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# Fuel Choices during Natural Shocks: Evidence from Nepal

**Naveen Adhikari[1], Nirmal Kumar Raut[2]**

## Abstract

*The adoption and use of clean cooking energy is a global and national priority; however, the household energy landscape of Nepal continues to rely heavily on biomass fuels like firewood, cow dung, and charcoal. Natural shocks can disrupt the utilization of relatively cleaner energy sources like biogas and liquefied petroleum gas (LPG). This study examines the impact of natural shocks on the adoption and usage of clean cooking fuels focusing on LPG. Using data from the third wave of the Household Risk and Vulnerability Survey - 2018 logistic regression is employed to analyze both the likelihood of LPG adoption and household expenditure on LPG under conditions of natural shocks. The findings reveal that households experiencing natural shocks are 5 percent less on average likely to adopt biogas or LPG. Furthermore, household expenditure on LPG decreases by 4.43 percent relative to cooking fuel expenses particularly for firewood by the households experiencing natural shocks. This reduction highlights a decline in the intensity of clean energy use among households concurrently using LPG and firewood. These results underscore the negative effects of natural shocks on the transition to clean cooking fuels posing challenges to achieving sustainable adoption of clean energy solutions.*

**Keywords:** *Natural shocks, Clean energy, Household cooking, Nepal*
**JEL Classification:** *Q54; Q42; O13; D12*

## Introduction

Promoting clean energy for cooking is a global priority and commitment. The seventh goal of Sustainable Development Goals (SDGs) is to ensure universal access to affordable, reliable, sustainable, and modern clean cooking energy or

1. **Mr. Adhikari** is a Lecturer at Central Department of Economics, Tribhuvan University. He is currently pursuing Ph.D. in Economics from Tribhuvan University, Email: naveen.adhikari@cdec.tu.edu.np, ORCID: https://orcid.org/0000-0003-0347-4108
2. **Dr. Raut** (Corresponding Author) is an Associate Professor at the Central Department of Economics, Tribhuvan University, and currently a post-doctoral fellow at the Institute of Social Sciences, University of Tokyo, Japan, Email: nirmal.raut@cdec.tu.edu.np, ORCID: https://orcid.org/0000-0002-4234-4739.

fuel for all by 2030 (Arora & Mishra, 2019). The 2050 net zero goal aims to bring the $CO_2$ emissions on cooking from bio-mass fuels to zero by 2040 (IEA, 2023; United Nations, 2023). It is well established now that traditional biomass fuels like wood, charcoal, and dung lead to severe health, environmental, and economic consequences (Lee et al., 2020). The use of inefficient biomass contributes to deforestation, increases greenhouse gas emissions, and exacerbates climate change (WHO, 2022; IEA, 2023). Transitioning to cleaner cooking solutions like LPG, biogas, and electric stoves could not only mitigate health risks and environmental damage but also support sustainable development by reducing household labor and allowing more time for economic activities (IEA, 2023; WHO, 2023).

In developing countries, a substantial proportion of households continue to rely on biomass fuels like firewood, charcoal, dung, and agricultural residues for cooking. This dependency is largely driven by limited access to affordable, clean energy sources, infrastructural constraints, and socio-economic factors. Approximately, 2.4 billion people globally, primarily in low and middle-income countries, rely on traditional biomass for cooking due to the high cost or limited availability of alternatives like LPG and electricity (IEA, 2021). In sub-Saharan Africa, for example, over 80 percent of the population still uses solid biomass for cooking, with similar rates observed in South Asia (WHO, 2022). In South Asia, reliance on biomass fuels for cooking remains high, especially in rural areas where access to cleaner energy sources is limited due to socio-economic, infrastructural, and policy challenges. In these countries, a significant percentage of households, particularly in low-income and rural communities, depend on firewood, crop residues, and animal dung for cooking (IEA, 2021).

In Nepal, around 90 percent of the population relies on biomass fuels like firewood, dried dung, coal, and agricultural residue, while approximately 5 percent use LPG and another 5 percent use biogas, electricity, or solar sources to meet their energy needs (WECS, 2023). In 2011, about 68 percent of households used biomass as their primary cooking fuel, followed by 21 percent using LPG, 3 percent using biogas, and 1 percent using other sources. By 2021, the share of households (HHs) using firewood had dropped to 54 percent, while 44 percent (CBS, 2011) relied on LPG, and around 2 percent transitioned to renewable energy sources. This indicates a nearly 16 percent increase in LPG use over the past decade (NSO, 2021). However, the proportion of households using electricity for cooking remained unchanged. Interestingly, electricity use for cooking shows significant variation between urban (0.55%) and rural (0.34%) areas (NSO, 2021). While the electricity supply has increased in recent years, low electricity usage for cooking purposes in rural areas may be attributed to poor affordability, low levels of awareness, and irregular electricity supplies.

Nepal has witnessed an increase in the use of relatively cleaner fuels, particularly LPG, over the last two decades, and such progress may be halted given the frequent occurrence of climatic and natural shocks to which Nepal remains highly susceptible. Access to clean energy can also be disrupted by frequent natural shocks like floods, droughts, and hailstorms, which carry significant socio-economic implications, including welfare loss. There is already some evidence to this account suggesting that households tend to use firewood in the face of natural shocks or any other adversary (Feeny et al., 2021; Osman et al., 2023). The negative consequences of the climatic and economic shocks are also documented in Nepal. These earlier studies in Nepal have shown that other economic adversaries, load shedding, economic blockade, and earthquakes have negative impacts on the clean energy uses for cooking (Acharya & Adhikari, 2021; Koirala & Acharya, 2022; Paudel, 2023). This could potentially threaten to ensure access to cleaner fuel by 2030. At the same time, it could have worrisome health and environmental implications.

Therefore, the study focuses on exploring the association between more frequent natural shocks and clean energy uses in Nepal. This is more relevant in the context of Nepal, where its unique geographical landscape featuring steep hills and expansive plains greatly intensifies its vulnerability to disasters like landslides, floods, and glacial lake outburst floods (GLOFs) (Karki et al., 2016; Paudel et al., 2012). Nepal is one of the top seven countries globally most vulnerable to natural disasters due to the convergence of complex terrain, climate change impacts, and socio-economic challenges. In this context, it is important to understand whether exposure to climatic shocks affects the adoption of clean energy sources and related expenses.

This paper examines the association between clean energy usage and the disruptive effects of natural shocks in Nepal with a particular focus on LPG as a cleaner alternative to traditional biomass fuels like firewood, cow dung, and charcoal. The study explores two key hypotheses. First, it investigates whether households experiencing natural shocks are less likely to adopt or continue using cleaner energy sources like LPG and biogas, as these shocks can disrupt fuel access through supply chain interruptions or financial challenges. Second, it examines whether households concurrently using both LPG and traditional biomass fuels shift their reliance on biomass fuels during natural shocks, leading to a relative decrease in LPG usage. These insights highlight how natural shocks affect the adoption and usage of clean cooking energy, underscoring the need for policies that promote energy resilience and ensure the sustained use of cleaner fuels in the face of such disruptions.

The motivation for this study is twofold. First, existing literature from Nepal highlights an increased reliance on firewood in response to large-scale shocks, such as earthquakes and blockades (Koirala & Acharya, 2022; Paudel, 2023).

However, there has been limited exploration of the effects of natural shocks that are more frequent, less intense, and occur intermittently throughout the year. This paper aims to fill this gap by focusing on the impacts of high-frequency, low-intensity natural shocks. Second, the study examines the dynamics of increased reliance on or substituting cleaner fuels like LPG and traditional biomass fuels, including firewood during such shocks. This focus is particularly relevant in Nepal, where fuel stacking using multiple types of fuel concurrently is common with households often relying on LPG and firewood. Exploration of cooking fuel substitutions during the shocks will complement the existing literature that predominantly relies on discrete choice models emphasizing a discrete choice between clean and traditional fuels.

The remainder of this article is organized as follows. The literature review section examines existing research on mechanisms through which natural shocks may disrupt clean energy usage. The subsequent data and methodology section outlines the data sources and empirical strategies employed in the analysis, providing a foundation for the study's approach. This is followed by the results section, which presents descriptive and empirical findings and interpretations of these results. The discussion section contextualizes the findings exploring potential pathways to explain the observed effects. Finally, the conclusion summarizes the main insights and highlights policy implications to mitigate the impacts of natural shocks on clean energy adoption.

## Review of Literature

Literature provides extensive insights into factors influencing household choices and utilization of clean energy, particularly since the 1990s. This shift at the household level is often framed within the Energy Ladder Hypothesis (ELH), which posits that households transition from traditional to cleaner energy sources based on various socioeconomic factors (Delgado-Plaza et al., 2022; Van der Kroon et al., 2013). The ELH suggests that as household income and wealth rise, so does energy consumption, leading households to ascend the 'energy ladder' from using traditional, low-quality fuels to modern and high-quality energy sources (Lewis & Pattanayak, 2012; Muller & Yan, 2018; Poddar et al., 2021; Malla, 2022).

Empirical evidence supports that income, urbanization, and affordability are central drivers of clean energy adoption. For instance, studies demonstrate that as household income increases, Zimbabwean urban households shift from wood to kerosene and electricity (Hosier & Dowd, 1987), while in Burkina Faso, higher income motivates urban households to choose natural gas over kerosene (Ouedraogo, 2006). Similarly, in rural Nigeria, households transition from fuelwood to kerosene, natural gas, and electricity as their income rises (Baiyegunhi & Hassan, 2014), and in urban India, rising income levels encourage the switch to LPG (Gupta & Köhlin, 2006).

Fuel prices are also crucial with evidence showing that lower LPG prices boost its usage in Burkina Faso (Ouedraogo, 2006) while rising kerosene prices in India encourage households to switch to LPG (Gupta & Köhlin, 2006). Affordability remains a significant barrier for low-income households for whom price sensitivity directly impacts the adoption of modern fuels (Jingchao & Kotani, 2012; Zhou et al., 2013). Systematic reviews also affirm that higher socio-economic status significantly enhances the likelihood of adopting improved cookstoves (Lewis & Pattanayak; 2012; Lee et al., 2020; Batchelor et al., 2022;). In line with ELH, most literature in Nepal also explores the determinants of fuel choices focusing on the demand for firewood (Giri & Goswami, 2018; Joshi & Bohara, 2017; Nepal et al., 2011).

Recently, interest has grown in understanding how natural shocks influence energy choices and usage behaviors, particularly given the rising frequency of climate-related disasters. The evidence of this impact remains mixed. For example, some argue that extreme weather events affect energy transitions in Puerto Rico, where Hurricane Maria accelerated a shift toward solar energy as the existing power grid was severely damaged (Echevarria et al., 2023; Krantz, 2020). The post-disaster rescue strategy could incorporate the promotion and provision of clean energy sources, like solar power or cylinder-based LPG, to address disruptions in the gas pipeline or main grid electricity (Babu, 2023). This approach ensures access to essential energy services during emergencies, enhancing the resilience of affected communities. Developed countries have adopted such strategies, integrating clean energy into disaster preparedness and recovery frameworks. Although similar initiatives have begun to take root in developing countries, their implementation remains limited and sporadic (Doytch & Klein, 2018). Acharya & Adhikari (2021) also documented that households had a propensity to use electricity during the Indian blockade of Nepal, which interrupted the supply of LPG and other fossil fuels.

However, empirical evidence supporting the effectiveness of these strategies in developing contexts is still scant and often not in favor of using clean energy. Economic shocks, such as natural disasters, exacerbate financial strain by disrupting household income and requiring urgent reallocations of funds toward immediate recovery, limiting the ability to cover the higher initial costs associated with clean energy sources (Gebreegziabher et al., 2012). This finding aligns with research on energy poverty, which indicates that financial vulnerability restricts households' capacity to invest in long-term solutions like clean energy, even when they recognize the health and environmental benefits (Khandker et al., 2012a, 2012b). For instance, the economic hardship post-disaster can drive households toward cheaper, more polluting cooking fuels (Avazkhodjaev et al., 2024; Xia, 2022).

In Nepal, as previously mentioned, Paudel (2023) observes that households affected by major seismic shocks were 40.83 percent more likely to use firewood for cooking post-earthquake, coinciding with decreased spending on electricity and reduced adoption of LPG cylinders. Similar observations are made on account of the decade-long load shedding in Nepal that pushed households to opt for multiple fuels and the traditional biomass fuel acting as the cushion against the uncertainty (Koirala & Acharya, 2022).

The review revealed that natural shocks impact household energy choices and reveal mixed findings. While some studies suggest that disasters can catalyze a shift toward cleaner energy options, others indicate that economic and infrastructural constraints often push households back to traditional fuels. Despite this, there is limited understanding of how different climatic shocks specifically impact cooking fuel choices in Nepal, particularly regarding how such disruptions interact with factors like income, fuel affordability, and access to clean energy. Addressing this gap, the present study analyzes how natural shocks influence fuel choices among Nepalese households, aiming to complement the existing literature.

## Data and Methodology

This study uses the third wave of the 'Nepal Risk and Vulnerability Survey-2018' conducted by the World Bank in 2018 (The World Bank, 2020). This survey employs a stratified random sampling approach, collecting data from 6,041 households across 400 primary sampling units (PSUs) randomly selected to reflect population distribution across non-metropolitan (rural and urbanizing) areas in 50 districts. The country was divided into 11 analytical strata, mirroring the strata structure of the 'NLSS - III Survey' but excluding the Kathmandu Valley. From each PSU, 15 households (HHs) were randomly selected for interviews with an additional 5 households chosen as alternates.

This study mainly utilizes Sections 4, 6, and 15 of the datasets to construct the dependent variable and key variables of interest, particularly those related to natural shocks. Section 4 includes information on cooking fuel choices alongside various household characteristics, while Section 6 details non-food expenditures, including household spending on energy sources like firewood and LPG gas. Section 15 provides data on different types of natural and household-specific shocks like illness or death of family members, debt, or economic crisis, among others experienced by households within a one-year period. Additional socio-economic variables relevant to the analysis are drawn from other dataset sections.

### *Estimation Strategy*

The basic estimation framework for examining the impact of natural shocks on the clean energy-related outcomes is given by:

$$EO_{id} = \beta_0 + \beta_1 NS_{id} + \sum \gamma_k H_{id} + \delta D + e_{id} \ldots\ldots (1)$$

Where, $EO_{id}$ is the energy outcome of the $i^{th}$ household in the $d^{th}$ district, $NS_{id}$ is the number of natural shocks reported by the household during a recall period of one year preceding the interview, $H_{id}$ includes a number of the household characteristics described below and presented in Table 1, and 'D' includes the district-level fixed effect (province-level fixed effects in the second specification). $e_{id}$ is the residual clustered at the primary sampling unit level.

This study employs two outcome variables. The first outcome variable is whether a household uses a cleaner energy source, specifically LPG or biogas. Section 4 of the dataset provides information on the primary cooking fuel used by households, categorizing fuel types as firewood, dung, leaves, rubbish, straw/ thatch, cylinder gas, biogas, and others. The study classifies cylinder gas and biogas as 'clean' fuels for analytical purposes, while the remaining options are considered 'dirty' fuels. Consequently, our first outcome variable is binary, taking a value of '1' if the household uses clean energy for cooking and 0 otherwise. This first specification is analyzed using a logistic regression model as outlined in equation (2).

$$ln\left(\frac{P_{id}}{1-P_{id}}\right) = \beta_0 + \beta_1 NS_{id} + \sum \gamma_k H_{id} + \delta D + e_{id} \ldots\ldots\ldots\ldots (2)$$

Where, $P_{id}$ = Probability (Cooking fuel = 1) and meaning of the other variables are the same as defined in (1).

The second outcome variable of the is the proportion of household spending on LPG relative to total spending on cooking fuel over a one-year recall period. This ratio indicates the reliance of households on cleaner fuel with the hypothesis being that this dependence on cleaner fuel like LPG may decrease following natural shocks. This measure is important in Nepal, where households commonly stack multiple fuels. However, the first data set only reports the primary cooking fuel, which does not capture this fuel-stacking behavior. It can be expected that households may use multiple fuels and switch between them intermittently, especially during disruptions like natural shocks. To measure this association, the study relies on the sub-sample of the households that concurrently reported expenses on LPG and firewood.

Section 6B of the data set provides detailed information on the non-food expenditure of households during the recall period. For this analysis, the study examines household expenditures on LPG, charcoal LPG, and firewood, defining the outcome variable as the ratio of LPG gas expenditure to total cooking fuel expenditure (Sum of expenses on LPG, charcoal, and firewood). This estimation is confined to the sample that concurrently uses both LPG and firewood for cooking. The study estimates this relationship using the Ordinary Least Squares (OLS) method, as specified below.

$$E_{id}(\frac{lpgas\_exp}{fuel\_exp}) = \beta_0 + \beta_1 NS_{id} + \sum \gamma_k H_{id} + \delta P + e_{id} \quad \ldots\ldots (3)$$

Where, $lpgas\_exp$ is the expenditure on LPG, $fuel\_exp$ is the total expenditure on fuel, and the rest of the variables have the same meaning as (1), except that the study uses province-fixed effects in this specification.

The primary variable of interest in this study is the natural shocks reported by households during the one-year recall period. The dataset captures various natural shocks: floods, landslides, droughts, fires, hailstorms, pests, plant diseases, and post-harvest losses. While the questionnaire also records social shocks, this study focuses on natural shocks; the study aims to mitigate potential concerns about self-selection biases in the estimation results by excluding social shocks. The variable of interest, labeled 'Natural Shocks' (NS), represents the total number of these natural shocks reported by the household over the recall period. Households that did not experience these natural shocks are assigned to zero.

Drawing on the energy ladder hypothesis that explains the transition of households to cleaner forms of energy sources, the study controls several household-level factors that may influence the adoption of clean energy. The literature suggests that household income, wealth, and access to clean energy sources are key determinants of energy choices of households. Accordingly, the study includes various wealth and expenditure-related variables- a proxy for income, such as household economic status, which are classified into quintiles based on food expenditure, dwelling status, the number of rooms, and access to basic facilities like drinking water and sanitation. Access-related variables are also controlled, including the distance to the nearest market center where households can purchase LPG gas and the current place of residence (rural vs. urban municipality). The study also accounts for information channels, such as whether the household has television or internet access. Migration and remittance status are also included to capture migration and remittance-driven characteristics of contemporary Nepali households. Likewise, a measure of access to finance defined as whether the household has ever accessed the loan is also included in the estimation. A detailed description of these variables is provided in Table 1.

In the first specification, the study includes a district-level fixed effect to capture the district-level unobservable. These district-specific characteristics could influence household fuel choices but are not directly measured in our data. For instance, factors like the availability of forest resources (which affects firewood accessibility) and local supply conditions (like LPG distribution and pricing infrastructure) can differ significantly between districts. Including district-level fixed effects ensures that these unobserved, district-specific influences do not bias our estimates, more accurately isolating the impact of other variables of interest. Owing to the limited sample size, it only includes province-fixed effects

in the second specification of the study. The errors are further clustered at the primary sampling unit level.

**Table 1: Description of the Variables Used in the Study**

| Variables | Nature of Variables | Description of Variables |
|---|---|---|
| Cooking fuel type | Dummy | Cooking fuel type '1' if the household's current primary cooking fuel is LPG or Biogas, '0' for dirty fuels mainly firewood, cow dung, charcoal, and agriculture residue. |
| Share of expenses in clean fuel | Continuous | Proportion of household's annual fuel expenditure on LPG gas to total annual cooking fuel expenditure that includes expenses on firewood and charcoal. |
| Natural shock | Count | Number of natural shocks experienced by household during a recall period of one year. |
| HH's head age | Continuous | Age of the household head. |
| HH's head sex | Dummy | Sex of the household head '1' if female. |
| Household size | Continuous | Number of family members currently living at home. |
| Consumption quintile | Categorical (5 categories) | Quintile based on the food expenditure of the household (self-produced, purchased from market or received in kind with a recall period of one week). |
| Household type | Categorical (3 categories) | Household type based on the construction material of the wall classified as cement bonded bricks / stone, mud bunded bricks / stone, and others such as made from thatch & straw. |
| HH dwelling status | Dummy | Ownership of currently residing dwelling, '1' if owned by the household. |
| Piped drinking water | Dummy | Drinking water source of the household '1' if access to any kind of piped water. |
| Latrine type | Categorical (3 categories) | Latrine type currently used by households that include flush latrine connected to either sewage or pit, non-flush latrine, others (such as shared latrine, open defecation). |
| T.V. | Dummy | '1' if household owns a T.V. connected to cable. |
| Internet | Dummy | '1' if household has access to internet. |
| Migration members | Continuous | No. of migrant members from the household that includes both internal (within) and external (outside) migration. |
| Log of remittances | Continuous | Log of the remittances received by household during a year sent by the migrant (internal / external) members. |
| Loan | Dummy | '1' if household has a kind of loan including both formal and informal. |
| Distance to market center | Continuous | Distance to the nearest market measured in kilometer (KM). |
| Rural | Dummy | '1' if household currently residing at rural municipality, '0' otherwise that includes urban, sub-metro or metropolitan city. |

*Source*: Author's illustration based on HRVS, 2018.

## Results of the Study

Table 2 presents descriptive statistics for outcome variables and covariates, including the primary variable of interest exposure to natural shocks. Concerning the main outcome variables, approximately 22 percent of households report using LPG or biogas as their primary cooking fuel. This finding implies that nearly three-fourths of households continue to rely on biomass-based fuels like firewood, cow dung, charcoal, and agricultural residue, which are known to contribute to indoor air pollution and adverse health outcomes. Relating to the second outcome measure, the mean annual expenditure on firewood is NPR 3,694.29, with a standard deviation of NPR 3694. Notably, nearly 85 percent of households in the sample report some level of expenditure on firewood, highlighting its near ubiquitous usage. In contrast, the average annual expenditure on LPG is higher at NPR 5,701, with a standard deviation of NPR 3,960. Only about 31 percent of sampled households report any expenditure on LPG. These findings suggest that households, while largely dependent on firewood, tend to allocate a higher expenditure toward LPG when used. This spending pattern indicates a growing but limited adoption of cleaner cooking fuels within the recall period.

Regarding the natural shocks, the average number of shocks reported by the household is about 0.03, ranging to a maximum of 3 types of natural shocks. Further disaggregation of this information reveals that nearly 90.95 percent of the households have not reported any natural shocks during the recall period, while nearly 9 percent have reported exactly one shock, and the remaining have reported two or more shocks during this year. While such shocks are relatively less reported in the third wave of 'HRVS-2018', it also makes it ideal for our estimation as this is the normal year in terms of natural shocks faced by households. To account for the fact that relatively low numbers of households have reported the number of shocks, the study further estimates the model with a shocks dummy, yet it finds the results consistent with those presented in Tables (2) and (3).

The socio-economic covariates indicate that the average household size is approximately 4.84 members, and the average age of the household head is around 50 years, suggesting that these households are typically of moderate size with an experienced head. Nearly 23 percent of household heads are female. Access to essential resources varies across households: 53.7 percent have access to piped drinking water, while only about 33 percent have access to flush latrines, leaving the majority (63%) relying on non-flush pit latrines. Nearly 4 percent of households report using shared or no latrines. The average number of rooms per household is 3.23. Regarding housing quality, nearly 44 percent of households live in mud-bonded houses, 31 percent reside in houses made from thatch or straw, and only about one-quarter live in cement-bonded houses.

Access to information, particularly through the internet, appears to be limited. Approximately 45.9 percent of households own a television, indicating moderate access to basic utilities. However, internet access remains low, with only 15.5 percent of households reporting access, suggesting limited digital connectivity that may affect information dissemination and opportunities. On the other hand, access to finance appears relatively satisfactory, with nearly 65.6 percent of households having taken loans. Migration also plays a significant role in household livelihoods, with nearly 50 percent of households having at least one migrant member, either internal or external. These migrant members remit an average of NPR 67,798 annually back to their households. The average distance to the nearest market is about 5.5 km, and the sample includes a nearly equal distribution of households from rural and urban municipalities.

**Table 2: Descriptive Statistics of the Variables Used in the Study**

| **Variables** | **Obs.** | **Mean** | **Std. Dev.** | **Min** | **Max** |
|---|---|---|---|---|---|
| Cooking fuel type, '1' if HH is using LPG or Bio | 6045 | 0.23 | 0.42 | 0 | 1 |
| Annual expenses in firewood in NPR | 5034 | 3694.29 | 3135.85 | 50 | 100000 |
| Annual expenses in LPG in NPR | 1898 | 5701.85 | 3960.68 | 100 | 87000 |
| Share of expenses in clean fuel | 1055 | 63.91 | 17.69 | 3.84 | 99.17 |
| Number of natural Shocks | 6045 | 0.09 | 0.31 | 0 | 3 |
| Age of the HH head | 6045 | 50.23 | 13.85 | 15 | 95 |
| Sex of HH head, '1' if female | 6045 | 0.24 | 0.43 | 0 | 1 |
| Family size currently residing at house | 6045 | 4.84 | 2.03 | 1 | 17 |
| ***Consumption Quintile*** | | | | | |
| First | 6045 | 0.2 | 0.4 | 0 | 1 |
| Second | 6045 | 0.2 | 0.4 | 0 | 1 |
| Third | 6045 | 0.2 | 0.4 | 0 | 1 |
| Fourth | 6045 | 0.2 | 0.4 | 0 | 1 |
| Fifth | 6045 | 0.2 | 0.4 | 0 | 1 |
| ***House Type*** | | | | | |
| Cement bonded house type, '1' if yes | 6045 | 0.24 | 0.43 | 0 | 1 |
| Mud bonded house type, '1' if yes | 6045 | 0.44 | 0.5 | 0 | 1 |
| Other house type, '1' if yes | 6045 | 0.32 | 0.47 | 0 | 1 |
| Dwelling owned by HH member, '1' if yes | 6045 | 0.99 | 0.11 | 0 | 1 |

*Contd....*

| | | | | | |
|---|---|---|---|---|---|
| Access to piped drinking water, '1' if yes | 6045 | 0.54 | 0.5 | 0 | 1 |
| ***Latrine type*** | | | | | |
| Flush latrine type, '1' if yes | 6045 | 0.3 | 0.46 | 0 | 1 |
| Non-flush latrine type, '1' if yes | 6045 | 0.65 | 0.48 | 0 | 1 |
| Other or no latrine, '1' if yes | 6045 | 0.05 | 0.22 | 0 | 1 |
| Ownership of TV, '1' if yes | 6045 | 0.46 | 0.5 | 0 | 1 |
| Access to the internet, '1' if yes | 6045 | 0.16 | 0.36 | 0 | 1 |
| No. of migrants member | 6045 | 0.88 | 1.27 | 0 | 13 |
| Log of remittances received by household | 6045 | 4.16 | 5.64 | 0 | 15.42 |
| Household ever accessed loan, '1' if yes | 6045 | 0.66 | 0.47 | 0 | 1 |
| Distance to nearest market center in KM | 6045 | 5.51 | 8.07 | 0 | 85 |
| HH resides in the rural municipality, '1' if yes | 6045 | 0.5 | 0.5 | 0 | 1 |

*Source*: Author's computation from HRVS, 2018.

Regarding the discussion, the logistic regression results in Table 3 provide insights into the relationship between natural shocks and the adoption of cleaner cooking fuels like LPG and biogas. Column (1) of the table displays the log of odds ratios, while Column (2) shows the marginal effects for each variable. The negative and statistically significant coefficient for the variable measuring the number of natural shocks experienced by households indicates a negative association between natural shocks and the likelihood of adopting cleaner cooking fuels. Specifically, the marginal effect suggests that households, on average, experience a 5 percent decrease in the probability of adopting clean cooking fuels following a natural shock.

The results seem intuitive among other socio-economic covariates. Households with larger sizes are less likely to use cleaner cooking fuel. The marginal effects confirm these results, indicating that each unit increase decreases the probability of using this fuel type by 3 percent. The age and sex of household heads do not appear significant, suggesting that demographic characteristics may not strongly impact fuel choice.

Consumption quintiles significantly and positively influence the likelihood of adopting specific clean cooking fuels. Households in higher consumption, particularly the fourth and fifth quintiles, exhibit a higher probability of using cleaner fuels such as LPG or biogas. The marginal effects further indicate that being in the highest consumption quintile increases the likelihood of using clean cooking fuel by 13 percent. Household construction type also significantly affects fuel choice with households residing in cement-bonded homes showing

a strong association with cleaner fuel usage and a marginal effect of 14 percent as compared to those in mud-bonded homes. This finding emphasizes the role of wealth in facilitating access to cleaner energy.

Interestingly, households that own their dwellings show a significant negative association with clean fuel adoption with a marginal effect of -11 percent. This suggests that dwelling ownership might reduce the likelihood of adopting LPG or biogas, possibly due to the lack of physical space required to install traditional cooking stoves, which otherwise could be hindering factors for those residing in rented houses.

Access to amenities and information plays a significant role in cooking fuel choices. Households with piped drinking water, a flush latrine, television ownership, and internet access show positive and statistically significant associations with cleaner cooking fuels, with marginal effects ranging from 4 percent to 15 percent. This indicates that households with greater access to these amenities are more likely to adopt cleaner fuels like LPG. The number of household migrants also shows a positive association although with a smaller marginal effect of 1 percent, suggesting a modest impact on clean fuel adoption. However, the results on remittance are negative, possibly because of the simultaneity of migration and remittances in a single equation.

Conversely, factors like greater distance to the nearest market center in rural areas, and higher remittance levels exhibit negative effects on clean fuel use. This suggests that households in rural areas, those located farther from market centers, and those receiving more substantial remittances are less inclined to choose cleaner cooking fuels. These findings underscore the importance of amenity access and market proximity in shaping of cooking fuel decisions households highlighting that infrastructure and locational characteristics can enable or limit the adoption of clean energy sources.

**Table 3: Regression Results (Logistic and OLS)**

| **Variables** | **Model (1): Logistic Regression (Dependent variable: Clean Fuel = 1)** | | **Model (2): OLS Results (Dependent Variable: Share of LPG expenses to total cooking fuel expenses)** |
|---|---|---|---|
| | (1) | (2) | (3) |
| | Cook fuel | Marginal Effects | OLS Results |
| Natural Shocks | - 0.43** | - 0.05** | - 4.43** |
| | (0.17) | (0.02) | (1.67) |
| Age of the Household Head | - 0.00 | - 0.00 | - 0.03 |
| | (0.00) | (0.00) | (0.02) |

*Contd....*

| | | | |
|---|---|---|---|
| Sex of Household Head, '1' if female | - 0.03 | - 0.00 | 0.13 |
| | (0.08) | (0.01) | (0.74) |
| Family size currently residing at house | - 0.27*** | - 0.03*** | - 0.32 |
| | (0.03) | (0.00) | (0.20) |
| **Consumption Quintiles (reference category: first quintile)** | | | |
| Second | 0.23 | 0.03 | - 3.12** |
| | (0.18) | (0.02) | (1.03) |
| Third | 0.25 | 0.03 | - 3.68** |
| | (0.17) | (0.02) | (1.37) |
| Fourth | 0.58*** | 0.07*** | - 5.26** |
| | (0.19) | (0.02) | (2.21) |
| Fifth | 1.11*** | 0.13*** | - 7.34*** |
| | (0.20) | (0.02) | (1.44) |
| **House Construction Type (reference category, mud-boned house)** | | | |
| Cement bonded house, '1' if yes | 1.20*** | 0.14*** | 2.27** |
| | (0.15) | (0.02) | (0.97) |
| Other types of houses, '1' if yes | 0.15 | 0.02 | 0.71 |
| | (0.15) | (0.02) | (1.14) |
| Dwelling owned by HH members, '1' if yes | - 0.91* | - 0.11* | 13.48* |
| | (0.53) | (0.06) | (6.61) |
| Access to piped drinking water, '1' if yes | 0.34*** | 0.04*** | - 1.78 |
| | (0.12) | (0.01) | (1.32) |
| **Latrine type (reference category: non-flush latrine type)** | | | |
| Flush latrine type, '1' if yes | 0.49*** | 0.06*** | 2.93 |
| | (0.14) | (0.02) | (1.62) |
| Other or no latrine type, '1' if yes | - 0.53* | - 0.06* | 2.45 |
| | (0.27) | (0.03) | (3.88) |
| Ownership of TV, '1' if yes | 1.30*** | 0.15*** | 2.36* |
| | (0.09) | (0.01) | (1.13) |
| Access to the internet, '1' if yes | 0.55*** | 0.06*** | 4.13** |
| | (0.09) | (0.01) | (1.42) |
| No. of migrant members | 0.08* | 0.01* | 0.86** |
| | (0.04) | (0.01) | (0.30) |
| Log of remittances | - 0.02*** | - 0.00*** | - 0.13 |
| | (0.01) | (0.00) | (0.11) |
| Household ever accessed loan, '1' if yes | - 0.08 | - 0.01 | - 0.22 |
| | (0.10) | (0.01) | (1.23) |
| Distance to nearest market center (in KM) | - 0.09*** | - 0.01*** | - 0.11 |
| | (0.02) | (0.00) | (0.07) |
| Household resides in the rural municipality, '1' if yes | - 0.59*** | - 0.07*** | - 0.24 |
| | (0.15) | (0.02) | (1.09) |

*Contd....*

| | | | |
|---|---|---|---|
| Constant | - 2.33** | - | 62.76*** |
| | (0.92) | - | (7.26) |
| District fixed effect | Yes | Yes | - |
| Province fixed effect | - | - | Yes |
| Np. of observations | 5,459 | 5,459 | 1,055 |
| (Pseudo) R-square | 0.31 | 0.31 | 0.23 |

*Source*: Author's computation based on HRVS data.

Note: Standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

The regression results of the second specification of the study are presented in Column (3) of Table 3. The OLS regression results show various significant predictors affecting the proportion of household spending on clean energy (specifically LPG) as a share of total energy expenditure. Experiencing a natural shock is associated with a decrease in the proportion spent on LPG, with a coefficient of - 4.43, suggesting that households affected by natural shocks may allocate fewer resources toward clean energy sources. This coefficient suggests that households exposed to natural shocks could reduce their expenses in LPG gas relative to total fuel expenses by 4.43 percentage points. Household size is a significant predictor with a coefficient of - 2.63, implying that larger households tend to spend a smaller share of their energy budget on LPG. Other demographic factors like age and sex of the household head do not appear to have significant impacts.

Like previous findings, consumption quintiles are essential in predicting clean energy expenditure. Moving up the consumption quintiles shows a progressive increase in the share of spending on LPG with significant positive coefficients for quintiles 3, 4, and 5 (4.34, 7.09, and 11.81, respectively). This suggests that wealthier households allocate a higher share of their energy budget toward LPG, which aligns with greater access to or preference for cleaner energy. Household type is also significant with cement-bonded households showing a very strong positive coefficient of 17.92, indicating that certain household types are inclined to spend more on clean energy for cooking than mud-bonded households. In contrast, ownership of the dwelling is negative but not statistically significant, suggesting that owning a home does not heavily influence clean energy spending.

Access to amenities, information and location also influences energy spending decisions. Households with access to improved drinking water are more likely to allocate a larger share to LPG gas with highly significant coefficients. The coefficient of TV and households with internet access with LPG gas spending indicates that households with information are more likely to invest in cleaner cooking energy. However, distance to the market and living in a rural area are both significant negative predictors, suggesting that rural households and those farther from markets tend to spend less on LPG gas.

## Discussions

The findings of the study suggest that households affected by natural shocks show a lower propensity to adopt cleaner energy sources like LPG and allocate a smaller proportion of their energy budget to these options. This pattern consistently holds onto both analytical models as shown in Table 3. The literature on this topic presents mixed evidence about how natural disasters affect the uptake of cleaner fuels. Key factors influencing fuel choices after a disaster include availability, price, and the potential loss of traditional fuel sources (Khandker et al., 2012a; Xia, 2022). Further, disaster recovery programmes and external aid can impact fuel decisions; for instance, aid packages might include cleaner energy tools like improved cooking stoves or solar cookers, which can encourage a shift toward these options (Krantz, 2020).

On the other hand, these same natural shocks may present challenges to cleaner fuel adoption. In the aftermath of a disaster, access to clean fuels like LPG or electricity can be reduced, and costs for these fuels may increase, creating financial and logistical barriers. The economic strain caused by such events, widely documented in the literature, often leads to household income and wealth losses, further limiting the ability to invest in cleaner fuels (Koirala & Acharya, 2022; Paudel, 2023). The findings of the study align with studies that suggest natural and climatic shocks reduce the likelihood of households adopting clean energy sources.

While the study does not specifically investigate the mechanisms behind these effects, the results provide strong evidence of a negative association between natural shocks and clean fuel adoption. This suggests that households may turn away from clean energy in favor of more accessible but less environmentally friendly options. Cost and availability barriers, particularly for fuels like LPG, remain significant, especially in regions with limited access and high prices. Households affected by natural or economic crises may adopt a 'fallback' strategy, relying on traditional fuels perceived as more reliable during uncertain times (Kelly & Adger, 2000; Rashid et al., 2006). The review by Malla & Timilsina (2014) shows that financial disruptions often lead households to revert to cheaper fuels slowing the transition to cleaner energy in vulnerable communities. These insights indicate that clean energy policies should incorporate strategies like price subsidies, disaster-relief energy support, and resilient energy infrastructure for large or shock-affected households to reduce barriers and promote cleaner fuel adoption.

The study also finds that wealthier households, or those in higher consumption quintiles, are more likely to invest in clean energy sources like LPG and allocate a larger share of their energy budget toward these fuels. In the OLS analysis, higher consumption quintiles correspond to increased spending on LPG, while logistic regression results show a higher likelihood of cleaner fuel use among

these households. This aligns with the energy ladder hypothesis (Poddar et al., 2021) which suggests that higher-income households are better positioned to afford cleaner energy sources due to greater disposable income and access to information and infrastructure.

The results further suggest that access to essential amenities like improved drinking water, television, and the internet is associated with a higher probability of adopting clean fuels and dedicating a larger portion of household spending to these sources. Households with better infrastructure and resource availability tend to have greater awareness and preparedness to adopt modern energy solutions. These results suggest that broader development efforts aimed at improving infrastructure and resource accessibility could indirectly promote clean energy adoption in households.

## Conclusion

This paper examines the association between natural shocks and their impact on the cleaner fuel intake in Nepal using a third round of Nepal's Household Risk and Vulnerability Survey (HRVS) 2018. The paper intends to generate evidence regarding these associations in a context where mixed evidence is available worldwide. As such, promoting clean energy for cooking is a key global objective tied to the Sustainable Development Goals (SDGs), which aim to ensure universal access to clean cooking fuels by 2030, and to the 2050 net-zero targets, which seek to eliminate $CO_2$ emissions from biomass cooking fuels by 2040. However, in a context that approximately 2.3 billion people still rely on traditional biomass fuels, leading to severe health, environmental, and economic consequences, clean energy access remains vulnerable to frequent natural disasters like floods and landslides, which disrupt infrastructure and energy supply and affect public health and welfare. This paper contributes to the existing literature that examines such associations.

The study suggests that households affected by natural shocks show a lower propensity to adopt cleaner energy sources like LPG and tend to reduce their expenses for these options. In particular, the study finds that households affected by natural shocks are, on average, 5 percent less likely to adopt clean energy sources like LPG or biogas. Energy usage measured by the share of household expenditure allocated to LPG decreases by 4.43 percent relative to their total spending on cooking fuels. The study concludes that this shift is particularly evident among households that increase their reliance on firewood in response to these shocks. It also suggests a reduction in the intensity of clean energy usage among households that concurrently use LPG and firewood, highlighting a potential setback in clean energy adoption during times of distress.

The study proposes that policies prioritize affordable and accessible options for economically vulnerable households to bridge the clean energy adoption

gap. LPG and disaster-relief energy support subsidies can assist low-income and disaster-affected families in maintaining clean energy use. Enhancing infrastructure in rural areas and promoting awareness of the health of clean energy and its economic advantages can encourage broader adoption across different socioeconomic groups. By tackling financial, infrastructural, and informational barriers, policymakers can foster a more inclusive and sustainable shift toward cleaner energy sources.

## Limitations

This study has a few limitations. First, it covers only non-metropolitan households. Fuel choices during a natural disaster may differ in city areas characterized by different socioeconomic characteristics, infrastructural facilities, and service delivery mechanisms. Second, the study relies on cross-sectional data, which cannot account for the changes in observed and unobserved household and locational characteristics over time. The study can also be extended with the use of panel data.

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