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# Examining The Drivers of Sustained Use of Clean Cooking Technologies in Uganda: A Double Hurdle Model Analysis

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**Abstract**

*The paper examines the drivers of the adoption and sustained use of clean cooking technologies in Uganda's households using a double hurdle model. A multi-stage sampling technique was used for this study. Data was collected using a structured questionnaire and 379 households were selected randomly to take part in the study. The findings reveal that most household characteristics are predictors of both clean cooking technology adoption and its sustained use. Technology-related and behavioral factors were found to be strong determinants of sustained use rather than adoption. The study focused exclusively on the urban districts of Kampala, Mukono, and Wakiso, limiting the generalizability of the results to all households in Uganda. Second, the study employs a static analysis, which does not account for the influence of time on sustained use. This study used a double hurdle model to investigate the factors that affect the sustained use of clean cooking technologies in Uganda's households. The results from this study can support policymakers in making informed decisions regarding the sustainability of clean cooking technologies.*

**Keywords:** Adoption; sustained use; clean cooking technologies; Socio-economic factors; Technology specific attributes; Perceived welfare benefits; Energy ladder; double hurdle model

## Introduction

Adoption and consistent use of Clean Cooking Technologies (CCTs) is crucial for reducing household air pollution, enhancing public health and mitigating environmental impacts. However, achieving this remains an ambitious task for most of the developing countries. While 30.5% of the global population lacks access to sustainable and clean cooking fuels and technologies, this issue is even more pronounced in developing countries like Uganda, where over 90% of households are without such access (Bamwesigye *et al*., 2020; Wafula *et al*., 2022). The prevailing reliance on Traditional Cooking Technologies (TCTs) such as the three-stone or mud-based cook stoves fueled by wood, charcoal or animal waste poses major economic, health, and environmental problems. For example, current estimates place the number of people killed each year by indoor air pollution caused by traditional cooking methods at approximately four million with additional annual costs to the global economy of over $2.4 trillion (The Energy Sector Management Assistance Program [ESMAP], 2020). In Sub Saharan Africa, over 739,00 people are reported to die annually due to indoor air pollution related illnesses (WHO, 2017). The use of TCTs also worsens the energy poverty situation and hinders the economic and social development of a developing country, leading to loss of productivity due to poor health and time spent gathering fuel wood at the expense of working or studying (Thakur *et al*., 2019). This burden disproportionately affects both women and girls (CCA, 2019; Jagoe *et al*., 2020).

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According to the Global Alliance for Clean Cook-stoves [GACC] (2014), over 35 million people in Uganda are affected by exposure to cooking stove smoke, with 13,000 people experiencing premature death every year. Diseases related to indoor air pollution such as respiratory infections are the most prevalent health problems after malaria, particularly affecting women and children (Faisal *et al*., 2021). The environmental impact is equally alarming, as Uganda loses over 120,000 hectares of forest cover annually. Around 60% of this deforestation (72,000 hectares) can be attributed to firewood and charcoal burning. With Uganda's population growing at an annual rate of 3.7% and a rise in energy demand of 7.5% every year, the pressure on biomass resources is projected to increase significantly. To reduce the negative effects of TCTs, CCTs have been at the forefront of international and national policy discourse, as evidenced in the Sustainable Development Goal 7 target 7.1.2, which is dedicated to promoting universal access to clean fuels and cooking technologies. Whereas some regions have registered significant progress in the use of CCTs, for example, North America, Europe, Central Asia, the Middle East & North Africa, SSA progress has remained abysmal. Uganda presents an excellent example of the current trends and situations in this regard. CCTs have not been used sufficiently or consistently to determine the degree of displacing TCTs. Incidentally, health impacts related to traditional cooking methods may escalate if substantial counter measures are not implemented promptly (Uganda National Development Plan, [UNDP], 2021).

Against the backdrop, the government of Uganda set a target to reduce national wood consumption by 40% by 2030 (Gebru & Elofsson, 2023). To this end, the Ugandan government has rolled out numerous interventions aimed at achieving widespread access to clean cooking solutions. Specifically, The Uganda Vision 2040 aims to ensure universal access to clean, affordable, and reliable energy sources and the National Development Plan III aims to reduce the proportion of the population using TCTs from 85% to 50% by 2025 (Ministry of Finance, Planning, and Economic Development [MFPED],2019). Furthermore, the Electricity Regulatory Authority (ERA), through UMEME – Powering Uganda, introduced a cooking tariff called "Fumba ne yaka" designed to incentivize the use of electricity for cooking. Non-government organizations such as SNV, the World Bank, and GIZ are also playing crucial roles in promoting the uptake of clean cooking technologies. Despite these efforts, Uganda continues to trail behind its East African neighbors in terms of the population percentage utilizing CCTs (UBOS, 2018; IEA, 2021).

Empirical studies addressing the concept of sustained use in relation to CCTs are just beginning to emerge as literature has been awash with studies on adoption with little emphasis on sustained or continuous use. More so, available literature regarding sustained use of CCTs remains narrow and inconclusive. Several studies in Uganda have explored the concept of sustained use but within limited scope. For instance, Lwiza *et al*. (2017) conducted an analysis of biogas technology dis-adoption in Central Uganda, utilizing cross-sectional data gathered from the Luwero and Mpigi districts only. Notably, this study looked at biogas technology as a representative of clean cooking technologies in Uganda. Similarly, Namugenyi *et al.* (2023) evaluated the entrepreneurial opportunities inherent in biogas energy, which could potentially enhance energy supply and access within developing nations. In addition, Ogwang *et al.* (2021) investigated the suitability of digestate from anaerobic digestion of cow dung, pig dung, and human waste feedstock as a solid fuel for thermal applications. Furthermore, Namagembe *et al*. (2015) looked at the effects of select behavior change interventions on the purchase and the correct and consistent use of a locally fabricated top-lit updraft (TLUD) stove in Uganda. Sundararaman *et al.* (2016) analyze the adoption of improved cook-stoves specifically the locally manufactured tier 2 using stove use monitors. These studies, however, primarily target a single type of clean cooking technology and are largely focused on rural households. The exploration of urban and semi-urban household contexts remains scant (Martin *et al*., 2013; Namagembe *et al.,* 2015), leading to a knowledge gap in understanding and predicting household behaviours. To address these shortcomings, the present study takes a comprehensive approach, examining all types of clean cooking technologies utilized by households in both urban and semi-urban areas in Uganda.

**Motivation and Contribution of the Study**

The use of CCTs has received considerable attention in recent years, earning recognition as a viable approach in both scholarly and practical settings due to their associated health, environmental, and societal benefits. Despite the evolution and emergence of new CCTs, understanding their sustained use beyond initial adoption still requires further insight (Tigabu, 2017; Ang'u *et al*.,2023; Nabukwangwa, 2023). Existing research on CCTs has largely concentrated on their initial acceptance within households, placing more emphasis on the factors that induce households to adopt these technologies initially rather than those that influence their continued use (Gill-Wiehl *et al.,* 2021). Consequently, the success of CCTs has been predominantly gauged by the number of clean stoves disseminated, while studies focusing on their long-term viability remain scarce (Puzzolo *et al.,* 2016). This study, therefore, aimed to evaluate the determinants of the sustained use of clean cooking technologies at the household level using the double hurdle model. The analysed technologies vary from household cooking technologies that burn solid fuels more efficiently, often called "Improved" [Biomass] Cookstoves (ICS) and stoves that burn clean fuels, including Liquefied Petroleum Gas (LPG) stoves, electricity stoves, ethanol, and biogas.

The main contribution of this study is the holistic approach employed, which considers all the cooking technology options accessible and utilized by a household, unlike previous studies that have mainly focused on a particular technology type. Secondly, the study identifies and provides arguments for the factors that affect adoption and continuous use of CCTs within a household using a double hurdle model. Hence the study sought to find answers to the following;

Q1. What are the drivers of adoption and sustained use of clean cooking technologies in Uganda's household?

Q2. Are the drivers of sustained use different from those of the adoption of Clean Cooking Technologies in Uganda's households?

**Review of Literature**

**Theoretical Foundation**

This study is based on the Energy Ladder Model (ELM) and Fuel/stove stacking hypotheses. The Energy ladder (Leach, 1992) posits that households transition to cleaner cooking alternatives as their income increases. The Energy ladder hypothesis portrays households as neoclassical utility-maximizing consumers who, as their income increases, given a variety of energy options, will choose a cooking energy that is less time consuming, convenient, and less hazardous to the environment, even if it is more expensive (Meried, 2021). Hence the model assumes that increasing socioeconomic status is accompanied by a linear, smooth, systematic, and unidirectional progression leading to a movement from traditional cooking solutions to more clean, efficient cooking solutions (Leach, 1992; Meried, 2021). Non-income factors are thought to have little effect on fuel or stove selection. Although this model has had a significant influence in the energy transition literature, it has been criticized on two grounds: first, affordability is a significant but only a partial driver motivating households to fuel/stove switching (Lewis & Pattanayak, 2012); and second increase in income might motivate households to adopt cleaner cooking systems; however, there is strong evidence to show that solid fuels are never completely abandoned (Ruiz-Mercado *et al*., 2011).

Contrary to the Energy Ladder hypothesis, researchers have shown that households use multiple fuels and stoves, known as fuel/stove stacking, as their income increases instead of moving up the energy ladder (Masera *et al*, 2000; Ruiz-Macerdo & Masera, 2015; Shankar *et al*., 2020). The energy stacking model assumes that income is not the only determinant of household transition to more efficient energy sources, but that household preferences can also have an impact. As a result, climbing the energy ladder does not mean completely abandoning any fuel/stove (Han *et al*., 2018). There are three primary factors that contribute to fuel stacking: the high cost of modern energy sources, cultural preferences, and the desire to avoid complete dependence on a single fuel that may be vulnerable to price and supply.

**Empirical Review**

Empirical studies investigating the factors that affect adoption and sustained use of CCTs have produced inconsistent findings (Wolf *et al*., 2017; Seguin *et al*., 2018; Jagger *et al*.,2019; Adane *et al*., 2020; Asgele *et al*., 2020; Karanja & Gasparatos, 2020). The degree to which socioeconomic, technological, and environmental factors impact the selection of cooking equipment in households remains a topic of discussion and lacks uniformity. Furthermore, prior research has failed to consider alternative clean energy technologies and fuels that are utilized within households in less developed countries. Instead, their focus has primarily been on improving cook stoves.

**Socioeconomic Factors and Sustained Use of CCTs.**

We adopted Pillarisetti *et al*. (2019) conception of the sustained use of CCTs as the continuous usage of novel food preparation know-how beyond the preliminary of uptake. Continuous use of CCTs in communities persists and is a major challenge that should be addressed expeditiously (Tigabu, 2017; Shupler *et al*., 2021; Ang'u *et al*., 2023; Katutsi *et al*., 2024; Nabukwangwa, 2023). Empirical evidence has shown that households continue to rely on traditional cooking technologies for their cooking needs even in the presence of clean cooking technologies. Sustainable transition from traditional to CCTs has been linked to a range of socioeconomic attributes that affect communities disproportionately across different income levels (Armstrong *et al*., 2021; Emmanuel & Isaac, 2021; Kumar *et al*., 2022; Vigolo *et al*., 2018; Katutsi *et al*., 2023). Community barrazas have been associated with effective information dissemination models both in rural and urban areas, which in effect, influence member's attitudes and behavior is sustained use of CCTs (Armstrong *et al*. 2021). Both economic and social imperatives when well nurtured support a sustainable transition from conventional to contemporary cooking technologies (Kuhe & Bisu, 2020). For instance, localities with particular information centers, identifiable retail centers, and well-organized distribution networks are more likely to encourage households' likelihood to remain utilizing CCTs (Mahbub *et al.*, 2020). Ostensibly, communities' knowledgeable about the strategic value of sustained use of CCTs are most likely to cause a positive change in the behavioral attributes of their neighborhood (Broadhouse *et al*., 2020). When community members share affirmative proficiencies among themselves with regard to new technologies, they tend to associate with the practice (Bach *et al.*, 2020). For example, Barua (2018) posits that it becomes increasingly possible to rally women behind some form of action through group methodology.

Additionally, another socioeconomic aspect that influences the sustained use of CCTs is the aspect of Gender roles. Gender roles refer to the societal expectations, norms, and behaviors associated with individuals based on their perceived or assigned gender (Fingleton-Smith, 2018). These depict shared roles related to gender premised on the social constructivism of the members (Fong & Wyer, 2012). The conventional communities, where the female gender has become part and parcel of the labor market, domestic bills are now a shared responsibility between couples (Lieu *et al.,* 2020). It is now common knowledge that couples jointly agree to finance household basics on a voluntary model, which in a way, augments the relationships in the long run (Adams *et al.,* 2023; Fischer *et al.*, 2018). In the same vein, sharing roles among household stakeholders including children with regard to domestic chores does not only strengthen social bonding but also sheds off financial burden on individuals members (Kumar *et al.,* 2016). Extant works on clean cooking projects attach certain responsibilities to specific gender premised on cultural range of roles in a household (Ochieng *et al*., 2021). It is important to note that female gender are in most times the main users of food preparation solutions, and leveraging them in energy transition effort is critical for project success *(*Leary *et al*., 2021). Fundamentally, the energy transition advocates are likely to score high on adoption and sustained use of CCTs if they package their messages premised on gender roles. A study by Ali and Khan (2020) postulates that modeling energy transition promotional campaigns based on role play encourages mindset change among gender categorization. Hence, we hypothesize as follows:

$H_1$: There is a positive relationship between socioeconomic factors and sustained use of CCTs.

**Technology-Specific Attributes and Sustained Use of CCTs**

Several technological characteristics related to the sustainable utilization of CCTs have been thoroughly examined through empirical research. These factors encompass convenience, social repute, cultural compatibility, and perceived benefits. Traditional cooking practices are deeply rooted in numerous societies. Troncoso *et al*. (2011) found that technologies which align with regional culinary cultures and dietary preferences are more likely to be adopted and consistently used. Ardrey (2020) argues that comfort and convenience, together with other factors, play a significant role in motivating middle-income households to adjust to CCTs. The level of customer convenience offered by new innovations will influence whether users will exhibit recurrent purchasing behavior or not (Otieno, 2019). Consumer behavior is shaped not only by the availability and price of a technology, but also by how convenience it is assumed to be in terms of obtaining it and using it (Vigolo *et al*., 2018).

Furthermore, the influence of peer networks and community leaders has a significant role in determining the level of acceptance and ongoing utilization. Programs that incorporate community influencers tend to have higher rates of persistent use (Lewis & Pattanayak, 2012). In close-knit communities, the process of collectively adopting specific behaviours can create a sense of social pressure to conform. This can result in heightened levels of persistent utilization as individuals strive to maintain their social standing (Pattanayak *et al*., 2019). Relatedly, a study conducted by Jürisoo *et al*. (2018) demonstrates that consumers of CCTs have a strong inclination to persist in using the device due to the enhancement of their social standing. Irrespective of the ranking of individual factors, Kooser (2014) discovered that the perceived social status within a society significantly influences the sustainable adoption of a certain technology. Goswami *et al*. (2017) consistent research revealed a strong correlation between clean cooking practices and an individual's position on the energy ladder. This finding encourages users to prioritize the maintenance of their current circumstances. The primary motivation for fully adopting CCTs is partly influenced by the social standing within the community, alleviating the ongoing responsibilities placed on women and children, and advancing gender equality (Karanja & Gasparatos, 2019). Hence, we hypothesize as follows:

$H_2$: There is a positive relationship between Technology specific attributes and sustained use of CCTs.

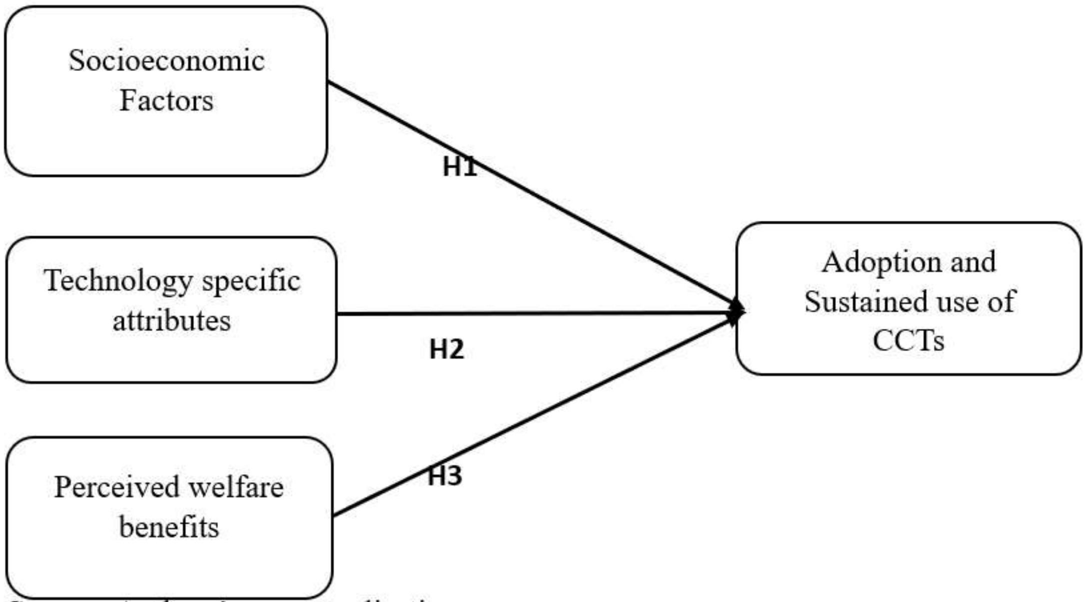
**Perceived Welfare Benefits and Sustained Use of CCTs**

We use health, environmental, and fuel efficiency advantage to review the variable perceived welfare benefits of CCTs. It has been observed that reduction in air pollution is one of the factors that motivates households to use clean cooking technologies as an alternative household energy source (Phillip *et al*., 2023). One reason why several communities have embraced novel cooking styles is their positive effects on human health including lower acute respiratory infections among children under five years (Geremew *et al*., 2020). Furthermore, clean air emissions from clean cooking stoves control the effects of chronic obstructive pulmonary disease in adults (Shankar *et al*., 2020). The enormous health benefits cited have attracted both public and private sectors to find the best interventions that trigger and sustain the uptake of CCTs. Improved health living arising from clean technologies comes with attendant benefits associated with women and children; who often find themselves fending for biomass energy sources (Gebreegziabher *et al*., 2018). A new generation of clean cooking technologies has improved the quality of life of women and are increasingly becoming more productive in commercial activities thereby contributing significantly to family welfare (Lindgren, 2020; Phillip *et al*., 2023). Making CCTs part and parcel of cooking culture reduces fuel-related costs and improves family livelihood (Katutsi et al., 2023; Durao, *et al*., 2020). In relation to the above, a study by Barua (2020) advocates for adoption and sustained use of improved cooking technologies to free more space to women for better child care (Goswami, *et al*., 2017). Health considerations are at the top of the agenda to cause a fundamental transition to CCTs, especially in developing countries with significantly high death rates.

The quality of future generations is subject to the current environmental conservation interventions linked to sustained use of CCTs. The prolonged use of CCTs stems from the realization of environmental conservation benefits for future generations ( Phillip *et al*., 2023). Mitigation of greenhouse gases has direct environmental conservation benefits which have attracted government to support in the sustained use of CCTs (Jeuland & Pattanayak, 2012). Reduction in air pollution, preservation of the biosphere, protection of endangered species, and conservation of natural resources have been cited as motivators for the sustainable use of modern cooking technologies (Geremew *et al*., 2020). It has been popularly held that reduction in environmental pollution and positive climate change are twin effects achievable through the sustained use of clean cooking (Gebreegziabher *et al*., 2018). The most efficient energy conservation mechanisms have been a major reason why most households in some communities have continuously practiced fuel-stacking behavior (Phillip *et al*.,2023). The quest for energy conservation mechanisms has motivated families to move away from the traditional cooking system which has of recent become expensive due to deforestation (Jeuland & Pattanayak, 2012). The continuous use of innovative household cooking technologies results into fuel efficiencies compared to conventional stoves thereby reducing household expenditures (Geremew *et al*., 2020). The correct and consistent use of clean technologies maximize energy consumption compared to conventional styles (Gebreegziabher *et al*., 2018). Empirical studies have alluded to fuel efficiency, speed of cooking, money savings, and reduced smoke emissions; all of which motivate the sustainable use of clean cooking solutions (Namagembe *et al*., 2015). Similar findings by Sundararaman *et al.* (2016) reveal that fuel efficiency was the most cited as the reason to why households purchase improved cookstoves. Hence, we hypothesize as follows:

$H_3$: There is a positive relationship between Perceived welfare benefits and sustained use of CCTs.

**Conceptual Framework**
The conceptual framework shows the relationship between socioeconomic factors, technology specific attributes, perceived welfare benefits and the sustained use of CCTs as depicted in Figure 1. It was derived from theory and the existing literature.




**Source.** Authors' conceptualisation

**Figure 1**. Relationship between socioeconomic factors, technology specific attributes, perceived welfare benefits and the sustained use of CCTs.

**Methods**
**Design, Population and Sample**
This study presents empirical findings from a quantitative investigation of households in three urban districts of Greater Kampala Metropolitan Area (GKMA) namely; Kampala, Wakiso and Mukono located in the central region of Uganda. The choice of the three districts was based on the assumption that they have relatively better access to clean cooking technologies compared to other regions in Uganda (UBOS, 2023). The study adopted a cross-sectional quantitative research design which is effective in addressing a phenomenon at a single point in time (Hair *et al*., 2014).

**Sampling and Data Collection**
The focus of this study was on urban areas that have a significant proportion of households who use Clean cooking technologies. A multistage sampling procedure was used to select respondents for the study. The first stage involved the purposive selection of three districts of Kampala, Mukono and Wakiso. The second stage involved a systematic selection of 21 villages from each district with Probability Proportional to size (PPS). During this stage, an exhaustive list of all households in each sampled village was compiled. These included both users and non-users of CCTs.Then, a simple random sampling method was used to select 384 households for the study. Out of the 384 households that were included in the sample, 379 were considered valid; representing 98.7% response rate. The data were gathered by the distribution of questionnaires to families. Research assistants participated in a comprehensive one-day

training session focused on data collection and ethical considerations. The questionnaire was segmented into sections covering demographic information, socio-economic factors, technology-specific qualities, and perceived welfare benefits. In order to ascertain the respondents' complete comprehension of the questions, a preliminary survey was conducted with 112 participants in one of the districts. Following the pretest, the questionnaire underwent slight revisions to address the identified concerns. The district in which the pretest occurred was identified and removed from the actual data collection process

**How the Dependent Variable was Measured and Operationalized**

The dependent variable is sustained use by those households that owned and used clean cooking technologies for the past twelve months. Sustained use was approximated by the frequency of stove use measured by how often the stove was used. We acknowledge that there are other measures of clean cooking technology use that could have been used, for example, the Stove Use Monitors (SUMs) (See Ruiz-Mercado *et al*., 2012; Lambe *et al*., 2020). SUMs can objectively quantify stove use and counts of the daily meals using records of temperature signals, heat flux, gas concentration, and other parameters (Ruiz-Mercado *et al*., 2012). However, these are quite expensive and would have been quite challenging to monitor for our research project. Evidence suggests that surveys can also provide reasonably consistent data with SUMs especially in resource-poor research settings (Ruiz-Mercado *et al*., 2013; Tigabu, 2017). Additionally, due to the lack of precise data on the time stove users spend on individual cooking activities, it was also not plausible to record the dependent variable using the number of hours a stove was used.

In light of the above, stove usage on a particular day was used to approximate sustained use. Since cooking is a daily task, we used the number of times a clean cooking technology was used over a reference period of 30 days. However, in order to reduce the bias from recall decay and telescoping, a short reference period of 7 days was used. The respondents were first asked about the type of cooking technologies they owned. Those who owned clean cooking technologies were asked if they had at least owned them for the past year. This was then followed by the question of how often they had used their clean cooking technologies in the past week. The number of days reported in the past week was then converted to a 30-day monthly basis using a conversion factor of 4.28571. In other words, the number of days reported for the past week was multiplied by the conversion factor, and the values were rounded off to the nearest whole number.

Our sample data contains some households that exclusively owned traditional cooking technologies. These households, therefore, recorded zero ownership and zero days of clean cooking technology usage. In contrast, we recorded daily usage of 30 days a month for the households that owned only clean cooking technologies. Additionally, some households owned both clean and traditional cooking technologies (henceforth stackers). Because of stacking, some households did not use their clean cooking technologies regularly. Hence, these reported zero values of clean cooking technology usage despite owning them, while others used them but less frequently. Consequently, our outcome variable is a count-dependent variable measured only at a few data points that reflect the days the stoves were used over the 30-day reference period.

**The Econometric Model**

We applied a double hurdle model (DHM) because the dependent variable measuring sustained use is a discrete count variable observed over a limited range of some positive values for the adopters. Most applications of the double hurdle model have used continuous data, and count data double hurdle models are only recent. These started with the model proposed by Mullahy (1986), which was later extended by Shonkwiler and Shaw (1996). The common Ordinary Least Squares (OLS) estimation procedure is primarily for continuous data but not discrete. It is also not appropriate for positively skewed count data, like the data used in the current study. Applying OLS to such data may lead to misleading results, such as non-zero mean values and incorrect standard errors. Generally, the limitation of OLS regression is that it does not account for the data being truncated at zero. The skewness in the data violates the normality of residuals, a critical validity assumption of OLS estimates. Moreover, the error term would be correlated with the independent variables, violating the homogeneity of variance of the residuals (Gardner *et al*., 1995). In this regard, the most appropriate approach is based on maximum likelihood estimation, and the standard models applied to such data are the Poisson, negative binomial, and double hurdle models.

The choice among the three models depends on the nature and interpretation of the zeros in the data. The Poisson model assumes that all the zeros come from the same data-generating process, implying that the processes generating zero adoption and positive usage are the same and the same variables influence the two decisions. It also makes a strong assumption of equidispersion, which means that the dependent variable's conditional mean and conditional variance are equal. However, there may be overdispersion in the presence of unobserved heterogeneity from differences in household habits and behavior. Heterogeneity can cause the variance to exceed the mean (Cameron & Trivedi, 2010). The Negative Binomial (NB) model, on the other hand, is a generalization of the Poisson that takes into account any overdispersion by allowing for a variation between the mean and variance. It, therefore, introduces a heterogeneous parameter in the model that is not related to the regressors. The null hypothesis is that the coefficient on this parameter is zero; if rejected, there is overdispersion.

Contrary to the Poisson and NB, the DHM assumes that the zeros and the positive outcomes are from different data-generating processes (Cameron & Trivedi 1998; 2010). The DHM has two parts implemented in two stages. The two parts of the model are assumed to be independent, and consequently, they can be run separately. The first stage estimates a probit or logit model that determines whether or not a household is an adopter, and the second part is a zero-truncated Poisson or zero-truncated NB model for only the adopters. The choice of the second model is dependent on the overdispersion test from the Poisson and NB models. Typically, the second part will be a zero-truncated NB in cases of overdispersion where the conditional mean of the dependent variable's distribution is different from its conditional variance. We depict the modelling process in Equations 1 to 4.

The first stage (adoption decision):
$yi$ is the dependent variable in the first stage represented by clean cooking technology ownership, and the probability of a zero outcome is given as:

$$P_1( y_i = 0|Z_i) = f_1(0) \qquad j = 0 \tag{1}$$

While the probability of a positive outcome is:

$$P_2(y_i = j|Z_i, X_i) = 1 - f_1(0) \qquad j > 0 \tag{2}$$

Where $Zi$ and $Xi$ and vectors of covariates that affect the first and second-stage decisions, respectively.
Hence the probability function of the double hurdle model is specified as follows:

$$P(y_i = j) = f(y_i) = \begin{cases} f_1(0) & j = 0 \\ \frac{1-f_1(0)}{1-f_2(0)} f_2(y_i) & j > 0 \end{cases} \tag{3}$$

Where the positive counts in the second hurdle from the truncated density are stated as:

$$f_2(y_i|y_i > 0) = \frac{f_2(y_i)}{[1-f_2(0)]} \quad (4)$$

Specifically, $f_1(0)$ is the density function corresponding to a zero-probability response and $\frac{f_2(y_i)}{1-f_2(0)}$ when the response is positive.

The conditional mean of the double hurdle model is specified as follows:

$$E(y_i|Z_i, X_i) = P_1(y_i > 0) * E(y_i|Z_i, X_i; y_i > 0) \quad (5)$$

And the likelihood function is given as:

$$L = \prod_{y_i=0} f_1(0) \prod_{y_i>0}[1 - f_1(0)] \prod_{y_i>0} \left[\frac{f_2(y_i)}{1-f_2(0)}\right] \quad (6)$$

The above likelihood function gives rise to the log-likelihood function stated as:

$$ln\, L = \sum_i 1(y_i = 0) \ln[P_1(y_i = 0|Z_i, X_i)] + \left(1 - 1(y_i = 0)\right) * \ln[1 - P_1(y_i = 0|Z_i, X_i)] + \sum_i \left[\left(1 - 1(y_i = 0)\right) * ln[P_2(y_i = j|Z_i, X_i)]\right] \quad (7)$$

The model was implemented using a maximum likelihood estimation procedure in STATA 15 software, generating maximum likelihood estimates for the two parts. In order to assess the effect of the explanatory variables on the dependent variable, we calculate the marginal effects of the explanatory variables. The marginal effect of a particular explanatory variable is derived by differentiating the combined terms of the conditional mean in Equation 5 with respect to that particular variable. However, since the two terms that make up the conditional mean correspond to the two different parts of the model, we calculated the marginal effects of each component separately (Cameron & Trivedi, 2010).

The empirical model can be implicitly specified as follows:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + ... + \beta_{11} X_{11} + \varepsilon$$

Where;

$Y$ = dependent variable (1 for user and 0 for non-user of a clean cooking technology), $X_1$- $X_{11}$ are vector of independent variables (socioeconomic factors, technology specific attribute and perceived welfare benefits) that might influence the adoption decision, $\beta_0$ = constant term $X_1$- $X_{11}$ = coefficients of independent variables estimated, and ε = error terms. Truncated regression was used in the second step to determine the factors that influenced the intensity of the use of CCTs.

$$Z = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + ... + \beta_{11} X_{11} + \varepsilon$$

Where;

$Z$ = intensity of use of a clean cooking technology), $X_1$- $X_{11}$ are vector of explanatory variables that may influence the intensity of use of CCTs, $\beta_0$ = constant term $X_1$- $X_{11}$ = coefficients of independent variables estimated, and $\varepsilon$ = error terms.

The definition of explanatory variables used in the double hurdle regression is shown in Table 1.

**Table 1:** Definition of variables for the double-hurdle model

| Variable name | Variable Description | Measurement | Expected sign | |
|---|---|---|---|---|
| **Dependent variable** | | | **Fist stage** | **Second stage** |

| | | | | |
|---|---|---|---|---|
| Sustained use. | Frequency of use of the clean cooking technology. | The number of days the respondent reported to have used the stove in a recall period of 7 days, multiplied by the factor 4.28571 for conversion to a 30-day reference period basis. | | |
| **Independent variables** | | | | |
| Age | Age of household head | 1 if 18-25, 2 if 26-45, and 3 for 46 and above | + | + |
| Gender | Sex of the household head | 0 for female and 1 for male | | |
| Employment status | Household head employment status | 0 if unemployed and 1 for employed | + | + |
| | | | | |
| Household size | Number of household members | 0 if below 9 and 1 if above 9 members | - | - |
| | | | | |
| Household income | Income of the household head | Approximated by household expenditure and it is measured as:<br>1 if below500,000/=,<br>2 if 500,001-1,000,000<br>3 if 1,000,001-1,500,000<br>4 if 1,500,001 & above | + | + |
| Education | Education of household head | 1 if primary and below<br>1 if secondary<br>3 if tertiary<br>4 if university | + | + |
| Residential ownership | Ownership status of the residence | 0 owned<br>1 rented | + | + |
| Marital status | Marital status of household head | 0 married<br>1 single | + | + |
| Gender roles | Whether household decisions are made by the husband, wife, or jointly. | 0 if joint<br>1 if wife<br>2 if husband | + | + |
| Customer satisfaction | Satisfaction from using the stove | Binary; 1: satisfied<br>0: not satisfied | + | + |
| Environmental concerns | Concern related to emissions | If showing environmental concern =1 otherwise = 0 | + | + |
| Compatibility with cultural needs | Meets cooking needs | If compatible =1 otherwise =0 | + | + |
| Convenience | Easy to use, fast, | If convenient =1 otherwise=0 | + | + |
| Fuel efficiency | The fraction of energy released in the process of combustion | If saves fuel=1 otherwise=0 | + | + |
| Health concerns | Reduced exposure to smoke | Reduces smoke=1 otherwise=0 | + | + |

| | | | | |
|---|---|---|---|---|
| Neighborhood influence | Peer effect from neighbors and surroundings | If influenced by neighborhood =1 otherwise =0 | + | + |
| Social reputation | Social Perception of the stove user | Perceive social prestige=1 otherwise=0 | + | + |

**Results and Discussion**

**Descriptive Statistics**

The test for multicollinearity showed no significant problem. Only two variables had variance inflation factor (VIF) values above 5, with 7.75 as the highest. However, as observed in Figure 2, the distribution of the dependent variable, sustained use (measured by the number of days) is not normally distributed. It depicts substantially large values at the upper limit as well as a significant number of zeros at the lower limit; hence, the application of a count data model.

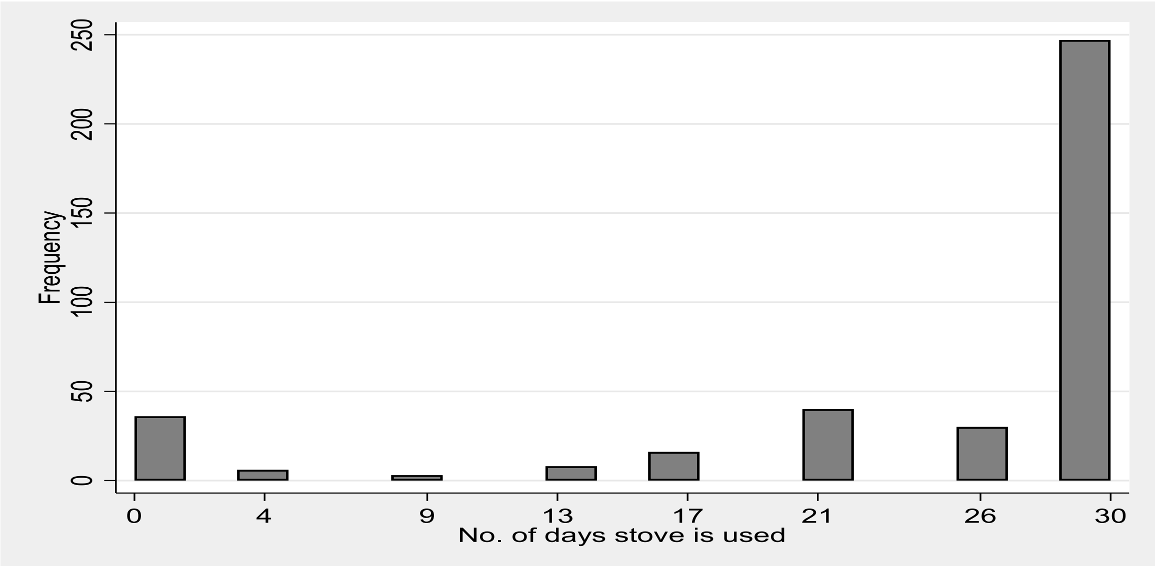



**Figure 2.** Histogram of "days used" as the dependent variable.
Source: Primary data

The study area was mainly urban and peri-urban. Cooking technologies in the sample included the three-stone open fire, traditional cooking stoves, improved stoves, electric stoves, biogas stoves, LPG stoves, liquid fuel stoves, and solar cookers. Overall, LPG was the most common, constituting 24% of all the stoves, followed by improved cookstoves (23%), Traditional stoves(18%), electric (15%) while solar cookers (5%) and liquid fuel stoves (4%) were the least observed (See Figure 3). All stoves were grouped into clean and traditional categories. The three-stone open fire and traditional cooking stoves belong to the traditional category, while the remaining six were classified as clean cooking technologies. As portrayed in Figure III, the majority of the households in the sample (64%) had clean cooking technologies compared to only those that exclusively owned traditional cooking technologies (6.5%). However, it is also evident that a significant number (29.5%) used a combination of traditional and clean cooking technologies (they stacked).

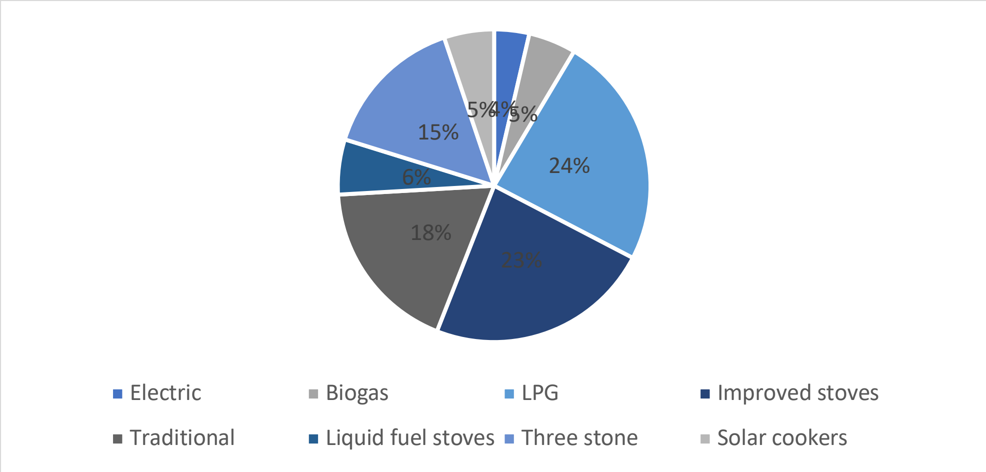



**Figure 3.** Distribution of cooking technology types among traditional use, clean cooking technologies use, and stacked.
Source: Primary data

As shown in Table 2, a significant number of respondents (70.21%) were in the age range of 26 and 45 years, 10.36% were between 18 and 25 years, and 19.43% were above 45 years. We also observed that those between 26-45 years constitute 70.75% of the households that exclusively owned clean cooking technologies, while younger and older-headed households account for 14.17% and 15.38%, respectively. A majority (96%) of the interviewed household heads to have attained formal education, that is, secondary level and above. A significant number of those headed by the highly educated with tertiary and university education levels were observed to own clean cooking technologies. While "Primary and below" were not exclusive owners of traditional stoves, they are stackers owing both the traditional and clean cooking technologies.

**Table 2. Distribution of age and cooking technology type used**

| Age | Clean cooking technology | Stacking | Traditional exclusively | Total |
|---|---|---|---|---|
| 18-25 | 35 | 5 | 0 | 40 |
| | 14.17% | 4.39% | 0% | 10.36% |
| 26-45 | 174 | 78 | 19 | 271 |
| | 70.45% | 68.42% | 76% | 70.21% |
| 46 and | 38 | 31 | 6 | 75 |
| | 15.38% | 27.19% | 24% | 19.43% |
| **Total** | **247** | **114** | **25** | **386** |
| | **100%** | **100%** | **100%** | **100%** |

**Double Hurdle Model**

We estimated a double hurdle model with a probit regression in the first part and a zero-truncated NB model for the second part. This choice is validated by the overdispersion test in both the Poisson and NB models. A t-test on the overdispersion coefficient of 0.348 from the auxiliary regression of the Poisson model rejected the null hypothesis of the variance being equal to the mean at a 1 % level of significance. Additionally, the NB overdispersion alpha parameter of 0.330 was also significant and close to the Poisson overdispersion coefficient. Moreover, these are further corroborated by the zero-truncated NB overdispersion parameter of 0.280 presented in Table 3 and the robust checks, as reported in the sub-section of diagnostic and robust tests.

Table 3 presents the Maximum Likelihood estimates from the two parts of the double hurdle model. While these estimates are not easily interpreted as OLS results, the signs on the coefficients can give an intuition about the effect of the variable. For example, the age and gender of the household's head, incomes, gender roles played by spouses, the fuel efficiency of the stoves, social reputation, and neighborhood influence increase the likelihood of adopting clean cooking technologies. Nevertheless, we observe a likely variation in the effect of some variables between the two models. Particularly, customer satisfaction, convenience in use, compatibility with cultural needs, and perceived safety of the stove increase the frequency of use decision than the decision to obtain the stove. Our detailed discussion is, however, based on the marginal effects presented in Table 3.

**Table 3. Maximum Likelihood estimates of the Double Hurdle model**

| | | **Participation model** | | **Sustained use (Count) model** | |
|---|---|---|---|---|---|
| | Variables | Coefficients | Standard Errors | Coefficients | Standard Errors |
| Age of household head | | | | | |
| | 26-45 years | 0.480*** | (0.158) | 0.014*** | (0.003) |
| | 46 and above | 0.035*** | (0.012) | 0.008*** | (0.002) |
| Gender of household head | | | | | |
| | female | 0.053*** | (0.013) | 0.019* | (0.010) |
| Employment status | employ | | | | - |
| | employed | 0.015** | (0.007) | 0.055*** | (0.015) |
| Household size | | | | | - |
| | Above 9 | -0.601* | (0.307) | -0.057* | (0.034) |
| Income of household head | | | | | |
| | 500,000 - 1,000,000 | 0.017*** | (0.006) | 0.044*** | (0.016) |
| | 1,000,001- 1,500,000 | 0.362*** | (0.110) | 0.013*** | (0.003) |
| | 1,500,001 & above | 0.108*** | (0.019) | 0.004*** | (0.001) |
| Education of household head | | | | | |
| | Secondary | 0.374** | (0.179) | 0.116* | (0.065) |
| | Tertiary | 0.207* | (0.121) | 0.109** | (0.045) |
| | University | 0.158*** | (0.038) | 0.123*** | (0.035) |
| Residential ownership | | | | | |
| | Rent | -0.090** | (0.040) | -0.020 | (0.026) |
| Marital status | | | | | |
| | Single | 0.108*** | (0.035) | 0.059*** | (0.013) |
| Gender roles | | | | | |
| | Wife | 0.082*** | (0.025) | 0.006* | (0.004) |
| | Husband | -0.14* | (0.075) | 0.008*** | (0.002) |
| Behavioral factors | | | | | |
| | Customer satisfaction | 0.062* | (0.0325) | 0.009*** | (0.001) |
| | Environmental concerns | 0.112 | (0.076) | 0.006 | (0.009) |
| | Compatibility with cultural needs | 0.113 | (0.072) | 0.009*** | (0.003) |

| | | | | |
|---|---|---|---|---|
| Convenience | 0.021** | (0.010) | 0.005*** | (0.001) |
| Fuel efficiency | 0.031*** | (0.004) | 0.003*** | (0.001) |
| Health concerns | 0.074 | (0.066) | 0.002* | (0.001) |
| Neighborhood influence | 0.099*** | (0.020) | 0.010*** | (0.003) |
| Perceived safety | 0.126** | (0.056) | 0.016*** | (0.005) |
| social reputation | 0.229*** | (0.071) | 0.007** | (0.003) |
| _cons | 0.643* | (0.362) | 2.168*** | (0.293) |
| | | | | |
| /lnalpha | | | -1.191*** | (0.121) |
| alpha | | | 0.280*** | (0.028) |

Robust standard errors in parentheses and significance levels are at: *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

**Source.** Estimates from the DHM

In order to clearly assess the effect of the explanatory variables on the dependent variable, we calculated the marginal effects of these variables for each part of the model, and these are presented in Table 4. The marginal effects for continuous independent variables are interpreted as the effect on the conditional mean of the dependent variable with respect to a small change in these variables. In contrast, the marginal effects for binary or categorical independent variables represent the proportional change in the conditional mean for a given change in one category of a binary or categorical explanatory variable relative to the reference category while holding other factors constant. Our presentation and results discussion follow the latter interpretation since all the independent variables are categorical.

**Table 4. The marginal effect of the participation (1st hurdle) and sustained use (2nd hurdle) models**

| | | Participation model **(2nd hurdle)** | | Sustained use **(2nd hurdle)** | |
|---|---|---|---|---|---|
| | Variables | Coefficients | Standard Errors | Coefficients | Standard Errors |
| Age of household head | | | | | |
| | 26-45 years | 0.180*** | (0.030) | 0.380*** | (0.122) |
| | 46 and above | 0.016*** | (0.002) | 0.221*** | (0.054) |
| Gender of household head | | | | | |
| | female | 0.007*** | (0.001) | 0.503 | (0.630) |
| Employment status employ | | | | | - |
| | employed | 0.002** | (0.001) | 1.527*** | (0.497) |
| Household size | | | | | - |
| | Above 9 | -0.116* | (0.063) | -1.499 | (1.468) |
| Income of household head | | | | | |
| | 500,000 - 1,000,000 | 0.012*** | (0.003) | 1.184*** | (0.289) |
| | 1,000,001- 1,500,000 | 0.043*** | (0.011) | 0.356*** | (0.112) |
| | 1,500,001 & above | 0.018*** | (0.005) | 0.101*** | (0.027) |
| Education of household head | | | | | |
| | Secondary | 0.033* | (0.020) | 2.973* | (1.740) |
| | Tertiary | 0.019* | (0.011) | 2.782** | (1.224) |
| | University | 0.011** | (0.005) | 3.157*** | (1.011) |

| | | | | | |
|---|---|---|---|---|---|
| Residential ownership | | | | | |
| | Rent | -0.013 | (0.044) | -0.541 | (0.703) |
| Marital status | | | | | - |
| | Single | 0.015*** | (0.003) | 1.603*** | (0.523) |
| Gender role | | | | | |
| | Wife | 0.011*** | (0.002) | 0.168* | (0.090) |
| | Husband | -0.091 | 0.143 | 0.248*** | (0.049) |
| Behavioral factors | | | | | |
| | Customer satisfaction | 0.009 | (0.066) | 0.239*** | (0.077) |
| | Environmental concerns | 0.016 | (0.072) | 0.161 | (0.239) |
| | Compatibility with cultural needs | 0.014 | (0.103) | 0.229*** | (0.039) |
| | Convenience | 0.003** | (0.001) | 0.138*** | (0.031) |
| | Fuel efficiency | 0.005*** | (0.001) | 0.083*** | (0.023) |
| | Health concerns | 0.010 | (0.066) | 0.038 | (0.168) |
| | neighbors' influence | 0.014*** | (0.002) | 0.259*** | (0.064) |
| | Perceived safety | 0.018 | (0.096) | 0.440*** | (0.079) |
| | Stove social reputation | 0.032*** | (0.010) | 0.180* | (0.101) |

Robust standard errors in parentheses and significance levels are at: *** p<0.01, ** p<0.05, * p<0.1.
**Source.** Estimates from the DHM

Most household characteristics are predictors of both clean cooking technology adoption and sustained use, as depicted in Table 4, for example, age. In the probit regression, households headed by older individuals have a higher probability of purchasing clean cooking technologies as compared to those headed by younger ones. However, the effect weakens when the household head advances in age. For example, the probability of purchasing increases by about 18% for the "26 - 45" while the increase is only 1.6% for the "46 and above" age category. Conditional on positive cooking technology use, the associated increase in use is 0.38 and 0.221 days for the "26 - 45" and "46 and above", respectively. Being employed has a positive but slightly weaker effect on the probability of purchasing clean cooking technologies, but the effect on usage gets stronger once the household is an adopter. Nonetheless, the effect of the household head's education is relatively similar in both regressions.

In comparison to the above variables, the effect of income is strong and significant in both decision levels, as observed in the columns for the participation and sustained use models of Table 4. A small increase in income raises the probability of purchasing clean cooking technologies, ranging between 1 and 4 percent, and it increases clean cooking technology usage by 1.1 to 1.184 additional days. We notice that larger households tend to have a negative impact on both decisions, but this effect is only valid at a 90% level of significance in the adoption model. While male dominance in household decision-making significantly causes an increase of 0.248 days of use, it is not a significant predictor of purchasing decisions. On the contrary, women's decision-making increases the probability of adopting clean cooking technologies relative to joint decision-making. The probability increases by about 1%, but the effect is less significant on the frequency of use.
Being a single household head leads to the adoption of clean cooking technologies, and it significantly contributes to the number of days the stoves are used. However, residential ownership status is a poor predictor of both decisions.

Regarding cooking technology -related and behavioral factors, we found a dissimilarity in how these factors determine the two decisions. Most of them are strong determinants of sustained use than adoption, and only a few are significant in both models. On the one hand, stove convenience, fuel efficiency, and neighborhood influence positively affect both the probability of adoption and the frequency of use. The convenience of stove use increases the probability of adoption by about 0.3%, resulting in about 0.138 additional days of usage if the household owns a clean cooking technology. Fuel efficiency and neighborhood influence raise the probability of adoption by roughly 0.5% and 1.4% and increase the frequency of use by 0.083 and 0.259 days, respectively. On the other hand, customer satisfaction, the compatibility of the stove with cultural needs, and perceived safety only affect sustained use, increasing the days of usage by 0.239, 0.229, and 0.44, respectively. However, the social reputation of the stoves only predicts adoption. Our findings also show that health and environmental variables are less important in adoption and clean cooking technology use.

**Diagnostic and Robust Tests**

All four models were compared, and the results are presented in Table 5. The Poisson and NB are nested models, and these were first compared using the likelihood ratio test. The null hypothesis that the nested model (Poisson) provides the best fit to the data was rejected in favor of the NB model. We further compared all four models: the Poisson, negative binomial, and the two variants of the double hurdle model – the zero-truncated Poisson and zero-truncated NB on the basis of their log-likelihood, Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC). AIC penalizes a model that uses more parameters yet explains the same amount of variation as the one with fewer parameters. Hence, the model with a lower AIC provides the best fit. In contrast, the BIC penalizes the model for its complexity but more than the AIC does. This means that more complex models will have larger BIC scores. Similarly, the lower the BIC score, the better the model. All criteria support the double hurdle zero-truncated NB as the best-fitting and parsimonious model as shown in Table 5.

**Table 5: Diagnostic and robust test results**

**Likelihood ratio test**

Ho: Poisson specification
H1: NB specification

LR chi2(1) = 805.02
Prob > chi2 = 0.0000

| Model | Log-likelihood | AIC | BIC |
|---|---|---|---|
| Poisson | -1,966.92 | 3,987.84 | 4,094.65 |
| NB | -1564.4071 | 3,184.81 | 3,295.58 |
| Double Hurdle Poisson | -1759.0213 | 2,694.08 | 2,802.11 |
| Double Hurdle NB | -1211.0972 | 2,292.01 | 2,396.25 |

Akaike Information Criterion (AIC); Bayesian Information Criterion (BIC); Likelihood ratio (LR)

**Discussion of Results**

The positive association between income and adoption aligns with the energy ladder hypothesis, which posits that an increase in income results in advancement to modern and cleaner fuels (Leach, 1992). Moreover, literature on clean fuel adoption and usage supports the positive effect of household income on the adoption and use of these fuels (See Kumar *et al*.,2020; Gould *et al*., 2020). Cleaner fuels are relatively expensive compared to traditional ones; therefore, higher incomes permit households to substitute traditional fuels for cleaner fuels and to afford the stoves in which they are used. Our results are also consistent with the findings of previous studies on clean cooking technologies (For example, Mamuye *et al*., 2018). The positive effect on both the probability of adopting and the conditional level of cooking technology usage reflects affordability. The higher the income, the higher the household's probability of purchasing clean cooking technologies and the higher the frequency of use. We, therefore, argue that households with higher incomes can afford to purchase clean cooking technologies and the fuels used, hence, an increase in the probability to adopt and the increase in usage.

Other demographic factors also influence both the decision to purchase and the frequency of clean cooking technology usage, for example, the age of the household head. Households that are headed by older individuals were more likely to adopt clean cooking technologies than younger-headed households. For example, the study by Behera and Ali (2016) in which they find a high likelihood for older-headed households to adopt electricity and other clean fuels relates to our positive effect of age on both decisions. While some studies have found an inverse relationship between the age of the household head and the adoption of clean fuels (Aziz *et al*., 2022), our findings depict a scenario where clean cooking technologies benefits may override the conservativeness, loyalty, and cultural rigidities toward traditional cooking technologies and fuels as one gets older. Moreover, a higher age of the household head may imply higher economic status, especially when comparing the reference age group of 18-25 against 26 -45. Comparatively, households headed by educated individuals are more likely to adopt and use clean cooking technologies, although this effect is slightly stronger on the latter. Our results are consistent with the findings by Lewis *et al*. (2012) and Mamuye *et al*. (2018) on clean cooking technologies. As expected, they also align with the findings of studies on clean fuels. For instance, Behera and Ali (2016) report an increase in the likelihood of using electricity, LPG, and kerosene for cooking as the education level of the household head increased. It is argued that higher education levels transform individuals into being less conservative and more willing to experiment with new cooking technologies. Moreover, higher education may imply a higher economic status, which enhances affordability. This inference is also supported by our data distribution, in which highly educated households earned comparatively more than their counterparts.

Household size marginally reduces the probability of adopting, and it has no impact on usage. Despite just a 90 percent level of significance, the sign is indicative of a negative effect, which is in line with Pine *et al*. (2011), who found an inverse relationship between non-adopters and larger household sizes. Nonetheless, some contend that larger household sizes are likely to drive the adoption of cooking technologies. This point is illustrated by Aziz *et al*. (2022), who found more clean fuel usage by larger households than smaller ones. It has been argued that such households face more energy needs, which makes cooking technology usage a more efficient and beneficial alternative. Whereas this might be true, the cost of fuels may compromise purchase decisions and the extent to which the stoves are used. Ordinarily, dirty fuels used in traditional stoves are comparatively cheaper and apparently cost-saving for larger households than the clean fuels used in clean cooking technologies (Nnaji *et al*., 2012). Moreover, at any given level of household income, a large household size implies higher average expenditure, which exerts a heavy burden on household resources. These arguments, therefore, may support the negative effect on the decision to adopt. As a priori expected, female-headed households are more likely to adopt clean cooking technologies compared to male-headed households. Research has also shown a higher motivation for women to adopt clean cooking technologies or fuels than men. This is largely because women are responsible for cooking and thus directly impacted by the consequences of poor cooking technologies (Choudhuri & Desai, 2020; Gould & Urpelainen, 2020). Secondly, with regard to gender roles, the probability of adopting clean cooking technologies increases by about 1% in households where women are decision-makers. However, female household heads and women's power to make decisions do not effectively translate into the actual use of clean cooking technologies. It is noteworthy that the distribution of income across men and women may matter for both male and female-headed households. Our dataset portrayed a positively skewed distribution of income toward males earning relatively higher incomes than females. Consequently, our findings suggest our frequency variable is mainly driven by income disparities than power asymmetries in households.

As reported in Table IV, convenience and Fuel efficiency positively determine both the probability of adopting and the intensity of clean cooking technology use. The significance of these factors in both models is an indication that individuals will purchase a stove if they perceive it to confer benefits, such as fuel saving, the ease with which it is used, and the ability to cook fast. These factors further influence the extent to which the stoves are used. Similar findings are reported by (Mudombi *et al*., 2018). In their study, the convenience of the stove measured by attributes such as the ease to light and putting it off, the time it takes to start, and the conditions under which it can be used positively impacted the adoption of an ethanol cookstove in Mozambique. Mudombi *et al*. (2018) also found a positive relationship between peer influence and adoption, which is similar to our positive effect of the neighborhood influence variable. However, our findings contrast with the randomized control trial by Beltramo *et al*. (2015), which found that a prominent member of the community could affect the chances of favoring the stove but not necessarily the purchase decision.

On the one hand, the social reputation of the stoves strongly predicts adoption but not the frequency of use. In contrast, Tigabu (2017) shows that reputation is a significant determinant of fuel-efficient stoves' regular use, and this was justified by the positive responses in relation to the stove's attractiveness and cooking speed. In our analysis, social reputation is explained by attributes such as positive feedback, influential persons' use, and the prestigiousness of the stoves. They, therefore, suggest that usage is mainly motivated by the actual users' experiences in relation to these attributes and not necessarily by the opinions of others. In other words, such attributes may attract new buyers but may not necessarily be crucial for the actual users. On the other hand, customer satisfaction, the compatibility of the stove with cultural needs, and perceived safety only affect sustained use. The insignificance of these factors on the probability of stove purchases is a revelation of the infectiveness of the current awareness in terms of these factors in driving adoption. It is, rather, the households' own experiences through actual usage that matters for sustained use. For instance, it might not be easy to envisage the taste of food and how the stove meets a household's cooking needs unless the household actually uses it. Therefore, holding everything else constant, households will continue using the stove if such perception continues to hold. Our positive effect of customer satisfaction on actual usage coincides with the positive effect on the quantity of LPG used that Gould *et al*. (2020) reported.

While education is expected to create awareness of the health and environmental benefits of clean cooking technologies, it is not the case, as these variables are insignificant in both decisions. Environmental concerns are potential determinants of clean fuels or clean cooking technology adoption. For example, Wang *et al*. (2020) found a significant positive effect of environmental concerns on farmers' intentions toward biogas adoption. Our findings show that environmental and health factors remain less relevant in ordinary households' cooking technology choices. This may not be so surprising as such concerns may become apparent with rising incomes and living standards.

**Conclusion and Policy Implications**

This study investigated the factors that affect adoption and continuous use of CCTs using a double-hurdle model. It was found out that the majority of cooking technology -related and behavioral factors are strong predictors of sustained use than clean cooking technology adoption. The distinction between non-adoption and actual use and the variation in the predictors provide insight into the corrective and improvement measures in tackling the barriers to clean cooking technology adoption and sustained use. Particularly, appropriate marketing strategies for non-adopters can be designed, as well as those that uniquely promote usage among adopters. For example, strategies targeting adoption can emphasize awareness of the stove attributes, such as perceived safety. Furthermore, while adoption is relatively on an upward trend, there is still a need for strategies and policies that promote awareness of the health and environmental benefits in order to realize the full benefits of improved cookstoves.

**Limitations and Areas for Further Research**

This study provides valuable insights into the sustained use of clean cooking technologies (CCTs) by households; however, it has certain limitations. First, the study focuses exclusively on the urban districts of Kampala, Mukono, and Wakiso, limiting the generalizability of the results to all households in Uganda. To address this, future research should encompass a broader scope, covering households in various regions of Uganda to facilitate comparisons and generalizations. Second, the study employs a static analysis, which does not account for the influence of time on sustained use. Therefore, longitudinal studies that assess sustained use over time would make a significant contribution to this field.

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