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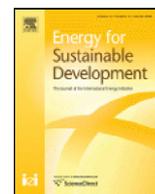
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Transition to LPG for cooking: A case study from two states of India

Ashutosh Sharma *, Jyoti Parikh, Chandrashekhar Singh

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ABSTRACT

This study uses 810 households data collected from two states of India-Raipur district in Chhattisgarh State and Ranchi in Jharkhand- to analyse the LPG cooking transition. Most of the available studies for the South Asia region and particularly for India had mainly focused on the access aspect of clean cooking in terms of fuel or stove. In this study, we particularly focus on the household transition to clean cooking fuel (LPG) in terms of its usage. Using the Tobit regression model for censored data the study highlights the socioeconomic and other factors that may influence LPG transition. The study finds that there could be common as well as location specific factors driving LPG transition. Income linkages with LPG usage may be weak in regions with high prevalence of home produced or collected solid fuel consumption. Duration of LPG acquisition, considered in the study as a factor of behavioural aspect, has emerged as an important variable promoting LPG transition over time. *The analysis suggests that LPG capital subsidy scheme, PMUY, has provided a trigger for LPG transition among beneficiary households. Increasing the share of LPG in monthly cooking fuel may require good LPG services such as doorstep delivery.*

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Introduction

Energy has long been recognised essential for human development and economic growth. A large proportion of the world population, mainly living in developing countries, lacks access to modern energy sources. Nearly 1.1 billion people in this world are living without access to electricity and 2.8 billion people lack access to clean cooking (WEO, 2017). In India alone, more than 800 million people depend on traditional solid fuels such as wood, dung cakes and coal for their cooking needs (WEO, 2017). Usage of traditional solid cooking fuels has an environmental and health cost due to significant smoke generated in burning. Moreover, the gender aspects of cooking with solid fuel have been highlighted by several previous studies (Cecelski, 1995; McDade & Clancy, 2003; Parikh, 1995; Parikh, Smith, & Laxmi, 1999; Skutsch, 1998; Skutsch, 2005).

Political recognition of the need for clean cooking has led to increased policy efforts in many developing countries. Evidence suggests that improved wood burning stoves do not achieve health relevant exposure reductions, especially of PM_{2.5} levels, as prescribed by WHO air quality guideline (Mortimer et al., 2017; Pope, Bruce, Dherani, Jagoe, & Rehfuess, 2017; Sambandam et al., 2015). Fire wood-based improved cookstoves (ICTs) reduces biomass consumption but does not obviate the hardship and drudgery of fuelwood gathering, transportation, and processing. Moreover, burning woods generates about five times more

carbon of LPG per unit of delivered cooking heat (World LPG Association (WLPGA), 2018). LPG offers unmatched PM_{2.5} exposure reductions for cooking activities compared to most other fuel sources (Grieshop, Marshall, & Kandlika, 2011). Quinn et al. (2018) noted that LPG is the clean cooking fuel with the greatest current and historical scale-up activities around the world.

India has a long history of price subsidy on LPG cylinder refilling for domestic cooking purposes (Gangopadhyay, Ramaswami, & Wadhwa, 2005).¹ The assessment of India's universal LPG price subsidy scheme followed until 2015, suggests that the benefits of LPG price subsidies were mostly going to the higher income groups (Anand, Coady, Mohommad, Thakoor, & Walsh, 2013; Government of India of India (GoI), 2015). Since 2015, the Government of India (GoI) in coordination with public sector oil marketing companies (OMCs) has introduced a set of reforms to rationalise LPG subsidy and at the same time promoting LPG access, especially for poor households. Direct Benefit Transfer for LPG (DBTL) scheme was to rationalise LPG subsidy by removing the incentive for subsidised LPG diversion to other uses. The "GiveItUp" campaign appealed to the economically well-off people to voluntarily surrender their LPG subsidy entitlement. An income threshold was also introduced to determine household eligibility for subsidised LPG. These set of measures were implemented to check the subsidy leakages and fiscal burden while increasing the LPG access for poor households. Pradhan Mantri Ujjwala Yojana (PMUY) was launched in 2016 to provide

* Corresponding author at: C-80, Shivalik, Malviya Nagar, Delhi 17, India.
E-mail addresses: asharma@irade.org (A. Sharma), jparikh@irade.org (J. Parikh), chandrashekhar@irade.org (C. Singh).

¹ LPG price subsidy in India is given only to public sector oil companies consumers. The private sector oil companies LPG consumers do not get LPG price subsidy, however the consumer base for these companies is very small.

a capital subsidy for LPG start-up kit to the women member of BPL (Below Poverty Line) households. Based on the data available from Petroleum Planning & Analysis Cell, the performance of India's domestic LPG sector in recent years has been presented in Fig. 1. During the period 2016–17 to 2018–19, the growth of LPG consumption quantity and number of LPG distributors have been slower compared to number of LPG registered customers (Fig. 1). At present, public sector OMCs have more than 265 million registered customers which comprises nearly 72 million LPG connection under PMUY scheme.

The achievement for scaling-up LPG access in India has been substantial in recent years. Access to clean fuels for cooking is though prerequisite to address the time poverty and health hazards arising from biomass burning. However, the actual benefits depend upon the usage of clean fuels by the households. Johnson and Chiang (2015) had argued that sustained clean fuel use, which displaces the majority of traditional solid fuel used, is vital for realizing its benefits. Therefore, the transition to modern cooking fuel like LPG is two-stage process - having access and sustained usage. However, the available literature on household choices for cooking fuel in developing countries had mainly focused on the access aspect of clean cooking (Bansal, Saini, & Khatod, 2013; Bhojvaid et al., 2014; Israel, 2002; Lewis & Pattanayak, 2012; Rao & Reddy, 2007). It is important to understand the barriers and driving factors for clean fuel usage. Quinn et al. (2018) propounded that what works to promote energy transitions and the barriers of clean cooking transition needs to be examined. This paper specifically looks at factors affecting household's clean cooking transition in terms of LPG usage. The purpose of this study is to fill the knowledge gaps regarding clean cooking fuel transition and to facilitate policy design for promoting the usage of LPG. This paper presents the finding based on household's survey carried out in two States of India from April 2017 to June 2017.

This paper is organized as follows: Section 2 presents a brief background; Section 3 describes the study area and sample; Section 4 describes the data and methodology; Section 5 depicts the analysis and discussion and Section 6 provides the conclusion.

Background

The existing research suggests a hierarchy of fuel preferences, which depends upon a household's income (Behera, Rahut, Jeetendra, & Ali, 2015; Farsi, Filippini, & Pachauri, 2007; Khandker, Barnes, & Samad, 2012; Leach, 1992; Masera, Saatkamp, & Kammen, 2000; Rao & Reddy, 2007). Households with a limited budget may be forced to choose the inconvenient but less costly energy source (Ekholm, Krey, Pachauri, & Riahi, 2010). Is the transition to modern energy services uniform across income group? Lahoti, Suchitra, and Goutam (2012) conclude that once

various social and economic variables have been controlled for, urbanization and income are two closely correlated factors with increased use of LPG. Khandker et al. (2012) found that energy poverty in urban households is commensurate with economic status, but in rural India, many non-poor households are energy poor. Gould and Urpelainen (2018) reported that travel distance required to purchase LPG is very problematic for rural Indian LPG households. Therefore, it is quite probable that apart from household income status, the transition to modern fuel like LPG may depend upon the local services availability and delivery status.

Many previous researchers have studied the link between modern fuel consumption and household characteristics. Large household size has been found to use more biomass and dirty fuel for cooking (Deshmukh, Jinturkar, & Anwar, 2014; Pandey & Chaubal, 2011). Women, who mainly manage biomass chain, will unquestionably benefit from sustained LPG usage, which provides more flexibility and convenience in use and generates less indoor air pollution. Women as the principal decision makers for household expenditure will use high-quality energy sources which saves time, ensures better health and more leisure time for them (Israel, 2002; Rahut, Behera, Ali, & Marenya, 2017). However, while the cook (often female members) would have an important role in the decision-making process for fuel and stove, the financial decision maker (often male members) may enjoy veto power (Kar & Zerriffi, 2018; Miller & Mobarak, 2013).

Several studies have found that increasing levels of education are associated with a higher probability of using modern energy sources, and a lower incidence of solid fuel use (Heltberg, 2005; Mensah & Adu, 2015; Rao & Reddy, 2007). Education may change the opinion of households in favour of modern fuels or it may improve the decision-makers' understanding of the costs and benefits of using a modern form of energy (Israel, 2002; Rao & Reddy, 2007). The behavioural aspect of clean cooking has been discussed by Matinga, Clancy, Doyle, and Annegarn (2016) who pointed that over time benefits and costs of clean fuel adoption will become explicit, enabling a household to choose the more convenient and cost-effective fuel. To best of our knowledge, behavioural aspect linkages to clean cooking transition have remained less discussed and untested empirically.

Previous studies (Farsi et al., 2007; Israel, 2002) have highlighted that the fixed costs associated with LPG act as a barrier to LPG access. Household's survey for this study was conducted after the launch of PMUY scheme. Several of the sampled poor households reported getting access to LPG under this scheme. Therefore, one can assume that when the barrier to access is high initial cost, free connection given under PMUY scheme may have impacted the LPG usage among the beneficiary households. Given the socioeconomic conditions of the PMUY

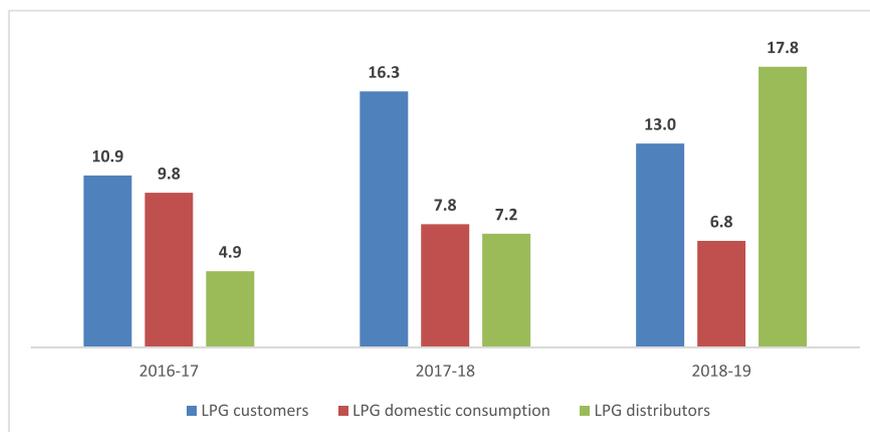


Fig. 1. Annual growth rate (%) of domestic LPG sector.
Source: Petroleum Planning & Analysis Cell.

beneficiaries' households, it is important to understand that whether PMUY capital subsidies encourage service provision or only encourage the purchase of equipment.

Study area and sample

The study was conducted in Raipur district of Chhattisgarh and Ranchi district of Jharkhand as shown in Map 1. As per Census of India (Census, 2011), 29.5% of households in Ranchi and 19.3% households in Raipur use LPG as predominant² fuel for cooking. Based on this indicator, the study planned to carry out a larger survey in Raipur than in Ranchi. The study conducted 300 household surveys in Ranchi and 510 in Raipur. The household survey was conducted in Raipur and Ranchi from April 2017 to June 2017 that is after the launch of PMUY scheme. Therefore, it is reasonable to believe that compared to census 2011 (Census, 2011) the LPG access landscape in the district must have changed in 2017.³

The study used stratified random sampling. First, study districts were split into rural and urban strata. The planned 300 samples of Ranchi and 510 of Raipur were allocated in proportion to the population in rural and urban strata. Accordingly, Ranchi sample was allocated as 180 rural and 120 urban households and Raipur sample were allocated as 300 rural and 210 urban households. The rural and urban strata were divided into sub-stratum comprising villages in rural area and wards in the urban area,⁴ by using population parameter.⁵ The district wise rural and urban sub-strata list was used to randomly select- (i) 6 sub-strata from rural Ranchi, (ii) 4 sub-strata from urban Ranchi, (iii) 10 sub-strata from rural Raipur and (iv) 7 sub-strata from urban Raipur, with replacement. Further, from each selected rural sub-strata, one village and from each selected urban sub-strata one ward was randomly selected for the survey. Therefore, our study covered 6 villages, 4 urban wards in Ranchi, 10 villages, and 7 urban wards in Raipur. In each selected village and urban ward, 30 households were surveyed. Our sample consists of 480 rural households and 330 urban households. Selection of sample household was done through first randomly choosing a household, followed by choosing every sixth household from the randomly selected initial household. In case where a particular household was found closed for the survey, the succeeding sixth household replaced that particular household.

The survey was conducted by interviewing a family member of the households based on a printed structured questionnaire. The questionnaire collected information pertaining to gender, age, education, marital status, employment status, monthly income, types and quantity of fuels used in last 30 days, source of fuel, unit price paid for each purchased fuels, LPG use duration in years, LPG delivery status and other variables relating to household characteristics and energy usage.

Data and methodology

This study specifically focuses on the household transition to LPG for cooking. Therefore, from the overall survey data, we have used specific indicators related to household demographic characteristics, income status, source wise monthly cooking fuel consumption, and LPG related

information. Apart from them, we also make use of the information related to LPG acquisition year and PMUY beneficiaries.

Household member monthly income data for salaried persons, self-employed and daily wageworker was collected using a 30-day recall period. As income from agriculture activities arrives only during the crop-harvesting season and not throughout the year. Therefore, we have used a 365-day recall period for agriculture household income and monthly income was derived by dividing it. Fig. 2 below presents the distribution of sample households according to monthly household income level in Indian Rupees.

Field investigators measured the sample of daily fuel use for dung cake, fuelwood and coal using a spring balance. Monthly LPG consumption was calculated based on the date of LPG cylinder replacement and remaining LPG weight in that particular cylinder. Following, Gregory and Stern (2014), where measurements of this type could not be made, participants guesses were accepted as the best approximation. Rates for converting to useful energy for cooking fuels are calculated by assuming specific average levels of efficiency in the use of cooking (Farsi et al., 2007). We have used the average useful energy at the final consumption stage of cooking in MJ for different fuels as given by O'Sullivan and Barnes (2006).

Fig. 3 presents the fuel share in monthly useful cooking energy (MJ) for rural and urban surveyed households. In rural households, firewood is the dominant source of useful energy followed by LPG. On the other hand, LPG is the major source of useful cooking energy in urban households followed by the firewood. The surveyed households reported that kerosene is mostly used as ignition fuel (to light fire) for dung cake, fuelwood, and coal. Therefore, we can say that kerosene is merely an associated cooking fuel linked with the use of solid fuels for firing purpose and are less likely to be an independent cooking fuel for households. Fig. 4 presents the distribution sample households according to monthly useful LPG consumption at the final stage. Out of our sample of 810 households, only 405 households were found to have access to LPG gas stove and cylinder.

To understand the factors affecting LPG usage we have considered two dependent variables. Firstly, we have considered LPG consumption (MJ) per capita (*LPG_PC*) as the dependent variable. In the second case, we considered LPG share in household total monthly useful energy (*LPG_share*) as the dependent variable. The independent variables have been selected after developing a detailed understanding of the survey data, which are explained below:

Household income (*H_income*)

This variable takes into account the income of the household expressed in USD. We have converted the household income reported in Indian rupees by assuming exchange rate 1\$ = 70 Indian rupees.

Household size (*H_size*)

This variable takes into account the number of family members in the household. The size of the household is expected to affect the cooking energy demand and therefore may have implications for the clean cooking transition. Fig. 5 presents the distribution of sample households according to household size.

Sex of household head (*H_head*)

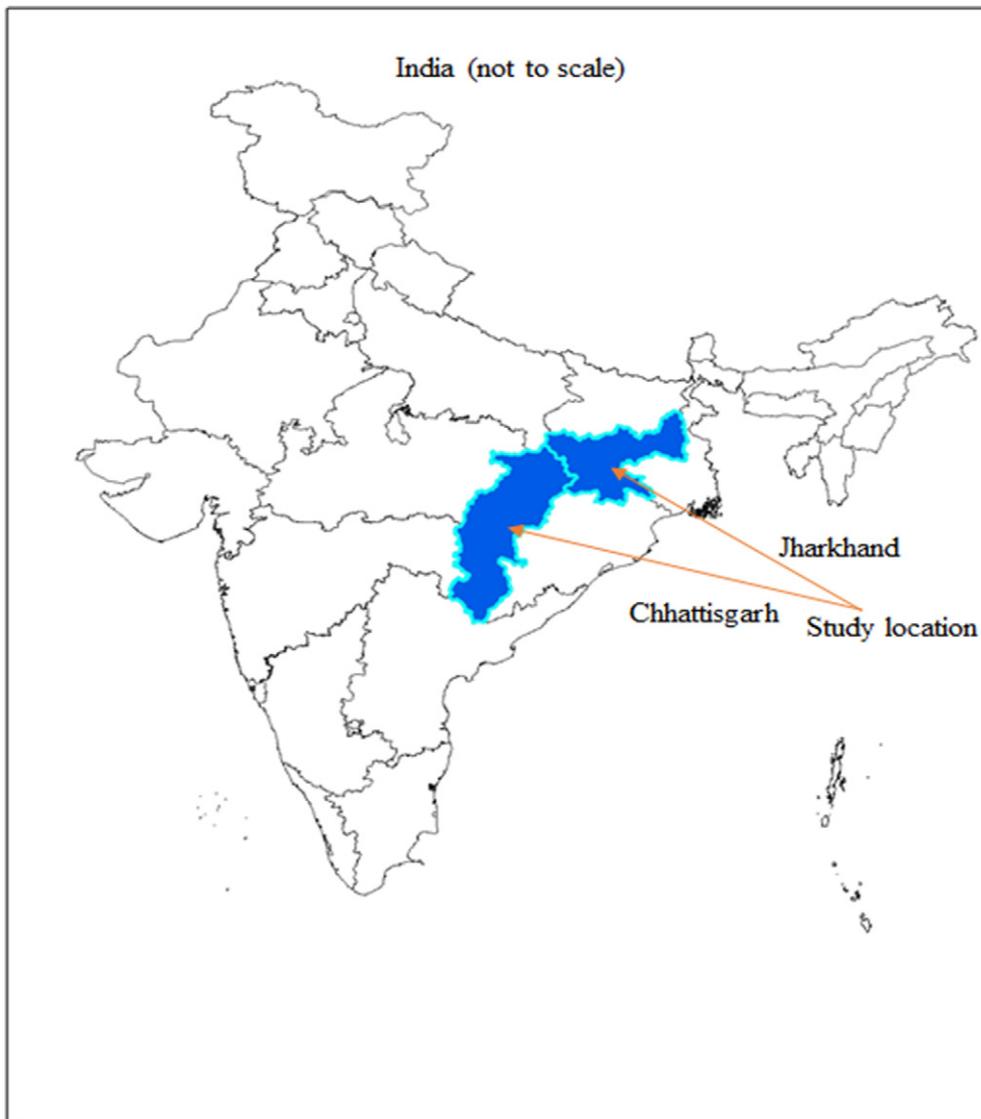
This variable defines the sex of the household head as reported by the respondent using a dummy variable. For the female-headed household, dummy takes the value 1 and 0 otherwise. In our sample, 235 households were reported to be female-headed and remaining 575 households were male-headed.

² Census in India records the type of fuel used mostly for cooking. If the household is using more than one fuel for cooking, the predominant fuel used for cooking is recorded.

³ As per Government of India data till 31st March 2017 more than 1.1 million LPG connection in Chhattisgarh and 0.54 million in Jharkhand were given under PMUY scheme. Further, up to 17th October 2018, more than 2.6 million LPG connections in Chhattisgarh and nearly 2.5 million in Jharkhand has been given under PMUY scheme. <http://www.pmujiwalayojana.com/>.

⁴ Census data is made available for the country as a whole and by state, union territory, district, sub-district and down to village level in rural areas and ward level in towns.

⁵ The sub-strata in rural and urban area were formed such that each have nearly 10,000 populations.



Map 1. Study location in India: Chhattisgarh and Jharkhand.

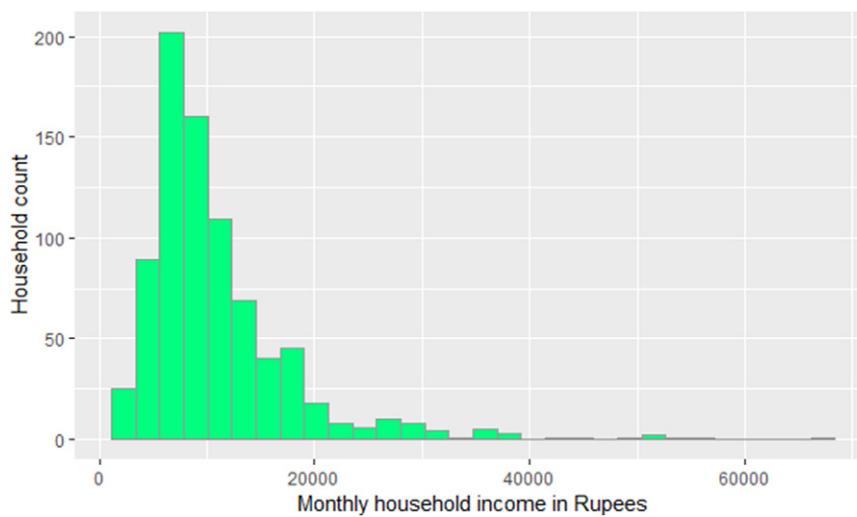


Fig. 2. Monthly household income of the sample households.

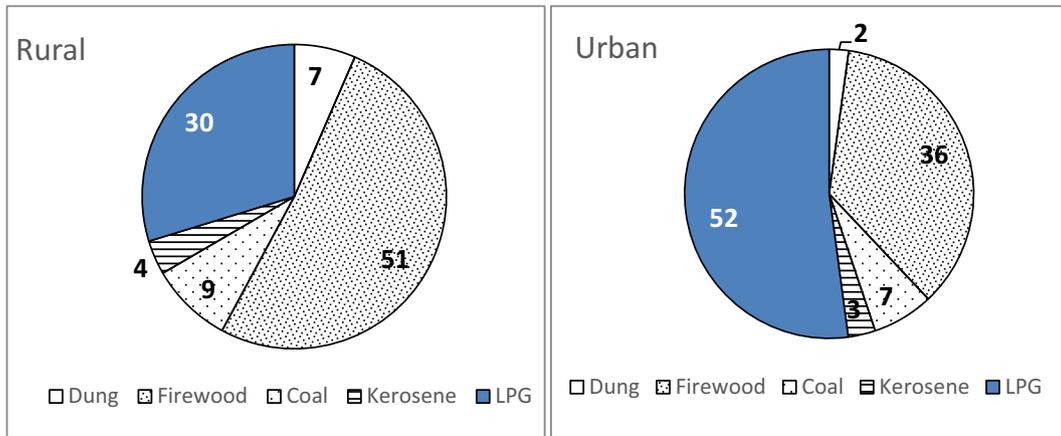


Fig. 3. Fuel source wise percentage share in monthly total useful cooking energy, in sample households.

Age of household head (HH_age)

This variable defines the age of the household head in years on the date of the survey.

Male education (Male_education)

This is a continuous variable and is calculated as the highest level of education achieved by any of the male member, aged 16 years and above, in the household on the date of survey (Fig. 6). If the highest education attained among male members in a household is class 5, then the variable takes the value '5' and so on.

Female education (Female_education)

This is a continuous variable and is calculated as the highest level of education achieved by any of the female members, aged 16 years and above, in the household on the date surveyed (Fig. 7). For example, if the highest education attained among female members in a household is class 5, then the variable takes the value '5' and so on.

Pradhan Mantri Ujjwala Yojana (PMUY_D)

This variable defines whether the LPG user is a beneficiary of the Pradhan Mantri Ujjwala Yojana (PMUY) using a dummy variable. The dummy takes the value 1 for PMUY beneficiary households and 0 otherwise. In our sample, 126 households were PMUY beneficiary. We have introduced this dummy variable in the regression model to control the net effect of this policy intervention on LPG usage for beneficiary households.

Acquisition year (Acqui_year)

Duration of LPG acquisition shows the year since a household is using LPG for cooking. The variable takes the value based on year of LPG acquisition for example if the household does not have LPG connection, then the value will be 0, if it is the first year of LPG acquisition then the value will be 1 and so on.

LPG delivery (LPG_del)

A dummy variable, which takes the value 1 if LPG is delivered at doorsteps in the surveyed village or urban wards and 0 otherwise. It is

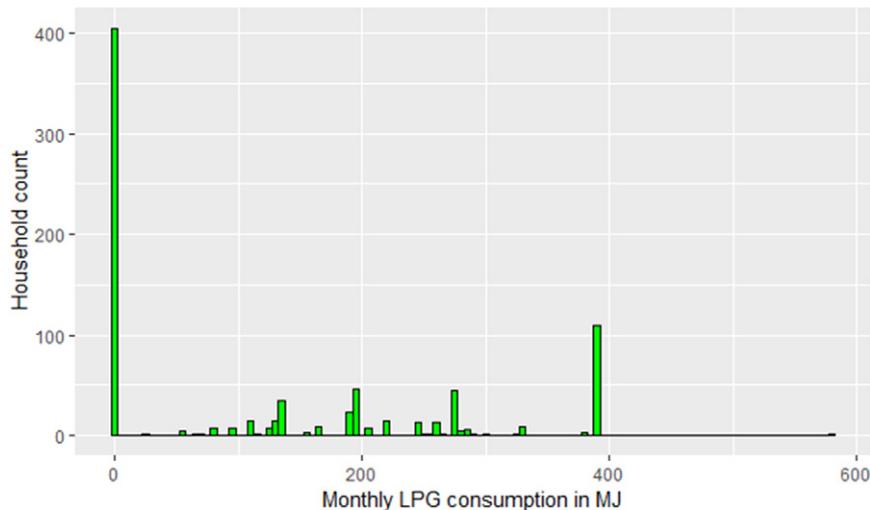


Fig. 4. Monthly useful LPG consumption (in MJ) at the final stage in the sample households.

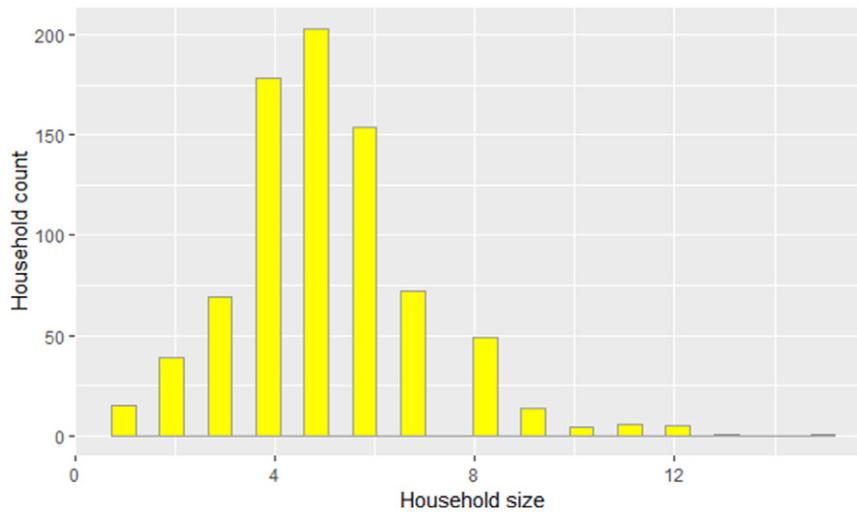


Fig. 5. Household size of the sample households.

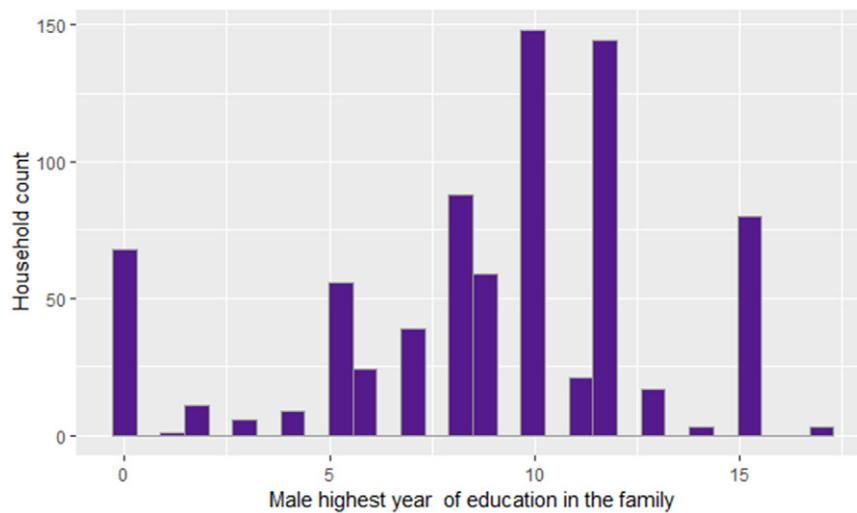


Fig. 6. Highest year of male education the sample households.

assumed that easy access to LPG refill will promote LPG transition. Out of 405 LPG users in our sample, only 210 households were getting LPG delivery at their doorsteps.

Location (*Loca_D*)

A dummy variable, which takes value 1 for urban location and 0 otherwise. This variable will help in understanding the rural-urban differences in LPG usage.

We calculated the solid fuels (in kg) average prices⁶ for both the districts, separately for rural and urban area. As compared to purchased solid fuels, subsidised LPG is the cheapest source of cooking energy, in both the districts, in terms of price per MJ useful cooking energy (Not reported for brevity). Households purchasing solid fuels (dung cake, fuelwood and coal) for cooking have to pay higher prices for useful cooking energy as compared to subsidised LPG. However, a large sum of solid fuel used for cooking is either home produced or gets collected which has no associated

monetary cost, in terms of payment. For instance, in rural Raipur 71%, urban Raipur 11%, rural Ranchi 81% and in urban Ranchi 66% of solid fuels used for cooking are either home produced or collected. Therefore, we have not included fuel prices in our regression model as we cannot determine the prices of home produced or collected solid fuels. Moreover, for a household with access to subsidised LPG, it is expensive to cook with purchased solid fuel.

LPG consumers, district and location wise, fuels share in monthly useful cooking energy is presented in Fig. 8. The PMUY beneficiary consumers have lower share of LPG in monthly cooking energy mix as compared to non-PMUY LPG⁷ consumers. Compared to district Raipur, Ranchi has lower LPG share in monthly useful cooking energy, both in rural and urban area. In urban Ranchi only 63% of useful energy comes from LPG in non-PMUY households, which stands at 94% in Raipur. The home produced/collected solid fuels, for which households do not have to pay in terms of money, is also quite high in urban Ranchi.

⁶ To calculate the location wise (rural-urban) average price of fuels in a district we have calculated the weighted average price, where weights are the quantity consumed by households in the last 30 days.

⁷ Households who have bought LPG connection by paying the capital cost, we term them non-PMUY households.

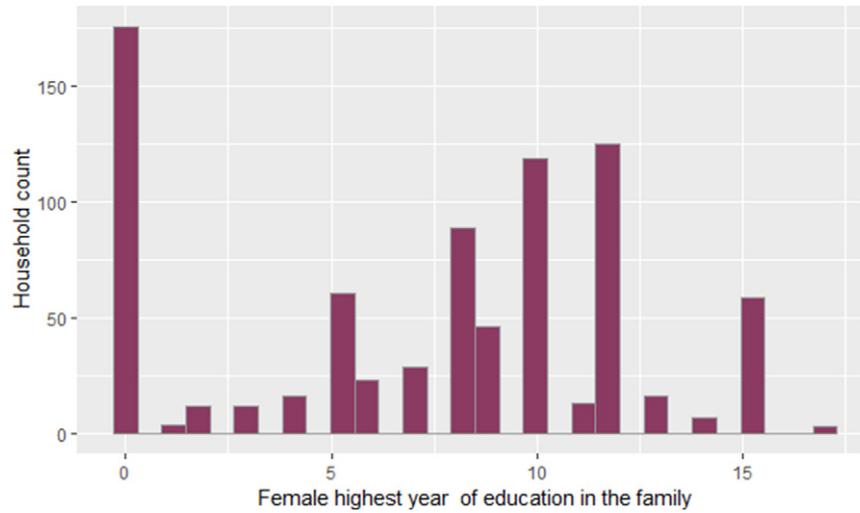


Fig. 7. Highest year of female education of the sample households.

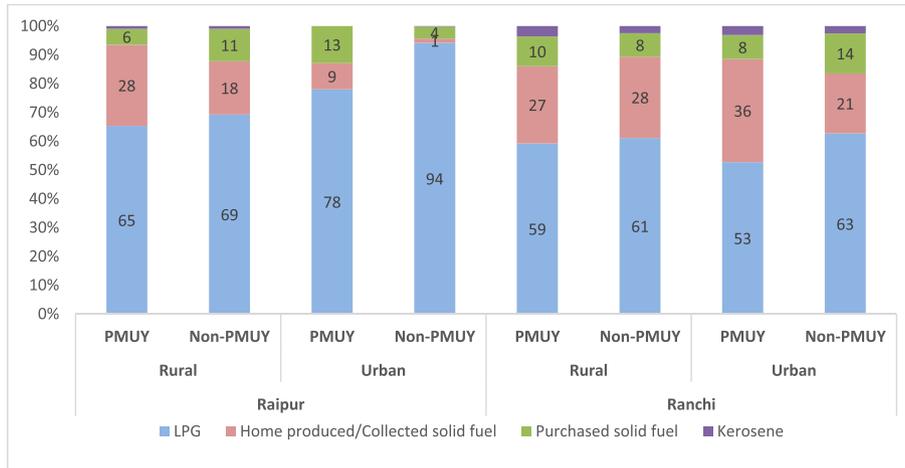


Fig. 8. Fuel source wise percentage share in monthly total useful cooking energy of PMUY and non-PMUY LPG households (in %).

Given that there are differences in cooking fuel consumption pattern in Raipur and Ranchi (Fig. 8), we have analysed the samples from two districts separately. This has been also done to understand whether the LPG usage drivers are same or different in the two districts. As discussed above, only 405 sample households had access to LPG in our sample and remaining households were not having access to LPG. Thus, our dependent variable, LPG consumption per capita and LPG share in total monthly useful energy, will be zero for non-LPG households. It reflects, our dependent variable is left censored (Tobin, 1958) which can be estimated using the Tobit model (Greene, 2000; Henningsen, 2010). Tobit model, also known as a censored regression model account for left- and/or right-censoring in the dependent variable. Tobit model coefficient allows estimation and inference of an exposure effect on the latent dependent variable (Wang & Griswold, 2015). Therefore, advantage of the Tobit model is that it permits determining the intensity of use of technology once adoption has taken place. The application of Tobit models for examining the determinants of household energy use in developing countries have been applied by several studies in the past (Mottaleb, Rahut, & Ali, 2017; Pope et al., 2017; Rahut, Behera, & Ali, 2016). Details of Tobit model

have been provided in Appendix A. The Tobit estimation has been performed using censReg R package (Henningsen, 2017). The two models, which this study estimate, are as follows:

Tobit Model 1:

$$LPG_PC = \beta_0 + \beta_1 \log H_income + \beta_2 \log H_size + \beta_3 H_head + \beta_4 \log HH_age + \beta_5 (\log HH_age)^2 + \beta_6 Male_education + \beta_7 Female_education + \beta_8 PMUY + \beta_9 Acqui_year + \beta_{10} (Acqui_year)^2 + \beta_{11} Loca_D + \beta_{12} LPG_del \quad (1)$$

Tobit Model 2:

$$LPG_share = \beta_0 + \beta_1 \log H_income + \beta_2 \log H_size + \beta_3 H_head + \beta_4 \log HH_age + \beta_5 (\log HH_age)^2 + \beta_6 Male_education + \beta_7 Female_education + \beta_8 PMUY + \beta_9 Acqui_year + \beta_{10} (Acqui_year)^2 + \beta_{11} Loca_D + \beta_{12} LPG_del \quad (2)$$

Table 1
Marginal effects of Tobit regression estimation for Model 1.

Independent variable	Dependent variable and coefficients					
	Model 1: LPG_PC					
	Raipur ^a			Ranchi ^b		
	Marginal effect	Std. error	P-value	Marginal effect	Std. error	P-value
<i>logH_Income</i>	6.69	2.54	0.009***	4.50	2.28	0.049**
<i>logH_size</i>	−15.87	3.31	0.000***	−22.84	4.35	0.000***
<i>H_head_D</i>	1.08	2.31	0.640	−3.38	3.26	0.302
<i>logHH_age</i>	126.63	84.94	0.137	−6.60	123.54	0.957
(<i>logHH_age</i>) ²	−16.87	11.49	0.143	0.16	16.29	0.992
<i>Male_education</i>	0.65	0.30	0.032**	−0.03	0.36	0.929
<i>Female_education</i>	0.50	0.26	0.056	0.30	0.29	0.302
<i>PMUY_D</i>	26.45	3.01	0.000***	35.57	3.01	0.000***
<i>Acqui_year</i>	8.06	0.67	0.000***	13.75	0.98	0.000***
(<i>Acqui_year</i>) ²	−0.29	0.03	0.000***	−0.62	0.06	0.000***
<i>Loca_D</i>	11.29	3.11	0.000***	3.20	2.69	0.235
<i>LPG_del</i>	9.33	3.31	0.005***	1.78	2.70	0.511

** Significant at the 5% level.

*** Significant at the 1% level.

^a Total sample 486, left-censored 233, uncensored 253 and right-censored 0. Log-likelihood: −1368.514 on 14 Df.

^b Total sample 290, left-censored 151, uncensored 139 and right-censored 0. Log-likelihood: −692.1682 on 14 Df.

Analysis and discussion

Table 1 presents the Tobit regression estimated marginal effects for model 1. The results presented in Table 1 suggests that at 5% level significance household income, household size, male education, PMUY scheme, LPG acquisition duration, location and LPG doorstep delivery status drives household's *LPG_PC* in Raipur In Ranchi, household income, household size, PMUY scheme and LPG acquisition duration drives *LPG_PC* at 5% level of significance (Table 1). Unlike Raipur, location and LPG delivery status were not found to be significantly influencing *LPG_PC* in Ranchi. Our finding suggests that household income positively influences *LPG_PC*. Moreover, income effect on *LPG_PC* is higher in Raipur as compared to Ranchi. A larger household size negatively impacts the *LPG_PC* in both Raipur and Ranchi. With increasing household size, lesser *LPG_PC* may arise due to economies of scale achieved for cooking. The policy intervention dummy for PMUY is

Table 2
Marginal effects of Tobit regression estimation for Model 2.

Independent variable	Dependent variable and coefficients					
	Model 2: LPG_share					
	Raipur ^a			Ranchi ^b		
	Marginal effect	Std. error	P-value	Marginal effect	Std. error	P-value
<i>logH_Income</i>	8.39	4.07	0.039**	3.53	2.38	0.139
<i>logH_size</i>	−9.76	5.29	0.065	−11.64	4.49	0.009***
<i>H_head_D</i>	1.17	3.72	0.753	−4.19	3.42	0.221
<i>logHH_age</i>	205.31	136.70	0.134	−65.20	128.02	0.610
(<i>logHH_age</i>) ²	−27.63	18.49	0.136	8.64	16.85	0.608
<i>Male_education</i>	1.12	0.49	0.022**	−0.03	0.38	0.944
<i>Female_education</i>	0.69	0.42	0.100	0.27	0.30	0.369
<i>PMUY_D</i>	49.04	4.86	0.000***	37.70	3.09	0.000***
<i>Acqui_year</i>	14.16	1.08	0.000***	15.83	1.02	0.000***
(<i>Acqui_year</i>) ²	−0.53	0.05	0.000***	−0.71	0.06	0.000***
<i>Loca_D</i>	19.60	4.98	0.000***	0.70	2.85	0.805
<i>LPG_del</i>	14.43	5.32	0.007***	1.97	2.84	0.489

** Significant at the 5% level.

*** Significant at the 1% level.

^a Total sample 486, left-censored 233, uncensored 253 and right-censored 0. Log-likelihood: −1475.396 on 14 Df.

^b Total sample 290, left-censored 151, uncensored 139 and right-censored 0. Log-likelihood: −689.0328 on 14 Df.

positive and significant. This suggests that even after controlling for the effects of other variables in the regression, net effect of this policy intervention variable is positive on *LPG_PC* in the beneficiary households. LPG acquisition year coefficient has positive sign whereas square of acquisition year has a negative sign. This explains that *LPG_PC* increases with year of acquisition at a decreasing rate. In Raipur, urban household's usage higher *LPG_PC* compared to rural area. Easy service provision, through delivering LPG cylinder at doorsteps, positively impacts the *LPG_PC* in Raipur.

The regression results for model 2 have been presented in Table 2. The estimated coefficients for model 2 suggests in Raipur household income, male education, PMUY scheme, LPG acquisition duration, location and LPG doorstep delivery are significant (at 5% level) drivers for *LPG_share* (Table 2). In Ranchi, household size, PMUY scheme, and LPG acquisition duration were found to be driving *LPG_share*, at 5% level of significance. Low *LPG_share* with increasing household size in Ranchi, suggests that with increasing cooking energy demand, a household chooses more useful cooking energy from the dirty fuel. Interestingly, household income does not impact LPG share in cooking energy mix, in Ranchi.

The analysis for the two districts suggests that there could be common as well as location specific factors driving LPG usage. For Raipur, our finding suggests that household income positively impacts *LPG_PC* and *LPG_share*. Whereas, in Ranchi income only positively impacts *LPG_PC*. The absence of income effect on *LPG_share* in Ranchi could be due to high availability of home produced or collected solid fuels. Both in rural and urban Ranchi, more than 20% of cooking energy used by LPG consumers is either home produced or collected solid fuels (Fig. 8). The higher availability of free solid fuels may have developed inertia among LPG consumers for using solid fuels and thereby keeping *LPG_share* low.

The negative coefficient of household size in model 1 suggests that in both the districts *LPG_PC* declines with increase in household size. Household's with more number of family members may consume higher amount of cooking energy but this increase in cooking energy consumption is not monotonic, due to economies to scale. Therefore, with increasing household size per capita *LPG_PC* can fall. However, falling *LPG_share* with increase in household size in Ranchi is a cause of concern. With larger household size and thereby higher cooking energy demand, a household may choose to use more home produced or collected solid fuel to keep the expenditure low for cooking energy. This may be likely the case in Ranchi, where a large proportion of solid cooking fuel is either home produced or collected, which do not involve monetary burden.

Rising education level may raise awareness regarding negative externalities of using solid fuel for cooking and therefore higher education can positively influence the LPG transition. We find mixed result for impact of male and female education level on LPG transition. In Raipur, only male education has significant positive impact on both *LPG_PC* and *LPG_share*. In Ranchi, impact of education level does not significantly impact LPG transition. Sehjpal, Ramji, Soni, and Kumar (2014) had also reported that that education levels do not seem to directly impact household fuel choices.

PMUY dummy has significant positive impact on *LPG_PC* and *LPG_share* in both the districts. It shows that capital subsidy provided for LPG access is helping in LPG transition. Several studies in the past had cited higher cost of LPG connection as a major reason for continuing use of biomass for cooking. PMUY scheme is though onetime capital subsidy scheme but it also entitles the beneficiary households to avail 12 subsidised LPG refills in a year. The results suggest that after controlling for the impact of income, household size, education and other variables, PMUY policy intervention is encouraging service provision among beneficiary households. This is important finding from the policy perspective because if the capital-cost subsidies leave possibilities for dropouts from those who cannot afford the fuel costs, it results in dead investments.

The coefficients in model 1 and 2 suggests that LPG acquisition year positively and significantly influences LPG transition. We find evidence in favour of Matinga et al. (2016) view that based on the consumer's experience over time, a household will choose the more convenient and cost-effective fuel. This can be useful finding for the ongoing PMUY scheme. One can argue that in the initial years even if beneficiaries of PMUY scheme may have low uptake of LPG refills; over time behavioural change will push them for sustained LPG usage. GoI had initiated measure for rationalise LPG subsidy to reduce fiscal burden. The policy makers can use this finding, along with others variables, to understand the duration of LPG subsidy support required for a new customer to attain sustained LPG transition.

Both the model result suggests that LPG delivery at doorsteps positively and significantly impact LPG usage in Raipur. However, we do not find this for Ranchi. We may infer that the supply chain management and LPG delivery status requires policy attention. In India, Public sector OMCs distributors deliver LPG cylinders at doorsteps in most of the urban households, whereas in rural areas it is mainly the consumers who have to collect it from the distribution center. Compared to urban settlement implicit cost of purchasing LPG cylinder is higher in rural India where it involves covering a distance up to the distribution center. Therefore, improving the LPG supply infrastructure and doorstep delivery in the geographically feasible locations will promote cooking with LPG.

It was expected that location dummy, which represents urban households, would be positive for LPG usage. For Raipur, we find this true as location dummy is positive and significant suggesting that *LPG_PC* and *LPG_share* is higher in urban area as compared to rural area. However, for Ranchi we do not find location dummy significant for both the models. As a policy measure, the Government of India needs to identify the low LPG uptake locations through the available LPG sales data and come up with targeted promotional as well as awareness-raising activities to promote clean cooking transition.

Conclusion

It is important to understand the factors that affect the household choice of using clean fuel like LPG. Using 810 primary samples collected from district Raipur of Chhattisgarh and Ranchi of Jharkhand, this study identifies the factors that promote LPG usage for cooking. Applying a Tobit model approach for censored data, this study estimated two models: *LPG_PC* and *LPG_share*. The first model examined the factors affecting per capita LPG consumption in the household whereas the second model analysed the factors promoting LPG share in the household cooking energy mix. The econometric estimation was carried out separately for Raipur and Ranchi sample. The econometric finding suggests that household income, household size, male education, PMUY scheme, LPG acquisition duration, location and LPG doorstep delivery status significantly impact *LPG_PC* in Raipur. Excluding household size, above mentioned variables also impact *LPG_share* in Raipur.

In Ranchi, household income, household size, PMUY scheme and LPG acquisition duration drives *LPG_PC*. *LPG_share* in Ranchi gets impacted by household size, PMUY scheme and LPG acquisition duration. Household income do not significantly impact *LPG_share*. This finding is at odds with existing theory which suggests that with rising income households moves to cleaner energy source. There, is no significant difference between rural and urban area of Ranchi either for *LPG_PC* or for *LPG_share*.

Promoting education particularly in poor households suffering from behavioural inertia may raise their awareness and understanding of negative externalities of burning solid fuels and benefits of usage of cleaner fuel like LPG. The analysis based on our sample data suggests that LPG capital subsidy scheme, PMUY, has provided a trigger for LPG transition among beneficiary households. However, to increase the use of LPG share in monthly cooking fuel, good LPG services such as

doorstep delivery will be required. Going forward, a more in-depth analysis of PMUY scheme can be taken up to understand the efficacy of this scheme in detail. We find that LPG access over time promotes LPG usage both in terms of LPG per capita consumption and its share in the cooking energy mix. This finding also indicates that sustained LPG transition for new customers may happen over time, once they understand the costs and benefits of clean fuels. This can be useful finding for the ongoing PMUY scheme. One can argue that in the initial years even if beneficiaries of PMUY scheme may have low uptake of LPG refills; over time behavioural change will push them for sustained LPG usage. GoI had initiated measure to rationalise LPG subsidy, to reduce fiscal burden. The policy makers can use this finding, along with other variables, to understand the duration of LPG subsidy support required for a new customer to attain sustained LPG transition.

There exist regional differences in LPG usage. The results emerging from Ranchi indicates that apart from access to LPG, level of household income, availability of service infrastructure, more is needed for districts like Ranchi to promote LPG transition. Availability of large amount of home produced and collected solid fuel may be acting as a deterrent for LPG transition, even in the economically well off households. Therefore, apart from awareness raising campaigns, developing a market for alternative use of locally available biomass will create an opportunity cost of burning it. Based on the LPG uptake (sales) data, the government should target the region lagging in terms of LPG consumption to promote LPG usage.

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Appendix A. Tobit model

The dependent variable can be either left-censored, right-censored, or both left-censored and right-censored, where the lower and/or upper limit of the dependent variable can be any number (see Henningsen, 2010).

For censored dependent variable *y*, the model can be written as:

$$y_i^* = x_i'\beta + \varepsilon_i \tag{A.1}$$

Here, *i* = 1, 2, 3, *N* indicates the observation, *y_i^{*}* is an unobserved (“latent”) variable, *x_i* is a vector of explanatory variables, *β* is a vector of unknown parameters, and *ε_i* is an disturbance term.

$$y_i = \begin{cases} a & \text{if } y_i^* \leq a \\ y_i^* & \text{if } a << y_i^* << b \\ b & \text{if } y_i^* \geq b \end{cases} \tag{A.2}$$

Here *a* is the lower limit and *b* is the upper limit of the dependent variable. If *a* = −∞ or *b* = ∞, the dependent variable is not left-censored or right-censored, respectively.

Censored regression models can be estimated using Maximum Likelihood method assuming that the disturbance term *ε* follows a normal distribution with mean 0 and variance *σ*², the log-likelihood function is given as,

$$\log L = \sum_{i=1}^N \left[I_i^a \log \Phi \left(\frac{a - x_i'\beta}{\sigma} \right) + I_i^b \log \Phi \left(\frac{x_i'\beta - b}{\sigma} \right) + (1 - I_i^a - I_i^b) \left(\log \varphi \left(\frac{y_i - x_i'\beta}{\sigma} \right) - \log \sigma \right) \right] \tag{A.3}$$

where *φ*(.) and *Φ*(.) denote the probability density function and the cumulative distribution function, respectively, of the standard normal

distribution, and I_i^a and I_i^b are indicator functions with

$$I_i^a = \begin{cases} 1 & \text{if } y_i = a \\ 0 & \text{if } y_i \gg a \end{cases} \quad (\text{A.4})$$

$$I_i^b = \begin{cases} 1 & \text{if } y_i = b \\ 0 & \text{if } y_i \gg b \end{cases} \quad (\text{A.5})$$

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