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Not just income: The enabling role of institutional confidence and social capital in household energy transitions in India

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ABSTRACT

Transitioning to cleaner forms of cooking energy is a key facet of sustainable development. Despite numerous programs, the transition in developing countries remains slow and sometimes non-existent. Even when cleaner sources of cooking energy are adopted, their use is often temporary, with households continuing to use traditional energy sources. While literature identifies the importance of affordability and access, factors such as trust in local institutions and social capital remain under-explored. We aim to fill this gap by using household-level panel data to estimate drivers of clean cooking technology adoption and sustained fuel use in India. We add to the current scholarship on determinants of household energy transition by analyzing the relationship between household energy choices and institutional factors and social capital. We employ a logistic regression analysis to examine stove technology adoption, and complement it with an ordinary least squares model to measure factors that drive sustained fuel usage. The results indicate that participation in local community organizations and trust in local government is positively related to both adoption of stove technologies and expenditure on liquefied petroleum gas. Female education and membership in women-led networks also play an important role in driving fuel adoption. Policies aimed at promoting transitions to cleaner cooking fuels should, therefore, leverage community and social networks to promote sustained fuel use. Any national programs should be anchored in local contexts and involve local actors.

1. Introduction

The World Health Organization lists indoor air pollution from burning traditional fuels as the leading environmental cause of premature deaths in the world [1]. In 2015, the United Nations General Assembly adopted seventeen Sustainable Development Goals (SDGs), among which Goal 7 specifically focuses on energy access and poverty. The target is to provide access to affordable and clean energy for all by 2030 [2]. This target is particularly relevant in the case of cooking fuels where nearly three billion people worldwide rely on polluting sources of cooking energy [3]; of whom, over 680 million live in India [4]. These households rely on traditional fuels like firewood rather than modern sources of energy such as electricity and liquefied petroleum gas (LPG). Affordability and access have been identified as barriers to households' transition to modern cooking fuels [5].

In 2009, the Government of India introduced the Rajiv Gandhi Gramin LPG Vitarak Yojana (RGGLVY) to expand the distribution infrastructure for LPG in rural areas in the country. Then, in 2016, the Government launched the Pradhan Mantri Ujjwala Yojana (PMUY) which provides LPG connections to households below the poverty line, along with the 'Pahal' and 'Give-it-Up' campaigns encouraging rich urban households to give up subsidized LPG connections so that more connections may be provided to poor rural households. The programs have vastly expanded access to LPG connections in the country; as of June 01, 2022, over 92.7 million LPG connections had been released to households [6].

Notably, both RGGLVY and PMUY focus on increasing the availability of and access to LPG, incorporating components of female empowerment. RGGLVY expanded the infrastructure and the presence of LPG stoves in households; PMUY focuses on providing capital subsidies to households seeking LPG connections. The RGGLVY scheme provides support for expanding the LPG network in rural areas by assisting rural households in setting up distribution agencies. As a way of incorporating female empowerment, the agencies are allocated in the name of both husband and wife in a family. The PMUY focuses on expanding household access to clean cooking fuels and provides LPG

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connections for women below the poverty line. However, neither policy provides continued support to households for sustained purchase of LPG cylinders. In other words, the subsidies were primarily directed at alleviating the up-front capital cost of acquiring and setting up LPG stoves and connections but not at addressing the operational cost of purchasing cylinders to continue using the fuel [7,8].[1]

Despite the presence of several policy measures and instruments, the transition remains slow, with a large proportion of households continuing to use traditional solid fuels even if they have an LPG connection. Furthermore, even in cases where clean cooking technologies are adopted, use of fuels like LPG is low, indicating that capital subsidies may not result in sustained long-term transitions [9].

Scholarship in this area provides rich evidence of factors affecting the transition to cleaner cooking fuels, particularly in the global South. However, studies primarily focus on revealed financial, and capability related barriers, largely focusing on individual and household characteristics [10,11]. Transitioning to modern sources of energy is also related to growing dependence on formal markets and supply chains, and using government-administered programs [12,13]. Therefore, local politics, trust and confidence in local institutions and governments are likely to play a role in determining the likelihood and extent of transitions [14]. Research in environmental governance and policy points to linkages between community-level factors, trust, and environmental outcomes [15–17]. Polarized political environments and centralization of government schemes as witnessed in recent years can also affect the relationship between trust in one's local, state, and national leaders and policy makers in determining reliance on public services provision. Limited evidence exists on the role of community level trust and social capital in driving energy transitions.

This study contributes to the energy transitions and policy scholarship in three ways. First, it examines the drivers of household-level energy use in India over time. Rather than evaluating the effect of a single policy change, we leverage a large panel dataset to examine the importance of several factors that operate at the community level (e.g., village infrastructure and local LPG price) as well as factors that operate at the household level (e.g. income, caste and occupation). Second, we expand the current understanding of the determinants of household level energy transitions by examining the effect of household-level psychological and sociological factors including trust in institutions and social capital. Finally, to establish transitions, we go beyond stove technology adoption to also examine sustained use of the fuel in terms of spending.

2. Energy transitions and their determinants

Extant literature can be categorized into studies focusing on defining energy transitions, and those analyzing the various factors that drive household energy transitions. In the following sections we start by examining the prevailing and emerging definitions of energy poverty and transitions. This is followed by an exploration of the key drivers of energy choices in developing countries.

2.1. Defining household energy transitions

Although the term household level energy transition[2] is broadly understood and widely applied, its specific definitions can take a variety of forms. Gerald Leach [18] provided one of the earliest definitions of energy transitions, characterizing it as a move from traditional biomass-based sources of energy (also referred to as 'solid fuels') to modern fuels, like natural gas, LPG, or electricity linked with an improvement in economic well-being. As defined in this early conceptualization, the transition to modern fuels could be considered as "climbing the energy ladder", where users made a complete switch from one fuel to another with an improvement in economic status. This transition can also be studied through the choice of energy carriers, energy services, and technology [19], and through the concept of energy poverty [20–22].

Over time, however, studies adopted a more nuanced approach to studying energy transitions. The expanded approaches identify evidence for "fuel stacking" or "multiple fuel" models of household energy usage rather than the previously conceptualized linear transition [5,19,23]. The observed addition rather than substitution of fuel sources can be attributed to the lack of dependable infrastructure and supply of modern fuel sources. Most literature appears to indicate that complete transitions are limited, and fuel (and stove) stacking is found to be more prevalent for cooking fuels [24–26].

Finally, recent studies have further expanded our understanding of transitions by contrasting technology and fuel transitions. In the case of cooking energy transitions, the dichotomy manifests as cookstove transitions versus fuel- or energy-carrier transitions. While the two types of transitions are complementary, they may not always happen concurrently. In the absence of a sustained fuel transition, a stove technology transition alone does not yield long-term effects on energy usage [9,25,27] and households often regress or "backslide" to using solid biomass fuels [9,26].

2.2. Drivers of household energy transitions

Affordability is one of the most important determinants of energy transitions. Variables commonly used to study affordability include income, the price of fuels and energy technologies, and inequality. Other determinants of household energy choices include social and cultural factors, fuel types, and technology. The following sections discuss each in more detail.

2.2.1. Affordability as a driver of energy transitions

Income is one of the key drivers of energy transitions [18,28–32]. As noted, the energy ladder approach links higher levels of economic prosperity with cleaner energy choices. In the absence of suitable measures of income, scholars have also used household expenditures [28], wealth measured using asset ownership [33], and access to credit [13] as determinants of energy consumption. At the country level, in addition to GDP, other macroeconomic indicators such as size of population and higher levels of inequality [29] drive energy transitions. Embedded within affordability are the prices of the fuels themselves [5,34]. Prices are generally inversely related with the adoption of modern fuels and technology [21,35,36]. As noted in the introduction, moving from solid biomass-based fuels also necessitates a move towards market based, often relatively expensive modern fuels such as LPG.

Studies have also questioned the strength and sustainability of the relationship between economic well-being and household fuel transitions [25,36]. Using data from a randomized intervention designed to

[1] While the Indian Government did provide price subsidies on LPG for several years [7], these were largely insufficient in relative size to cause a significant transition to large scale LPG usage, especially in rural areas. Over time, the subsidy has been largely phased out and replaced with targeted support through capital subsidies described here [8].

[2] We recognize that fuel transitions have also been studied at a systems, or economy-wide, level, particularly in the context of energy generation in the developed world. This study focuses on household level transitions in the global South. As such, the literature presented in this section also spans household-level definitions and drivers of fuel choices.

examine the effects of asset transfers in rural India, [25] find that a significant increase in a rural household's assets does not lead to the adoption of cleaner cooking fuels. Kumar [37] investigates the role of improved lighting in commercial enterprises in rural India and finds that while there is no evidence of higher earnings due to better lighting, in some cases, business owners reported fuel savings by transitioning to solar lanterns [37].

2.2.2. Social and cultural factors as drivers of transitions

Social and cultural factors impacting household cooking energy choices include cooking and food preferences, neighborhood effects, gender, religion, caste, education, and urban vs rural location [10,21,30,35,38–42].

Education and energy usage are positively related; specifically, education of women leads to a reduced usage of biomass-based fuels [10,21]. The link between gender and energy choices manifests in many ways including household leadership, female education, networks, and occupational opportunities. Typically, the burden of collecting the fuel and cooking falls on female household members, disproportionately exposing them to adverse health and societal effects. Girls often miss or drop out of school and spend their productive time collecting fuelwood, and women cannot seek employment even if they want to [43,44]. Research concludes that female empowerment is virtuously related to overall economic upliftment and household energy transitions [45]. Male headed households consume less energy [10,39]; households where women have formal employment are more likely to choose modern fuels for cooking [30,32] and depend less on biomass-based energy sources [46]. In the context of socio-religious strata in India, households belonging to the scheduled tribe and scheduled caste communities have significantly lower access to LPG and electricity usage as compared to the upper caste households [40,42,47,48]. Cultural factors, such as food habits of households, also play a role in determining fuel and technology choices [19,23].

2.2.3. Fuel and technology characteristics as drivers of transitions

In addition to fuel prices, technology, stove design, and fuel delivery mechanisms play a role in determining household fuel choices. Recent research on improved cookstoves offers insights on household decision making in fuel and technology adoption [49–53]. Using stated preferences and a discrete choice experiment to assess household choices for improved cookstoves in India, Jeuland and colleagues [54] conclude that preference heterogeneity plays a crucial role in decision making and should inform policy. Accessibility of energy sources also affects households' fuel choices [34,54]. For instance, in areas where it is difficult to reach markets to purchase LPG cylinders, households may be less likely to use it as a primary source of energy. In case of biomass-based fuels, accessibility manifests in the form of forest cover and the distance to closest sources of firewood [55,56].

2.2.4. Role of community level factors in household energy choices and a proposed framework

As household energy portfolios move to market-based mechanisms of procurement and delivery, the process of fuel purchases and consumption gets formalized [57]. As a result, sustainability of energy transitions hinges on households' trust in governments, institutions, and communities. While literature examines the role of trust as a determinant of energy production, especially in citing energy facilities [58–60], fuel subsidy reform [61], land possession and environmental quality [15–17], zoning [62], climate adaptation and governmental services [63,64], this relation remains largely unexplored in the case of household energy choices. Additionally, research also examines the role of networks such as rural microlending [65,66], self-help groups [65,67] and public private partnerships [68].

We focus specifically on the role of social capital and trust in institutions in enabling household energy transitions. Increased usage of fuels like LPG also implies that communities need to rely on markets and formal service delivery systems. The extent to which consumers choose to rely on such formal set-ups depends on their trust in communities and public agencies, and politicians. The perceived ability of politicians to deliver on promises, especially for timely and consistent fuel supply can determine the extent to which households rely on modern fuels. Based on the literature and the gaps, we propose a framework to analyze household transitions in Fig. 1. Transition to LPG as a cleaner cooking fuel is measured in two ways - the adoption of technology (presence of an LPG connection), and sustained fuel use (spending on LPG).

We contribute to the literature by adding a category of variables related to confidence in institutions and social capital of households. The other independent variables, or drivers of transitions are disaggregated into social, access and economic factors. Among social factors, we include indicators of female empowerment (measured by education and membership of female led groups called Mahila Mandals [69,70]), caste, and religion. Mahila Mandals are informal community-level associations of women that provide a platform to organize, discuss, and address local issues. In recent studies, scholars have [67,69] concluded that women's self-help groups increase political engagement and awareness of public-entitlement programs. These groups could act as potential channels for women to provide and receive information and might, therefore, act as catalysts for providing information on clean cooking energy fuels in rural areas. We include these measures as independent variables in our regressions. Access related factors include road infrastructure and price of LPG in rural areas. Economic factors relate to household expenditure, poverty status, number of household members, source of income, and geography.

In Fig. 1 below, we present an overview of how social capital and confidence in institutions, gender-related factors, fuel access, and economic factors are measured and how they affect the adoption and sustained use of LPG.

3. Methods

In the following paragraphs, we describe the independent and dependent variables, followed by a brief discussion of our model specifications.

3.1. Data

We use data from the Indian Human Development Survey (IHDS) - a joint research effort of the University of Maryland and the National Council of Applied Economic Research (NCAER) [71]. The IHDS is a large, nationally representative panel dataset. It comprises one of the few publicly available sources of economic and social well-being data for India. The first wave (IHDS I) was conducted in 2004–05, and the second wave (IHDS II) in 2011–12. The IHDS panel surveys 40,018 households across India, of whom approximately 28,000 (70 %) live in rural areas [71].

A key advantage of the IHDS dataset for our purposes is that it includes several questions about respondents' social capital – indicators that are absent from more recent large-scale questionnaires on the issue. For example, the IHDS asks whether respondents know members of local government, politicians, police, military, doctors, teachers etc. Extensive geographic coverage and sampling across different villages ensure that the dataset comprises a representative sample. The survey provides indicators of households' economic well-being, including information on household income, aggregate expenditures, accessibility of villages via road networks, and membership of different social groups. Further, as recognized in the literature, fuel choices at the household level can vary based on the occupation of household members. The survey data allows us to control for several occupation types. Finally, social factors such as caste, household size, and the role of women in the household are also included in the analysis. Caste can often play a role in determining the accessibility to the different public, financial, and social services. Further, a household's economic mobility can itself depend on the caste

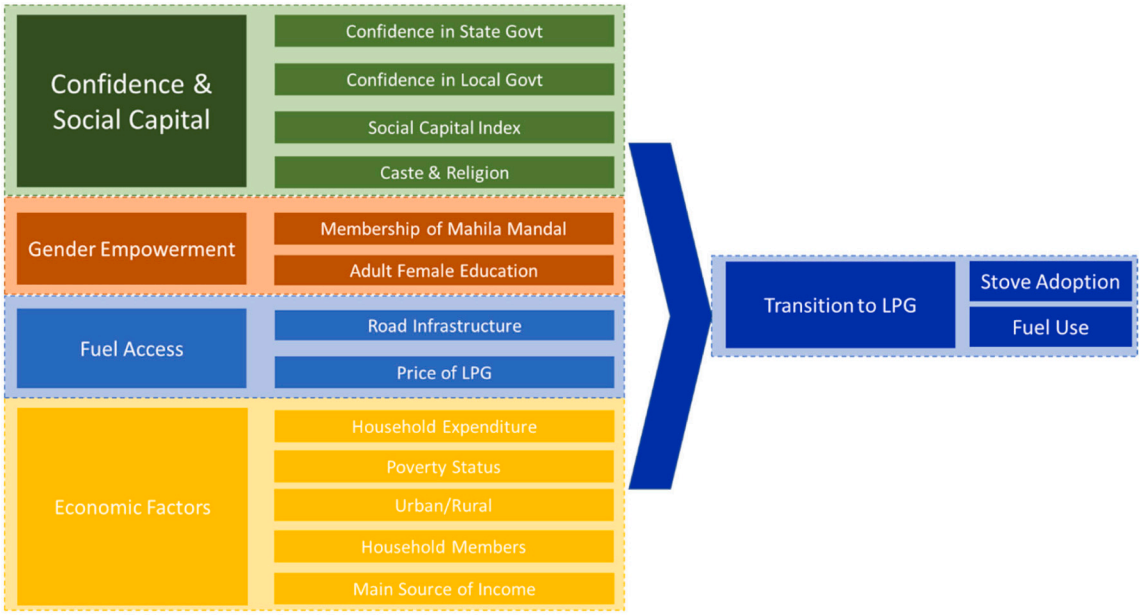

Fig. 1. Framework analyzing energy transitions.
Note: The factors affecting transition to clean cooking fuels are categorized into confidence in institutions and social capital (green), gender empowerment (orange), access to clean fuels measured at the village level (in blue) and economic indicators (yellow). The transition to LPG includes both the extensive margin of adoption of LPG stoves as well as the intensive margin of sustained use of LPG. The variables used in the empirical analysis are described in detail in Sections 3.2 and 3.3.

of the household or household head. A total of six caste and religion categories are included in the dataset - Forward caste, Other Backward Castes (OBCs), Dalits, Adivasis, Muslims, and Christians/Sikhs/Jains.

3.2. Dependent variables

We consider two related dependent variables to examine both adoption and sustained use of LPG. The IHDS Long Panel public use codebook[3] describes that LPG use and expenditure by households are coded as FULPG and FU11B respectively. We use both of these as dependent variables in the analysis.

The first dependent variable (FULPG) is binary, taking a value of 1 for households that use LPG and 0 for those that do not. The second dependent variable (FU11B) is the total spending reported on purchasing LPG cylinders in the past 30-day period. We code households' LPG expenditure to 0 for households that report not using LPG at all. Table 1 summarizes the statistics for the dependent and independent variables used in our analysis.

3.3. Independent variables

Confidence: The IHDS questionnaire asks respondents about their degree of confidence in state-level and local institutions. Specifically for our purposes, we include (i) confidence in state governments to look after the people and (ii) confidence in local governments (village panchayats, *nagar panchayats* or *nagar palikas*) to implement public projects. The variables are categorical and can take 3 values (1, 2 or 3) that increase with the level of confidence expressed by the respondent ("hardly any confidence", "only some confidence" and "a great deal of confidence").[4]

Social Capital: We use respondents' social connections as an indicator of their social capital. Following Narayan and Cassidy's [72] approach, we use factor analysis to develop an index and include it as an independent variable in the analysis. The focus of this analysis is to assess the role of local connections within the community in supporting household level transitions to clean cooking energy. In the IHDS survey, respondents are asked "Do you or any members of your household have personal acquaintance with someone who works in any of the following occupations ...." with the options including doctors and health workers; school teachers; government, politicians, police, military; government.

Caste and religion: Caste and religion are strongly associated with access to resources and household wealth. Inter-caste mobility is relatively low in India, and households from different castes often reside in different areas in the same village, leading to an asymmetric flow of information regarding fuel usage options.

Membership in Mahila Mandal and Female Education: The IHDS questionnaire asks respondents if anybody in the household is a member of a Mahila Mandal and the highest education level among adult female household members.

Price of LPG and access to roads in rural areas: The IHDS village-level dataset provides measures of the price of LPG per kilogram and the status of road infrastructure in rural areas. We merge the village-level dataset with the household panel dataset based on geographic identifiers, allowing us to examine how these factors affect adoption and use of LPG. Since these indicators are not codified for urban areas, we do not include them in specifications that do not focus solely on rural areas.

Household expenditure: The IHDS dataset codes annual expenditure as total expenses on >50 different items including food, clothing, entertainment, electricity, medical expenses etc. We use the logarithm of reported annual expenditures in our estimations.

Poverty status: We use a dummy variable in the IHDS dataset that indicates whether a household would be classified as falling below the poverty line according to the Tendulkar Committee estimates for 2011/12 for the second wave of the survey, and for 2004/05 for the first wave.

Urban/rural: The IHDS dataset classifies primary sampling units (PSUs) into urban and rural locations, based on the 2001 Census for IHDS-I (2004–05) and the 2011 Census for IHDS-II (2011–12). We use this binary variable to run separate estimations for urban and rural

[3] Available at https://www.icpsr.umich.edu/web/DSDR/studies/37382/datadocumentation#.

[4] Note that the original/raw IHDS dataset codes these values in decreasing order of confidence (1 being highest confidence and 3 being lowest). We chose to recode the values by reversing the ordering for easier interpretation of the coefficient.

Table 1
Summary statistics.

	Mean	Std. Deviation	Min	Max	Observations
Dependent variables					
LPG connection (0 = No; 1 = Yes)	0.40	0.49	0	1	78,069
LPG spending (monthly expenditure on LPG (INR/month))	161.36	229.27	0	3000	77,998
Independent variables					
Confidence state (1 = Hardly any confidence; 2 = Only some confidence; 3 = A great deal of confidence)	2.06	0.70	1	3	79,248
Confidence local (1 = Hardly any confidence; 2 = Only some confidence; 3 = A great deal of confidence)	2.12	0.70	1	3	79,261
Social capital index	0.00	1	−1.43	1.63	78,516
Member of Mahila Mandal (0 = No; 1 = Yes)	0.08	0.27	0	1	79,912
Highest education level of adult female household member (number of years of education)	4.96	5.08	0	15	78,832
Household consumption expenditure (INR per year)	107,896	108,322	180	4,080,760	79,967
Poverty status (0 = Not Poor; 1 = Poor)	0.20	0.40	0	1	79,967
Number of household members	5.35	2.71	1	21	80,035
Urban households (0 = Rural; 1 = Urban)	0.31	0.46	0	1	80,036
LPG price in rural areas (INR per kilogram of LPG)	26.30	9.94	0.21	300	47,299
Access to roads in rural areas (0 = No access; 1 = Unpaved Road access; 2 = Paved Road access)	1.73	0.52	0	2	53,514

	Percentage
Breakdown of caste and religion	
Forward caste	21.32 %
Other Backward Castes	34.40 %
Dalit	21.39 %
Adivasi	8.52 %
Muslim	11.39 %
Christian/Sikh/Jain	2.98 %
Breakdown of income source	
Cultivation	26.54 %
Allied agriculture	1.00 %
Agricultural wage labor	12.55 %
Non-agricultural wage labor	20.27 %
Artisan/independent	3.54 %
Petty shop	7.55 %
Organized business	3.41 %
Salaried	17.53 %
Profession	0.75 %
Pension/rent etc.	4.26 %
Other	2.61 %

Note: table shows summary statistics of all dependent and independent variables used in analysis. Caste and religion, and income source are disaggregated by percentage, since these are unordered categorical variables.

samples. Some variables, specifically price of LPG and road access as mentioned above, are available only for rural PSUs from the IHDS village level dataset.

Number of household members: The IHDS dataset provides a measure of the number of persons in each household during each wave of the survey. We include this as an independent variable in our regressions.

Income source: The IHDS questionnaire codes respondents' main income source into 10 categories (Table 1). We include this indicator as a categorical variable in our regressions.

3.4. Regression analyses

To analyze the relationship between fuel use and the independent variables of interest, we run the following regressions on the extensive (having an LPG connection) and intensive (expenditure on LPG) margins of LPG usage.

1. A logistic regression with a binary dependent variable indicating whether a household uses LPG or not.

$$y_{it} = \beta_1 + \beta_2 * Confidence\_State_{it} + \beta_3 * Confidence\_Local_{it} + \beta_4 * SocialCapital_{it} + \beta_5 * SelfHelpGroup_{it} + \beta_6 * FemaleEduc_{it} + \beta_7 * log(ConsumptionExpenditure)_{it} + \beta_8 * PovertyStatus_{it} + \beta_9 * Caste/Religion_{it} + \beta_{10} * IncomeSource_{it} + \theta_t + \varepsilon_{it} \quad (1)$$

2. An ordinary least squares regression with the dependent variable being the household's expenditure on LPG over the last 30 days.

$$e_{it} = \beta_1 + \beta_2 * Confidence\_State_{it} + \beta_3 * Confidence\_Local_{it} + \beta_4 * SocialCapital_{it} + \beta_5 * SelfHelpGroup_{it} + \beta_6 * FemaleEduc_{it} + \beta_7 * log(ConsumptionExpenditure)_{it} + \beta_8 * PovertyStatus_{it} + \beta_9 * Caste/Religion_{it} + \beta_{10} * IncomeSource_{it} + \theta_t + \varepsilon_{it} \quad (2)$$

In the logistic regression Eq. (1), y_{it} is a binary variable which takes the value 1 if household i in survey wave t uses LPG, and 0 otherwise. In the ordinary least square regression Eq. (2), the explanatory variables remain the same as those in Eq. (1), while the dependent variable, e_{it}, is household i's expenditure on LPG over the last 30 days in survey wave t.

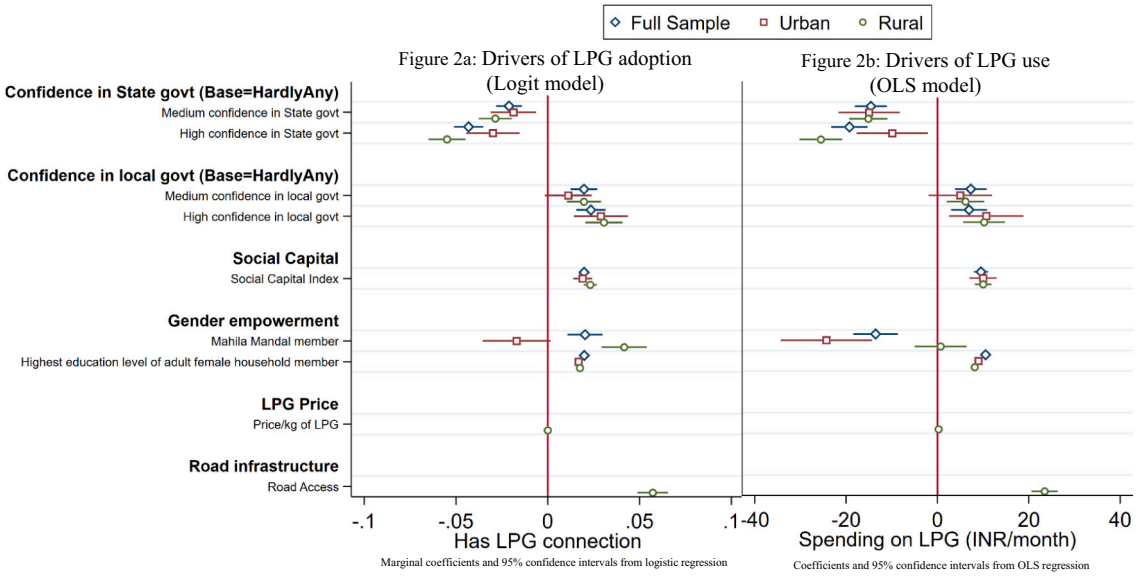

Fig. 2. Drivers of LPG adoption and usage.

4. Results

Tables A1 and A2 (Appendix) contain the results from estimating Eqs. (1) and (2), respectively. Results for the entire sample are included in column (1). Columns (2) and (3) present the disaggregated results for urban and rural areas, respectively. Urban areas are more likely to have greater access to LPG and, therefore, present important geographical differences in the explanatory power of other covariates. Moreover, the IHDS village questionnaire contains information on price per kilogram of LPG at the village level as well as access to roads – both of which are potentially important determinants of fuel use. Since these variables are available only for the rural sample survey data, we include them in the model where we analyze rural households. Fig. 2 summarizes our key findings.

The results indicate that institutional confidence and social capital are significantly related to the probability of a household having an LPG connection (Fig. 2 (a)) and their sustained use of the fuel as measured by spending (Fig. 2 (b)). Confidence in state government is negatively associated with adoption and sustained use of LPG. Compared to 'hardly any' confidence in state government, having 'only some' and 'a great deal of' confidence is associated with 2 and 4 percentage point (p.p.) lower probability of having an LPG connection, respectively. The reduction in spending on LPG associated with the two categories are INR 14.59 and INR 19.28, respectively. The results on confidence in local governments operate in the opposite direction. Households reporting 'only some' and 'a great deal of' confidence in local governments each have a 2 p.p. higher probability of having an LPG connection and INR 7.28 and INR 6.92 higher spending on LPG, respectively, compared to having hardly any confidence. Results are in the same direction but with higher magnitudes in rural households compared to urban households.

Higher social capital is positively associated with both the probability of having an LPG connection and sustained fuel use. A one standard deviation increase in social capital is associated with a 2 p.p. increase in the probability of having an LPG connection and INR 9.53 increase in spending on LPG.

Next, focusing specifically on gender empowerment, the results show that an additional year of education of female household members is associated with a 2 p.p. increase in the likelihood of having an LPG connection and an INR 10.54 increase in spending on LPG. Overall, membership in a Mahila Mandal is associated with a 2 p.p. increase in the probability of having an LPG connection, but an INR 13.55 reduction in spending on LPG. Interestingly, the associations between membership in a Mahila Mandal and LPG use and spending are in different directions between the rural and urban samples. In the rural sample, membership is associated with a 4 p.p. increase in the probability of having an LPG connection and no statistically distinguishable association with spending. In the urban sample, however, membership is associated with a 2 p.p. reduction in the probability of having an LPG connection and an INR 24.32 reduction in spending.

For households in rural areas, price does not have a statistically significant relationship with having an LPG connection and is associated with an INR 0.23 increase in spending on LPG. Having access to all-weather "pucca" roads is positively associated with the likelihood of having an LPG connection (5.7 p.p. increase) and spending more on the fuel (INR 23.44 increase).

From Tables A2 and A3, we also see that social structures continue to determine access to LPG - households belonging to forward castes are more likely to have an LPG connection than Other Backward Caste (OBC), Dalit (lower caste), Adivasi (tribal) or Muslim households, in both urban and rural areas, with the reduction in probability of having a connection ranging between 7.1 p.p. for OBCs to 18.3 p.p. for Adivasis. Similarly, forward castes spend more on LPG compared to OBCs (INR 33.72 less), Dalits (INR 45.67 less), Adivasis (INR 29.96 less) and Muslims (INR 29.72 less). However, other minority households (Christians/Jains/Sikhs) are 11.7 p.p. more likely to own an LPG connection and spend INR 33.41 more on the fuel per month.

As expected, economic well-being of the household, as measured by the consumption expenditure, is positively related with LPG ownership as well as spending. Households below the poverty line are less likely to have an LPG connection in both rural and urban areas. Further, households engaged in occupations other than cultivation and agricultural wage labor are more likely to have an LPG connection and to spend more on the fuel. Finally, the coefficients on survey wave indicate that while probability of LPG adoption increased by 1.3 p.p. between 2004/05 and 2011/12, spending on LPG reduced by INR 49.

We employ several robustness tests to verify the consistency of these results. Specifically, we include (i) parsimonious models with confidence in institutions, social capital, and female empowerment as the only independent variables without any other controls, (ii) linear probability and probit models with LPG adoption as the independent

variable, (iii) additional binary independent variables measuring whether the household uses alternative fuels, including firewood (following the specifications in Mani et al. [73]).

In the following section, we discuss our results, limitations of the data and methodology, address why some of our estimates are counterintuitive, and further contextualize our findings.

5. Discussion

Addressing household level cooking energy choices is critical to the global goal of achieving an equitable transition to sustainability and improving access to cleaner forms of energy. Even as the overall adoption of improved cooking technologies continues to increase, sustaining the transition is a daunting task with multifaceted issues. Thus far, international, and national programs have focused largely on providing subsidies that increase affordability of stove technology with limited attention to long-term use or the importance of community and social factors, and access indicators that determine LPG adoption and sustained use.

Existing work in the area often evaluates single programs or pilot projects using case studies, regional or national datasets focusing primarily on cross-sectional coverage [21,30]. We contribute to this literature by analyzing institutional factors and social capital indicators such as confidence in institutions and membership of networks by analyzing a large panel dataset. This dataset allows us to isolate the importance of specific factors at the household level. Moreover, we explicitly examine both the intensive and extensive margins of LPG use - analyzing the transition to stove technology as well as sustained fuel use.

As noted earlier, thus far, government programs to increase LPG access have focused on addressing the issue of high capital costs. As a result, the policies have targeted acquisition and connection costs for households seeking new LPG connections with limited focus on infrastructure expansion and alleviating recurring fuel expenses. Further, while on the one hand, capital subsidies have decreased the cost of setting up LPG stoves at home, the increasing costs of the fuel itself have dampened the actual transition with few households reporting consistent use of the fuel [9].

Although the presence of LPG connections has expanded significantly since the data in this study was collected, recent studies have confirmed that the transition in terms of actual fuel (LPG) use has been slow to non-existent in most cases (see for e.g., Kar et al. [9] and Mani et al. [9,73]).

We do recognize some limitations of the present study. The first limitation applies to any analyses using self-reported survey data. Responses depend on recall and do not represent revealed preferences. Further, social desirability bias may affect responses, especially around expenditure and social capital. Two reasons might reduce social desirability bias in the context of our paper. First, although the consent procedure in the IHDS survey mentions that the survey administrators (NCAER and University of Maryland) will retain 'names and other personal information in a confidential manner'; the respondents are told '*If you decide to answer some or all of the questions, we will use the information you give us only for the purposes of research and publication. People will be able to learn about the health and well-being of the people of India, but not what you personally said.*' Second, given the variables that we include are mostly objective indicators that do not include reference to taboo or socially undesirable behavior, we do not expect significant misreporting due to social desirability bias.

The second limitation of utilizing survey data is that our estimates may be subject to omitted variable bias. For instance, it could be the case that a person identifies more with the party in power at the local or state government, which affects their confidence in the institution(s) as well as their adoption and use of LPG, since the fuel is delivered by public sector agencies and companies. This would potentially lead to our results overestimating the association between confidence in institutions and adoption or use of LPG. Unfortunately, the IHDS survey instrument does not include questions on respondents' party identification. Similarly, the survey instrument does not include questions on respondents' cooking habits or dietary preferences. These factors can be correlated with sociodemographic factors such as caste, religion, and household expenditure and also with LPG adoption and usage, biasing our estimates. Further research should be conducted to mitigate these potential biases and pin down the contributions of these underlying factors that are often difficult to include in large scale surveys.

Third, the most recent data in the IHDS panel dataset used here is for 2011/12. Echoing the findings of other studies (see for example Kar et al. [9]), we also emphasize the need for more frequent data collection and reporting to facilitate policy evaluation. However, we believe that social dynamics and cultural factors remain largely similar in terms of LPG adoption and use – pointing towards continued relevance of the factors we identify and analyze in the study. Further, we can highlight only associative relationships in this paper, and our findings may be subject to omitted variable biases for data that is not included in the IHDS survey. Future studies could build on the findings of this analysis and aim to address these limitations.

With these limitations in mind, our regression results show that while household level economic well-being (as measured by expenditure) is an important driver of technology adoption and fuel use, confidence in institutions and social capital play a role in driving energy transitions. Respondents with high confidence in local governments are more likely to adopt LPG stoves and sustain use by spending more on the fuel. Interestingly, and counterintuitively, an increase in respondents' trust in state government is negatively associated with the probability of the household having an LPG connection and their LPG spending. While surprising, this result does align with similar findings by Cooper and Knotts [62] in the context of zoning where trust in local government was found to be positively (and significantly) related to support whereas the trust in state government is negatively (but not significantly) related to support for zoning, respectively. Further, the IHDS questionnaire has a slightly different statement to elicit confidence in state and local governments. For the former, it asks about respondents' confidence in their state government "to look after the people". For the latter, the question is more directly linked to publicly administered programs, asking about respondents' confidence in their local government "to implement public projects". This difference in framing is also emblematic of the inherent intergovernmental relations and different roles played by the hierarchical levels in government structures. Higher confidence in local government is associated with higher probability of a household having an LPG connection as well as an increase in the households' spending on LPG.

Higher social capital (knowing government personnel, politicians, doctors, teachers, etc.) is positively associated with spending on LPG for both urban and rural areas. We consider this as adding to recent work identifying caste divisions as an impediment to energy transitions [40]. Without more attention to increasing acceptability and information about LPG adoption and sustained use, the transition may leave behind people with lower social capital.

Among other social factors, caste, and religion are associated with adoption as well as sustained fuel usage. Households belonging to Other Backward Castes (OBCs), Dalits, Adivasi, and Muslim communities are less likely than forward caste Hindu Brahmins to adopt LPG and also spend less on the fuel. This disparity indicates the persistent lack of access along social fault-lines in India, where religion and caste continue to drive economic and social development. Information campaigns, regular engagement with households from different caste groups offer possible mechanisms for a targeted response to these deep-rooted gaps.

Gender empowerment also plays an important role in promoting the use of LPG. Education levels of adult female household members are

strongly positively associated with LPG adoption and use. Furthermore, in rural India, Mahila Mandal membership is positively associated with the household access to LPG. Surprisingly, we find that in urban areas, Mahila Mandal membership is negatively associated with spending on LPG. It is unclear why this might be the case. We speculate that Mahila Mandal membership in urban areas is a less accurate indicator of gender sensitivity than in rural areas [70].

In our regression results, price of LPG at the village level is not significantly associated with LPG ownership and spending. This could be due to two reasons. First, LPG price does not vary significantly at the village level. The average price of LPG per kilogram is Rs. 26.30, with a standard deviation of Rs. 9.94, while the values of the 10th percentile and 90th percentile are at Rs. 21.03 and Rs. 31.72, respectively. Second, our regression specification includes several other independent variables apart from price. Indeed, the pairwise correlation between spending on LPG and price per kilogram is negative (Pearson correlation coefficient of -0.012 with p-value of 0.013) which is in line with the average spending on LPG decreasing with an increase in average price at the village level.

Our results also indicate that while the probability of having an LPG connection increased, the average spending on LPG decreased between the two survey waves in 2004/05 and 2011/12. Even with the vast expansion in access to LPG in India, a study funded by the Government of India's Petroleum Planning and Analysis Cell (PPAC) from 2016 [74] also notes that consumption has not increased commensurately with access. While high initial and recurring costs have both been seen as barriers in transitioning and sustained use of LPG, thus far, policy has largely focused on the initial cost component.

6. Conclusions and future research

For decades, energy access policy in developing countries has largely focused on increasing the affordability of modern household fuels either by reducing prices through subsidies or increasing real income through transfers or a combination of the two. These policies have had limited success. Even when transitions occur, they might be limited to technology adoption where households procure new stoves but do not use them on a sustained basis. The dependence on biomass-based fuels is deeply entrenched in rural households. Easy access to fuel wood and other solid fuels coupled with the financial costs and uncertain supply-chains for LPG make it difficult to make sustained transitions in cooking energy.

Perhaps, in addition to the ongoing price and income-based support policies, more targeted efforts such as providing easy access to LPG cylinders and refilling options would facilitate rural households to increase and maintain their use of cleaner and modern forms of cooking energy. As noted in existing literature, transitioning to cleaner cooking fuel can have multiple benefits. These include reduction in indoor air pollution which disproportionately affects women, as well as gender disparities in time spent on gathering traditional fuels like biomass for cooking.

This transition could be aided by leveraging the role of social capital to identify key individuals and households who can provide information about, and promote the transition to, cleaner cooking fuels. Trusted local government officials may also be useful channels for encouraging households to adopt and sustain their use of cleaner cooking fuels in India. Specifically in rural India, Mahila Mandals and educated females in the households may act as pillars of influence for sustaining the use of LPG [70].

This study also highlights the importance of collecting, preserving, and sharing updated data on household fuel use. In the absence of national level data released by the National Sample Survey Organization (NSSO), recent analyses have largely been based on data collected by researchers [9], private organizations and think-tanks [73,75]. Most recent surveys are limited to a few states often with smaller sample sizes compared to national surveys. While some of these surveys have provided detailed insights into energy consumption patterns, it is difficult to find correlates with indicators of socio-political and trust related factors. As it relates to this study, information on trust, social networks, and communities can provide useful insights for sustained energy transitions that go beyond stove adoption. The findings also reiterate the need for investing in infrastructure and access to mechanisms for meeting the refueling needs of households in rural areas.

Finally, the findings from India also provide insights for other developing countries in the process of transitioning to cleaner forms of household cooking energy usage. In rural China, for example, a recent study [76] shows that households adopt biogas in response to information provided by trusted friends and family members while local government officials can 'lead by example' to promote technology adoption. Research in Ecuador [77, 78], a country with some of the largest LPG subsidies also, for example, points to the importance of prices in driving household energy transitions. Additionally, the findings on road access and spending on LPG point to the importance of supply chains and markets in ensuring a sustained transition to LPG [79]. The findings from this study could also be used to design and implement new programs in other regions. Paying more attention to factors beyond affordability could promote energy transitions in developing countries where similar social divisions exist. Areas that are better connected to markets and able to access modern fuels might witness a more sustained transition. Future studies in the space could also look to factor in the role of trust in different levels of government and intergovernmental relations in sustaining transitions to cleaner sources of energy.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Appendix A

Table A1
Diagnostic tests and factor loadings for social capital index.

Diagnostic tests	
Bartlett test of sphericity	
Chi-square = 1.30e+05	
Degrees of freedom = 10	
p-value = 0.000	
H0: variables are not intercorrelated	
Kaiser-Meyer-Olkin measure of sampling adequacy	
KMO = 0.659	
Variables	**Factor loadings**
Respondent knows someone who is:	
Politicians, police, military	0.860
Government officials (except politicians, police and military)	0.810
Teachers, school workers	0.736
Doctors, health workers	0.696
Close to or a member of village panchayat/nagar palika/ward committee	0.272
Factor characteristics	
Eigenvalue	2.493
Cronbach's Alpha	0.733

Table A2
Determinants of LPG adoption – marginal effects from logit estimations.

Dependent variable	LPG (0/1)	LPG (0/1)	LPG (0/1)
Sample	Full sample	Urban sample	Rural sample
Confidence in State government			
Base category: 'Hardly any confidence'			
Only some confidence in State government	−0.021***	−0.019***	−0.029***
	(0.004)	(0.006)	(0.005)
A great deal of confidence in State government	−0.043***	−0.030***	−0.055***
	(0.004)	(0.007)	(0.005)
Confidence in local government			
Base category: 'Hardly any confidence'			
Only some confidence in local government	0.020***	0.011*	0.020***
	(0.004)	(0.007)	(0.005)
A great deal of confidence in local government	0.023***	0.029***	0.031***
	(0.004)	(0.007)	(0.005)
Social capital index	0.020***	0.019***	0.023***
	(0.001)	(0.003)	(0.002)
Gender sensitivity			
Mahila Mandal member	0.020***	−0.017*	0.042***
	(0.005)	(0.009)	(0.006)
Highest education level of adult female household member	0.020***	0.017***	0.017***
	(0.000)	(0.000)	(0.000)
Log(consumption expenditure)	0.201***	0.185***	0.168***
	(0.003)	(0.006)	(0.003)
Below Poverty Line	0.017***	−0.020***	−0.024***
	(0.005)	(0.008)	(0.007)
Number of household members	−0.025***	−0.020***	−0.019***
	(0.001)	(0.001)	(0.001)
Caste and religion			
Base category: Forward caste			
Other Backward Castes	−0.071***	−0.071***	−0.078***
	(0.004)	(0.007)	(0.005)
Dalit	−0.113***	−0.129***	−0.109***
	(0.005)	(0.008)	(0.006)
Adivasi	−0.183***	−0.148***	−0.211***
	(0.006)	(0.015)	(0.008)
Muslim	−0.054***	−0.095***	−0.062***

(*continued on next page*)

Table A2 (*continued*)

Dependent variable	LPG (0/1)	LPG (0/1)	LPG (0/1)
Sample	Full sample	Urban sample	Rural sample
	(0.005)	(0.008)	(0.007)
Christian/Sikh/Jain	0.117***	0.004	0.172***
	(0.010)	(0.015)	(0.015)
Occupation/income source			
Base category: 'Cultivation'			
Allied agriculture	0.065***	0.105***	0.025
	(0.014)	(0.038)	(0.015)
Agricultural wage labor	−0.014**	−0.028	−0.029***
	(0.005)	(0.023)	(0.006)
Non-agricultural wage labor	0.095***	0.038**	0.005
	(0.004)	(0.016)	(0.005)
Artisan/independent	0.181***	0.109***	0.069***
	(0.008)	(0.018)	(0.011)
Petty shop or small business	0.214***	0.111***	0.114***
	(0.006)	(0.017)	(0.009)
Organized trade or business	0.252***	0.180***	0.124***
	(0.009)	(0.018)	(0.014)
Salaried employment	0.260***	0.162***	0.160***
	(0.005)	(0.016)	(0.007)
Profession not elsewhere classified	0.197***	0.112***	0.099***
	(0.019)	(0.030)	(0.025)
Pension/Rent/Dividend etc.	0.279***	0.190***	0.208***
	(0.009)	(0.018)	(0.012)
Others	0.202***	0.171***	0.115***
	(0.010)	(0.020)	(0.013)
IHDS2	0.013***	0.029***	0.013***
	(0.003)	(0.005)	(0.004)
Price/kg of LPG in rural areas			−0.000
			(0.000)
Road access in rural areas			0.057***
			(0.004)
Pseudo-R^2	0.401	0.328	0.330
Variance inflation factor	1.330	1.300	1.330
Log-likelihood	−30,126.258	−9169.401	−16,855.871
Observations	74,416	23,123	43,017

Coefficients and standard errors are marginal effects on probability of having an LPG connection.
Standard errors are clustered at the household level; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table A3
Determinants of LPG spending – linear regression model estimations.

Dependent variable	LPG Spending (INR/month)	LPG Spending (INR/month)	LPG Spending (INR/month)
Sample	Full sample	Urban	Rural
Confidence in State government			
Base category: 'Hardly any confidence'			
Only some confidence in State govt	−14.586***	−14.987***	−15.137***
	(1.802)	(3.423)	(2.138)
A great deal of confidence in State govt	−19.283***	−9.904**	−25.537***
	(2.027)	(3.982)	(2.388)
Confidence in local government			
Base category: 'Hardly any confidence'			
Medium confidence in local govt	7.288***	4.981	6.138***
	(1.780)	(3.542)	(2.084)
High confidence in local govt	6.915***	10.670**	10.207***
	(2.017)	(4.160)	(2.330)
Social capital index	9.528***	9.995***	9.992***
	(0.793)	(1.510)	(0.938)
Gender sensitivity			
Mahila Mandal member	−13.551***	−24.317***	0.675
	(2.498)	(5.102)	(2.899)
Highest education level of adult female household member	10.535***	8.965***	8.138***
	(0.179)	(0.325)	(0.222)
Log(consumption expenditure)	99.991***	80.424***	85.369***
	(1.575)	(2.941)	(1.910)
Below Poverty Line	15.767***	−71.979***	20.721***
	(1.892)	(4.845)	(1.981)

(*continued on next page*)

Table A3 (*continued*)

Dependent variable	LPG Spending (INR/month)	LPG Spending (INR/month)	LPG Spending (INR/month)
Sample	Full sample	Urban	Rural
Number of household members	−8.146***	5.357***	−7.646***
	(0.398)	(0.932)	(0.434)
Caste and religion			
Base category: Forward caste			
Other Backward Castes	−33.723***	−38.163***	−30.841***
	(2.114)	(3.543)	(2.638)
Dalit	−45.669***	−59.887***	−38.636***
	(2.363)	(4.470)	(2.794)
Adivasi	−29.956***	−39.104***	−46.156***
	(3.168)	(9.891)	(2.909)
Muslim	−29.718***	−62.224***	−23.063***
	(2.986)	(4.871)	(3.773)
Christian/Sikh/Jain	33.405***	−20.176***	99.701***
	(5.044)	(7.020)	(7.122)
Occupation/Income source			
Base category: Cultivation			
Allied agriculture	22.911***	57.651**	0.492
	(6.757)	(23.749)	(6.998)
Agricultural wage labor	8.739***	−26.870**	−2.397
	(1.857)	(11.578)	(2.024)
Non-agricultural wage labor	40.010***	16.003*	4.343**
	(1.892)	(9.673)	(2.029)
Artisan/Independent	92.647***	71.673***	26.094***
	(4.556)	(11.273)	(5.759)
Petty shop or small business	119.639***	83.414***	55.299***
	(3.121)	(9.826)	(4.358)
Organized trade or business	161.023***	124.011***	71.714***
	(4.839)	(10.683)	(8.050)
Salaried employment	145.013***	108.291***	79.281***
	(2.588)	(9.541)	(3.625)
Profession not elsewhere classified	117.645***	88.976***	55.448***
	(8.744)	(14.833)	(12.511)
Pension/Rent/Dividend etc.	137.173***	114.310***	83.147***
	(3.991)	(10.388)	(5.387)
Others	87.419***	85.748***	40.467***
	(4.519)	(11.840)	(5.315)
IHDS2	−49.070***	−71.590***	−41.074***
	(1.291)	(2.543)	(1.989)
Price/kg of LPG in rural areas			0.228*
			(0.137)
Road access in rural areas			23.441***
			(1.472)
Constant	−985.000***	−699.966***	−867.965***
	(16.964)	(34.086)	(20.688)
Adjusted R^2	0.403	0.343	0.292
Variance inflation factor	1.470	2.390	1.420
Observations	74,347	23,089	42,988

Standard errors clustered at the household level in parentheses.
* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.

A.1. Robustness checks

Table A4 below tests for consistency of our main results by including only key independent variables of interest – namely confidence in state government, confidence in local government, social capital index and gender sensitivity. Our estimated effects are consistent between these alternate specifications and the preferred specifications in the paper.

Table A4
Determinants of LPG adoption and spending – key independent variables.

Dependent variable	LPG (0/1)	LPG (0/1)	LPG (0/1)	LPG Spending (INR/month)	LPG Spending (INR/month)	LPG Spending (INR/month)
Estimation	Logit MEs	Logit MEs	Logit MEs	OLS	OLS	OLS
Sample	Full sample	Urban sample	Rural sample	Full sample	Urban sample	Rural sample
Confidence in State government *Base category: 'Hardly any confidence'*						

(*continued on next page*)

Table A4 (*continued*)

Dependent variable	LPG (0/1)	LPG (0/1)	LPG (0/1)	LPG Spending (INR/ month)	LPG Spending (INR/ month)	LPG Spending (INR/ month)
Only some confidence in State govt	−0.038***	−0.025***	−0.043***	−23.116***	−22.961***	−21.787***
	(0.00)	(0.01)	(0.00)	(2.02)	(3.77)	(2.17)
A great deal of confidence in State govt	−0.066***	−0.035***	−0.082***	−35.115***	−22.361***	−41.532***
	(0.00)	(0.01)	(0.01)	(2.28)	(4.38)	(2.42)
Confidence in local government *Base category: 'Hardly any confidence'*						
Medium confidence in local govt	0.020***	0.013*	0.020***	7.478***	1.059	8.832***
	(0.00)	(0.01)	(0.00)	(2.00)	(3.88)	(2.04)
High confidence in local govt	0.018***	0.023***	0.044***	10.432***	11.450**	23.791***
	(0.00)	(0.01)	(0.01)	(2.25)	(4.55)	(2.33)
Social capital index	0.069***	0.070***	0.067***	29.020***	30.111***	27.029***
	(0.00)	(0.00)	(0.00)	(0.85)	(1.58)	(0.91)
Gender sensitivity						
Mahila Mandal member	0.007	−0.036***	0.050***	−22.467***	−49.227***	7.472**
	(0.01)	(0.01)	(0.01)	(2.77)	(5.65)	(2.99)
Highest education level of adult female household member	0.038***	0.030***	0.030***	19.775***	17.339***	13.752***
	(0.00)	(0.00)	(0.00)	(0.18)	(0.32)	(0.22)
Pseudo R^2	0.231	0.200	0.195	–	–	–
Adjusted R^2	–	–	–	0.245	0.191	0.169
Log-likelihood	−38,684.560	−10,920.639	−23,820.683	−499,585.686	−157,215.075	−336,551.634
VIF	1.12	1.13	1.11	1.57	1.55	1.57
Observations	74,465	23,150	51,315	74,396	23,116	51,280

Standard errors clustered at the household level in parentheses.
* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.

Table A5 below compares results of a linear probability model (LPM), our preferred logit model, and a probit model on the probability of having an LPG connection. Comparing results in the three columns, all the associations discussed in the main paper remain in the same direction and are of similar magnitudes. We prefer the logit specification, in line with previous literature, given the binary nature of LPG adoption as our dependent variable of interest and the improvement in the log-likelihood compared to the LPM.

Table A5
Determinants of LPG adoption – linear probability model and non-linear (logit/probit) specifications.

Estimation	LPM	Logit MEs	Probit MEs
Confidence in State government *Base category: 'Hardly any confidence'*			
Only some confidence in State government	−0.021***	−0.021***	−0.021***
	(0.00)	(0.00)	(0.00)
A great deal of confidence in State government	−0.043***	−0.043***	−0.043***
	(0.00)	(0.00)	(0.00)
Confidence in local government *Base category: 'Hardly any confidence'*			
Only some confidence in local government	0.018***	0.020***	0.020***
	(0.00)	(0.00)	(0.00)
A great deal of confidence in local government	0.023***	0.023***	0.024***
	(0.00)	(0.00)	(0.00)
Social capital index	0.023***	0.020***	0.020***
	(0.00)	(0.00)	(0.00)
Gender sensitivity			
Mahila Mandal member	0.026***	0.020***	0.020***
	(0.00)	(0.00)	(0.00)
Highest education level of adult female household member	0.025***	0.020***	0.020***
	(0.00)	(0.00)	(0.00)
Log(consumption expenditure)	0.203***	0.201***	0.199***
	(0.00)	(0.00)	(0.00)
Below Poverty Line	0.025***	0.017***	0.015***
	(0.00)	(0.00)	(0.00)
Number of household members	−0.026***	−0.025***	−0.025***
	(0.00)	(0.00)	(0.00)
Caste and religion *Base category: Forward caste*			
Other Backward Castes	−0.079***	−0.071***	−0.073***
	(0.00)	(0.00)	(0.00)
Dalit	−0.123***	−0.113***	−0.115***
	(0.00)	(0.00)	(0.00)
Adivasi	−0.147***	−0.183***	−0.185***
	(0.01)	(0.01)	(0.01)

(*continued on next page*)

Table A5 (*continued*)

Estimation	LPM	Logit MEs	Probit MEs
Muslim	−0.064***	−0.054***	−0.056***
	(0.01)	(0.01)	(0.01)
Christian/Sikh/Jain	0.115***	0.117***	0.111***
	(0.01)	(0.01)	(0.01)
Occupation/Income source *Base category: 'Cultivation'*			
Allied agriculture	0.073***	0.065***	0.068***
	(0.01)	(0.01)	(0.01)
Agricultural wage labor	−0.002	−0.014**	−0.009*
	(0.00)	(0.01)	(0.01)
Non-agricultural wage labor	0.081***	0.095***	0.094***
	(0.00)	(0.00)	(0.00)
Artisan/Independent	0.190***	0.181***	0.183***
	(0.01)	(0.01)	(0.01)
Petty shop or small business	0.247***	0.214***	0.219***
	(0.01)	(0.01)	(0.01)
Organized trade or business	0.272***	0.252***	0.257***
	(0.01)	(0.01)	(0.01)
Salaried work	0.289***	0.260***	0.264***
	(0.00)	(0.00)	(0.00)
Profession not elsewhere classified	0.212***	0.197***	0.202***
	(0.02)	(0.02)	(0.02)
Pension/Rent/Dividend etc.	0.292***	0.279***	0.279***
	(0.01)	(0.01)	(0.01)
Others	0.214***	0.202***	0.203***
	(0.01)	(0.01)	(0.01)
IHDS2	0.008***	0.013***	0.014***
	(0.00)	(0.00)	(0.00)
Constant	−1.937***		
	(0.03)		
Adjusted R^2	0.439	–	
Pseudo R^2	–	0.401	0.401
Log-likelihood	−31,139.845	−30,126.258	−30,108.326
Observations	74,416	74,416	74,416

Standard errors clustered at the household level in parentheses.
* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.

In the two tables (A6 and A7) below, we consider alternative cooking fuels as additional independent variables to our main specifications. This is due to the fact that households typically use multiple fuels (fuel-stacking) for cooking and lighting, and this could affect both adoption and spending on LPG. The results show that even when controlling for use of all other potential cooking fuels, our results on confidence in state government, confidence in local government, social capital, and gender sensitivity remain in the same direction as in our preferred specification.

Table A6
Determinants of LPG adoption - alternative fuel use controls.

Dependent variable	LPG(0/1)	LPG(0/1)	LPG(0/1)
Sample	Full sample	Urban sample	Rural sample
Confidence in State government *Base category: 'Hardly any confidence'*			
Only some confidence in State govt	−0.020***	−0.006	−0.030***
	(0.003)	(0.006)	(0.005)
A great deal of confidence in State govt	−0.040***	−0.020***	−0.052***
	(0.004)	(0.007)	(0.005)
Confidence in local government *Base category: 'Hardly any confidence'*			
Only some confidence in local government	0.011***	0.006	0.014***
	(0.003)	(0.006)	(0.005)
A great deal of confidence in local government	0.025***	0.022***	0.030***
	(0.004)	(0.007)	(0.005)
Social capital index	0.021***	0.020***	0.024***
	(0.001)	(0.002)	(0.002)
Gender sensitivity			
Mahila Mandal member	0.017***	−0.006	0.030***
	(0.004)	(0.008)	(0.006)
Highest education level of adult female household member	0.015***	0.011***	0.015***
	(0.000)	(0.000)	(0.000)
Alternative fuel use			
Household Uses Firewood (0/1)	−0.259***	−0.229***	−0.197***

(*continued on next page*)

Table A6 (*continued*)

Dependent variable	LPG(0/1)	LPG(0/1)	LPG(0/1)
Sample	Full sample	Urban sample	Rural sample
	(0.004)	(0.006)	(0.007)
Household Uses Dung (0/1)	−0.082***	−0.078***	−0.057***
	(0.003)	(0.006)	(0.004)
Household Uses Crop residue (0/1)	−0.066***	−0.034***	−0.055***
	(0.003)	(0.011)	(0.004)
Household Uses Coal/charcoal (0/1)	−0.168***	−0.312***	−0.032***
	(0.005)	(0.011)	(0.011)
Log(consumption expenditure)	0.159***	0.115***	0.158***
	(0.003)	(0.005)	(0.003)
Below Poverty Line	0.004	−0.016**	−0.023***
	(0.004)	(0.007)	(0.007)
Number of household members	−0.014***	−0.005***	−0.015***
	(0.001)	(0.001)	(0.001)
Caste and religion *Base category: Forward caste*			
Other Backward Castes	−0.057***	−0.046***	−0.070***
	(0.004)	(0.007)	(0.005)
Dalit	−0.088***	−0.082***	−0.096***
	(0.004)	(0.007)	(0.006)
Adivasi	−0.150***	−0.081***	−0.195***
	(0.006)	(0.013)	(0.008)
Muslim	−0.046***	−0.064***	−0.058***
	(0.005)	(0.007)	(0.007)
Christian/Sikh/Jain	0.114***	0.013	0.164***
	(0.010)	(0.013)	(0.015)
Occupation/Income source *Base category: Cultivation*			
Allied agriculture	0.038***	0.052*	0.019
	(0.013)	(0.030)	(0.015)
Agricultural wage labor	−0.039***	−0.056***	−0.040***
	(0.005)	(0.017)	(0.006)
Non-agricultural wage labor	0.031***	−0.018	−0.010*
	(0.004)	(0.012)	(0.005)
Artisan/Independent	0.076***	0.013	0.039***
	(0.008)	(0.015)	(0.011)
Petty shop or small business	0.108***	0.025*	0.082***
	(0.006)	(0.013)	(0.008)
Organized trade or business	0.119***	0.063***	0.074***
	(0.009)	(0.015)	(0.014)
Salaried work	0.138***	0.051***	0.127***
	(0.005)	(0.012)	(0.007)
Profession not elsewhere classified	0.100***	0.031	0.061**
	(0.018)	(0.027)	(0.024)
Pension/Rent/Dividend etc.	0.174***	0.081***	0.173***
	(0.008)	(0.015)	(0.012)
Others	0.119***	0.078***	0.087***
	(0.009)	(0.017)	(0.012)
IHDS2	0.035***	0.043***	0.031***
	(0.003)	(0.005)	(0.004)
Price/kg of LPG in rural areas			−0.000
			(0.000)
Road Access in rural areas			0.052***
			(0.004)
Pseudo R^2	0.478	0.469	0.363
Log-likelihood	−25,574.989	−7101.965	−15,568.018
Observations	72,632	22,547	42,049

Standard errors clustered at the household level in parentheses.
* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.

Table A7
Determinants of LPG spending - alternative fuel use controls.

Dependent variable	LPG Spending (INR/month)	LPG Spending (INR/month)	LPG Spending (INR/month)
Sample	Full sample	Urban sample	Rural sample
Confidence in State government *Base category: 'Hardly any confidence'*			
Only some confidence in State govt	−14.038***	−10.634***	−15.434***
	(1.688)	(3.080)	(2.079)

(*continued on next page*)

Table A7 (*continued*)

Dependent variable	LPG Spending (INR/month)	LPG Spending (INR/month)	LPG Spending (INR/month)
Sample	Full sample	Urban sample	Rural sample
A great deal of confidence in State govt	−18.735***	−8.246**	−24.313***
	(1.902)	(3.631)	(2.323)
Confidence in local government *Base category: 'Hardly any confidence'*			
Only some confidence in local govt	3.552**	3.864	4.276**
	(1.647)	(3.190)	(2.013)
A great deal of confidence in local govt	10.491***	11.157***	10.696***
	(1.888)	(3.779)	(2.264)
Social capital index	10.663***	10.562***	10.650***
	(0.739)	(1.362)	(0.911)
Gender sensitivity			
Mahila Mandal member	−7.644***	−12.079**	−0.882
	(2.354)	(4.769)	(2.811)
Highest education level of adult female household member	7.064***	5.150***	7.098***
	(0.169)	(0.299)	(0.215)
Alternative fuel use			
Household Uses Firewood (0/1)	−156.136***	−153.106***	−114.791***
	(2.066)	(3.285)	(3.332)
Household Uses Dung (0/1)	−41.688***	−67.975***	−22.260***
	(1.466)	(4.181)	(1.654)
Household Uses Crop residue (0/1)	−32.534***	−42.703***	−27.563***
	(1.473)	(6.900)	(1.618)
Household Uses Coal/charcoal (0/1)	−99.808***	−163.088***	−10.962*
	(3.854)	(5.523)	(6.229)
Log(consumption expenditure)	77.566***	52.654***	79.011***
	(1.514)	(2.725)	(1.854)
Below Poverty Line	6.142***	−55.536***	17.841***
	(1.765)	(4.380)	(1.925)
Number of household members	−2.177***	12.693***	−5.827***
	(0.390)	(0.878)	(0.424)
Caste and religion *Base category: Forward caste*			
Other Backward Castes	−23.650***	−21.692***	−27.941***
	(1.914)	(3.153)	(2.518)
Dalit	−30.051***	−31.486***	−33.374***
	(2.122)	(3.933)	(2.662)
Adivasi	−17.945***	−2.615	−41.626***
	(2.998)	(9.330)	(2.782)
Muslim	−18.919***	−39.185***	−20.823***
	(2.706)	(4.402)	(3.581)
Christian/Sikh/Jain	40.763***	−7.123	92.940***
	(4.843)	(6.590)	(7.045)
Occupation/Income source *Base category: 'Cultivation'*			
Allied agriculture	9.603	25.660	−6.430
	(6.530)	(21.075)	(6.863)
Agricultural wage labor	−8.348***	−51.263***	−7.405***
	(1.797)	(10.580)	(1.984)
Non-agricultural wage labor	14.183***	−19.780**	−1.003
	(1.771)	(8.781)	(1.980)
Artisan/Independent	43.287***	8.829	14.161**
	(4.117)	(10.284)	(5.498)
Petty shop owner or small business	60.586***	21.664**	39.127***
	(2.865)	(9.000)	(4.079)
Organized trade or business	87.006***	48.611***	46.573***
	(4.434)	(9.853)	(7.509)
Salaried work	78.261***	34.263***	61.406***
	(2.493)	(8.821)	(3.464)
Profession not elsewhere classified	60.298***	26.731*	36.068***
	(7.977)	(13.850)	(11.698)
Pension/Rent/Dividend etc.	81.125***	46.549***	66.688***
	(3.740)	(9.651)	(5.197)
Others	49.665***	30.042***	28.722***
	(3.944)	(10.584)	(5.006)
IHDS2 2	−35.942***	−62.065***	−31.527***
	(1.262)	(2.406)	(1.966)
Price/kg of LPG in rural areas			0.192

(*continued on next page*)

Table A7 (*continued*)

Dependent variable	LPG Spending (INR/month)	LPG Spending (INR/month)	LPG Spending (INR/month)
Sample	Full sample	Urban sample	Rural sample
			(0.130)
Road Access in rural areas			22.402***
			(1.444)
Constant	−585.446***	−271.733***	−678.059***
	(16.797)	(31.989)	(20.587)
R-squared	0.489	0.469	0.332
Observations	72,564	22,514	42,020

Standard errors clustered at the household level in parentheses.
* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.

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