

Patel, Utkarsh; Kumar, Deepak

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The Indian energy divide: Dissecting inequalities in the energy transition towards LPG

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The Indian Energy Divide:

Dissecting inequalities in the energy transition towards LPG

UTKARSH PATEL

DEEPAK KUMAR

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Abstract

Indoor air pollution in Indian households due to traditional biomass burning is a significant health burden. Clean fuels, such as liquified petroleum gas (LPG), offer sustainable alternatives. Over the years, the LPG adoption rate in India has increased; however, it is not enough to meet the UN Sustainable Development Goals by 2030. Inequalities in energy access owing to socio-cultural, regional and economic reasons persist among households. Using the India Human Development Survey 2005, 2011-12 panel data, we estimate the likelihood of energy transition based on LPG accessibility of vulnerable households, from nine low-income states of India. Among other factors, we find strong positive evidence of cultural factors such as gifting LPG-based cooking kits in weddings, income security through formal employment or entrepreneurship, and awareness via media exposure on LPG adoption. We also highlight the existence of significant regional disparities in LPG access among the states under study and between rural-urban areas. An interaction-based analysis reveals that the difference in probability of LPG adoption between rural and urban households can be attenuated by improving economic status, creating job opportunities in non-agricultural sectors and disseminating information through mass media. Energy policies that are more inclusive and integrated with rural development programmes are recommended.

Keywords: *UN SDG 7, indoor air pollution, energy access, energy inequality, urbanisation, clean fuels*

JEL Classification: *D15, D63, I15, O13, Q52*

Authors' email: *utkarsh@outlook.com; dkumar.jnu@outlook.com*

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The Indian Energy Divide: Dissecting inequalities in the energy transition towards LPG

Utkarsh Patel¹ and Deepak Kumar²

1. Introduction

Of the three targets of the UN Sustainable Development Goal 7, one is to ensure universal access to affordable, reliable and modern energy services to everyone by the year 2030, which includes access to clean fuels and technology for cooking. As per the World Health Organisation, 51 per cent of the total population of India relied on conventional biomass fuels in the form of firewood, charcoal and dung for their energy requirements, in 2018 (WHO, 2020). These fuels, when burnt in traditional cookstoves, emit toxic gases like carbon monoxide, oxides of sulphur and nitrogen and particulate matter. Deaths of an estimated 1.09 million people in India in 2016 could be attributed to household air pollution, i.e. 820 deaths per one million people (WHO, 2018). Women, who are typically responsible for cooking and are regularly exposed to these pollutants, and consequently the infants they mother, are more vulnerable to health effects, which include lower respiratory tract infections, lung cancer, stroke/heart disorder and pulmonary diseases (Gupta, 2019; Spears, et al., 2019).

The use of clean fuels and technologies, such as liquefied petroleum gas (LPG), biogas, electricity, advanced biomass cookstoves and solar cookers, improves indoor air quality and also saves time and effort spent on gathering fuel, which is generally borne by women (Burke & Dundas, 2015; Alem, et al., 2016). The transition of households from traditional and inefficient methods of cooking to clean fuels and modern technologies is therefore crucial to mitigate the adverse health effects.³ Between 2000 and 2018, the proportion of the population with primary reliance on clean fuels grew by 4.5 per cent annually, which, however, is inadequate to meet the UN's '100 per cent by the year 2030 target' (WHO, 2020). In order to meet the target, further research and policy efforts are needed to identify and remove the barriers to clean fuel adoption.

In this study, we model a multi-dimensional framework to assess inequality in energy access by estimating the probability of LPG adoption over time based on social, cultural and economic factors, for vulnerable households in nine 'low-income' Indian states. Furthermore, we analyse inter-state disparities in India in terms of likelihood of transition to LPG, and examine the differential effect of urbanisation on LPG access. We use a nationally representative dataset, the *India Human Development Survey panel 2005 and 2011-12* (IHDS, IHDS-II) to conduct a logit regression analysis. The longitudinal nature of the data allows us to track changes in households' fuel choices over time (i.e. 2005 – 2011-12), which

¹ Institute of Philosophy, Leibniz University Hannover (Germany).

² Centre for Economic Studies & Planning, Jawaharlal Nehru University, New Delhi (India).

³ Extensive firewood harvesting over years has led to degradation of forest cover and is also a serious issue (Baland, et al., 2010).

otherwise is unobservable in cross-section data (Alem, et al., 2016; Srinivasan & Carattini, 2020). In brief, our main findings are: frequent and long exposure to mass media like newspapers and television improves the probability of transition to LPG; cultural factors, like belonging to a community which usually gifts LPG cooking systems in weddings, promotes LPG adoption; households with salary as the primary source of income or with formally employed members/entrepreneurs have significantly high prospects of switching to LPG. Among the states analysed, households in Assam and Rajasthan have the highest probability of transition, while those in Jharkhand and Odisha have the lowest. Finally, the differential effect of urbanisation on the probability of switching to LPG in rural households can be minimised by improving economic status, creating formal employment opportunities, and increasing women's awareness through mass media exposure. We recommend that government policies be more inclusive, take into account regional heterogeneities, emphasise the exclusive use of LPG, increase awareness among women and augment rural skill development and employment programmes to ensure higher uptake and continued usage of LPG.

The remainder of the paper is organised as follows: Section 2 reviews the relevant literature; Section 3 describes the data and method; Section 4 presents the results with discussion, and Section 5 concludes.

2. Literature Review

Several researchers of energy policy have identified the factors that influence energy transition within households based on descriptive statistics and cross-section data (Muller & Yan, 2018). The existing literature provides strong evidence of the effect of income and prices, as well as of education and social groups, on the likelihood of fuel transition and rate of access by the households (Gundimeda & Köhlin, 2008; Gupta & Köhlin, 2006; Pachauri & Jiang, 2008; Saxena & Bhattacharya, 2018). Some authors have also challenged the popular energy ladder theory which hypothesises that households graduate to cleaner fuels as incomes rise (Van Der Kroon, et al., 2013; Ravindra, et al., 2019; Malakar, 2018), while few found it consistent with their results (Ahmad & De Oliveira, 2015). However, as documented in the studies, households seldom forgo traditional fuels entirely because of cost considerations, cooking habits, cultural preferences, perception and availability (Alem, et al., 2016; Gupta, et al., 2020; Sharma, et al., 2019; Pachauri & Jiang, 2008). Hence, it is observed that households often use multiple complementary fuels for their energy supply, known as 'fuel stacking' (Farsi, et al., 2007; Gould & Urpelainen, 2018; Heltberg, 2004).

A vast majority of studies on Indian households is based either on single or on pooled cross-section data. Gundimeda & Köhlin (2008) use the 55th round of the National Sample Survey Organisation's (NSS) Consumer Expenditure Survey, 1999-2000, and analyse household fuel choices based on energy prices and substitution effects between different fuels. Their results suggest positive substitution between firewood and kerosene in rural areas and between electricity, LPG and firewood in urban areas, indicating an essential role of energy prices in the transition to cleaner fuels. Pachauri & Jiang (2008) use the same data for India and

compare it with an analogous dataset for Chinese households. They find local fuel availability critical to enabling energy transition towards clean fuels, particularly in rural regions. Similarly, Farsi et al. (2007) investigate the dynamics between the use of firewood and kerosene vis-à-vis LPG in the same dataset and conclude that the share of energy expenditure in a household's total spending is a vital determinant of the use of modern fuels. Correspondingly, Rao & Reddy (2007) add that the educational status of the head of the household and occupation of the household members also significantly affect fuel-transition related decisions. Pandey & Chaubal (2011) analyse the 61st round of NSS (2004-05) using logistic regression and find that possession of a ration card, belonging to a reserved caste, family size and size of farmland have a significant negative effect on the probability of using clean cooking fuels in rural Indian households. More recently, targeting social inequalities in energy access in India, Saxena & Bhattacharya (2018) examine the role of caste, tribe and religion in access to modern energy sources, using data from the 68th round of NSS (2011-12). They determine that scheduled caste and scheduled tribe households face the most discrimination in accessing LPG, as compared to other castes. Gupta, Gupta & Sarangi (2020) use 15 energy indicators from the same round of NSS to create a state-wise household energy poverty index. Their results show that 65 per cent of the households in India, particularly from the central and eastern states, belong to the 'more or most energy poor' category.

Studies employing other datasets include Ahmad & De Oliveira (2015) and Gould & Urpelainen (2018); the former is based on IHDS 2005 data and estimates drivers of fuel switching in urban slum and non-slum households in India, while the latter uses 2014-15 ACCESS data from rural households in six energy-poor states of India and finds that both users and non-users of LPG believed it to be a convenient and clean fuel, with the cost being the biggest barrier to widespread adoption. Several papers are based on primary surveys conducted in select regions which emphasise other factors like the role of subsidies (Gupta & Köhlin, 2006), information about the benefits of using LPG and awareness of government incentives (Malakar, 2018), cooking patterns (Ravindra, et al., 2019), formal employment opportunities for women (Sehgal, et al., 2014), and duration of LPG acquisition (Sharma, et al., 2019). Srinivasan & Carattini (2020) use multiple sets of cross-section data (1987-88, 1999-00, 2004-05 and 2009-10 rounds of the NSS and 2014-15 ACCESS survey) and panel data (IHDS 2005, 2011-12) to provide historical as well as more recent evidence of the effect of social spillovers on LPG adoption. They suggest that spillovers are stronger for households that belong to social networks than otherwise, underscoring the importance of social capital in accelerating the energy transition in India.

Only recently, researchers have started using panel data to have more accurate estimates by controlling for unobserved household heterogeneity (Alem, et al., 2016; Srinivasan & Carattini, 2020). Kuo & Azam (2019) utilise the IHDS 2005, 2011-12 panel data to construct a random-effects multinomial logit model and examine the factors that drive the choice of cooking fuel in rural and urban India, respectively. They find road infrastructure, social spillovers and women's bargaining power to be positively associated with clean fuel usage in rural areas. Similarly, Choudhuri & Desai (2020) using the IHDS panel data, find the

significance of intra-household gender inequalities on households' fuel choice. They argue that income earned by women independently influences clean fuel adoption via both income and substitution effects and that women tend to value clean fuel much more than other household goods. Gupta et al. (2020) use a newer panel data – *2014 SQUAT Survey/ 2018 Survey of Rural Sanitation and Solid Fuel Use* – of 1,216 rural households from 11 districts in north India. They find that despite increased LPG ownership as a result of a government scheme⁴, most households still relied on biomass. The findings highlight the significance of prevailing beliefs and attitudes towards LPG vis-a-vis traditional fuels. The authors call for policies that encourage the exclusive use of LPG by households. In a contemporary paper based on 2014-15, 2018 ACCESS panel data, Mani et al. (2020) advocate for village- and community-level interventions, creation of opportunity cost for 'free-of-cost' biomass, augmentation of distribution centres in remote areas, and generation of predictable income opportunities for households to facilitate a sustained energy transition towards clean fuels in India.

Despite the wide-ranging literature on this topic, information on household-specific characteristics such as socio-cultural effects, exposure to mass media, income security, and regional disparities remains limited. We incorporate these factors into our analysis and add a novel set of predictors of energy transition to corroborate the existing findings. Additionally, we assess regional differences in LPG access as observed across states and between urban and rural areas of India. Lastly, we estimate the point of convergence of rural and urban households' likelihood of LPG transition with respect to different socioeconomic factors.

3. Data and econometric model

The IHDS panel data, used in this study, is a nationally representative, multi-topic survey of 42,152 households, conducted in 1,503 villages and 971 cities/towns across India. Data were initially collected from households in 2005, with surveyors returning to the same households in 2011-12 for the second round of interviews—re-contact rate of 83 per cent, including split households⁵ (Desai, et al., 2019). For this study, we analyse data for vulnerable households, i.e. which did not have access to LPG in 2005, in nine low-income states of India viz. Rajasthan, Uttar Pradesh, Bihar, Assam, Jharkhand, Odisha, Chhattisgarh, Madhya Pradesh and West Bengal. These states constitute 56 per cent of India's population and their per capita net state domestic product is lower than the all India average (2017-18 values (RBI, 2019)).^{6,7} Further, in these states, the share of households using LPG for cooking is below the national average (RGI, 2012) (Chart 1).

⁴ The Pradhan Mantri Ujjwala Yojana (pmuy.gov.in), launched in 2016.

⁵ Those households which split into two or more units since the first round of the survey in 2005. See IHDS II User Guide for more information (Available at: icpsr.umich.edu/web/pages/DSDR/ihds-II-data-guide.html).

⁶ Report of the Technical Group on Population Projections, National Commission on Population (India), 2019. Available at: nhm.gov.in/New_Updates_2018/Report_Population_Projection_2019.pdf (Accessed: 20-06-2020).

⁷ At factor cost, constant 2011-12 prices. The smaller states from Northeast India and the erstwhile state of Jammu & Kashmir also fall below the India average, but are not a part of this analysis.

After excluding some observations due to data inconsistencies, our final sample consists of 11,437 households. We check whether these households gained access to LPG by 2011-12 and delineate the underlying factors which supported the transition. Chart 2 shows household-level shifts in fuel choice between 2005 and 2011-12. Although LPG access rates improved by over 7 per cent during the period, the number of households using the fuel exclusively increased only by a margin, as seen in the chart. The variables that capture household-level characteristics in the regression analysis include economic status, highest level of education attained, social group (caste/religion), region, primary occupation and source of income, exposure to mass media and other cultural factors. The descriptive statistics of the explanatory variables are presented in the appendix Table A1.

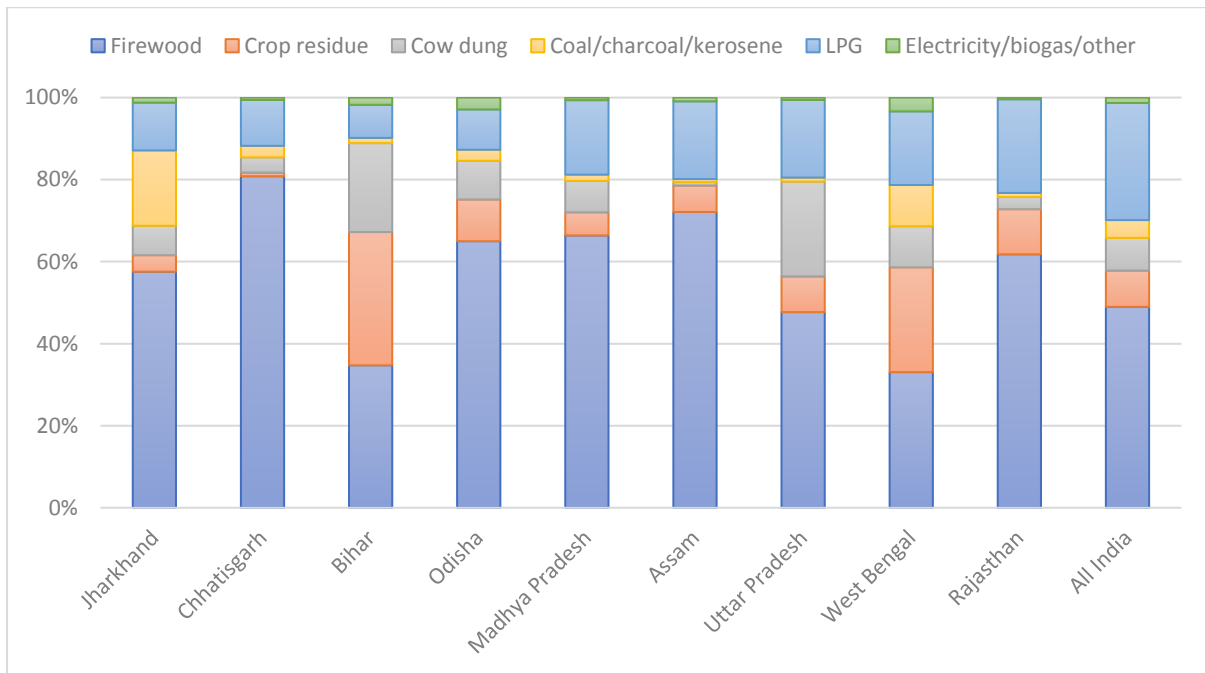
We quantify the economic status of households using the natural log of monthly per capita consumption expenditure ($\ln\text{MPCE}$), as a proxy for income. Household's assets are incorporated using the IHDS Asset Index⁸, which measures the long-term economic resources of a household. The change in a household's economic status, i.e. no change or better/ worse off since 2005, is also captured through the variable $\Delta\text{eco_status}$. The education level of a household is measured as the number of years of schooling completed by the highest educated adult (i.e. age > 21 years) male as well as female in the household. To examine the caste- and religion-based disparities among the households, we construct social group dummy variables comprising six categories: Upper Caste Hindus, Other Backward Classes (OBC) Hindus, Scheduled Castes (SC), Scheduled Tribes (ST), Muslims, and other minority religions (OMR, i.e. Christians, Sikhs, Jains, Buddhists).

The region, i.e. rural or urban, and the state to which the households belong are also controlled for, to capture region-wise and state-wise heterogeneities. Further, a household's primary source of income is categorised into five sources viz. formal employment (salaried), agriculture and allied activities, agricultural labour, non- agricultural labour and others. Additionally, three distinct variables capture the number of working members of a household – salaried employees, casual workers and farm- or animal-related workers. To factor the effect of exposure to mass media on the choice of fuel by the households, time spent per day (in hours) by women watching television and the frequency of reading newspaper (never, sometimes, and regularly) by men, are also taken into account.

The IHDS questionnaire records the response to a quintessential question which factors in a traditional element of the society relevant to this analysis. It asks: "Generally in your community and a family like yours, what are the kind of things gifted at the time of the daughter's marriage?". One of the items in the options listed following the question is LPG-based cookstoves with gas cylinders. We include the responses to the question (never/rarely, sometimes and usually) from the set of households in our analysis to determine their influence on the choice of fuel.

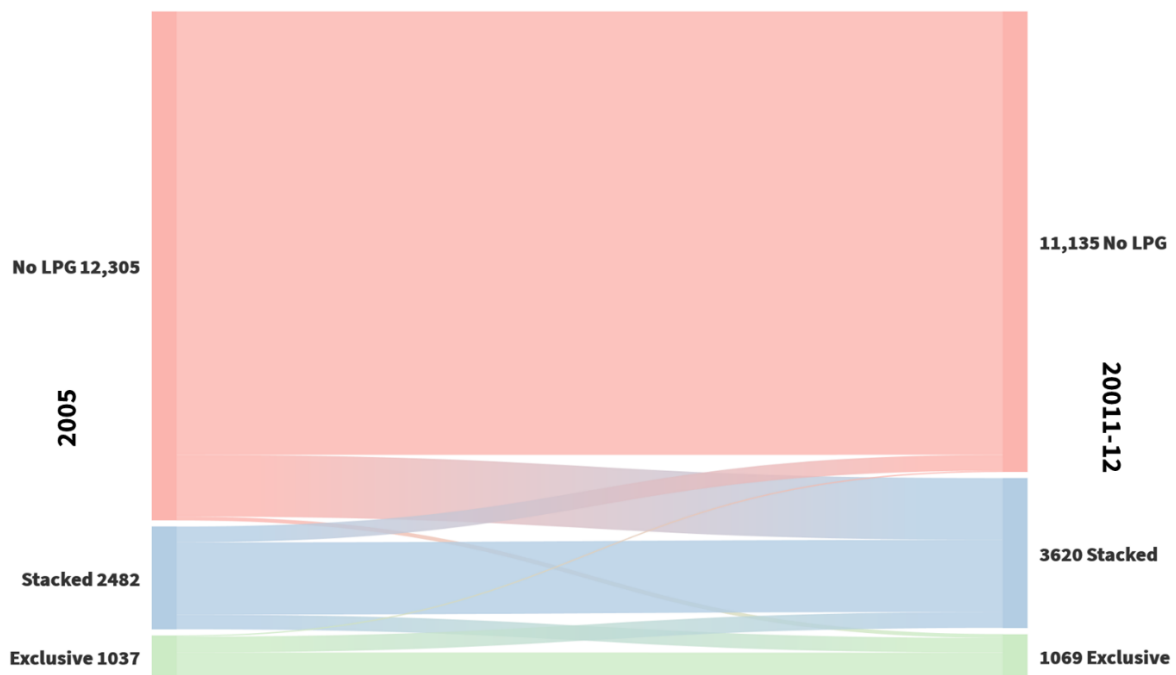
⁸ The index value ranges from '0' to '30'. An index value close to '0' indicates the poorest households while closer to '30' indicates the richest households. Research studies show that family assets are a better indicator of the long-term economic resources of a family compared to income (Nam & Huang, 2009). For the sample in this analysis, the maximum observed value of the index is 24.

Chart 1: State-wise shares of different cooking fuels used by households in 2011



Source: RGI, 2012.

Chart 2: Household-level shifts in fuel choice between 2005 and 2011-12



Source: Author's calculations, based on IHDS 2005, 2011-12 panel data.

The dependent variable in our regression equation is LPG access status of households in 2011-12 (for those which did not have access in 2005). The binary outcome variable is equal to '1' if a household has access to LPG in 2011-12 and '0' otherwise. We use logit regression

modelling to examine the factors guiding a household's transition to LPG over time. The logit coefficients are used to estimate the post-regression average marginal effects and the predicted probabilities (Karaca-Mandic, et al., 2012).⁹

In the first (of five) specifications, a logit regression analysis incorporating all explanatory variables in the model is conducted (Regression 1). The resulting coefficients and the average marginal effects are presented in Table 1. Augmenting the results, we incorporate a regional interaction term (rural/urban), with four different socioeconomic factors viz. education, economic status, formal employment opportunities and media exposure, in regressions 2 to 5, respectively, to analyse the differential effect of urbanisation (i.e. quantify the rural-urban gap) on a households' likelihood of transition (Table A2). As revealed from the analysis, the socioeconomic factors have varying effects with respect to the region; and in three out of four cases, the gap narrows with increments in these factors (Chart 5).

4. Results

Table 1 provides the regression coefficients and average marginal effects that estimate the likelihood of a household's transition to LPG between 2005 and 2011-12. In-line with the general notion, the probability is higher, by nearly 7 per cent for urban households to switch to LPG, relative to those in rural regions, owing to its easier access and lack of availability of alternative fuels (like firewood, dung cakes) (Rao & Reddy, 2007; Pachauri & Jiang, 2008; Gupta, Gupta & Sarangi, 2020). The same holds for the economic status of a household. Regardless of the region, both *ln*MPCE and Household Assets are positively related to the likelihood of transition, primarily owing to the higher cost of LPG, which renders it unaffordable for poorer households (Gundimeda & Köhlin, 2008; Gould & Urpelainen, 2018). For households which were economically better off in 2011-12 relative to 2005, the probability of transition to LPG is higher by 3.4 per cent – a likely outcome of higher disposable income with a rise in economic status.

The number of years of schooling of the highest educated male and female members of a household is positively and significantly associated with the chances of shifting to cleaner sources of energy and is consistent with the existing literature (Gupta & Köhlin, 2006; Farsi, et al., 2007; Rao & Reddy, 2007). Further, the probability of a household's fuel transition increases significantly by 2.3 per cent with every extra hour women spend watching television. An increase in the frequency of reading newspaper by men in households has a similar effect. From the regression analysis, compared to 'never reading', the probability increases by 2.5 per cent for 'reading sometimes' and by 5 per cent for 'reading regularly'. This effect of exposure to mass-media can be explained by *infomercials* and other similar content on TV and in newspapers, which increase awareness about the benefits of using LPG and the various government incentives to support its adoption. Moreover, activities like reading a newspaper and watching television are implicitly associated with more educated and wealthier households, respectively—especially television, which is generally preferred by households prioritising recreation and social status (Malakar, 2018).

⁹ Calculated using *margins* command in Stata 14.

Factors related to traditions also appear to influence the likelihood of LPG adoption, as seen from the average marginal effect of ‘LPG as a wedding gift’ variable. Households belonging to communities which usually gift LPG cylinders and cookstoves are nearly 8 per cent more likely to choose one themselves, versus those which have never or seldom given one. Within relatively poor households, especially in rural regions, LPG cooking kit is considered as a prestigious household asset, like a motorcycle or a television. Therefore, having a kit or gifting one during weddings, along with other household items, is linked to a household’s economic prosperity. Moreover, poor households with limited savings may tend to rely on weddings to acquire household assets.

In the case of social groups/ castes, SC and ST households have significantly lower chances of shifting to LPG compared to upper-caste Hindu households. In Indian society where caste and religion permeate deeply into the livelihoods of people, it has been well documented in studies that poor people belonging to lower castes or minority groups face discrimination in accessing resources, including energy, which further swells the existing inequalities (Gupta & Köhlin, 2006; Saxena & Bhattacharya, 2018). As per our regression analysis, the probability of transition is 3.4 per cent less for SC households and markedly lower (by 9 per cent) for those of STs. A reason for the disparity in ST households is because they are generally located in remote regions, deemed as tribal areas. Households belonging to SC/ST communities represent a quarter¹⁰ of the total population of India and are essential to be covered for an inclusive and complete modernisation of the Indian energy sector. The findings presented here hold important policy implication and necessitate special attention from the authorities for the inclusion of the marginalised sections into mainstream schemes and programmes.

For the households with the primary source of income from agriculture and allied activities, the probability of switching to LPG falls by almost 3 per cent when compared to salaried households. Further, considering the number of workers in a household, the probability falls marginally with every extra casual earner or a farm/ animal worker. It, however, rises by 1.6 per cent with each additional member running a business or having a regular salary, which corresponds to income security. Several underlying reasons are at play for the difference in energy access with respect to the type of work and the number of workers in a household, ranging from availability to opportunity cost (Rao & Reddy, 2007). For instance, firewood collection could take anywhere between three to ten hours per week depending upon the location and requirement (IEA, et al., 2020). Those involved in agriculture or farm/animal-related services, common to rural areas, find it easy to access crop residue, firewood or dung cakes which are also relatively cheaper (or even free). In contrast, those working in non-agriculture sectors do not have easy access to conventional fuels and face a much higher opportunity cost (e.g. allocating time between working, collecting fuel and cooking), particularly in urban/ semi-urban areas (Rao & Reddy, 2007; Pachauri & Jiang, 2008; Sehgal, et al., 2014; Mani, et al., 2020).

¹⁰ Socio-Economic Caste Census (2011) of India. Available at: secc.gov.in/stateSummaryReport (Accessed 20-06-2020).

Probability of transition also differs with the states: relative to Rajasthan (arbitrary to the regression), only Assam's households have a higher chance of shifting to LPG (by about 8 per cent), while all the other states have lower chances.

Table 1: Logit model analysis - predictors of LPG adoption in India

Explanatory Variables	Coefficients	Avg. Marginal Effects
Urban (ref: Rural)	0.767*** (0.0932)	0.068*** (0.0091)
<i>ln</i> (MPCE)	0.370*** (0.0676)	0.029*** (0.0053)
Household assets	0.142*** (0.0114)	0.011*** (0.0009)
Better off since 2005 (ref: Same)		
Better	0.411*** (0.0739)	0.034*** (0.0062)
Worse	-0.186 (0.1300)	-0.013 (0.0091)
Highest male education	0.039*** (0.0093)	0.003*** (0.0007)
Highest female education	0.026*** (0.0099)	0.002*** (0.0008)
Time spent watching TV by women	0.293*** (0.0256)	0.023*** (0.0020)
Men's newspaper reading freq. (ref: Never)		
Sometimes	0.319*** (0.0807)	0.025*** (0.0065)
Regularly	0.593*** (0.1130)	0.050*** (0.0103)
LPG gifted in a wedding (ref: Never/rarely)		
Sometimes	0.452*** (0.0830)	0.036*** (0.0068)
Usually	0.901*** (0.0969)	0.078*** (0.0094)
Social group (ref: UC Hindus)		
OBC Hindus	-0.129 (0.0974)	-0.011 (0.0084)
SCs	-0.423*** (0.1120)	-0.034*** (0.0091)
STs	-1.442*** (0.2270)	-0.092*** (0.0115)
Muslims	-0.118 (0.1220)	-0.010 (0.0104)

Explanatory Variables	Coefficients	Avg. Marginal Effects
OMR	0.439 (0.7090)	0.042 (0.0735)
Income Source (ref: Salaried)		
Agriculture/allied	-0.352*** (0.1220)	-0.028*** (0.0102)
Agriculture labour	-0.232 (0.1750)	-0.019 (0.0143)
Non-agriculture labour	-0.179 (0.1260)	-0.015 (0.0106)
Others	-0.007 (0.1160)	-0.001 (0.0010)
No. of salaried/business workers in Hh	0.198*** (0.0379)	0.016*** (0.0030)
No. of casual wage workers in Hh	-0.187*** (0.0364)	-0.015*** (0.0028)
No. of farm/animal workers in Hh	-0.065*** (0.0226)	-0.005*** (0.0018)
State (ref: Rajasthan)		
UP	-0.607*** (0.1130)	-0.056*** (0.0106)
Bihar	-0.588*** (0.1510)	-0.055*** (0.0135)
Assam	0.687*** (0.1770)	0.079*** (0.0215)
West Bengal	-0.961*** (0.1390)	-0.083*** (0.0115)
Jharkhand	-1.650*** (0.1900)	-0.124*** (0.0120)
Odisha	-2.014*** (0.1620)	-0.140*** (0.0103)
Chhattisgarh	-1.364*** (0.1770)	-0.109*** (0.0125)
Madhya Pradesh	-0.518*** (0.1180)	-0.049*** (0.0111)
Constant	-5.825*** (0.4600)	
Prob. > Chi2	0.0000	
Pseudo - R ²	0.3264	
Observations	11,437	

*Note: Standard errors in parentheses; Ref. is the reference category of a categorical variable; the highest pairwise correlation coefficient value observed is 0.47; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$*

4.1 *State-specific disparities in LPG adoption*

The predicted probabilities for different states in the analysis are depicted in Chart 3. Households in Assam, with an average projected likelihood of 27.6 per cent, have the highest chances of transitioning to LPG in the sample, followed by Rajasthan at 19.7 per cent. The chances are lowest in the states of Chhattisgarh, Jharkhand and Odisha, with estimated probabilities of 8.8 per cent, 7.3 per cent and 5.7 per cent, respectively. The results are in line to those of Gupta, Gupta & Sarangi (2020), who find majority of the districts from the eastern states of India to be among the ‘most energy poor’, compared to the rest of the country. Chart 4 shows the number of domestic LPG subscriptions per 1000 population across the nine states and the all-India average for 2006 and 2013 – without exception, the states in the sample have fewer subscribers than the national mean. According to the Census 2011, firewood is the most common cooking fuel across all the nine states, and all of India; while the share of LPG ranges from 23 per cent in Rajasthan to 8 per cent in Bihar (Chart 1) (RGI, 2012). There are multiple reasons for the prevailing heterogeneity among the states.

Availability of alternatives significantly influences the probability of LPG transition. For example, in Rajasthan, due to arid or semi-arid climatic conditions, which are unsuitable for raising and rearing cattle, availability of cow dung is limited; likewise in Assam, excessive annual rainfall prohibits the use of firewood during prolonged periods. On the other hand, availability of coal in Jharkhand, used by 18 per cent of the state’s households for cooking (much higher than the national average of 4 per cent), is a potential deterrent to higher LPG adoption (RGI, 2012). Jharkhand has the largest proven reserves of coal and is one of the leading producers in the country.¹¹ Moreover, as compared to the other states in question, the price of LPG is less in Assam and Rajasthan owing to presence of oil/natural gas fields – in India, the public sector oil companies handle the distribution and selling of LPG at prices approved by the Central government (or a state government in some cases).^{12,13,14} Other possible factors for the higher probability of transition can be the density of LPG distributors in the state – both Assam and Rajasthan, along with Madhya Pradesh, had close to 10 distribution centres per 1000 people as of 1st April 2013 (MoPNG, 2014). Further Rajasthan also has the highest per-capita net state income¹⁵, which corroborates our findings. On the contrary, domestic LPG cylinders were 13 per cent costlier in Jharkhand, than in Rajasthan,

¹¹ Coal Directory of India 2017-18, Coal Controller’s Organisation (India), 2019. Available at: coalcontroller.gov.in/writereaddata/files/download/coaldirectory/CoalDirectory2017-18.pdf (Accessed: 20-06-2020)

¹² LPG pricing in India is based on the import parity formula. It is the sum of the international FOB (freight on board) price, inland freight, marketing costs and margins of the oil companies, bottling charges, dealer commission and taxes.

¹³ Nearly 62 per cent of India’s LPG demand was met by domestic production in 2012-13 (MoPNG, 2014).

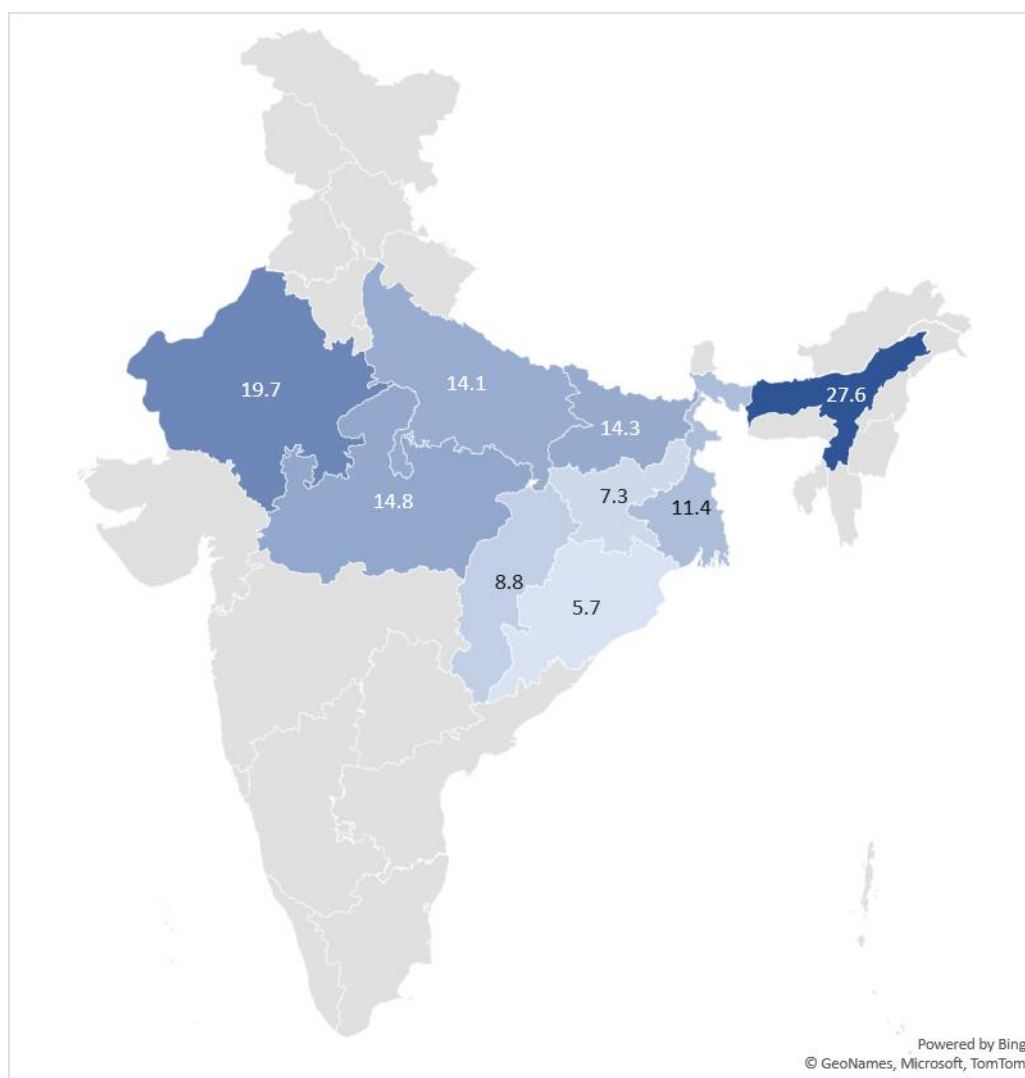
¹⁴ Distribution and retailing of domestic usage LPG cylinders (available in 5 kg and 14.2 kg options) is a regulated business in India under the LPG (Regulation of Supply and Distribution) Order 2000 of the Government of India (Available at jklm.nic.in/pdf/LPG_regulation_of_distribution.pdf).

¹⁵ At factor cost, constant 2011-12 prices (RBI, 2019).

in 2012¹⁶, while the former state had 24 per cent less per capita net state domestic product compared to the latter in the same year (RBI, 2019).

Even after the introduction of a uniform goods and services tax across India in 2017, the retail price of LPG differs across states owing to logistical factors. Although the customers under a certain level of income receive a subsidy on the retail price of LPG cylinders, it is still too expensive for many, especially when the alternative is virtually ‘free’ (Gupta, et al., 2020). To ensure equitable access to LPG, schemes must be tailored to offset any regional disparities, such that the cost to households is uniform across states. This calls for having more decentralised policies, suited to specific regions/states (Gupta, Gupta & Sarangi, 2020). In the next sub-section, we discuss in detail the differences in the probabilities of transition to LPG for urban and rural households.

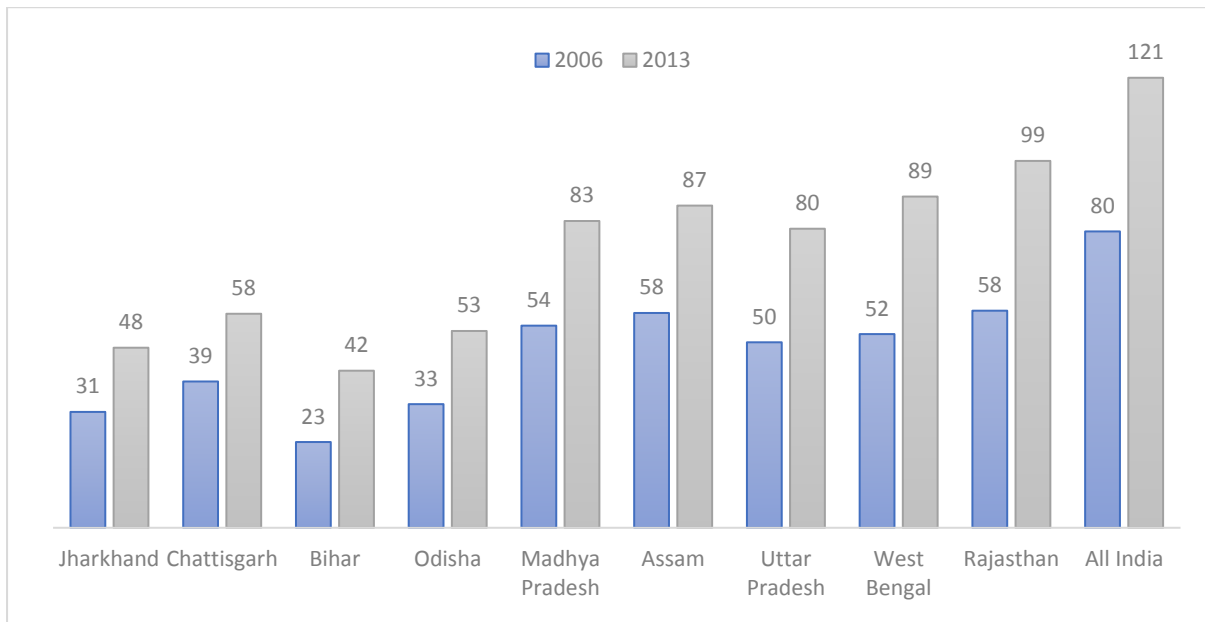
Chart 3: State-wise predicted probabilities (%) of LPG adoption in India



Source: Authors' calculations.

¹⁶ Retail Selling Price of Domestic LPG (14.2kg) 2012-13, Petroleum Planning and Analysis Cell (India), 2012. Available at: 164.100.47.193/intranet/Petroleumprices.pdf (Accessed: 20-06-2020).

Chart 4: Domestic LPG subscriptions per 1000 population



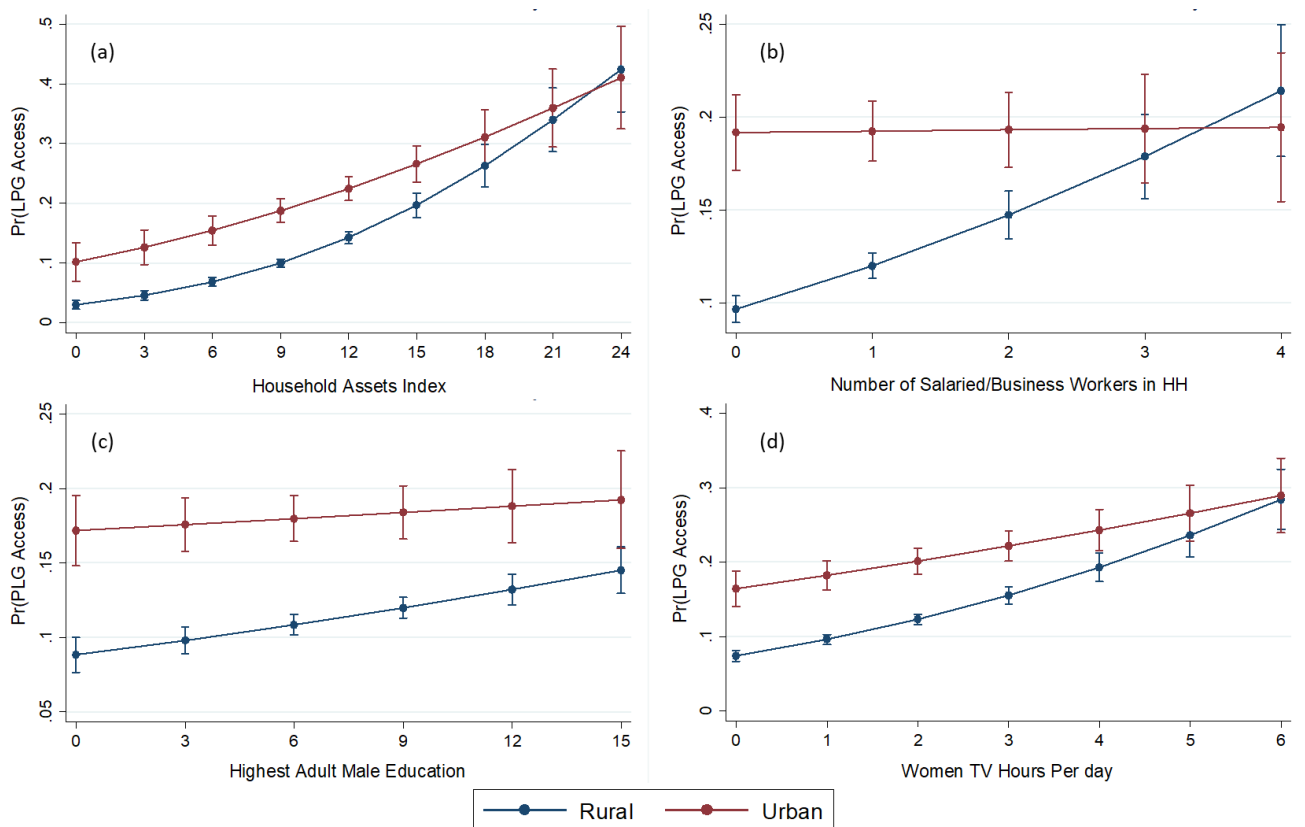
Note: Data as on 1st April of the respective year; sorted in the increasing order of subscriptions added. Source: MoPNG, 2007 & 2014.

4.2 The rural-urban divide in LPG adoption

The 2011 Census of India highlights the existence of a vast regional disparity in access to clean cooking solutions – only 11.4 per cent of rural households use LPG, compared to 65 per cent in the urban regions (RGI, 2012). Urban areas, generally owing to infrastructure and availability, enjoy greater access to clean fuels and technologies (IEA, et al., 2020). However, other social and economic factors also significantly influence the probability of adoption. In this section, taking our analysis a step further, we augment the econometric model with a region-specific interaction term (i.e. rural or urban) to the included set of variables. The objective behind this exercise is to assess how the probability gap between rural and urban households narrows with increments in their economic status, education level, formal employment and mass-media exposure. The results are relevant from a policymaking perspective because the efforts made to improve these factors will consequently help bridge the rural-urban divide in LPG access rates. The post-estimation predicted probabilities of the interaction terms, controlling for all the other variables in the model, are depicted in Chart 5.

Chart 5a presents the predicted probabilities of accessing clean fuel for rural and urban households at various levels of the Household Assets Index - a proxy for economic status. The overall probability of LPG access increases with the rise in a household's economic status in both the regions, but marginally more so for rural households. The curves converge around the index value 22 – corresponding to upper middle-income households, indicating an equal likelihood of transition in both the regions at this point. It further implies that at higher levels of economic status, the differential effect of urbanisation on the probability of LPG adoption is minimum, revealing the spillover effects of raising rural households' incomes.

Chart 5: Predicted probabilities of LPG adoption by rural and urban households



Source: Authors' calculations.

As regards to the number of household members involved in formal employment or business activities/ entrepreneurship, the curve for urban households is nearly horizontal, while that for rural households is steeper, as seen in Chart 5b. It intersects the urban curve at the value of 3.4 workers per household.¹⁷ It means that if a rural household has more than three members employed with regular salaries or are running a business, the likelihood of transition to LPG is equal (or even higher) to those in urban areas. It explains the significance of income security on a household's decision to switch to LPG, which tends to have a recurring cost that is higher than the alternatives and inflexible. The finding holds policy relevance for the government since, through diversification of the rural economy with formal employment opportunities in non-agriculture sectors and promoting micro, small and medium enterprises at the village level, access to clean fuels could be ensured and sustained. Mani et al. (2020) make a similar inference while recommending that government programmes on rural livelihoods and employment guarantee¹⁸ should be integrated with LPG promotion schemes to enable predictable cash flows among rural households.

Lastly, charts 5c and 5d present the predicted probabilities for LPG access corresponding to the number of years of schooling completed by the adult male in a household and to women's

¹⁷ The upper limit of 4 corresponds to the maximum value in 99 per cent of the observations.

¹⁸ For example, the National Rural Livelihood Mission (NRLM) and the National Rural Employment Guarantee Act (MGNREGA).

exposure to mass media (measured as time spent watching television in hours/day), respectively, for rural and urban households. The probability gap in case of male education narrows due to steeper gradient of the rural curve, however, it is insufficient to purge the difference even with 15 years of education (i.e. graduate level), underscoring the greater effect of other factors like household income and occupation. Whereas in the case of women's mass media exposure, the two curves converge at about 6 hours per day (also the maximum value in 99 per cent of the observations), denoting parity in the probability of transition for the two regions. Studies have documented the positive effects of prolonged exposure to mass media on improving women's status and their decision-making authority within a household in India (Jensen & Oster, 2009). As stated earlier, infomercials on television about the benefits of using clean fuels and on the government's promotional schemes increase awareness and generate demand for LPG from women. Mass media interventions if focussed on women's skill development would further augment their authority by opening employment avenues, and accelerate the transition towards clean fuels (Choudhuri & Desai, 2020).

5. Conclusion and Policy Implications

Lack of access to clean cooking fuels and technologies is a major health hazard, exposing millions of households to harmful, and even toxic, indoor air pollutants. Nearly four million people in low- and middle-income countries die each year due to diseases linked to household air pollution. India, by itself, accounts for a quarter of the global population that lacks access to clean cooking, making it the country with the largest access-deficit households (IEA, et al., 2020). In this paper, we use the India Human Development Survey Panel 2005, 2011-12 data in an attempt to (a) estimate the probability of LPG adoption over time for Indian households, (b) quantify and analyse the provincial disparities seen across households of different states in India in terms of likelihood of transition, and (c) examine the differential effect of urbanisation on LPG access, and project the point of parity between rural and urban households. The sample consisted of households which did not have access to LPG in 2005, from nine low-income states across India, to determine the socioeconomic and cultural factors that influence LPG adoption.

The results reveal the following: (1) urban location, income, economic status and education level have a positive effect and increase the chances of adopting LPG, and (2) frequent/longer exposure to mass media like newspapers and television also improves the probability of transition. Cultural factors, like (3) belonging to a community in which LPG cooking systems are usually gifted in weddings, are also likely to promote LPG adoption; however, social factors such as (4) being of a 'backward/lower' caste could be detrimental to the uptake owing to unequal access to energy, among other reasons. Economic determinants like (5) salary as the primary source of income and number of formally employed members or entrepreneurs in a household significantly raise the prospects of switching to LPG. Even as the LPG access rates have risen, (6) majority of new households use it as a complement with other fuels. Also, among the selected group of states, there exist substantial dissimilarities in probabilities of accessing LPG – (7) households in Assam and Rajasthan have the highest

predicted probabilities, while those in Jharkhand and Odisha have the lowest. Lastly, as regards the differential effect of urbanisation on the probability of switching to LPG, we find that (8) the gap between rural and urban regions can be bridged by improving economic status, formal employment opportunities, and raising awareness among women using mass media.

The findings have policy implications and are also discussed in this article. Our analysis highlights that (i) inclusive policies are needed that target households belonging to marginalised sections of the society, (ii) regional LPG subsidy schemes that incorporate the price and income differences across states should be introduced, (iii) emphasis should be placed on exclusive and sustained usage of LPG, (iv) information on the advantages of LPG and the government schemes to promote adoption should be extensively disseminated, especially to women, and (v) special development programmes that focus on increasing rural household incomes and generating formal employment or entrepreneurship opportunities in rural regions are required to bridge the rural-urban gap in LPG access rates. This analysis measures the likelihood of LPG adoption by Indian households, rather than LPG usage which is beyond the scope of this paper, and a subject for future research. So is an appraisal of the prevailing policy regime.

Notes

1. As per a logit model:

$$P(Y_i = 1) / (1 - P(Y_i = 1)) = e^{(\beta X_i)}$$
$$\Rightarrow P(Y_i = 1) = \left(e^{(\beta X_i)} / (1 + e^{(\beta X_i)}) \right) = F(\beta X_i)$$

where: $X_i = \{X_{ij}, j = 1 \dots J\}$ represents the vector of observations, for individual 'i' on 'j' variables, and $\beta = \{\beta_j, j = 1 \dots J\}$ is the associated vector of coefficient estimates (Amemiya, 1981; Greene, 2003).

2. The data on ownership of resources as a household asset index is available in IHDS 2005 that contains data on different variables of goods and house owned by the household, and the quality of housing. This index is based on the values of 36 distinct kinds of household assets like 'pukka' or 'kaccha' house, TV, refrigerator, car, laptop/computer, and AC. See IHDS I User Guide for more information (Available at: www.icpsr.umich.edu/web/pages/DSDR/ihds-data-guide.html).

Data availability statement: The data that support the findings of this study are openly available at Inter-university Consortium for Political and Social Research [ICPSR] accessible via doi.org/10.3886/ICPSR37382.v1 [doi], [V1, 2019-11-19] (Desai, et al., 2019).

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Appendix

Table A1: Descriptive statistics

Predictors (in 2005 and 2011-12)	LPG access (in 2011-12)			No LPG Access (in 2011-12)		
	Observations	Mean	S.D.	Observations	Mean	S.D.
Urban	1,566	0.39	0.49	10,641	0.12	0.32
In (MPCE)	1,566	6.44	0.53	10,638	6.05	0.54
Household Assets	1,566	11.54	3.80	10,641	7.09	3.43
Highest Education Male	1,566	8.02	4.54	10,641	4.89	4.48
Highest Education Female	1,566	4.02	4.35	10,641	1.84	3.24
Per day women's TV hours	1,552	2.13	1.45	10,451	1.02	1.21
No. salaried workers	1,566	0.97	1.04	10,641	0.40	0.76
No. casual wage workers	1,566	0.57	1.05	10,641	1.38	1.50
No. of farm/animal workers	1,566	1.34	1.79	10,641	1.83	1.88
Better off in last 6-7 years						
Same	1,548	0.51	0.50	10,515	0.62	0.49
Better	1,548	0.43	0.49	10,515	0.27	0.44
Worse	1,548	0.07	0.25	10,515	0.12	0.32
Social group						
Upper Caste Hindus	1,566	0.22	0.41	10,641	0.10	0.30
OBC Hindus	1,566	0.40	0.49	10,641	0.37	0.48
SCs	1,566	0.18	0.38	10,641	0.26	0.44
STs	1,566	0.02	0.14	10,641	0.14	0.35
Muslims	1,566	0.18	0.39	10,641	0.14	0.34
OMR	1,566	0.00	0.05	10,641	0.00	0.02
Household Income Source						
Salaried	1,566	0.20	0.40	10,641	0.06	0.24
Agriculture/Allied	1,566	0.30	0.46	10,641	0.39	0.49
Agriculture Labour	1,566	0.04	0.20	10,641	0.17	0.37
Non-Agriculture Labour	1,566	0.18	0.38	10,641	0.24	0.43
Others	1,566	0.28	0.45	10,641	0.14	0.35
Men's Newspaper Frequency						
Never	1,535	0.32	0.47	10,203	0.67	0.47
Sometimes	1,535	0.45	0.50	10,203	0.28	0.45
Regularly	1,535	0.23	0.42	10,203	0.05	0.22
LPG as a wedding gift						
Rarely/never	1,562	0.46	0.50	10,622	0.69	0.46
Sometimes	1,562	0.28	0.45	10,622	0.22	0.41
Usually	1,562	0.26	0.44	10,622	0.09	0.29

Source: Authors' calculation based on IHDS 2005, 2011-12 panel data.

Table A2: Effect of regional (rural/urban) interaction on LPG adoption

Explanatory Variables	Regression 2	Regression 3	Regression 4	Regression 5
Urban	1.492*** (0.2410)	1.019*** (0.1460)	1.085*** (0.1140)	1.154*** (0.1380)
<i>ln</i> (MPCE) consumption	0.371*** (0.0678)	0.374*** (0.0677)	0.372*** (0.0674)	0.370*** (0.0676)
Household assets	0.163*** (0.0131)	0.141*** (0.0114)	0.141*** (0.0114)	0.140*** (0.0114)
Better off since 2005 (ref: Same)				
Better	0.410*** (0.0738)	0.408*** (0.0738)	0.406*** (0.0740)	0.417*** (0.0740)
Worse	-0.182 (0.1290)	-0.179 (0.1290)	-0.189 (0.1300)	-0.183 (0.1300)
Highest male education	0.038*** (0.0093)	0.050*** (0.0105)	0.038*** (0.0093)	0.039*** (0.0093)
Highest female education	0.025** (0.0098)	0.025** (0.0098)	0.025** (0.0099)	0.024** (0.0098)
Time spent watching TV by women				
	0.288*** (0.0255)	0.289*** (0.0255)	0.291*** (0.0256)	0.354*** (0.0307)
Men's newspaper reading freq. (ref: Never)				
Sometimes	0.329*** (0.0806)	0.325*** (0.0807)	0.316*** (0.0807)	0.320*** (0.0807)
Regularly	0.592*** (0.1130)	0.606*** (0.1130)	0.575*** (0.1130)	0.581*** (0.1130)
LPG gifted in a wedding (ref: Never/rarely)				
Sometimes	0.457*** (0.0828)	0.454*** (0.0830)	0.454*** (0.0830)	0.444*** (0.0833)
Usually	0.899*** (0.0973)	0.904*** (0.0970)	0.902*** (0.0971)	0.897*** (0.0972)
Social group (ref: UC Hindus)				
OBC Hindus	-0.121 (0.0976)	-0.123 (0.0971)	-0.137 (0.0974)	-0.133 (0.0975)
SCs	-0.407*** (0.1120)	-0.419*** (0.1120)	-0.432*** (0.1120)	-0.421*** (0.1120)
STs	-1.410*** (0.2280)	-1.434*** (0.2270)	-1.448*** (0.2280)	-1.455*** (0.2270)
Muslims	-0.105 (0.1210)	-0.133 (0.1220)	-0.126 (0.1220)	-0.133 (0.1220)
OMR	0.453 (0.7390)	0.445 (0.7110)	0.487 (0.7170)	0.403 (0.6900)
Income Source (ref: Salaried)				
Agriculture/allied	-0.373*** (0.1220)	-0.364*** (0.1220)	-0.316*** (0.1220)	-0.359*** (0.1220)
Agriculture labour	-0.220	-0.228	-0.214	-0.246

Explanatory Variables	Regression 2	Regression 3	Regression 4	Regression 5
	(0.1750)	(0.1750)	(0.1760)	(0.1750)
Non-agriculture labour	-0.213*	-0.198	-0.176	-0.208*
	(0.1250)	(0.1260)	(0.1260)	(0.1260)
Others	-0.027	-0.010	-0.008	-0.026
	(0.1140)	(0.1150)	(0.1160)	(0.1150)
No. of salaried/bsns workers in Hh	0.195***	0.195***	0.321***	0.195***
	(0.0376)	(0.0378)	(0.0449)	(0.0379)
No. of casual wage workers in Hh	-0.182***	-0.186***	-0.197***	-0.187***
	(0.0365)	(0.0365)	(0.0368)	(0.0365)
No. of farm/animal workers in Hh	-0.065***	-0.064***	-0.065***	-0.066***
	(0.0228)	(0.0226)	(0.0226)	(0.0226)
Interaction with Urban				
Urban # HH Assets	-0.065***	---	---	---
	(0.0203)			
Urban # Highest male education	---	-0.037**	---	---
		(0.0164)		
Urban # Salaried/Business worker	---	---	-0.315***	---
			(0.0705)	
Urban # Women TV hours	---	---	---	-0.186***
				(0.0497)
State (ref: Rajasthan)				
UP	-0.597***	-0.619***	-0.607***	-0.599***
	(0.1130)	(0.1130)	(0.1130)	(0.1140)
Bihar	-0.579***	-0.585***	-0.589***	-0.599***
	(0.1510)	(0.1510)	(0.1510)	(0.1530)
Assam	0.725***	0.716***	0.691***	0.692***
	(0.1780)	(0.1790)	(0.1790)	(0.1800)
West Bengal	-0.948***	-0.946***	-0.952***	-0.940***
	(0.1380)	(0.1390)	(0.1380)	(0.1380)
Jharkhand	-1.621***	-1.621***	-1.678***	-1.649***
	(0.1870)	(0.1890)	(0.1910)	(0.1880)
Odisha	-1.986***	-1.994***	-1.999***	-1.990***
	(0.1600)	(0.1610)	(0.1600)	(0.1600)
Chhattisgarh	-1.356***	-1.359***	-1.350***	-1.376***
	(0.1760)	(0.1750)	(0.1760)	(0.1750)
Madhya Pradesh	-0.510***	-0.515***	-0.521***	-0.517***
	(0.1180)	(0.1180)	(0.1180)	(0.1190)
Constant	-6.039***	-5.919***	-5.898***	-5.884***
	(0.4660)	(0.4630)	(0.4600)	(0.4610)
Prob. > Chi2	0.000	0.000	0.000	0.000
Pseudo - R ²	0.327	0.327	0.329	0.328
Observations	11,437	11,437	11,437	11,437

*Note: Robust standard errors in parentheses; Ref. is the reference category of a categorical variable; *** p<0.01, ** p<0.05, * p<0.1*

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