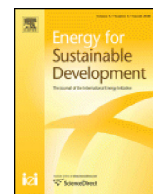




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Factors affecting access to clean cooking fuel among rural households in India during COVID-19 pandemic

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ABSTRACT

This paper investigates the factors affecting access to clean cooking fuel among rural Indian households during the COVID-19 outbreak, based on World Bank's rural impact survey, covering 2731 rural households. Our analysis shows a significant decline in access to clean fuel among rural households from 35% in 2018 i.e. before COVID-19 to 19.7% during the COVID-19 pandemic. This implies that in order to meet their cooking needs, many rural households have switched from conventional fuels, which have numerous health and environmental concerns. The association between states and socio-demographic profiles of rural households with access to sources of cooking fuel shows a significant difference. The analysis results further indicate that socio-demographic characteristics and asset holdings of the rural households are the key factors that determine access to clean cooking fuel during COVID-19. Among the socio-demographic variables, age, gender, family size, social category, and income level are estimated to be significant factors that affect the access to clean fuel for cooking. Similarly, ownership of assets such as exclusive kitchen room, refrigerator, pressure cooker, television, and furniture are significant factors affecting access to clean cooking fuel among Indian rural households. Additionally, this study provides policy insights on developing mechanisms to ensure that rural households have an access to clean cooking fuel during crisis situations such as COVID-19.

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Introduction

One of the critical obstacles in the path of socio-economic development is the lack of access to clean cooking fuel, which not only raises environmental hazards but also creates health issues in developing countries including India (Sehgal, Rizwan, & Krishnan, 2014; Baquié & Urpelainen, 2017; Choudhuri & Desai, 2020; Kapsalyamova, Mishra, Kerimray, Karymshakov, & Azhgaliyeva, 2021). The severity of the problem regarding access to clean energy gets amplified in rural households, which have a high dependence on conventional sources of cooking fuels. According to the 2011 Census of India, only 11.4% of the households have reported access to clean fuel in the form of Liquefied Petroleum Gas (LPG), while the majority of the remaining households have reported dependence on firewood (62.6%), crop residues (12.3%), and cow-dung cakes (10.9%). The provisioning of access to uncontaminated fuels for cooking is one of the key policy agendas due to the high health, economic, social, and environmental burden of the solid fuels widely

used in the rural households (Choudhuri & Desai, 2021). Gould and Urpelainen (2018) assessed the adoption, use, and impact of Liquefied petroleum gas (LPG) among the households in rural India and concluded that the rural population has been highly positive towards adoption of LPG, although the adoption is critically hindered due to its high cost.

Under the target 7.1 of the Sustainable Development Goals (SDGs) of the United Nations, India is committed to ensuring universal access to affordable, reliable, and modern energy services by 2030. The goals and target of sustainable development came into effect from January 1, 2016 and about 41% population in India reported having access to clean fuels and technology for cooking at that point of time, which has increased to 92% by the year 2020. For boosting the access to clean cooking fuel among poor families in rural India, the Government of India launched a central scheme, namely the Pradhan Mantri Ujjwala Yojana (PMUY) in 2016, for providing about 80 million connections of LPG to rural families belonging to the Below Poverty Line (BPL) category. The scheme has been instrumental in contributing towards providing a significant replacement for traditional cooking fuels. Patnaik, Tripathi, and Jain (2018) discussed the Indian government's policies and plans for strengthening the accession of clean energy for cooking fuels on the principles of equity and inclusivity. However, a study by

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Ranjan and Singh (2020) indicated that about 43.2 million LPG connections became inactive in the country in the year 2019, as compared to 35.8 million in 2017.

After the COVID-19 outbreak, the government announced a three-week nationwide lockdown to prevent the spread of coronavirus on March 24, 2020 leading to a disruption in social and economic activities across the country. A number of measures were initiated by both central and state governments for enhancing public awareness on social distancing along with a restriction on mass gatherings and limitations on movement by closing the transportation system, as key strategies for mitigating the spread of infection (Dutta & Fischer, 2021). Arafat, Kar, and Kabir (2021) argued that panic buying during COVID-19 has not only raised the level of anxiety, fear, panic, and agitation among the people, it has also pushed the prices of necessary goods out of the hands of people particularly the poor ones (Lufkin, 2020). Considering the widespread impact of the COVID-19 outbreak, the government of India announced the COVID-19 social assistance package of INR 1.7 lac crore (or 25 billion US\$) under the Pradhan Mantri Garib Kalyan Yojana (PM-GKY) to provide immediate relief to poor families. These relief measures focused primarily on social protection and healthcare, which included support in terms of food supplies, ensuring access to cooking gas, cash transfers to lower-income households, wage support and employment provision to wage-labourers, and insurance coverage for workers in the healthcare sector. This relief package also included the provision of providing LPG free of cost to 8.3 crores Below Poverty Line (BPL) families that hold LPG connections under the Ujjwala Scheme, starting from April 2020. However, ownership of LPG connections is still a critical issue in rural India, which is causing social, economic, and environmental distress in everyday life, particularly to females.

Empirical evidence indicates that one of the major concerns is the threat to the physical health of women and girls in India, who primarily engage in the cooking of food that raises significant air pollution causing severe respiratory diseases among the rural households (Smith & Sagar, 2014; Debbi, Elisa, Nigel, Dan, & Eva, 2014; Schilman et al., 2019). According to the World Health Organization (2002) report, use of solid fuels for cooking within enclosed spaces causes indoor air pollution, which is the 4th leading health risk in developing countries with high mortality due to increased incidences of diseases such as acute upper and lower respiratory illnesses, chronic bronchitis, chronic obstructive pulmonary disease, asthma, and tuberculosis. Several studies have evaluated the various interventions for improving the usage of conventional fuel stock with improved stoves and devices since majority of the rural households are unable to afford clean fuels like LPG (Brooks et al., 2016; Kumar, Dhand, Tabak, Brownson, & Yadama, 2017; Gitau, Mutune, Sundberg, Mendum, & Njenga, 2019). James, Shetty, Kamath, and Shetty (2020) analyzed the impact of household cooking fuel on the state of health of the rural women because of indoor air pollution and examined the relationship between socio-demographic variables of the respondents and the use of biomass fuel. Very few studies have identified the key drivers that affect the adoption of LPG as the main source of cooking fuel among rural households. Baquié and Urpelainen (2017) evaluated dimensions of subjective satisfaction such as convenience, cost, access, and ease of usage. In another study, Malakar (2018) attempted to assess household's decision-making using the example of adopting a TV and clean cooking fuel options in a micro-study of a village in Chittoor, Andhra Pradesh. Further, Sharma, Parikh, and Singh (2019) assessed the factors influencing transition to LPG for cooking in Chhattisgarh and Jharkhand, covering capital districts of both the states and highlighted the socio-economic and other factors that may influence LPG transition. Goswami, Bandyopadhyay, and Kumar (2017) explored the transition in cooking fuel options in eight districts of Bihar and identified a variety of economic, social, and technological factors responsible for the adoption of improved cooking stoves. The delivery and usage of clean cooking fuel has always been an area of concern in India for promoting a sustainable society and protecting the

health of vulnerable groups (Srivastava & Rehman, 2006; Bhattacharyya, 2012; Arora, Sharma, Kumar, & Jain, 2020). This study aims to provide an understanding on determinants of clean fuel adoption for cooking during COVID-19 pandemic, which becomes imperative in the current pandemic scenario.

Given the unexpected nature of the shock and urgency due to the outbreak of COVID-19, Indian policymakers needed to formulate strategies to protect the life and livelihood of about 1.4 billion people. To help the government in its efforts, the World Bank, IDinsight, the Development Data Lab, and John Hopkins University sought to produce rigorous and responsive data for policymakers on key issues including access to relief. Based on the data on access to cooking fuel sources among rural households before and during the COVID-19 outbreak, this study offers a significant contribution to the cooking fuel energy knowledge base in a number of ways. Firstly, as access of clean cooking fuel has significantly declined during the COVID-19 outbreak across the sampled states, and this study provides timely assessment of the impact of COVID-19 on access to clean cooking fuel among rural households. Secondly, our study complements and supplements the existing studies and provides extended coverage of determinants of adoption of LPG for cooking among rural households. Thirdly, the association of sources of cooking fuels with states and socio-demographic characteristics of rural households has been assessed to understand the variations in adoption of different fuel categories during the COVID-19 outbreak. Fourthly, our study reveals that gender of the head of households as female and social and income categories are key socio-demographic determinants of LPG adoption for cooking during the COVID-19 outbreak. Fifthly, the study has also revealed that asset ownership such as exclusive kitchen, refrigerator, pressure cooker, television, and furniture is the determining factor for clean cooking fuel adoption during the COVID-19 outbreak. There is limited evidence on the impact of COVID-19 pandemic on adoption of clean fuel and reversal of cooking fuel choice during the pandemic. A recent study by Ravindra, Kaur-Sidhu, Mor, Chakma, and Pillarisetti (2021) has tried to primarily provide insights on strategies to be adopted for handling the supply-side issues in managing clean fuel programs in India. Our current study mainly focusses on identifying the factors affecting the adoption of clean fuel among rural households during the COVID-19 outbreak.

After the Introduction section, this paper has been structured as follows; the literature review is given in the Literature review and research framework section along with the conceptual research framework, while data and methods constitute the Data and methods section. Result and discussion section includes results and discussion on access to clean fuel among rural households and its determinants. Finally, the conclusion and implications of the findings are given in the last section of the paper along with the limitations of the study.

Literature review and research framework

Access to clean cooking fuel is an area of concern for rural households across developing nations (Muller & Yan, 2018; Puzzolo et al., 2019; Guta, 2020; Liu, Wang, Xiong, & Liu, 2020; Ochieng, Zhang, Nyabwa, Otieno, & Spillane, 2020). Empirical evidence indicates that rural households by and large use mixed fuel for their cooking needs and adoption of clean fuel is influenced by household characteristics, asset holdings, price of fuel, and supply factors (Kuo & Azam, 2019; Schunder & Bagchi-Sen, 2019; Pye et al., 2020). As biomass cooking fuels is cheaper in price, most rural homes in low-income countries widely use locally available cooking fuel sources (Pant, 2012). Several studies have discussed the problems of indoor air pollution due to the use of bad cooking fuels. While, Gautam, Suresh, Sharma, and Sehgal (2013) argued that cow dung is the most polluting fuel for cooking followed by wood and kerosene, Sehgal, Rizwan, and Krishnan (2014) stressed the severity of health burden due to biomass cooking fuels among women in India as they assume the primary responsibility of household cooking. A study by Tian, Tian, Shen, and Shao (2021)

evaluated the rural-urban gap in health issues related to cooking fuel choices in China and concluded that rural households are prone to higher health risks due to their high dependence on solid fuels for cooking.

The emerging global concerns regarding clean cooking under the United Nation's Sustainable Development Goals has necessitated the need for implementing strategies in promoting adoption of clean cooking fuel among the households of lower-income countries (Rosenthal, Quinn, Grieshop, Pillarisetti, & Glass, 2018). In the process of revival of clean cooking fuel sources, Chalise, Kumar, Priyadarshini, and Yadama (2018) suggested the implementation of a dynamic community-system based approach in utilizing the abandoned biogas in rural India and argued that timely repair and demonstration of indigenous technical knowledge might enhance biogas use among rural families. The adoption of clean cooking fuel such as Liquefied Petroleum Gas (LPG) has always been an area of concern in rural India. Cabiyo, Ray, and Levine (2021) evaluated the benefits of using LPG for cooking in terms of health and saving time; however, the gap between the adoption of LPG and refilling has been reported to be critical due to affordability issues among the poor families. As affordability is one of the major challenges in the process of adopting clean cooking fuel, Gill-Wiehl, Ray, and Kammen (2021) emphasised the need for developing financing strategies based on income and expenditure capacity of the poor households.

The factors affecting the adoption of clean cooking fuels have been assessed by many studies in developing countries. Socio-demographic constraints have been highlighted as critical factors affecting households' choices of primary cooking fuels in Sudan (Suliman, 2013). Similarly, Karimu (2015) examined the major factors that influence the choice of cooking fuels and identified variables like income, education, urban location, and infrastructural access to be the key determinants of a family's main fuel selection choice in Ghana. The adoption choice of the household for cooking fuel among Nigerian households has been substantially influenced by income, location, firewood prices, and electricity supply duration (Danlami, Applanaidu, & Islam, 2018). Further, Nduka (2021) discussed the issues related to getting the Nigerian rural homes out of the energy poverty trap and recommended that the policy-makers should attract investors for providing affordable clean energy to the rural population. Another study by Wassie, Rannestad, and Adaramola (2021) conducted in southern Ethiopia tried to understand the probable factors that affect the selection of fuels for cooking and lighting among rural homes, and found that level of income, educational level, access to credit, access to contemporary energy sources, access to market and road network enhance the likelihood of choosing cleaner fuels. A significant relationship has been found between cooking energy-mix and socio-economic attributes of households in peri-urban areas of Tanzania and rise in income, increase in market information on LPG and creation of awareness on health hazards of fuelwood as cooking fuel has potential contribution in enhancing the clean fuel adoption (Ishengoma & Igangula, 2021).

Despite several government initiatives, the penetration of electricity and clean cooking fuel in energy-mix is relatively low among the poor in India (Bhattacharyya, 2006). Accessibility and affordability have been major areas of concern hampering the adoption of clean fuel among rural households. The progression in adoption of cleaner cooking fuel among the households in India is being influenced by a subsidy on LPG and doorstep distribution, which directly encourages a household to increase the proportion of monthly LPG consumption (Sharma, Parikh, & Singh, 2019). Urbanization and a fast-growing middle-class segment leading to a rise in consumerism have transformed the residential energy demand, including that of LPG in India (Bhattacharyya, 2015). Choudhuri and Desai (2020) evaluated gender inequality in Indian households in terms of fuel choices and concluded that households with empowered females have more chances of using and investing in cleaner fuels for cooking. This assessment is in tandem with the key objective of

Pradhan Mantri Ujjwala Yojana (PMUY) of the union government, which aims at empowering women by ensuring access to safe and healthy cooking fuel to female-headed households.

Numerous other studies have assessed the situation of using clean cooking fuel among rural households in India. Srinivasan and Carattini (2020) analyzed that in spite of the health and environmental hazards associated with solid biomass, rural households generally rely on it as cooking fuel, while the adoption of LPG is being influenced by social interactions and networks. Further, it is argued that access to clean energy may not be sufficient for cooking as the rural families prefer to combine and use solid fuels, which are locally available to them (Kapsalyamova, Mishra, Kerimray, Karymshakov, & Azhgaliyeva, 2021). The decision-making process of rural households towards adopting clean cooking fuel is being influenced by a variety of socio-demographic variables (Pandey & Chaubal, 2011). A study by Chindarkar, Jain, and Mani (2021) evaluated that family size, regular flow of income, price, and subsidy are key enablers of clean fuel adoption among Indian rural households. Mamidi, Marisetty, and Thomas (2021) investigated the role of transition from dirty to clean fuel on the socio-economic development of a household and reported an average 12.2% enhancement in their development. Pelz, Chindarkar, and Urpelainen (2021) assessed historical access to energy by marginalized communities and highlighted the energy policy reforms considering caste-based inequalities in the country. Gupta and Pelli (2021) assessed the causal relationship between electrification and contemporary cooking fuel (such as LPG) adoption and found an inverse relationship between the two, implying that the additional financial burden of electricity pushes back the rural poor on the energy ladder.

The outbreak of the COVID-19 pandemic has affected everyone across the globe, and the impact on rural communities is considered to be comparatively high due to significant divide in terms of living standards, access to basic amenities, access to resources, and livelihood sources (Singh et al., 2020; Modak et al., 2020; Kansime et al., 2021; Gupta & Pelli, 2021). To mitigate the risk of the COVID-19 outbreak, governments have undertaken a number of initiatives for creating sustainable livelihood, improving logistics support, leveraging technology, decentralizing public distribution system, ensuring fair trade, implementing disaster relief packages, creating self-reliance and improving public awareness. The relief to the rural household during COVID-19 outbreak has been provided by the central and the state governments through various schemes (Kumar, Varshney, & Joshi, 2020; Mitra, 2020). A few studies have attempted to analyze the impact of the COVID-19 outbreak on achieving the Sustainable Development Goal 7 of the United Nations, which provides commitments to member countries towards ensuring access to affordable, reliable, sustainable, and modern energy for all (Lo, 2020; Pachauri, Pobleto-Cazenave, Aktas, & Gidden, 2021). Shupler et al. (2021) assessed the nature of energy consumption among the households in Kenya during the COVID-19 pandemic and reported that a quarter of households have switched from LPG to kerosene and wood due to a decline in livelihood and income opportunities. Similarly, Ravindra, Kaur-Sidhu, Mor, Chakma, and Pillarisetti (2021) reviewed the impact of COVID-19 pandemic on the clean fuel program in India and highlighted the concerns for the rural population on affordability and accessibility of clean cooking fuel due to loss of income and livelihood during the lockdown.

Based on the literature review, we have developed a research framework to analyze the factors affecting the access to clean cooking fuel among rural households during the COVID-19 pandemic in India. It is evident from the reviewed literature that the socio-demographic characteristics of the households are determining factors in making the cooking fuel choices. Similarly, the asset holding capabilities of rural households have also been assumed to be influencing the clean cooking fuel adoption (Fig. 1). Based on the COVID-19 rural impact survey, we have identified the determinants of clean cooking fuel adoption among rural households in India.

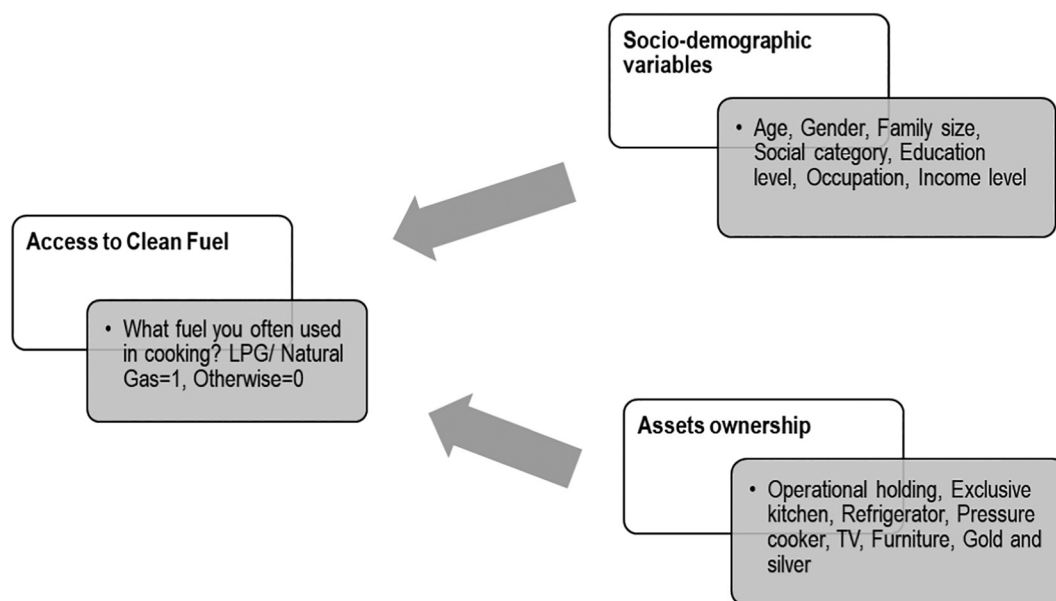


Fig. 1. Research framework for access to clean cooking fuel.

Data and methods

Data source

To design a proper policy framework to weaken the impact of COVID-19, comprehensive and timely available data is essentially needed for developing the desired intervention. Therefore, a quick survey on 'COVID-19 Related Shocks in Rural India' was launched jointly by the World Bank, IDinsight, the Development Data Lab, and the John Hopkins University, which collected data on rural households in India in 3 rounds of surveys. The observations have been taken from 6 states in India, namely Andhra Pradesh, Bihar, Jharkhand, Madhya Pradesh, Rajasthan, and Uttar Pradesh. Out of the 3 rounds of surveys, we have used the data from the 3rd round of survey commissioned in the month of September 2020. This survey covered a comparatively larger number of rural households on various indicators of the COVID-19 pandemic, related to the life of rural households. A stratified cluster random sampling technique has been used for collecting the data from 5200 rural households. Computer Assisted Telephone Interview (CATI) technique was used for conducting all the rounds of surveys through surveyors' smartphones in the local languages. Based on the missing variables, we have considered the survey data of 3 major states of the country viz. Bihar, Madhya Pradesh, and Uttar Pradesh for our study, covering 2731 rural households. The study's main objective is to examine the access to clean fuel during the COVID-19 outbreak by rural households.

The rural households under this survey were based on the sample frame under the National Rural Livelihoods Project (NRLP) in Bihar, Madhya Pradesh, and Uttar Pradesh. The phone numbers used in this survey were assembled from the impact evaluation of the World Bank funded National Rural Livelihoods Project conducted by the Ministry of Rural Development, Government of India. Few of the studies based on mobile-phone surveys during COVID-19 pandemic have raised the ethical challenges in data collection and endorsed taking oral consent and maintenance of privacy for overcoming such issues (Hensen et al., 2021; Khalil et al., 2021). The high frequency mobile phone survey of the World Bank has been conducted giving special consideration to ethics and data security (Himelein et al., 2020). Therefore, a prior appointment and consent were taken from each respondent to ensure their agreement with the mobile phone survey and to avoid non-responses. In case of failure to reach, surveyors attempted to call back the respondents upto 7 times with a successful response rate of about 55%. IDinsight and Johns Hopkins University ensured that data was of

good quality, clean, and without any discrepancies and errors for further processing and analysis. Finally, personal information of all the respondents has been removed from the datasets to ensure security and privacy of the respondents and to avoid any biases in data analysis and reporting of the results.

Survey instrument and variables

The data from rural households has been collected through a semi-structured questionnaire, covering 6 modules along with demographics. The first module covered information related to agricultural decision-making with respect to the area under cultivation, crop selection, use of various fertilizers, and type of market selection for crop selling during the COVID-19 outbreak. The second module included questions related to the migration status of households, such as returned rate, income level of the migrant, and their future plans of employment. The next module investigated the consumption level of rural households during the pandemic, wherein the responses were recorded for the expenditure of the households and access to food during the pandemic. Labour and income-related questions were included in module four, covering the employment availability, and compensation during the lockdown. Access to relief in terms of cash and workfare under government programs and the extent to which relief was accessed were covered in the fifth module of the questionnaire. Finally, the last module covered information related to health-related aspects such as awareness about symptoms of COVID-19 and its preventive measures.

We extracted the required information on the access to clean fuel among rural households from the comprehensive survey. A question on "what fuel do you most often use for cooking your food?" has been taken from the survey data, which was part of the sample frame of the National Rural Livelihoods Project (NRLP). In accordance with the responses of the rural households and missing values in the data, we included three major states under this study, namely Bihar, Madhya Pradesh, and Uttar Pradesh. Based on the research framework, access to various fuel sources for cooking have been considered as dependent variable, which has further been transformed into a binary variable with the use of LPG/Natural Gas as 1 and other sources of fuel as 0. Two sets of independent variables were identified from the surveyed data. The first set of independent variables comprised of socio-demographic characteristics of the rural households in terms of the age of the respondents, gender of the head of the family, number of family members, social category, education level of the female-head of the

household, occupation, and income level. Similarly, the ownership of assets by the rural household was considered as another set of independent variables, which included operational landholding, presence of exclusive kitchen in the house, refrigerator, pressure cooker, television, availability of basic furniture such as table, chairs and bed, and ownership of gold and silver jewelry. The description of variables used in the study is given in Table 1.

Data analysis

We used techniques such as descriptive statistics, chi-square statistics, and a binary logistics regression analysis with marginal effects to analyze the data. The descriptive analysis of variables used in the study has been undertaken to provide a brief of the nature of the data. The association of states and demographic characteristics of the rural households with the sources of fuel for cooking has been analyzed using chi-square statistics. Further, the key determinants of access to clean cooking fuel among rural households have been estimated using a binary logistics regression analysis. The access to cooking fuels has been converted into binary scale by categorizing LPG/natural gas = 1, otherwise = 0. As discussed earlier, two sets of explanatory variables (1) socio-demographic characteristics of rural households and (2) assets ownership of the households, have been used to identify the factors affecting access to clean cooking fuel. The regression model is defined as follows:

$$L_i^* = \ln \left(\frac{P_i}{1 - P_i} \right) = \alpha + \sum_{i=1}^n \beta_i X_i$$

where, L_i^* is the unobserved response on access to clean fuel, $P_i = 1$, if the households have access to clean fuel, $P_i = 0$, if the households have access to another kind of fuel, β_i is the regression coefficients of explanatory variables, α represent the intercept and X_i is the matrix of predictors related to socio-demographic characteristics (age, gender, family size, social category, education level, occupation, and income level), and assets ownership (operational holding, exclusive kitchen, refrigerator, pressure cooker, Television, furniture, and gold & silver) of the rural households.

Result and discussion

Sources of fuel for cooking by states

In India, majority of the rural households primarily depend upon solid fuels and firewood for meeting their daily cooking needs, causing severe health and environmental hazards (Sehgal, Rizwan, & Krishnan, 2014; Gould, Hou, Richmond, Sharma, & Urpelainen, 2020). The Government

of India initiated the ‘Pradhan Mantri Ujjwala Yojana’ (PMUY) on 1st May 2016 with key objectives of empowering women, providing healthy cooking fuel, and safeguarding millions of rural people from health-risks arising as a result of the use of fossil fuel. However, it is critical to note that there are limited number of rural households with access to clean cooking fuel because of the demand and supply constraints (Viswanathan & Kavi Kumar, 2005; Pelz, Chindarkar, & Urpelainen, 2021). The Petroleum Planning and Analysis Cell under the Ministry of Petroleum and Natural Gas, Government of India, conducted a survey in the year 2015 covering more than one lakh unconnected households (i.e. households not having LPG connection) and captured the awareness and key barriers in adoption of LPG among the surveyed households. Though the awareness level on LPG as cooking fuel across the 13 surveyed states was reported by about 93% respondents, the key barriers to adoption were reported in terms of affordability, i.e. high initial and refilling costs, non-availability, delay in application approval, and waiting time for refill. The report also included LPG penetration across the states, including Bihar (28%), Madhya Pradesh (39%), and Uttar Pradesh (50%), which is the aggregate percentage of rural and urban together.

A study by Jain et al. (2018) indicated significant increase in access to clean fuel during 2015 to 2018 among the rural households in the state of Bihar, Madhya Pradesh and Uttar Pradesh among others. However, a recent survey on COVID-19 rural shocks revealed decline in access to LPG/Natural Gas (19.7%) among the rural households during COVID-19 outbreak. Table 2 represents the access to various sources of cooking fuel by rural households in sampled states before and during COVID-19 outbreak. It is clear from the analysis that the access to clean cooking fuel (LPG) among rural households in Bihar has increased from 14% in 2015 to 40% in 2018, which has declined to 17% in the year 2020 i.e. during COVID-19 outbreak. Similar trends have also been reported in Madhya Pradesh whereby the access to clean cooking fuel has declined from 28% in 2018 to 18% in 2020. In Uttar Pradesh, access to LPG increased from 17% to 37% during 2015 to 2018 among rural households, which declined to 25% in 2020 during COVID-19 outbreak. Results clearly indicate that during the COVID-19 pandemic, access to clean cooking fuel by rural households has sharply declined in the study states. This implies that majority of the rural households replaced their clean cooking fuel with firewood and dung cakes during the COVID-19 outbreak, which has critical implications for social, economic, health, and environment-related aspects. Earlier studies on cooking fuel sources in India have indicated low penetration of clean fuels such as LPG in rural areas, and barriers to adoption of LPG have been attributed to affordability, pricing, and reliability of the distribution channel in rural areas (D’Sa & Murthy, 2004; Timilsina & Malla, 2020), which further got declined during the COVID-19 outbreak.

Table 1 Descriptive statistics and variable definition.

Variables	Description	Code	N	Min	Max	Mean	STDEV
<i>Dependent variable</i>							
Access to clean fuel	What fuel you often used in cooking?	LPG/natural gas = 1, otherwise = 0	2731	0	1	0.197	0.398
<i>Independent variables</i>							
Age	Age of the respondent	Number	2717	15	88	37.510	12.086
Gender	Gender of the household head	Male = 1, female = 0	2731	0	1	0.813	0.390
Family size	Number of family members	Number	2701	1	27	6.497	2.928
Social category	Which category does your household belong to?	Gen = 1, otherwise = 0	2603	0	1	0.117	0.321
Education level	Schooling female head of household	Schooling = 1, no schooling = 0	2434	0	1	0.488	0.500
Occupation	Have you cultivated this season?	Cultivation = 1, otherwise = 0	2731	0	1	0.240	0.427
Income level	Income quartile	1–4	2731	1	4	2.666	1.137
Operational holding	Ownership of land holding	Area in hectare	2731	0	182.11	0.629	4.261
Exclusive kitchen	Household have exclusive separate room as kitchen	(Yes = no = 0)	2731	0	1	0.370	0.483
Refrigerator	Ownership of refrigerator	(Yes = no = 0)	2472	0	1	0.068	0.252
Pressure cooker	Ownership of pressure cooker	(Yes = no = 0)	2539	0	1	0.368	0.482
Television	Ownership of TV	(Yes = no = 0)	2559	0	1	0.365	0.482
Furniture	Household have furniture	(Yes = no = 0)	2443	0	1	0.499	0.500
Gold and silver	Ownership of gold and silver	(Yes = no = 0)	2743	0	1	0.847	0.360

Source: Authors' calculations from Rural Impact Survey, 2020.

Table 2
Sources of cooking fuel among rural households by states.

Sources of cooking fuel	Pre COVID-19						During COVID-19		
	2015			2018			2020		
	Bihar	Madhya Pradesh	Uttar Pradesh	Bihar	Madhya Pradesh	Uttar Pradesh	Bihar	Madhya Pradesh	Uttar Pradesh
LPG/natural gas	14	9	17	40	28	37	17	18	25
Firewood	32	82	56	32	55	41	53	67	28
Dung	38	7	26	22	17	22	24	13	44
Others	16	1	3	6	0	1	7	1	3

Source: CEEW analysis, 2018 for 2015 & 2018 and authors' calculations from Rural Impact Survey for 2020.

Access to sources of cooking fuels among rural households

After evaluating the decline in access to clean fuel during COVID-19 outbreaks across the states, access to various cooking fuel types during COVID-19 by demographic characteristics of rural households is given in Table 3 along with the results of the chi-square statistics. The analysis indicates a significant association between access to fuel categories by demographic variables. The respondent's age is significantly associated with access to cooking fuel types ($\chi^2 = 17.037, P < 0.05$), which implies that access to clean cooking fuel increases with the age of the respondents, whereas for dung cakes, there is an inverse association. The gender of rural household heads has also indicated a significant association with access to various cooking fuel sources ($\chi^2 = 15.421, P < 0.01$). It is evident from the analysis that female-headed households have better access to clean fuel (24.5%) than those headed by males (18.6%). It may be because there is a direct impact of hazardous cooking on females as they are generally responsible for preparing foods in rural households (see Manjula & Gopi, 2017; Cabiyo, Ray, & Levine, 2021).

Table 3
Access to the sources of cooking fuels among rural households by socio-demographic profiles.

	LPG/natural gas	Firewood	Dung cakes	Others	χ^2	P-value
Age						
<25 years	15.1	53.4	27.3	4.2	17.037***	0.048
26–40 years	19.0	52.0	25.8	3.2		
41–60 years	23.1	47.7	25.1	4.1		
>60 years	23.9	51.4	20.2	4.6		
Gender					15.421***	0.001
Female	24.5	43.7	28.2	3.5		
Male	18.6	52.6	25.1	3.7		
Family size					14.614**	0.023
1–5 members	22.2	50.5	23.8	3.4		
5–10 members	17.7	52.1	26.2	3.9		
More than 10 members	18.0	45.6	32.7	3.7		
Education level					41.607***	0.000
No schooling	16.2	51.2	27.7	4.8		
Less than 5th class	18.5	54.7	23.6	3.1		
6th to 10th class	22.7	53.4	22.1	1.8		
Above 10th class	30.5	41.4	24.7	3.4		
Social category					27.856***	0.000
General	30.3	46.1	22	1.6		
SC/ST/others	17.8	52.3	25.6	4.3		
OBC	20.1	50.6	26	3.4		
Income quartile					114.583***	0.000
1	9.6	55.4	29.6	5.5		
2	15.7	51.8	27.6	4.9		
3	18.7	50.6	27.5	3.2		
4	29.8	47.7	20.5	2		

Source: Authors' calculations from Rural Impact Survey, 2020.

*** Significant at 0.01 level.
** Significant at 0.05 level.
* Significant at 0.10 level.

The result of chi-square statistics reveals a significant association between family size and access to various types of cooking fuels ($\chi^2 = 14.641, P < 0.05$). The analysis indicates that rural households with smaller family sizes have reported more use of LPG/Natural Gas for cooking while the households having bigger family sizes use wood and dung cake more as their cooking fuel. The education level among rural households indicates a significant association with access to various sources of fuel ($\chi^2 = 41.607, P < 0.01$). Analysis shows that the percentage of rural households accessing clean cooking fuel increases with the level of education. Further, the analysis result also highlights a significant association between social category of the rural households and access to cooking fuel types ($\chi^2 = 27.856, P < 0.01$). It is noticeable that households belonging to upper social class have more access to clean fuel for cooking as compared to socially backward sections. Finally, the income level of the rural households has also indicated a positive association with access to cooking fuel types ($\chi^2 = 114.583, P < 0.01$). This implies that rural households belonging to higher income groups access clean energy for cooking more than those belonging to the lower-income categories. The results of our study match with the finding of a number of similar studies conducted in developing countries (Yonemitsu, Njenga, Iiyama, & Matsushita, 2014; Karimu, 2015; Sharma, Parikh, & Singh, 2019; Gould, Urpelainen, Hopkins, & J., 2020; Wassie, Rannestad, & Adaramola, 2021). Sutar, Kumar, Patel, Kumar, and Mokashi (2020) argued that though the government has promoted adoption of LPG for cooking among the population of India, the refilling of LPG is not affordable for majority of the poor families.

Factor affecting the access to clean fuel among rural households

A binary regression model has been developed and estimated to examine the factor affecting the adoption of clean fuel among rural households in India during COVID-19 outbreak. Table 4 provides the parameter estimates of the regression coefficient, marginal effects, and significant level. We utilized two sets of explanatory variables comprising of socio-demographic characteristics and asset ownership among rural households. The regression analysis indicates that out of the 7 socio-demographic variables, 5 variables namely age, gender, family size, social category, and income level, significantly determined the access to clean cooking fuel among rural households. The regression analysis for age exhibits positive and significant marginal effects on access to clean cooking fuel ($P < 0.10$), implying that older people are more likely to have access to clean cooking fuel as compared to younger people. Gupta and Köhlin (2006) and Chattopadhyay, Arimura, Katayama, Sakudo, and Yokoo (2017) also concluded that higher age group people are more likely to adopt clean fuel. It may be due to the fact that purchasing power and health concerns increase with age, which induces the adoption of clean fuel for cooking. The marginal effect of gender of the rural household head was found to be negative and significant ($P < 0.01$), which implies that gender has a significant impact on access to clean fuel. Male-headed households are 6% less likely to have access to clean fuel as compared to female-headed households. As females are majorly associated with cooking in rural communities, they are more aware of the advantages of using clean fuels for cooking, particularly

Table 4
Factors affecting access to clean fuel among rural households during COVID-19 pandemic.

Variables	β	P-value	Marginal effect	P-value
Socio-demographics				
Age	0.008*	0.075	0.001*	0.074
Gender	-0.418***	0.002	-0.061***	0.002
Family size	-0.055***	0.009	-0.008***	0.009
Social category	0.256*	0.098	0.037*	0.098
Education level	0.154	0.174	0.022	0.173
Occupation	0.134	0.296	0.019	0.296
Income level	0.342***	0.000	0.050***	0.000
Assets ownership				
Operational holding	0.009	0.357	0.001	0.357
Exclusive kitchen	0.235**	0.037	0.034**	0.036
Refrigerator	0.381*	0.057	0.055*	0.057
Pressure cooker	0.359***	0.004	0.052***	0.003
TV	0.269**	0.029	0.039**	0.029
Furniture	0.232**	0.046	0.034**	0.046
Gold and silver	0.162	0.328	0.023	0.327
Constant	-2.815	0.000		
Number of obs	2286			
LR chi ² (14)	163.86			
Prob > chi ²	0.000			
Pseudo R ²	0.0727			
Log likelihood	-1044.87			

Source: Authors' calculations from Rural Impact Survey, 2020.

*** Significant at 0.01 level.

** Significant at 0.05 level.

* Significant at 0.10 level.

the health-related issues associated with unclean fuel usage (Kennedy et al., 2011; Gould & Urpelainen, 2018).

The marginal effect of family size shows a negative and significant impact on access to clean cooking fuel, which implies that households with comparatively smaller family sizes are more likely to have better access to clean fuel. The estimation of regression of social category clearly indicates positive and significant marginal effects on access to clean fuel for cooking ($P < 0.10$). Analysis indicates that rural households that belong to the upper social class are 3.7% more likely to have access to clean fuel as compared to the socially marginalized classes. Similar evidence on social category and access to clean fuel has been reported by earlier studies (Pandey & Chaubal, 2011; Gould, Urpelainen, Hopkins, & J., 2020). Saxena and Bhattacharya (2018) articulated that households belonging to lower social categories generally live in hamlets outside the villages and face discrimination when it comes to accessing the clean fuel supply. Further, income level is another strong predictor of access to clean fuel in rural India. The positive and significant marginal effects indicate that rural households belonging to the higher income category are 5% more likely to have access to clean fuel for cooking. Considering the price of clean fuel for cooking, household income and affordability are important factors affecting the adoption of LPG among rural communities (Quinn et al., 2018; Ravindra, Kaur-Sidhu, Mor, & John, 2019; Kapsalyamova, Mishra, Kerimray, Karymshakov, & Azhgaliyeva, 2021).

Gould, Hou, Richmond, Sharma, and Urpelainen (2020) identified a set of factors such as fuel and technology characteristics; household characteristics, including structural characteristics; knowledge, perceptions, and attitude; an external economic, market, and geographical environment, that are likely to affect the adoption of clean cooking fuel. According to PPAC (2016) report, non-availability of personal vehicles for transporting the LPG cylinders for household usage could hinder the adoption of LPG connections, while the availability of television may help create better awareness about clean cooking fuels among the households. The access to clean fuel among rural households has also been assessed with another set of explanatory variables namely assets ownership. Out of the 7 variables on asset ownership, five variables including the existence of an exclusive kitchen, refrigerator, pressure cooker, television, and furniture have been found to be the significant factors. The analysis indicates that an exclusive kitchen has a positive

and significant marginal effect on access to clean fuel ($P < 0.05$), implying that households with an exclusive kitchen are more likely to have access to clean cooking fuel. Similarly, the estimated coefficient of marginal effect is also positive and significant for refrigerator ($P < 0.1$), implying that households with refrigerators are 5.7% more likely to have access to clean cooking fuel. The regression analysis indicates that ownership of pressure cookers has positive and significant marginal effects ($P < 0.1$) on access to clean fuel. Similarly, ownership of television and furniture has positive and significant marginal effects, and rural households having ownership of these two assets are 3.9% and 3.4% more likely to have access to clean fuel, respectively. The marginal effect of asset ownership with LPG adoption provides an important understanding that sustainable adoption and usage of clean fuel may require household resources and capacity to ensure affordability in crisis situations like COVID-19 pandemic. The regression model summary such as LR chi², its corresponding level of significance, and the pseudo-R² statistics suggest that the logistic regression model is reasonably fit. In addition, negative and high values of log-likelihood (-1044.87) are indicating a better fitting model.

Conclusion, implications, and limitations

Cooking with solid fuel is one of the major challenges among the rural communities across developing counties, including India. The penetration level of clean cooking fuel such as Liquefied Petroleum Gas (LPG) among rural households is considered to be low due to the problem of affordability and accessibility. Our analysis of data on percentage of rural households in the states of Bihar, Madhya Pradesh and Uttar Pradesh with access to clean cooking fuel indicated an increasing trend before the outbreak of the COVID-19 pandemic. However, the percentage of rural households with LPG as cooking fuel has declined during the COVID-19 outbreak. Our analysis of the COVID-19 rural impact survey indicated that only about 20% of the rural households have reported access to clean cooking fuel in the states of Bihar, Madhya Pradesh and Uttar Pradesh on an average. The nationwide lockdown during COVID-19 pandemic has affected the life of everyone and the impact on the livelihood of poor, particularly those living in the rural areas, has been higher than anyone else. It is evident that since the COVID-19 lockdown, many rural households have shifted from clean fuel to firewood and cow-dung for cooking across Bihar, Madhya Pradesh and Uttar Pradesh due to disruption in supply on one hand, and loss of income and livelihood on the other.

The analysis of rural impact survey data depicts that about 80% of the rural households used unclean fuels for cooking during the COVID-19 pandemic, which eventually leads to air pollution inside the houses, causing social, economic, health-related, and environmental burdens on majority of the families in rural areas. Due to the high level of environmental and health risks associated with dirty biomass fuels, particularly among women, the government launched the Pradhan Mantri Ujjwala Yojana (PMUY) in the year 2016 for providing LPG connections to poor families. Further, the provision of a free LPG cylinder for six months was also part of the special relief package from the central government in 2020 under the Pradhan Mantri Garib Kalyan Yojana (PMGKY) to cope up with the economic losses faced by the poor families during COVID-19 outbreak.

Considering the importance of rapid policy response for handling the uncertainty during COVID-19 outbreak, the World Bank conducted a quick survey among rural households in India, covering a wide range of issues. We have extracted a set of variables to understand the impact of COVID outbreak on usage of various sources of cooking fuels among rural households in India and identify the determinants of the adoption of clean cooking fuel during the pandemic. As there is limited evidence on the implication of COVID-19 on clean cooking fuel program except a recent study by Ravindra, Kaur-Sidhu, Mor, Chakma, and Pillarisetti (2021), this study gives a few interesting insights, which may help in

developing a roadmap for providing safe and clean cooking energy to all during the time of crisis.

- The first thing to note is that there has been a decline in the use of clean fuel such as LPG during COVID-19 pandemic in all three states i.e. Bihar, Madhya Pradesh and Uttar Pradesh as compared to the pre-COVID period, which necessitates the need to devise proper mechanism for ensuring sustainable supply, access and affordability by provisioning financial relief through the direct benefit transfer scheme.
- Secondly, it is clear from the analysis that there is a significant association between socio-demographic profiles of rural households and access to cooking fuel sources. It is interesting to note that rural respondents over 40 years of age, female-headed households, with small family sizes, comparatively more educated, belonging to an upper social category, and having higher income are accessing clean fuel more as compared to their counterparts. A significant association of socio-demographic factors with access to clean cooking fuel among rural households provides a good policy direction for developing a targeted clean energy outreach program in the rural areas of India. The Pradhan Mantri Ujjwala Yojana is already focusing on poor women-headed households for strengthening the scheme's outcome. Findings of this study can help in developing COVID-19-specific packages for extending the penetration of clean cooking fuel among the rural households in a targeted manner.
- Finally, the marginal effect indicates that age, social category, and income level have a positive and significant impact on access to clean fuel, which implies that respondents with higher age, belonging to the general category, and having higher income are more likely to use clean fuel for cooking. Similarly, the households' marginal effect for ownership of assets such as an exclusive kitchen room, refrigerator, pressure cooker, television, and furniture indicate a positive and significant impact on access to clean fuel in rural India. This implies that schemes for clean cooking fuel should not only focus on supply-driven issues, but should also consider connecting with people based on their socio-demographic characteristics and asset ownership.

The assessment of factors affecting access to clean fuel among rural households in terms of their characteristics and level of asset holdings provides key insights for the government, energy organizations, international agencies, and the communities to understand the nature and magnitude of sources of cooking fuel and their implications for the society. Besides the delivery of subsidy to beneficiaries through Direct Benefit Transfer (DBT), there is a need to create awareness among the rural communities for adopting and using clean fuel on a regular basis for cooking every meal. A recent report by Radhakrishnan, Sen, and Nihalani (2021) indicated a significant difference between a household having LPG connection versus those using it for cooking and the magnitude of this difference is aggravated among the rural households. Therefore, there is a need for enhancing sustainable use of clean cooking fuel among rural communities and reducing the difference between the adoption and usage of LPG for cooking.

We have based this study on the data collected scientifically through the World Bank's rural impact survey of 3 states namely Bihar, Madhya Pradesh, and Uttar Pradesh, covering 2731 rural households. However, we have been constrained by the variables covered in the survey and have aligned our research framework accordingly. Moreover, the responses of the rural households were mainly recorded as a yes or no, which also provided limited scope for utilizing a sophisticated data analysis technique. The study could not cover much of the issues related to the supply side of the clean cooking fuel and its implication during the COVID-19 lockdown on the rural communities. Therefore, future researches may be developed based on primary surveys to assess the impact of psychographic variables and socio-demographics and asset ownership. This shall provide an opportunity to use robust data analysis

techniques for delivering a better and more enriched contribution to the existing knowledge base.

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Microdata on COVID-19-Related Shocks in Rural India 2020, Rounds 1–3 is available at <https://microdata.worldbank.org/index.php/catalog/3830>.

CRediT authorship contribution statement

Jabir Ali: Conceptualization, Methodology, Investigation, Writing – review & editing, Validation. **Waseem Khan:** Formal analysis, Investigation, Writing – original draft, Validation.

Declaration of competing interest

The authors declare that they have no competing interests.

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