66)
Never cooks (vs frequently)	0.03	-0.22	0.78	0.30	0.32	-0.20
	(0.57)	(0.42)	(0.48)	(0.39)	(0.49)	(0.87)
Wage/self employed (vs no wage income)	0.42**	0.12	0.19	0.16	0.08	0.11
	(0.18)	(0.14)	(0.14)	(0.13)	(0.17)	(0.24)
Age	-0.00	0.01**	-0.02***	-0.00	0.01	-0.00
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Characteristics of the head of the household						
Female head (vs male)	-1.21*	0.41	-0.28	-0.22	-1.19**	-1.02
	(0.64)	(0.44)	(0.56)	(0.43)	(0.53)	(0.93)
Never married (vs married)	0.18	1.97***	1.73**	0.62	-1.04	-2.60*
	(0.80)	(0.59)	(0.77)	(0.58)	(0.74)	(1.42)
Divorced (vs married)	0.64	0.32	0.56	0.29	-0.88	2.73**
	(0.90)	(0.67)	(0.86)	(0.65)	(0.82)	(1.16)
Widowed (vs married)	0.20	-0.40	1.00	-0.25	0.72	-0.12
	(0.65)	(0.51)	(0.64)	(0.49)	(0.57)	(1.06)
Cooks sometimes (vs frequently)	-0.97	0.48	-0.53	-0.30	-0.17	-16.63
	(0.59)	(0.39)	(0.54)	(0.38)	(0.44)	(1,536.12)
Never cooks (vs frequently)	-0.48	0.14	-0.40	-0.57	-0.71	1.12
	(0.58)	(0.41)	(0.47)	(0.38)	(0.47)	(0.91)
Household size	0.04	-0.09***	-0.02	-0.01	-0.05	-0.19***
	(0.04)	(0.03)	(0.03)	(0.03)	(0.04)	(0.06)
Share of female	-0.67	-0.68**	-0.48	-0.15	0.41	0.16
	(0.41)	(0.31)	(0.31)	(0.29)	(0.38)	(0.51)
Bank account	-0.02	0.91***	0.25*	0.71***	1.06***	0.02
	(0.19)	(0.14)	(0.14)	(0.13)	(0.18)	(0.23)
House Characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Attitudes of the head on energy related statements	Yes	Yes	Yes	Yes	Yes	Yes
District dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	4,521	4,617	4,617	4,617	4,617	4,617

[1] Note on dependent variable (cookstove types used) – the open fire tripod cookstove is the base/reference group excluded in the multinomial equation; the effects on the rest of the cookstoves is compared in reference to the open fire tripod cookstove.

Table 6 presents how the choice of cookstove is associated with the time women and girls spend on selected activities – fuelwood collection (for own use and for sales), cooking, childcare, schooling (studying or helping with schoolwork), and paid work. Time on fuelwood collection refers to time spend on gathering, collecting, or purchasing fuels including travel time separately for home use and for generating income from its sale. Time spent on childcare includes caring, attending, or playing with or for younger children. Cooking refers to total cooking time in minutes that women and girls spend per day in the household. Paid work is time women and girls spend working for pay outside of the house.

The results in Table 6 shows that in households that use only self-built stoves, women and girls spend more time on collecting fuel for sale and less time on cooking, compared to women and girls in households that use only open fire tripod stoves. In households that use only manufactured cookstoves, women and girls are likely to spend more time on childcare and working for pay outside the house, and less time collecting fuel for home use and for schooling, compared to women and girls in households that use only open fire tripod stoves.

In households that stack a stone and fire cookstove with a self-built stove, women and girls are likely to spend more time collecting fuel for home use, less time for collecting fuel for sale, and less time on cooking, compared to women and girls in households that use only open fire tripod stoves. This is partly because of increased demand for biomass energy form a stacking of two relatively less energy efficient stoves.

Women and girls in households that stack a manufactured cookstove with a self-built stove are likely to spend more time on childcare and work for pay and less time on collecting fuel for home use or for cooking, compared to women and girls in households that use only open fire tripod stoves. Relatedly, women and girls in households that stack a manufactured cook stove with an open fire tripod cookstove are likely to spend more time on childcare and work for pay and less time for cooking, but they also spend more time colleting fuel for home use, compared to women and girls in households that use only open fire tripod stoves. Households that stack all the three types of cookstoves are likely to spend less time on cooking (perhaps benefiting from simultaneous use of more than one stove at a time), but spend more time on collecting fuel for home use (possibly as a result of increased energy demand for the three stoves) and more time on schooling (possibly because the amount of time saved on cooking is greater than the amount of increased time for collecting fuel). The results on the associations of the characteristics of the house, attitudes of the head of the household on different energy related statements, and location (district) dummies with the amount of time women and girls spend on the selected activities are presented in Table A2 in the appendix.

Table 6: Choice of cookstove types and implications on the time women and girls spend on fuelwood collection, cooking, childcare, schooling, and paid work[2]

[2] The open fire tripod cookstove is the base/reference group excluded in the multinomial equation. Hence, the effects of the rest of the cookstoves are compared in reference to the open fire tripod cookstove.

Time Women and girls spend on:	Child care	Fuelwood for sale	Cooking	Fuelwood for home use	Schooling	Working for pay
Self-built	2.27	16.97***	-11.56**	0.91	-4.78	17.77
	(13.27)	(1.99)	(5.50)	(4.09)	(7.04)	(11.48)
Manufactured	30.89***	-0.88	2.32	-7.62**	-14.85***	46.48***
	(10.54)	(1.58)	(4.37)	(3.25)	(5.59)	(9.13)
Open fire tripod& self-built	10.72	-3.51**	-23.50***	8.48***	6.51	3.04
	(9.73)	(1.46)	(4.03)	(3.00)	(5.16)	(8.42)
Open fire tripod& manufactured	44.95***	0.68	-22.21***	6.28**	-2.73	40.99***
	(9.61)	(1.44)	(3.98)	(2.97)	(5.10)	(8.32)
Self-built & manufactured	68.50***	0.44	-21.28***	-8.67**	1.44	37.87***
	(12.86)	(1.93)	(5.33)	(3.97)	(6.82)	(11.13)
All three stoves	-5.33	-3.45	-52.55***	15.57***	22.20**	5.63
	(16.29)	(2.45)	(6.75)	(5.03)	(8.64)	(14.10)
Constant	131.51***	6.47*	136.33***	38.00***	-59.30***	-7.29
	(22.56)	(3.39)	(9.35)	(6.96)	(11.97)	(19.53)
Household characteristics	Yes	Yes	Yes	Yes	Yes	Yes
House Characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Attitudes of the head on energy related statements	Yes	Yes	Yes	Yes	Yes	Yes
District dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	4,617	4,617	4,617	4,617	4,617	4,617

*Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1*

5 Conclusion

Ethiopia's huge dependence on raw biomass energy disproportionately affected the welfare of women and girls, who primarily spent plenty of time collecting fuel and doing unpaid domestic work. The use of improved biomass cooking solutions is suggested as an intermediate solution to reduce women's burden and smooth future transition to cleaner alternatives. However, such a transition requires an informed decision on the types of stoves used within households, what influences the choice of cookstove types, and the impact of different cookstove types on the amount of time women and girls spend on cooking and collecting fuelwood, as well as its trade-off with the time they can spend on childcare, schooling, and paid work outside the house. The received literature on the topic so far is more focused on the characteristics of household heads, with intra-household decision-making dynamics on cookstove choices and the subsequent welfare effects not getting the focus it deserves. Thus, understanding the socio-economic characteristics of the person who makes the decision on what type of cookstove to be used in the house, how such characteristics are related to the type of cookstove the household ends up using, and the effect of the chosen

cookstove on the welfare of women and girls provide valuable policy input to address the gender gap in the domestic energy sector.

With the use of generalized structural equation modelling, this study addresses the factors associated with cookstove choices and the impact of the chosen cookstove type on women's time use. The findings show that the decision on cookstove choices is associated more with the characteristics of the person who makes such decisions within the household than the characteristics of the head of the household, a result that calls for better understanding of intra-household decisions in the effort to promote improved types of cookstoves in Ethiopia. Households are more likely to use improved cookstoves (manufactured and self-built) than open fire tripod cookstoves, when the person who makes the decision on the type of cookstoves to be used in the house is female, head of the household, has attended school, cooks frequently in the house, and is wage or self-employed.

The study also revealed significant variation in women's and girls' time use across different stove choices and combinations of stoves. The stacking of all three stoves frees up women's and girls' time for schoolwork by reducing cooking time though it increases fuel collection time. Women and girls in households that use a combination of manufactured and self-built stoves spend less time on cooking and collection of fuel for home use and spend more time on childcare and paid work outside the house. Women and girls in households that combine open fire tripod stove with self-built stove spend less time on cooking and collection of fuel for sales, but still spend more time for collecting fuel for home use. Women and girls in households that use only manufactured stoves spend less time on collecting fuel for home use and spend more time on childcare and paid work. However, they also spend less time on schooling. Women and girls in households that use only self-built stoves are associated with spending less time on cooking but more time on collecting fuel for sale, compared to women and girls in households that use only an open fire tripod cookstoves.

The study provides relevant policy implications, particularly to the demand side management and promotion of improved biomass-based cookstoves by justifying the importance of considering labour division and gender relations within the household. Education and extension campaigns aimed at improving the adoption of improved (manufactured and self-built) cookstoves in rural Ethiopia, would be more successful if they first identified who in the household makes the decision on cookstove choices, who are not always household heads. Cookstove program implementers will have a higher chance of convincing people to adopt self-built and manufactured stoves instead of open-fire stoves if their messaging focuses on female members of households than male members of households, focus on those household members who cook frequently than those who cook sometimes, and focus on educated than non-educated members of the household. Male-headed households are more likely to respond positively to programmes promoting of selling improved cookstoves but there is a need to place a particular emphasis or focus on female-headed households (who this research shows are more likely to be using traditional tripod stoves) if the objective is to reach the most vulnerable group who needs the nudge and support to switch to such improved stoves. The results in this study on the impact of different types of cookstoves on time uses of women and girls in Ethiopia is also believed to help cost-benefit analysis for programmes engaged in the promotion of improved cookstove in the country.

References

Adane, M.M., G.D. Alene, S.T. Mereta, and K.L. Wanyonyi. 2020. "Prevalence and risk factors of acute lower respiratory infection among children living in biomass fuel using households: a community-based cross-sectional study in Northwest Ethiopia." BMC public health 20:1–13.

Adrianzén, M.A. 2013. "Improved cooking stoves and firewood consumption: Quasi-experimental evidence from the Northern Peruvian Andes." Ecological Economics 89:135–143.

Akter, S., and C. Pratap. 2022. "Impact of clean cooking fuel adoption on women's welfare in India: the mediating role of women's autonomy." Sustainability Science 17:243–257.

Alem, Y., S. Hassen, and G. Köhlin. 2014. "Adoption and disadoption of electric cookstoves in urban Ethiopia: Evidence from panel data." Resource and Energy Economics 38:110–124.

Barnes, D.F., K. Openshaw, K.R. Smith, and R. Van der Plas. 1994. "What makes people cook with improved biomass stoves." World Bank technical paper 242:2004.

Beltramo, T., G. Blalock, D.I. Levine, and A.M. Simons. 2015. "The effect of marketing messages and payment over time on willingness to pay for fuel-efficient cookstoves." Journal of Economic Behavior & Organization 118:333–345.

Bensch, G., and J. Peters. 2015. "The intensive margin of technology adoption–Experimental evidence on improved cooking stoves in rural Senegal." Journal of health economics 42:44–63.

Benti, N.E., G.S. Gurmesa, T. Argaw, A.B. Aneseyee, S. Gunta, G.B. Kassahun, G.S. Aga,

and A.A. Asfaw. 2021. "The current status, challenges and prospects of using biomass energy in Ethiopia." Biotechnology for Biofuels 14:1–24.

Beyene, A., R.A. Bluffstone, Z. Gebreegzhiaber, P. Martinsson, A. Mekonnen, and

F. Vieider. 2015. "Do improved biomass cookstoves reduce fuelwood consumption and carbon emissions? Evidence from rural Ethiopia using a randomized treatment trial with electronic monitoring." Evidence from Rural Ethiopia Using a Randomized Treatment Trial with Electronic Monitoring (June 22, 2015). World Bank Policy Research Working Paper, pp. .

Beyene, A.D., and S.F. Koch. 2013. "Clean fuel-saving technology adoption in urban Ethiopia." Energy economics 36:605–613.

Bluffstone, R., A.D. Beyene, Z. Gebreegziabher, P. Martinsson, A. Mekonnen, and M. Toman. 2022. "Experience and Learning with Improved Technologies: Evidence from Improved Biomass Cookstoves in Ethiopia." Environmental and Resource Economics 81:271–285.

Brooks, N., V. Bhojvaid, M.A. Jeuland, J.J. Lewis, O. Patange, and S.K. Pattanayak. 2016. "How much do alternative cookstoves reduce biomass fuel use? Evidence from North India." Resource and Energy Economics 43:153–171.

Clancy, J.S., M. Skutsch, and S. Batchelor. 2003. "The Gender-Energy-Poverty Nexus: Finding the energy to address gender concerns in development." DFID project CNTR998521, pp. .

EDHS. 2016. "Ethiopia demographic and health survey 2016. Central Statistical Agency,

Addis Ababa, Ethiopia." Working paper.

Ezzati, M., B.M. Mbinda, and D.M. Kammen. 2000. "Comparison of emissions and residential exposure from traditional and improved cookstoves in Kenya." Environmental Science & Technology 34:578–583.

FAO. 2020. "Global Forest resource assessment 2020." report 68:133–140.

Foley, G., and A. van Buren. 1980. "Substitutes for wood. Turning to coal and other approaches to easing the pressure on fuelwood resources." Unasylva 32.

Gabisa, E.W., and S.H. Gheewala. 2018. "Potential of bio-energy production in Ethiopia based on available biomass residues." Biomass and bioenergy 111:77–87.

Gebreegziabher, Z., A.D. Beyene, R. Bluffstone, P. Martinsson, A. Mekonnen, and M.A. Toman. 2018. "Fuel savings, cooking time and user satisfaction with improved biomass cookstoves: Evidence from controlled cooking tests in Ethiopia." Resource and Energy Economics 52:173–185.

Gebreegziabher, Z., A. Mekonnen, M. Kassie, and G. Köhlin. 2012. "Urban energy transition and technology adoption: The case of Tigrai, northern Ethiopia." Energy Economics 34:410–418.

Gebreegziabher, Z., G.C. Van Kooten, and D.P. Van Soest. 2017. "Technological innovation and dispersion: Environmental benefits and the adoption of improved biomass cookstoves in Tigrai, northern Ethiopia." Energy Economics 67:337–345.

Guta, D.D. 2012. "Assessment of biomass fuel resource potential and utilization in Ethiopia:
sourcing strategies for renewable energies." International Journal of Renewable Energy Research (IJRER) 2:131–139.

Hassen, S., and G. Köhlin. 2017. "Does purchase price matter for the waiting time to start using energy efficient technologies: Experimental evidence from rural Ethiopia?" Energy Economics 68:133–140.

Jagoe, K., M. Rossanese, D. Charron, J. Rouse, F. Waweru, M. Waruguru, S. Delapena,
R. Piedrahita, K. Livingston, and J. Ipe. 2020. "Sharing the burden: shifts in family time use, agency and gender dynamics after introduction of new cookstoves in rural Kenya." Energy Research & Social Science 64:101413.

Jeuland, M.A., S.K. Pattanayak, S. Samaddar, R. Shah, and M. Vora. 2020. "Adoption and impacts of improved biomass cookstoves in rural Rajasthan." Energy for Sustainable Development 57:149–159.

Kammila S, Kappen JF, Rysankova D, Hyseni B, Putti VR (2014). Clean and improved cooking in SubSaharan Africa: a landscape report. Washington (DC): World Bank Group (https://openknowledge.worldbank.org/bitstream/handle/10986/22521/Clean0and0impr000a0landscape0report.pdf?sequence=1&isAllowed=y, accessed August 16th, 2022).

Kedir, M.F., T. Bekele, and S. Feleke. 2019. "Problems of Mirt, and potentials of improved Gonzie and traditional open cook stoves in biomass consumption and end use emission in rural wooden houses of Southern Ethiopia." Scientific African 3:e00064.

Köhlin, G., E.O. Sills, S.K. Pattanayak, and C. Wilfong. 2011. "Energy, gender and development: what are the linkages? Where is the evidence?" Where is the Evidence, pp. .

Kooser, S.H. 2014. "Clean cooking: the value of clean cookstoves in Ethiopia." Journal of Environmental and Resource Economics at Colby 1:9.

Kowsari, R., and H. Zerriffi. 2011. "Three-dimensional energy profile: A conceptual
framework for assessing household energy use." Energy Policy 39:7505–7517.

Krishnapriya, P., M. Chandrasekaran, M. Jeuland, and S.K. Pattanayak. 2021. "Do improved cookstoves save time and improve gender outcomes? Evidence from six developing countries." Energy Economics 102:105456.

Mekonnen, Z. 2020. "Consumption, preference, and access of biomass fuels at Ziway town, Ethiopia." Energy Sources, Part A: Recovery, Utilization, and Environmental Effects, pp. 1–9.

Miller, G., and A.M. Mobarak. 2013. “Gender differences in preferences, intra-household externalities, and low demand for improved cookstoves.” Working paper, National Bureau of Economic Research.

Mohapatra, S., and L. Simon. 2017. “Intra-household bargaining over household technology adoption.” Review of Economics of the Household 15:1263–1290.

Oparaocha, S., and S. Dutta. 2011. “Gender and energy for sustainable development.” Current Opinion in Environmental Sustainability 3:265–271.

Padam, G., D. Rysankova, E. Portale, B.B. Koo, S. Keller, and G. Fleurantin. 2018.

Ethiopia–Beyond Connections: Energy Access Diagnostic Report Based on the Multi-Tier Framework. World Bank.

Rabe-Hesketh, S., A. Skrondal, and A. Pickles. 2004. “Generalized multilevel structural equation modeling.” Psychometrika 69:167–190.

Takama, T., F. Lambe, F.X. Johnson, A. Arvidson, B. Atanassov, M. Debebe, L. Nilsson,

P. Tella, and S. Tsephel. 2011. Will African consumers buy cleaner fuels and *stoves?: a household energy economic analysis model for the market introduction of bio-ethanol cooking stoves in* Ethiopia, Tanzania, and Mozambique. JSTOR.

Takama, T., S. Tsephel, and F. Johnson. 2012. “Evaluating the relative strength of product-specific factors in fuel switching and stove choice decisions in Ethiopia. A discrete choice model of household preferences for clean cooking alternatives.” Energy Economics 34:1763–1773.

Wassie, Y.T., and M.S. Adaramola. 2021. “Analysis of potential fuel savings, economic and environmental effects of improved biomass cookstoves in rural Ethiopia.” Journal of Cleaner Production 280:124700.

Wilson, C., and H. Dowlatabadi. 2007. “Models of decision making and residential energy use.” Annu. Rev. Environ. Resour. 32:169–203.

Annexes

Table A1: Summary of women and girls' time use in minutes per day for various activities by stove choices

Activities in minutes per day	Only manufactured stove		Self-built & manufactured		Stone/fire & manufactured		Only self-built stove		Stone/fire & Self-built		Only stone/fire stove		All three	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Cooking (food, tea, boiling water)	92.34	84.52	108.89	92.87	103.63	98.38	98.11	82.70	113.93	81.90	94.70	88.58	160.28	118.15
Other time spent in cooking area	36.71	50.53	29.56	36.84	36.92	41.81	32.05	43.27	49.85	59.27	34.42	49.98	33.19	36.99
Working for pay outside of the house	125.10	215.60	118.16	205.70	104.80	203.72	53.15	159.65	27.09	120.45	18.42	90.50	53.79	159.86
Studying or helping with school	40.76	104.92	66.24	111.16	54.31	122.16	42.81	78.13	50.86	96.31	47.38	105.82	59.31	125.12
Gathering, collecting, or purchasing fuels including travel time for home use	17.56	31.02	23.77	38.41	40.99	77.26	54.13	66.06	68.34	64.43	60.08	62.68	63.19	104.30
Gathering, collecting, purchasing fuels (including travel time) to generate income	3.87	17.27	5.71	19.02	6.77	34.13	27.24	53.69	4.47	18.98	8.97	33.34	0.86	4.67
Caring, attending, or playing with/for younger children	83.81	196.97	133.30	267.39	106.65	212.59	91.31	170.86	99.23	182.38	84.52	168.52	60.69	132.20
Number of HHs	956		378		1076		262		642		1129		174	

Table A2: Full set of results from the generalized structural equation modelling

	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
	Stove types						**Time women and girls spend on**					
	Self-built	Manufactured	Stone/fire & self-built	Stone/fire & manufactured	Self-built & manufactured	All three	Child care	Fuelwood for sale	Cooking	Fuelwood for home use	Schooling	Paid work
The person who makes decision on the type of stove used in the house is												
Female	-0.14	-0.17	1.07*	0.71*	0.93*	0.43						
	(0.60)	(0.44)	(0.55)	(0.43)	(0.53)	(0.86)						
Spouse of the head	-0.72	-0.17	-0.18	-0.22	-1.09***	-1.23						
	(0.49)	(0.35)	(0.45)	(0.34)	(0.42)	(0.79)						
Another house member	-0.50	0.57	-0.21	-0.31	-0.97*	-3.71***						
	(0.61)	(0.41)	(0.51)	(0.43)	(0.57)	(1.32)						
Attended school	0.31*	0.68***	-0.14	0.59***	0.91***	-0.03						
	(0.18)	(0.15)	(0.14)	(0.13)	(0.19)	(0.24)						
Never married	-0.26	-1.38***	-2.10***	-0.53	0.02	2.55**						
	(0.68)	(0.52)	(0.66)	(0.51)	(0.62)	(1.25)						
Divorced	0.10	0.06	-0.54	0.02	1.15	-1.63						
	(0.90)	(0.66)	(0.83)	(0.64)	(0.80)	(1.21)						
Widowed	0.30	0.72	-0.69	0.37	-0.83	1.22						
	(0.69)	(0.54)	(0.67)	(0.51)	(0.62)	(1.10)						
Cooks sometimes	-0.14	-0.31	-1.16**	-0.47	0.13	-0.14						
	(0.45)	(0.33)	(0.49)	(0.31)	(0.36)	(0.66)						
Never cooks	0.03	-0.22	0.78	0.30	0.32	-0.20						
	(0.57)	(0.42)	(0.48)	(0.39)	(0.49)	(0.87)						
Wage/self employed	0.42**	0.12	0.19	0.16	0.08	0.11						
	(0.18)	(0.14)	(0.14)	(0.13)	(0.17)	(0.24)						
Age	-0.00	0.01**	-0.02***	-0.00	0.01	-0.00						
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)						
Characteristics of the head of the household												
Gender head	-1.21*	0.41	-0.28	-0.22	-1.19**	-1.02	-36.60**	-1.88	18.36***	-0.01	-18.10**	44.07***
	(0.64)	(0.44)	(0.56)	(0.43)	(0.53)	(0.93)	(15.10)	(2.27)	(6.26)	(4.66)	(8.01)	(13.07)
Never	0.18	1.97***	1.73**	0.62	-1.04	-2.60*	-103.70***	-2.06	-22.52***	-1.91	28.59***	12.54
married	(0.80)	(0.59)	(0.77)	(0.58)	(0.74)	(1.42)	(15.29)	(2.30)	(6.34)	(4.72)	(8.11)	(13.24)
Divorced	0.64	0.32	0.56	0.29	-0.88	2.73**	-42.09***	0.59	-11.36**	4.84	-7.39	23.29**

	(0.90)	(0.67)	(0.86)	(0.65)	(0.82)	(1.16)	(12.91)	(1.94)	(5.35)	(3.98)	(6.85)	(11.17)
Widowed	0.20	-0.40	1.00	-0.25	0.72	-0.12	-69.81***	-1.14	-16.87***	-3.39	0.44	-8.60
	(0.65)	(0.51)	(0.64)	(0.49)	(0.57)	(1.06)	(11.06)	(1.66)	(4.58)	(3.41)	(5.87)	(9.57)
Cooks sometimes	-0.97	0.48	-0.53	-0.30	-0.17	-16.63	-5.03	2.97	9.60	-2.62	16.67**	36.82***
	(0.59)	(0.39)	(0.54)	(0.38)	(0.44)	(1,536.12)	(14.53)	(2.18)	(6.02)	(4.48)	(7.71)	(12.58)
Never cooks	-0.48	0.14	-0.40	-0.57	-0.71	1.12	-17.69	-0.95	12.67**	0.70	-31.94***	5.07
	(0.58)	(0.41)	(0.47)	(0.38)	(0.47)	(0.91)	(14.26)	(2.14)	(5.91)	(4.40)	(7.56)	(12.34)
Household size	0.04	-0.09***	-0.02	-0.01	-0.05	-0.19***	9.33***	0.15	4.93***	3.66***	14.64***	3.17**
	(0.04)	(0.03)	(0.03)	(0.03)	(0.04)	(0.06)	(1.57)	(0.24)	(0.65)	(0.48)	(0.83)	(1.36)
Share of female	-0.67	-0.68**	-0.48	-0.15	0.41	0.16	36.89***	0.69	2.38	17.32***	80.26***	78.15***
	(0.41)	(0.31)	(0.31)	(0.29)	(0.38)	(0.51)	(14.29)	(2.15)	(5.92)	(4.41)	(7.58)	(12.37)
Bank account	-0.02	0.91***	0.25*	0.71***	1.06***	0.02	13.01*	-2.98***	-1.15	-9.99***	12.81***	34.88***
	(0.19)	(0.14)	(0.14)	(0.13)	(0.18)	(0.23)	(6.80)	(1.02)	(2.82)	(2.10)	(3.61)	(5.88)
Characteristics of the house												
Grid	0.12	1.92***	0.61***	1.96***	1.27***	1.11***	-10.77	-1.66	-25.43***	-15.02***	-7.30*	17.00**
connected	(0.20)	(0.19)	(0.14)	(0.15)	(0.22)	(0.24)	(8.26)	(1.24)	(3.43)	(2.55)	(4.38)	(7.15)
# of rooms	-0.32***	-0.35***	-0.14**	-0.22***	-0.10	0.20**	-13.70***	-0.31	-1.27	-0.96	1.14	-7.52***
	(0.08)	(0.06)	(0.06)	(0.05)	(0.06)	(0.08)	(2.66)	(0.40)	(1.10)	(0.82)	(1.41)	(2.31)
Wood/mud wall	-1.32***	-2.00***	-1.74***	-1.43***	-1.69***	-1.29***	-24.23***	-0.00	7.13**	-11.53***	5.97	-8.08
	(0.21)	(0.17)	(0.16)	(0.17)	(0.20)	(0.27)	(7.25)	(1.09)	(3.01)	(2.24)	(3.85)	(6.28)
Bamboo/reed wall	0.78***	1.82***	0.47***	1.82***	1.42***	2.30***	-23.45**	0.69	3.04	-7.21**	7.28	1.18
	(0.21)	(0.26)	(0.15)	(0.21)	(0.31)	(0.47)	(9.18)	(1.38)	(3.81)	(2.83)	(4.87)	(7.95)
Mud floor	-0.68**	-1.42***	0.25	-0.05	-0.65***	-0.76**	-14.30	3.10**	-7.47*	19.96***	0.38	-41.59***
	(0.29)	(0.20)	(0.24)	(0.19)	(0.25)	(0.33)	(9.64)	(1.45)	(4.00)	(2.97)	(5.11)	(8.34)
Cement floor	0.26	-0.11	-0.05	0.28	0.10	-0.56	-13.43	2.68**	-2.99	2.96	5.69	-23.38***
	(0.30)	(0.21)	(0.27)	(0.21)	(0.24)	(0.34)	(9.02)	(1.35)	(3.74)	(2.78)	(4.78)	(7.80)
Attitudes of the household head on energy sources and uses												
Smoke from cooking fuels is a big health problem in my family												
No opinion	0.04	-1.20**	0.51	-1.94**	0.29	-18.15	-5.30	13.11***	-15.50	-1.90	-4.53	-11.43
	(0.63)	(0.59)	(0.59)	(0.83)	(0.60)	(4,559.67)	(29.28)	(4.40)	(12.14)	(9.04)	(15.53)	(25.35)
Disagrees	0.31	0.20	0.15	0.35**	-0.08	-1.94***	-18.66**	4.88***	-18.59***	-0.47	5.97	-29.06***
	(0.22)	(0.19)	(0.18)	(0.17)	(0.25)	(0.64)	(8.87)	(1.33)	(3.68)	(2.74)	(4.70)	(7.68)
Cooking with firewood is not very convenient												
No opinion	0.05	-1.23**	0.60	-1.92**	0.28	-18.42	-5.30	13.11***	-15.50	-1.90	-4.53	-11.43
	(0.63)	(0.61)	(0.58)	(0.84)	(0.61)	(4,816.77)	(29.28)	(4.40)	(12.14)	(9.04)	(15.53)	(25.35)
Disagrees	0.29	0.16	0.11	0.34**	-0.12	-1.98***	-18.66**	4.88***	-18.59***	-0.47	5.97	-29.06***

	(0.23)	(0.19)	(0.19)	(0.17)	(0.25)	(0.64)	(8.87)	(1.33)	(3.68)	(2.74)	(4.70)	(7.68)
Cooking with charcoal is harmful to a person's health												
No opinion	-0.60	-0.20	-0.37	0.10	0.16	2.18***	-1.97	-4.39*	0.36	16.91***	-14.32*	-22.02
	(0.42)	(0.38)	(0.30)	(0.33)	(0.44)	(0.42)	(15.49)	(2.33)	(6.42)	(4.78)	(8.22)	(13.41)
Disagrees	-0.25	0.48***	0.05	0.42***	1.07***	1.05***	-9.29	-3.96***	3.51	17.31***	8.14*	-6.82
	(0.22)	(0.17)	(0.16)	(0.15)	(0.21)	(0.28)	(7.99)	(1.20)	(3.31)	(2.47)	(4.24)	(6.92)
Cooking with firewood is harmful to a person's health												
No opinion	0.61	-0.09	-0.46	-0.33	0.82	1.51**	-61.49***	16.69***	-10.06	13.40*	-2.87	21.24
	(0.49)	(0.54)	(0.55)	(0.56)	(0.55)	(0.68)	(23.75)	(3.57)	(9.85)	(7.33)	(12.60)	(20.56)
Disagrees	-0.12	-0.82***	-0.68***	-1.03***	-1.03***	-0.62	-7.62	1.88	-6.69	-11.78***	7.05	-2.23
	(0.29)	(0.24)	(0.24)	(0.22)	(0.32)	(0.45)	(11.65)	(1.75)	(4.83)	(3.60)	(6.18)	(10.08)
Firewood is hard to obtain												
No opinion	1.83***	-0.22	-0.30	-2.54***	-0.40	0.07	25.88	-2.89	-0.93	-20.65***	-11.35	4.79
	(0.51)	(0.54)	(0.67)	(0.79)	(0.61)	(0.97)	(24.55)	(3.69)	(10.18)	(7.58)	(13.02)	(21.25)
Disagrees	-0.41**	-0.11	-0.33***	-0.17	-0.74***	-0.89***	-7.84	1.51	-11.53***	-7.09***	-8.92***	-7.75
	(0.17)	(0.13)	(0.12)	(0.12)	(0.18)	(0.24)	(6.33)	(0.95)	(2.63)	(1.96)	(3.36)	(5.48)
Men usually make decisions on the distribution of family budget												
No opinion	-0.08	-0.28	-1.76**	0.31	1.13**	-16.46	-43.87*	5.05	-15.36	-9.52	13.28	-35.35*
	(0.56)	(0.59)	(0.82)	(0.53)	(0.56)	(2,819.97)	(24.23)	(3.64)	(10.04)	(7.48)	(12.85)	(20.97)
Disagrees	-0.17	-0.03	-0.60***	-0.03	0.04	-0.41	13.35	-4.33***	20.79***	-2.12	7.19	17.83**
	(0.26)	(0.19)	(0.20)	(0.18)	(0.24)	(0.33)	(9.34)	(1.40)	(3.87)	(2.88)	(4.95)	(8.08)
Men usually make decisions on purchasing of energy and energy devices												
No opinion	-0.36	0.12	-0.51	1.00**	0.04	-15.83	-11.02	8.33***	-15.86*	-3.36	-22.02**	-44.07**
	(0.56)	(0.48)	(0.52)	(0.42)	(0.55)	(2,333.07)	(20.64)	(3.10)	(8.56)	(6.37)	(10.95)	(17.87)
Disagrees	-0.19	0.02	0.53***	0.20	0.68***	1.88***	-12.26	2.04	-5.75	-1.24	1.95	-4.89
	(0.27)	(0.20)	(0.19)	(0.18)	(0.24)	(0.33)	(9.48)	(1.42)	(3.93)	(2.93)	(5.03)	(8.20)
Self-built							2.27	16.97***	-11.56**	0.91	-4.78	17.77
							(13.27)	(1.99)	(5.50)	(4.09)	(7.04)	(11.48)
Manufactured							30.89***	-0.88	2.32	-7.62**	-14.85***	46.48***
							(10.54)	(1.58)	(4.37)	(3.25)	(5.59)	(9.13)
Stone/fire & self- built							10.72	-3.51**	-23.50***	8.48***	6.51	3.04
							(9.73)	(1.46)	(4.03)	(3.00)	(5.16)	(8.42)
Stone/fire &manufactured							44.95***	0.68	-22.21***	6.28**	-2.73	40.99***
							(9.61)	(1.44)	(3.98)	(2.97)	(5.10)	(8.32)
Self-built &							68.50***	0.44	-21.28***	-8.67**	1.44	37.87***

manufactured												
							(12.86)	(1.93)	(5.33)	(3.97)	(6.82)	(11.13)
All three stoves							-5.33	-3.45	-52.55***	15.57***	22.20**	5.63
							(16.29)	(2.45)	(6.75)	(5.03)	(8.64)	(14.10)
Constant	1.18*	-0.70	0.74	-1.90***	-2.81***	-3.35***	131.51***	6.47*	136.33***	38.00***	-59.30***	-7.29
	(0.70)	(0.59)	(0.61)	(0.55)	(0.73)	(1.02)	(22.56)	(3.39)	(9.35)	(6.96)	(11.97)	(19.53)
District dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	4,521	4,617	4,617	4,617	4,617	4,617	4,617	4,617	4,617	4,617	4,617	4,617

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