Benefits of improved cookstoves: Evidence from MTF surveys in Nepal

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Table of Contents

Executive Summary

Introduction

Clean cooking energy has become the focus of many governments, researchers, and nonprofits, especially in low-income developing countries. However, 43% of the global population, approximately three billion people are still relying on traditional unclean biomass energy for their daily household cooking, and many of them are in developing countries.

In developing countries, women and girls manage most household cooking activities, and therefore are impacted most using unclean cooking energy. Clean cooking energy on the other hand could substitute the unclean energy and bring many benefits to humans, so it seems logical that clean cooking could benefit women more than men.

However, there is a know-do gap between what researchers "know" about the gender impacts of clean cooking and what clean cooking practitioners and businesses "do" to promote gender equality. Practitioners have been undertaking clean cooking interventions while researchers have insufficient evidence to support the assumption that clean cooking benefits women more than men. Additionally, researchers do not "know" enough how people value clean cooking interventions.

This study intends to close at least some of the know-do gap existing in the arena of clean cooking's gender impacts. By analyzing the Multi-Tier Framework (MTF) survey data of Nepal, the study tries to answer whether clean cooking, specifically improved cookstoves yield more benefits to females than males.

Key Findings

- An individual on average saved 33 mins/day on all cooking-related activities in Nepal.

- Males on average saved 31 mins a day; females on average saved 35 mins a day on all cooking-related activities.
- There is no statistically significant time saving difference between females and males on all cooking-related activities.
- People in Nepal have low willingness to pay for improved cookstoves. Yet, slightly more households are willing to purchase an improved cookstoves at a certain price when households are given more time to make the payment.

Discussion

People in Nepal saved time and benefit from the use of improved cookstoves while undervaluing the benefits of improved cookstoves and having low willingness to purchase them. So, other interventions are needed to promote clean cooking energy access in Nepal.

One possible path would be trying to first assess demand and then, if there is demand, to promote people's willingness to pay for improved cookstoves. Making people more aware of the benefits of improved cookstoves might be one effective way to increase people's willingness to pay for improved cookstoves. Postponing the payment time might be another way to increase people's WTP.

Another path would be finding a better financing method for the public or private sector to provide subsidy to improved cookstoves or even free improved cookstoves. Development impact bond and social impact bond might be effective to provide with a new and more sustainable way of financing public interventions such as improved cookstoves promotion, and help improved cookstoves uptake in developing countries where people's willingness to pay is relatively low.

1. Introduction

Clean energy has been a critical aspect of the United Nations' Sustainable Development Goals (SDG) since 2015, where SDG 7 emphasizes the importance to "ensure access to affordable, reliable, sustainable and modern energy for all" (United Nations and General Assembly, 2015). Within the clean energy arena, clean cooking energy has become the focus of many governments, researchers and nonprofits, especially in low-income developing countries. In low-income countries, cooking represents the most significant energy use compared to other services that are consumed in the residential sector, such as lighting, refrigeration, heating and cooling (Daioglou, Ruijven, and Vuuren 2012).

However, 43% of the global population, approximately three billion people are still relying on traditional unclean biomass energy for their daily household cooking (WHO 2017). Traditional biomass energy including fuelwood, agriculture residues and animal dung accounts for 35% of the global household energy consumption. The share is much higher in the developing regions, with 86% in Africa and 49% in the developing Asia (Timilsina and Malla 2021). The widespread use of the traditional unclean energy has severe implications, including health issues through indoor air pollution and environmental issues through deforestation and climate change, and as a result human wellbeing and the economy (Timilsina and Malla 2021; Pattanayak et al., 2019).

In many low- and middle-income countries, women and girls manage most household cooking activities, and therefore are impacted most by the use of unclean cooking energy (Robinette et al, 2020; Gould and Urpelainen, 2018). As the cooks, women and girls spend more time indoor and near the cooking stoves, and they experience more exposure to indoor air pollution from inefficient cookstoves and bear more health burden than men (Robinette et al,

2020; Das et al, 2020). Additionally, women are also in charge of fuel collection and need to spend time collecting fuels, which decreases their available time for education, employment, leisure or other types of activities (Robinette et al, 2020; Matinga et al., 2019; Carr and Hartl, 2010).

Clean cooking energy, such as biogas, liquefied petroleum gas (LPG), electricity, and natural gas, on the other hand could substitute the traditional unclean energy and bring many benefits to humans. The benefits of clean cooking energy include lower levels of air pollution, decreased fuel collection time, and greater opportunities to engage in other activities (Robinette et al, 2020; Gupta, 2019). Given the logic outlined earlier, clean cooking could benefit women more than men. Unsurprisingly, many clean cooking advocates even list promoting gender equality as one of the benefits of clean cooking (Robinette et al, 2020 draft).

However, there is a know-do gap between what researchers "know" about the gender impacts of clean cooking and what clean cooking practitioners and businesses "do" to promote gender equality (Robinette et al, 2020). Practitioners undertake clean cooking interventions with the assumption that women will benefit more from clean cooking than men, considering more improvements in health, time savings, and education. Yet, researchers have insufficient evidence to support the assumption that clean cooking benefits women more than men. Many of the studies advocate that cleaning cooking promotes gender equality only measure impacts on women but do not comment on impacts on men (Sovacool, 2012). Without the comparison, these studies might not provide sufficient evidence of clean cooking's promotion of gender equality (Robinette et al, 2020).

In addition, although practitioners are actively promoting clean cooking interventions (e.g., improved cookstoves), the adoption rates are relatively low in most regions (Beltramo et

al., 2015; Lewis and Pattanayak, 2012). Researchers do not "know" enough how people value clean cooking interventions and their benefits, and what impact how people value those interventions (Beltramo et al., 2015).

This study intends to close at least some of the know-do gap existing in the arena of clean cooking's gender impacts. By analyzing the Multi-Tier Framework (MTF) survey data of Nepal, the study tries to answer the question that does clean cooking yield more benefits to females than males. The MTF surveys record detailed data about households and individual time use, so this study focuses on the time saving benefits. This study also analyzes the data collected from the MTF surveys about people's willingness to pay (WTP) for improved cookstoves. As WTP data helps with assessing effective demand and benefits of products and services (Gunatilake et al., 2007), it would help us examine how people value the benefits generated by improved cookstoves (Jeuland and Pattanayak, 2012).

2. Background

2.1 Nepal: Fuel Use and Policy

Nepal is the focus of this study as Nepal currently heavily relies on unclean solid biomass to meet its cooking fuel needs and needs to find clean cooking energy solutions. The Government of Nepal has recognized the significance of clean cooking access and committed to maximizing energy access benefits for its people (Pinto et al., 2019).

Pinto et al. (2019) shows basic data of Nepal's fuel use. 52.4% of the households in Nepal used firewood as their main source of cooking fuel, according to the Annual Household Survey in 2016–17. A larger share of households in rural areas use firewood to meet their fuel needs, with 65.8% of households in rural areas and 35.4% in urban areas. Clean fuels are also common in Nepal. 33.1% of the households used LPG and 3.1% used biogas. There is a larger

share of households in urban areas (54.1%) used LPG to meet their fuel need than rural areas (16.5%).

Pinto et al. (2019) also shows some examples of Nepal's clean cooking policies. The National Planning Commission proposes a target of sustainable development from 2016 to 2030, with some emphasizes on clean cooking access: 1) a reduction to 30% (from the current 75%) of households who use firewood for cooking; and 2) a limit on the use of liquefied petroleum gas (LPG) to less than 40% of the households. The Government of Nepal has undertaken projects to develop and introduce more efficient and cleaner fuels. Specifically, in addition to actively developing and introducing more efficient and cleaner fuels, the Government of Nepal has also promoted improved biomass cookstoves that burn fuel more efficiently. The Government of Nepal has also collaborated with the World Bank to conduct the Multi-Tier Framework (MTF) surveys and hope to obtain guidance on setting energy access targets, policies, and investment strategies.

2.2 Academic Literature

Krishnapriya et al. (2021) provide a comprehensive literature review on households' time savings from the use of improved cookstoves. They show that different empirical studies focus on different research regions, fuel and cookstove types, time-using activities, specific groups or individuals experiencing time saving, research designs and other aspects. For example, some studies focus entirely on time spent on fuel collection, some focus on time spent on cooking and others combine both fuel collection and cooking time and sometimes also including fuel preparation time. Another example is on different research designs. Some studies rely on simple pre-post comparisons in a population that use ICS without including control groups, and some conduct simple means comparisons between ICS owners and non-owners. Other studies use

regression-based comparisons trying to account for impacts of other variables. Finally, there are also studies use econometric strategies trying to account for selection bias and others applies rigorous quasi-experimental or experimental designs.

The results of different empirical studies also vary substantially. After standardizing the results from different studies into common units, Krishnapriya et al. (2021) show that time savings range from about 1 minute per day to nearly 190 min/day. The overall mean of time saving is 67.9 min/day.

3. Data and Methods

3.1 Data Description

The Multi-Tier Framework (MTF) is an initiative launched in June 2015 by the Energy Sector Management Assistance Program. The MTF survey approach redefines the way energy access is measured by introducing a new multi-tier framework, going beyond the traditional binary measurement of energy access. For instance, access is traditionally reported as having or not having a connection to electricity, or using or not using clean fuels in cooking. The MTF survey captures different technologies and sources that can provide energy access, while also accounts for the wide differences in users' experience (Pinto et al, 2019). In addition to energy access data, the dataset also includes information on households' demographic and socio-economic characteristics.

Time-use data

Two aspects of the MTF survey data provide an opportunity to examine clean cooking access's different impacts on time use for females and males. The first aspect is that the MTF surveys collect detailed data on households' cookstove types, which helps define whether the households are using clean cookstove as their primary cookstove or not. Based on the dataset,

following Krishnapriya et al. (2021), I construct an indicator variable *clean_ICS* that takes the value of 1 if the household used as its primary cookstoves one that uses LPG/cooking gas, solar energy, electricity, or biogas in the last 12 months. This was coded as 0 otherwise.

The second aspect is that the MTF surveys record self-reported time-use data for different groups of individuals within households, including women, men, girls and boys. It helps examine different time use impacts on females and males. For the sake of this study, females represent women and girls collective, and males are men and boys. The time-use data recorded in the dataset can be categorized into two main types, that are cooking-related and non-cooking-related time-use. Cooking-related time-use data records the time spent on 1) fuels gathering, collecting or purchasing including travel time, 2) fuel preparation (e.g., chopping or making pellets), 3) cooking (food, tea, boiling water), and 4) other activities that happened in cooking areas. Non-cooking-related time-use data records the time spent on 1) caring, attending or playing with/for younger children, 2) studying or helping schoolwork, 3) income generating activities and 4) entertainment or socializing.

Table 1 summarizes some sample characteristics for Nepal. The first part presents the following household level demographic and socio-economic characteristics: household size, share of households in the rural area, household consumption/expenditure in last 7 days, gender and age of household head, whether household head has completed high school, gender and age of primary cooker, whether primary cooker has completed high school, share of the adult females in the household, the number of children under 5, and a female empowerment index. The female empowerment index is calculated by getting the mean of two sub-indices: mobility index and access index (Krishnapriya et al, 2021). There are three questions in the survey represents females' mobility as they ask whether a female can 1) visit parents/relatives/friends,

Table 1. Sample characteristics

	Obs	Mean	Std. Dev.	Min	Max
Household characteristics					
Household size	5,993	4.61	2.05	1	31
Share of household in rural areas	5,993	45.24%	0.50	0	1
Consumption/Expenditure in last 7 days (local currency)	5,970	3647.55	6697.98	90	201485
Share of household that are female-headed	5,993	19.69%	0.40	0	1
Age of household head (years)	5,993	49.33	13.97	19	96
Share of household head completed high school education	5,993	50.73%	0.50	0	1
Share of female as primary cooker	6,003	70.25%	0.46	0	1
Age of primary cooker	6,003	41.11	13.98	2	94
Share of primary cooker completed high school education	6,003	55.06%	0.50	0	1
Share of adult females in the household	5,993	37.34%	0.17	0	1
Number of children under 5	5,993	0.38	0.65	0	5
Female empowerment index	5,943	0.53	0.31	0	1
Household use of improved cookstoves					
Any use of ICS (%)	5,993	49.81%	0.50	0	1
Any use of clean ICS (%)	5,993	41.03%	0.49	0	1
Individual time use					
Time spent on all cooking-related activities (mins/day)	27,685	90.36	119.95	0	1278
Time spent on fuel collection or purchase (mins/day)	27,685	4.91	18.09	0	650
Time spent on fuel preparation (mins/day)	27,685	12.37	42.33	0	888
Time spent on cooking (mins/day)	27,685	61.85	86.15	0	600
Other time spent in cooking areas (mins/day)	27,685	11.23	31.38	0	888
Time spent on caring, attending or playing with/for younger children (mins/day)	27,685	56.39	156.64	0	1440
Time spent on studying or helping schoolwork (mins/day)	27,685	48.01	115.35	0	840
Time spent on income generating activities (both inside and outside the house) (mins/day)	27,685	184.92	266.32	0	2400
Time spent on entertainment or socializing (mins/day)	27,685	61.89	78.22	0	888

Source: Multi-tier Framework data of Nepal

2) go to markets/banks/commercial centers/places of work, and 3) go outside the village. The response is assigned a value of 1 if the answer is yes, and 0 otherwise. The mobility index is the average of the values assigned to the three mobility-related questions. Similarly, the accessibility index is the average of the values assigned to the questions which ask whether a female is a member of an organization, and whether she owns an account in a bank or financial institution. If she is a member of an organization the value is 1, and 0 otherwise. If she owns an account in a bank or financial institution, the value is 1; if she owns a joint account the value is 0.5, and 0 otherwise.

The first part of Table 1 shows that 70.25% of the households in the Nepalian sample have a female primary cooker while only 19.69% of them are female headed. It accords with the background section that women and girls manage most household cooking activities in many low- and middle-income countries (Robinette et al, 2020). Table 1 also summarizes household usage of ICS and self-reported time-use data. It indicates that 49.81% of households used ICS[1] in the last 12 months as their primary cookstove and 41.03% of households used clean ICS as their primary cookstove, which is consistent with Nepal's cooking access situation that clean fuels are common in Nepal (Pinto et al, 2019). On average, an individual spends 90 mins per day on all cooking-related activities[2], including fuel collection, preparation, cooking and other activities in the cooking area. Among all cooking-related activities, individuals spend the most time on the actual cooking, which is 62 mins per day. Individuals also spend significant time on non-cooking-related activities, like caring younger children, studying or helping with schoolwork,

[1] Besides the types of cookstoves that are identified as clean ICS, ICS also include improved stove and stoves that use kerosene, coal briquette, biomass briquette, and processed biomass (pellets)/ woodchips.
[2] When doing the descriptive analysis of time-use data, all missing values are assigned to 0. It is because that different groups of people do different types of activities, which makes different variables incomparable. Generating the means of the full sample size makes different variables comparable.

income generating activities and entertainment. On average, individuals in Nepal spent the most time on income generating activities (185 mins/day).

Willingness to Pay for improved cookstoves

The MTF surveys also contains a section asking about households' WTP for an ICS, using contingent valuation method (Pattanayak et al., 2006). The surveys interviewed households in the sample that did not have an ICS and the respondent was either the household's primary cooker or the household member who decided to purchase the cookstove. The surveys then to examine households' WTP. Each interviewed household would be randomly assigned to a type of ICS (either a Metal ICS or a Mini Moto) and a prefilled price for the assigned ICS type. The responded would then answer whether the household would be willing to purchase the cookstove at the provided price. If the answer is no, the respondent would be asked whether his/her household would be willing to purchase the stove if he/she was given 6 months to make the payment. If the answer is still no, the payment time would be further prolonged to 12 months and 24 months.

3.2 Estimation Strategy

Time saving for females and males

As discussed in the last section, it is possible to examine clean ICS's different impacts on females and males with the *clean_ICS* variable and time-use data. However, the impacts estimation might be biased when using the ordinary least squares (OLS) regression as the characteristics of households that use clean ICS may be different from households that do not use clean ICS. For example, households that used clean ICS as their primary cookstove in the last 12 months may face different constraints (e.g., education or income level) or value the benefits of clean ICS differently from those who do not (Krishnapriya et al, 2021 draft). In this study,

propensity score matching (PSM) method is used to account for the potential selection bias, as it would minimize observed differences between households that use clean ICS and those who do not (Rosenbaum and Rubin 1983).

Propensity scores of households' choice of a clean ICS is firstly calculated (Pattanayak, 2009). After checking balance of the *clean_ICS* variable and household characteristics, 12 characteristic variables are identified as impacting households' cookstove usage: household size, a variable indicating whether the household is in the rural area, household consumption/expenditure, gender of household head, age of household head, a variable indicating whether the household head has completed high school education, gender of household primary cooker, age of household primary cooker, a variable indicating whether the household primary cooker has completed high school education, share of adult females in household, number of children under 5 and a female empowerment index. Based on these characteristics, running a regression of the *clean_ICS* variable on identified variables gives us a probability of use for each household. For each of the household that used clean ICS as its primary cookstove, a counterfactual from households that did not use clean ICS would be constructed after matching similar probability/propensity scores (Pattanayak, 2009).

The matching algorithms used in this study is the kernel matching, which matches each household that used clean ICS in the common support to a weighted average of the households that do not use ICS (Caliendo and Kopeinig 2008). And worth noting that PSM is not a perfect method as it only controls for selection bias arising from the observable differences across households (i.e., 12 characteristic variables identified). It is possible that other unobservable or unidentified characteristics or factors also impact households' clean ICS choice (Pattanayak, 2009).

After the PSM, the following OLS model is used to examine clean ICS usage's impact on household time use:

$$y_{hi} = \alpha + \beta clean\_ICS_h + \gamma X_h + \varepsilon_{hi}\ , (1)$$

where y_{hi} is the time spent on all cooking-related activities for an individual i in a household h, $clean\_ICS_h$ is the dependent variable indicating whether the household used a clean ICS in the last 12 months as its primary cookstove (all individuals in a household share the same value for this variable). X_h is a vector of the 12 household characteristics identified in the previous analysis (all individuals in a household share the same value for each of the characteristic). ε_{hi} is the error term.

Equation 1 is also applied to the female and male sub-datasets to examine clean ICS's impacts for females and males respectively.

Additionally, the following difference-in-difference (DID) model is also utilized to directly examine the different time-use impacts experienced by females and males:

$$y_{hi} = \alpha + \beta_1 clean\_ICS_h + \beta_2 female_i + \beta_3 clean\_ICS_h * female_i + \gamma X_{hi} + \varepsilon_{hi}, (2)$$

where $female_i$ is a dummy variable indicating whether the individual i is a female (value 1 for female and 0 for male) and $clean\_ICS_h * female_i$ is an interaction term of the variable indicating whether the household used a clean ICS and the gender variable.

Willingness to Pay for improved cookstoves

Multivariate regression is used in this study to estimate mean WTP for the two subsets for two different types of ICS covered in the MTF surveys. As the dependent variable is a binary variable indicating whether the household is willing to purchase the assigned ICS at a pre-specific price, a logit model will be used to estimate WTP (Gunatilake et al., 2007). In the logit model, the independent variable is prefilled randomly assigned price for the ICS. To calculate the

mean WTP, the coefficient on regression constant will be divided by the coefficient on the dependent variable and multiply by –1. The confidence interval around the WTP estimate will be calculated by using the confidence interval of the coefficient of the regression constant and the dependent variable.

4. Results

4.1 Time saving for females and males

Table 2 shows the results for different models used to examine clean ICS's impacts on individual's time use in the sample. All the models show that clean ICS significantly reduce individuals average time use per day. The time saving ranges from 29 mins per day from the simple t-test to 33 mins per day from the OLS model with covariates (i.e., the 12 household characteristic variables identified before). As previously discussed about the selection bias issue, the most accurate result might be the one got from the OLS model after PSM (Equation 1), which shows that on average an individual in the sample saved 33 mins a day if his/her household used a clean ICS as their primary cookstove in the last 12 months. The time saving is statistically significant under the significance level of 1%.

Table 2. Results for different models of clean ICS's impacts on individual time use

	t-test	**OLS model with covariates**	**Probit model**	**After PSM**
Time use (mins/day)	-28.56***	-33.01***	-28.66***	-32.89***
	(1.47)	(1.64)	(1.47)	(1.81)

Note: clustered standard errors are given in the parentheses. * p<0.1, ** p<0.05; ***p<0.01

Source: Multi-tier Framework data of Nepal.

Table 3 summarizes the results for male and female subsets about clean ICS's impacts on individual's time use and the result for the DID model to examine whether females and males are

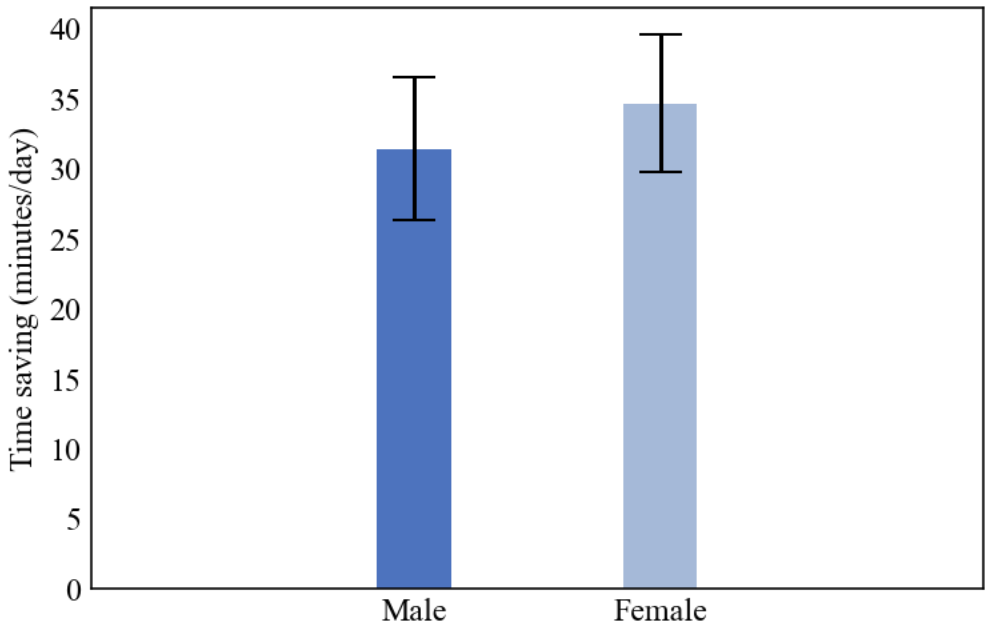
experiencing different time-use impacts from the clean ICS. The results show that males on average saved 31 mins a day if his household used a clean ICS as their primary cookstove in the last 12 months while females on average saved 35 mins a day. Both estimated timesaving for males and females are statistically significant under the 1% significance level.

Table 3. Results for male and female subsets of individual time use and the DID model

	Male subsample after PSM	**Female subsample after PSM**	**DID after PSM**
Time use (mins/day)	-31.39***	-34.61***	3.31
	(2.62)	(2.52)	(3.51)

Note: clustered standard errors are given in the parentheses. * p<0.1, ** p<0.05; ***p<0.01
Source: Multi-tier Framework data of Nepal.

Figure 1. Male and female's different time saving



Source: Multi-tier Framework data of Nepal.

The DID model result indicates that females on average saved 3.31 mins more a day than males, though the difference is not statistically significant. Figure 1 also shows the same result that there is no significant difference between males' and females' time saving. The reason why the difference is insignificant might be that that a clean ICS is beneficial for all household

members (though may not be equally beneficial) and it is hard to examine individual benefits. Because of statistical power issues, a much larger sample is needed to determine the different impacts on different household members.

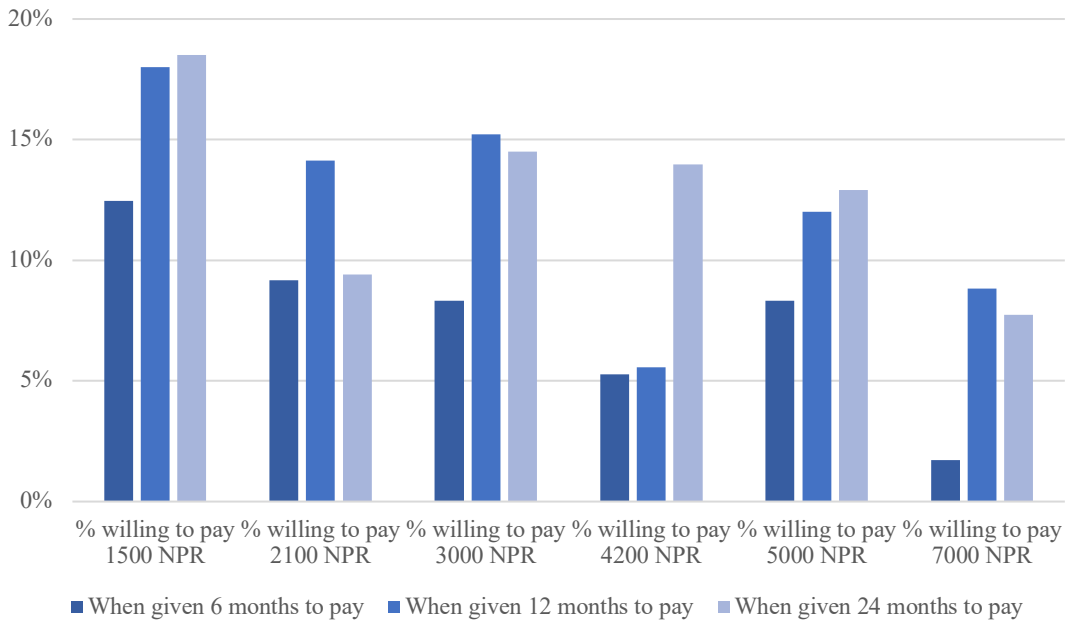
4.2 Willingness to Pay for improved cookstoves

Table 4. Percentage willing to pay for a metal ICS at different prices

Metal ICS Price (NPR)	1500	2100	3000	4200	5000	7000
% willing to pay	41.79%	23.78%	26.10%	8.98%	14.29%	3.89%

Source: Multi-tier Framework data of Nepal

Figure 2. WTP for metal ICS when given more time to make the payment



Source: Multi-tier Framework data of Nepal

Table 4 summarizes the results for household's willingness to purchase a metal ICS at a certain price. In general, not many households that did not use ICS want to purchase a metal ICS. At the lowest price provided by the survey, which is 1500 NPR in local currency (equals to US $14.4 in 2017, as the average exchange rate for NPR was 0.0096 USD in 2017), only 42% of

households are willing to purchase a metal ICS. When the price provided is at the highest level of 7000 NPR (US $ 67.2 in 2017), only 4% of households are willing to pay. Figure 2 shows that in general, when households are given more time to make the payment, slightly more households are willing to purchase a metal ICS at the provided price.

Table 5 shows the coefficient results of the logit regression of the variable indicating whether the household is willing to take the price on the assigned price. By getting the regression constant (0.2667) divided by the coefficient of the dependent variable (-0.0005) and multiple -1, we get the estimated WTP for a metal ICS is around 578 NPR (equals to US $5.55 in 2017). The 95% confidence interval of the estimated WTP is from 10.06 to 1392 NPR.

Table 5. Logit model results and estimation of WTP for Metal ICS

	Coef.	**Std. Err.**	**z**	**P>|z|**	**[95% Conf. Interval]**	
Price assigned	-0.0005	0.0000	-11.0600	0.0000	-0.0005	-0.0004
Regression constant	0.2667	0.1333	2.0000	0.0450	0.0055	0.5280
Estimated WTP	578.46				10.06	1391.67

Source: Multi-tier Framework data of Nepal

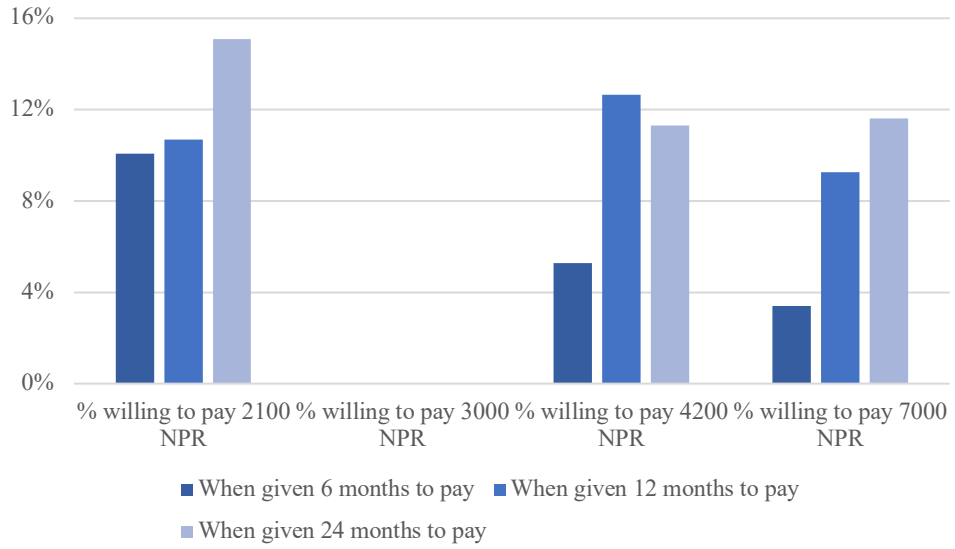
Table 6 summarizes the results for household's willingness to purchase a mini moto at a certain price. Share of households that are willing to purchase a mini moto is even lower than that of a metal ICS. At the lowest price provided by the survey, which is 2100 NPR in local currency (equals to US $20.16 in 2017), only 24.66% of households are willing to purchase a mini moto. When the price provided is at the highest level of 7000 NPR (US $ 67.2 in 2017), only 8.99% of households are willing to pay. Figure 3 shows that when households are given more time to make the payment, slightly more households are willing to purchase a mini moto at the provided price.

Table 6. Percentage willing to pay for a mini moto at different prices

Metal ICS Price (NPR)	2100	3000	4200	7000
% willing to pay	24.66%	0.00%	18.00%	8.99%

Source: Multi-tier Framework data of Nepal

Figure 3. WTP for mini moto when given more time to make the payment



Source: Multi-tier Framework data of Nepal

Table 7 shows the coefficient results of the logit regression of the variable indicating whether the household is willing to take the price on the assigned price. By getting the regression constant (-0.5969) divided by the coefficient of the dependent variable (-0.0002) and multiple -1, we get the estimated WTP for a mini moto is a negative number and is around -2487 NPR (equals to US -$23.88 in 2017). The 95% confidence interval of the estimated WTP is from -2889 to -13796 NPR.

Table 7. Logit model results and estimation of WTP for Mini Moto

	Coef.	Std. Err.	z	P>|z|	[95% Conf. Interval]	
Price assigned	-0.0002	0.0000	-7.3900	0.0000	-0.0003	-0.0002
Regression constant	-0.5969	0.1429	-4.1800	0.0000	-0.8771	-0.3168
Estimated WTP	-2487.14				-2888.86	-1795.74

Source: Multi-tier Framework data of Nepal

5. Discussion

Results of the data analysis of the MTF survey data indicate that both females and males saved time due to the use of clean ICS, with females on average saved 35 minutes a day and males saved 32 minutes a day. Both estimated timesaving for females and males are statistically significant. The results of the DID model shows that there is not a statistically significant time saving difference between females and males. It might be because that clean ICS is a "public" good that benefits all the household members, and it is hard to distinguish the different benefits enjoyed by different household members (Robinette et al., 2020). Another reason might be lack of observations and a much larger sample size is needed.

The data analysis also indicates that people in Nepal have relatively low willingness to pay for ICS. On average, households are only willing to pay around 579 NPR (equals to US $5.55 in 2017) to purchase a metal ICS, while the market price for a metal ICS was 7000 NPR in 2017 (US $ 67.2). For mini moto, the mean WTP is a negative number. The estimation of households' WTP for ICS show that people in Nepal undervalue the benefits of ICS.

Given that people in Nepal saved time and benefit from the use of the ICS, while undervaluing the benefits of ICS and have low willingness to purchase an ICS, other interventions are needed to promote clean cooking energy access in Nepal. One possible path would be trying to first assess demand and then, if there is demand, to promote people's willingness to pay for improved cookstoves (Pattanayak et al., 2019). Another path would be

finding a better financing method for the public or private sector to provide subsidy to ICS or even free ICS.

Making people more aware of the benefits of ICS might be one effective way to increase people's WTP for ICS. Research shows that willingness to pay is reduced by (among other factors) "low awareness of health, economic, and time-savings benefits" and by limited access to finance (Jeuland et al., 2015; Clean Cooking Alliance, 2011). Other research also shows that social marketing messages like "the cookstove can improve health" and "the cookstove can save time and money" could increase adoption rates for improved cookstoves (Lewis et al., 2015). Postponing the payment time might be another way to increase people's WTP (Beltramo et al., 2015).

Development impact bond (DIB) might be one way to serve as a better financing method to promote ICS usage. A DIB is a contract among several different actors with a common and shared development objective. DIB's are relevant here because the outcomes of ICS use are social (e.g., reduced greenhouse gases and pollutants) and quasi-private (e.g., benefits to kids and young mothers not factored into household decisions). Given this market failure, can an exogenous source of finance pay for socially optimal and increased ICS use? Investors provide funds to implement an intervention and here the intervention would be providing ICS. Service providers work to achieve this objective, and outcome funders and external development agencies repay investors their principal plus a financial return if the results are delivered (Alenda-Demoutiez, 2019). DIB is usually a private-private partnership that does not involve government participation, so it is believed to be a sustainable way of financing for public programs and reduce risks for the government (Alenda-Demoutiez, 2019). Social impact bond (SIB) is a similar financing method to DIB, which is also a contract among several actors, but

usually a public–private partnership. Both the DIB and SIB provide with a new and more sustainable way of financing public interventions such as ICS promotion, and help ICS uptake in developing countries where people's WTP is relatively low.

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