Environmental Challenges 5 (2021) 100254

Contents lists available at ScienceDirect

Environmental Challenges

journal homepage: www.elsevier.com/locate/envc

Clean energy choice and use by the urban households in India: Implications for sustainable energy for all

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ARTICLE INFO

Keywords:
Urban
Household
Cooking
Income
Choice
Expenditure
Fuel
Clean
Dirty

ABSTRACT

Despite rapid socioeconomic progress, households in developing countries face a severe challenge in accessing clean energy. More than one-third of the global population depends on biomass, dung cake, and firewood for cooking fuel, which are harmful to health and the environment. Thus, ensuring an adequate supply of non-polluting sources of fuel for households is crucial for protecting the environment and enhancing the well-being of people in developing nations. To provide affordable and non-polluting fuel for all by 2030, as per the Sustainable Development Goals of the United Nations, it is vital to understand the factors that influence the adoption of non-polluting fuels. Using information of urban households from NSSO 46th (1991–92), 63rd (2006–07), and 68th (2011–12) round surveys by the National Sample Survey Organization (NSSO), India, this study examines the factors influencing fuel choice and investigates the fuel consumption behavior of urban households. This study found that although reliance on firewood has been declining, a significant number of households continue to use it, and expenditure on firewood is more than 15% of the total energy expenditure of an urban family in India. Our econometric findings indicate that the schooling of the household head and spouse and economic status are the major factors in determining the choice of and reliance on clean or dirty fuels. Based on the findings, clean energy policies should target resource-poor households to guarantee non-polluting sources for all by 2030.

1. Introduction

In 2000, out of a total population of 6.1 billion, 51% (3.1 billion) had access to clean cooking fuel, whereas the remaining 49% (2.9 billion) were relying on solid pollutant fuels for cooking (United Nations, 2020). In 2017, access to clean cooking fuel had increased to 61% (4.6 billion), leaving 39% (2.9 billion) relying on solid fuel for cooking (United Nations, 2020). The reliance on solid fuels for cooking is generally high in low-income countries (Bonjour et al., 2013). For example, 45% of the total population of China, and 63% of the total population of India use solid fuel and biomass for cooking (WLPGA, 2019).

The harmful effects of indoor air pollution from the use of solid fuels such as cow dung and firewood have been extensively documented (Bruce et al., 2000; de Koning et al., 1985; Ezzati and Kammen, 2002; Fullerton et al., 2008; Jerneck and Olsson, 2013; Lelieveld et al., 2018; Mishra et al., 1999; Rahut et al., 2017a; Smith, 1993; WLPGA, 2018). According to the World Health Organization (WHO), there are 4 million deaths per year from indoor air pollution from using solid fuels, half of which are children below five years of age(WHO, 2020).

The over-extraction of biomass and firewood for cooking have been contributing to deforestation and desertification, thus adding to global carbon emissions (Akpalu et al., 2011; Duflo et al., 2008). As the quality of energy consumed by households affects human health, the environment, and sustainable development progress (AGECC, 2010), it is crucial to guarantee the adequate supply of clean and efficient fuel for all at affordable prices by 2030, as stated in the seventh Sustainable Development Goal (United Nations, 2020). However, inadequate supply, the relatively high price of clean fuels, and the relatively limited availability of clean energy are pushing poor urban households to rely on solid fuels for cooking across developing countries (Behera et al., 2015; Mottaleb et al., 2017; Rahut et al., 2017a,2019, 2020,2016,2014). To formulate an effective policy to enhance access to clean fuel, it is imperative to examine the factors that influence household choice and intensity of reliance on particular energy.

Empirical studies are in plenty that examined fuel choice at the household level. Some literature has empirically examined the energy ladder hypothesis (Leach, 1975, 1992), and confirmed that income is the major determining factor in deciding and relying on a particular

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https://doi.org/10.1016/j.envc.2021.100254
Received 12 December 2020; Received in revised form 22 August 2021; Accepted 22 August 2021

fuel (Hou et al., 2017; Karimu, 2015; Mottaleb et al., 2017; Özcan et al., 2013; Rahut et al., 2017a,2017b,2017c). In general, relatively poor households are more likely to depend on solid fuels such as biomass, cow dung, and firewood and chips (Bruce et al., 2000; Holdren et al., 2000; Rehfuess et al., 2006). With increasing income and related upgrading in economic status, households gradually switch to clean fuels, such as liquid petroleum gas (LPG) and electricity, as stated in the energy ladder hypothesis (Leach, 1975; Masera et al., 2000; Nansaior et al., 2011; Rahut et al., 2019). Furthermore, confirming the energy ladder hypothesis, studies have established that relatively poor households in South Asian countries mostly depend on firewood and dung, and relatively rich families depend more on clean fuel such as electricity or LPG (Behera et al., 2015; Leach, 1987; Mottaleb et al., 2017; Rahut et al., 2020). In addition to income and economic status, relative fuel prices also affect household fuel choice decisions and the reliance on particular fuels (Barnes and Floor, 1999; Barnes et al., 2010; Leach, 1992; Rahut et al., 2014). The relatively higher prices of clean fuels and the low opportunity costs of collecting biomass and firewood can largely explain the ubiquitous use of firewood in developing nations (Rao and Reddy, 2007). The household's demographic composition and the level of education of the head and spouse also influence fuel choice. There is a positive association between the level of education of the household head and their spouse, and the choice of and reliance on clean fuel (Heltberg, 2005; Pachauri and Jiang, 2008; Pandey and Chaubal, 2011; Rao and Reddy, 2007; Reddy and Srinivas, 2009). However, there is no consensus on the direction of the influence of the gender of the household head and gender composition of the households, and choice of a particular fuel (Muller and Huijie, 2014,2016). Recent studies found that *de jure* female-headed households mostly use dirty energy, while it is not the case for *de facto* female-headed households (Aryal et al., 2019).

Based on information collected from more than 87,069 urban households from three rounds of the National Sample Survey (NSS) datasets: NSS 46th (1990–91), NSS 63rd (2006–07), and NSS 68th (2011–12) rounds of the Government of India, this study explains the factors affecting fuel choice of urban households in India and then examines the factors affecting their fuel expenditure patterns. The motivation for focusing on urban households arises because many urban households use biomass for cooking despite having access to clean fuel. The novelty of this study is that it relies on large, nationally representative datasets consisting of only urban households in India. Secondly, this study use econometric approach to study the fuel choice and expenditure behavior of urban households in India using three waves of nationally representative datasets. The rest of the study is organized as follows: Section 2 presents a literature review and specifies the major objectives of this study; Section 3 presents materials and methods and specifies the econometric estimation procedure; Section 4 presents major findings, and Section 5 includes the conclusion and policy implications.

2. Literature review

Empirical studies that investigate the fuel choice and consumption patterns at the household level are abundant. In this section, however, we limited our literature review mainly to five major areas: wealth and income, education of the head and spouse, ethnicity, location, household demographic composition and fuel choice, and expenditure.

2.1. Wealth and Income and the choice and use of fuels

The widely acknowledged energy ladder hypothesis is based on the assertion that household wealth and income affect the choice of fuel (Leach, 1975, 1992), such that with increases in income, households gradually move from dirty to mixed to clean fuel in order to complete household chores. A number of empirical studies have confirmed a positive relationship between income and clean fuel use across countries (Behera et al., 2015; Khandker et al., 2012; Pachauri et al., 2004; Rao and Reddy, 2007). With increases in per capita expenditure, per capita energy consumption increases whilst households move away from solid fuels such as firewood and chips to use LPG and electricity (Pachauri et al., 2004; Rao and Reddy, 2007). Empirical studies in Bangladesh, Bhutan, and Pakistan also confirm the positive connection between income and wealth and the use of clean fuels (Aryal et al., 2019; Khandker et al., 2012; Mottaleb et al., 2017; Rahut et al., 2019; Rao and Reddy, 2007; Yasmin and Grundmann, 2019). Further, some studies have indicated the positive role of non-farm employment on clean energy usage, which can be partly linked (Lin and Zhao, 2021) with the energy ladder hypothesis as the household with non-farm employment are likely to earn a higher income and are also more educated.

2.2. Education and the choice and use of fuels

Studies confirm positive associations between schooling and the adoption of clean energy and negative associations with dirty fuel (Hou et al., 2017,2019; Joshi and Bohara, 2017; Karimu, 2015; Liao et al., 2019; Makonese et al., 2017; Muller and Huijie, 2014,2016; Rahut et al., 2017a,2017b,2017d), because education may enhance awareness about the detrimental effect of dirty fuel. Reliance on electricity and LPG increases as the education of the household head increases (Huang, 2015; Makonese et al., 2017; Mensah and Adu, 2015; Rao and Reddy, 2007). Clean energy use is correlated with the number of female members (aged between 10 and 50 years) who are educated (Pandey and Chaubal, 2011). The education level of the female and male adult is directly associated with the use of clean fuel (Ekholm et al., 2010; Farsi et al., 2007; Faye, 2002; Heltberg, 2004; Ouedraogo, 2006; Rahut et al., 2017c) and the level of dependency on clean fuel (Mottaleb et al., 2017; Rahut et al., 2016). The education level of the head and their spouse and the consumption of clean and nontraditional fuel is positively associated as it provides noteworthy savings in time (Mottaleb et al., 2017; Rahut et al., 2020; Rao and Reddy, 2007). The likelihood of using clean fuel increases with an increase in education, and the likelihood of using dirty fuel declines (Heltberg, 2004; Hou et al., 2019; Mottaleb et al., 2017; Rahut et al., 2017a,2017b, 2016c, 2017c,2017e). Fuel switching is strongly driven by education (Heltberg, 2005; Pachauri, 2004; Pachauri and Jiang, 2008); education is related with a greater prospect of the use of clean, and a diminished prevalence of use of solid fuel (Heltberg, 2004).

2.3. Gender of the head and demographic composition of households and fuel choice

The gender of the head of the family and the gender composition of the household influences household fuel choice. A higher proportion of female members in the family means more people available for the collection of firewood, thus reducing motivation to shift to modern sources of energy (Heltberg, 2005). As females are more concerned about the well-being of female household members and children who are engaged in the collection of firewood and cooking (Heltberg et al., 2000), an increase in female income and education is likely to diminish the use of solid fuels (Israel, 2002). Thus, acknowledging the role of gender in domestic energy use might help in scaling the use of renewable energy (Farhar, 1998).

Family demographic features, such as the age and gender composition of the household members, also can influence a household's fuel choice (Heltberg, 2004; Joshi and Bohara, 2017; Kuo and Azam, 2019; Liao et al., 2019; Rahut et al., 2019). Household size is negatively associated with the use of clean fuel (Pandey and Chaubal, 2011), which may be because bigger families mean more labor force available for gathering firewood (Dewees, 1989; Heltberg et al., 2000; Nepal et al., 2011). The affiliated profession of households seems to play a crucial role in fuel choice. As crop residue and cow dung are byproducts of agricultural households, in general, are more likely to use solid fuels for cooking (Ma et al., 2019; Rahut et al., 2016). In contrast, households whose heads or members are employed in non-agricultural sectors are more likely to use clean energy as the opportunity cost of collecting firewood would mean forgoing income from non-farm employment, which is greater (Ma et al., 2019).

2.4. Race and fuel use

There are also a strand of literature that focuses on the relationship between ethnicity and fuel choice. Many ethnic minorities live in remote and isolated areas and do not have access to clean fuel. A recent study in Australia shows that beside wealth, gender, and education, ethnicity is crucial for clean energy use and energy poverty (Awaworyi Churchill and Smyth, 2020; Poyer and Williams, 1993); hence, it is important to consider ethnicity while designing energy policy. This issue has also been considered in our current research paper.

2.5. Issues of fuel staking

Household in developing countries relies on more than one sources of fuel; hence the issues of energy staking has become pertinent in the household energy use literature. For instance, a study in Mexico shows that fuelwood is not completly replaced or dropped, even in families that have been using LPG for an extended period (Masera et al., 2000). Several recent literatures have focused on the issues of energy staking as it is relevant in developing countries. However, it is essential to note that even if the household continues to use traditional fuel, its share in the total energy basket is negligible. Many households use primary and secondary fuel, but the intensity of secondary fuel use is minimal, which has led to focus on the primary sources of fuel. Considering fuel staking theory, this paper considers that the household could use more than one fuel type for cooking and uses a multivariate probit model for analysis.

2.6. Spatial determinants of fuel choice

Location matters a lot in the choice of cooking fuel. For instance, the household in a remote area does not have access to clean fuel and are forced to rely on bio-mass. The far-flung villages are closer to the forest, making firewood more accessible and cheaper (Makonese et al., 2017; Pallegedara et al., 2021; Rahut et al., 2016,2014). Therefore, research on household fuel use should also control for the location.

The adoption and consumption of clean fuel can improve the quality of life by reducing pollution inside the residence as well as greenhouse gas emissions. The manufacturing sector consumes 33% of global energy, households consume 29%. Solid fuels such as firewood constitute 90% of the energy consumed by households in developing nations (International Energy Agency, 2006), and households are the third-biggest emitter of carbon dioxide (CO_2) (21%) in the world (International Energy Agency, 2008). A shift from dirty to clean sources of energy by decreasing the consumption of firewood and biomass could reduce CO_2 emissions considerably. In addition, the conservation of forests will help decrease CO_2 emissions by carbon sequestration. The findings of this study can contribute to developing effective policies in India to guarantee the supply of clean fuel for all by 2030.

3. Materials and methods

3.1. Data

This study relies on data collected by the National Sample Survey (NSS) Organization, India, from the NSS 46th round collected in 1990–91; NSS 63rd round collected in 2006–07; and NSS 68th round collected in 2011–12. Details of the sampling procedure and data collection process can be seen in National Sample Survey Office (NSSO), 1990; 2012; and 2014.

From 28,533 surveyed households in 46th round (1990–91), 14,794 households (51.8%) were from urban households. In the NSS 56th round (2000–01), 81,500 households were surveyed, and 50,938 households (62.5%) were urban households, the rest being rural households. In NSS 68th round (2011–12), 101,662 households were sampled, of which 41,967 households (41.0%) were from urban India

At the time of data cleaning, it is found that information of a few households on fuel expenditure is incomplete, and thus, we dropped a few observations; therefore, this study is based on data from 87,069 urban households collected by the NSSO in three rounds.

3.2. Model specification and estimation procedure

3.2.1. Multivariate probit estimation for energy choice

Urban households in India rely on different types of fuels simultaneously. A household may use kerosene or electricity for lighting, whereas the same household may use firewood, or dung cake, or LPG for cooking. To account for the simultaneity in choosing and using fuels for household chores, we have estimated a multivariate probit estimation in elucidating the choice of fuels by urban households of India. In our study, we have simplified that the sampled urban households of India use three broad categories of fuels: firewood (including firewood, chips, biomass, dung cake, and other fuels such as candle and match), kerosene (including kerosene and coal) and electricity (including LPG and electricity). Following Lin et al. (2005) in articulating the multivariate model, there are three categorical regressor variables, $y_1 \dots y_3$, such that:

$$y_i = 1 \text{ if } \beta_i X' + \varepsilon_i > 0 \tag{1}$$

and

$$y_i = 0 \text{ if } \beta_i X' + \varepsilon_i \leq 0, \ i = 1, \ 2, \ 3 \tag{2}$$

where x is a vector of the explanatory variables; $\beta_1, \beta_2,$ and β_3 are the vectors of parameters to be estimated and $\varepsilon_1, \varepsilon_2,$ and ε_3 are random errors distributed as multivariate normal distributions with zero mean, and unitary variance.

To empirically examine the factors that influence the choice of fuels at the household level, the following multivariate choice equations were used:

$$\begin{aligned} y_{im} = {} & \alpha_0 + (HCI)_{im}\lambda_i + \sum_{i=1}^{3} \varphi_s (SEDU)_s + \sum_{i=1}^{3} \theta_h (HEDU)_h \\ & + \beta_1 \ln(MPXP)_{im} + \sum_{i=1}^{3} \psi_i (Exp\ quartile)_{im} \\ & + \beta_2 (M\arg inal)_{im} + \beta_3 (Small)_{im} + \beta_4 (Caste)_{im} \\ & + \sum_{i=1}^{5} \gamma_d (\text{Region})_d + \zeta_{im} \end{aligned} \tag{3}$$

where y_{imt} is a regressor variable which takes the value 1, when a household i uses firewood, biomass, and dung cake as household fuel, or else 0; it is 1 when a household uses kerosene and/or coal and/or other fuels, or else 0; it is 1 when a household chooses LPG and electricity for domestic works, or else 0, otherwise. m is the number of equations, which in this case is $m = 3$ as we have simplified that households use three broad categories of fuels for cooking and lighting.

Of the explanatory variables, HCI is a vector of variables that include the age of the head and spouse, and gender of the head, which is 1 if male otherwise 0, and family size. The variables SEDU and HEDU are the education level of the head and spouse: primary school level dummy (up to 5 years), high school level (6–10 years) and university education (11 years and above), and the base category is zero years schooling of the head and spouse. The variable ln(MCXP) is the log of per capita consumption expenditure (per month) in Indian Rupees (INR); Exp. quartile is for four expenditure quartiles (Q1, Q2, Q3, and Q4) developed using per capita per month consumption expenditure, in which the lowest quartile (Q_1) is the base (poorest group = 0). The variable Marginal is 1, if the family-owned less than one hectare of land, or else, 0; Small is 1 if the family-owned 1-2 ha of land, otherwise, 0; Caste

Table 1
Background information of the sampled households by their choice of fuel and by the sampled years.

	All	NSS 46th round: 1990–91			NSS 63rd round: 2006–07			NSS 68th round: 2011–12		
		Major fuel category sampled households used								
		Firewood	Kerosene oil	Electricity and LPG	Firewood	Kerosene oil	Electricity and LPG	Firewood	Kerosene	Electricity and LPG
% Female headed households	11.8	9.9	10.0	9.6	11.4	12.2	11.4	12.5	13.5	12.4
Age, household head	45.4	43.8	43.8	44.6	46.1	45.9	45.8	46.5	47.1	46.1
No. of family members	4.3	4.9	4.954	4.99	4.2	4.5	4.2	4.3	4.6	4.3
% Household head with primary level education (up to 5 class)	14.7	24.3	25.4	23.0	5.2	7.0	5.0	18.3	23.3	18.0
% Household head up to secondary level education (5–8 class)	15.5	16.3	16.9	16.8	15.7	18.3	15.9	15.0	17.5	15.2
% Household head with secondary and above level education (9 and above)	46.7	36.4	33.1	44.2	53.2	37.8	55.7	44.5	33.0	46.2
Age, spouse	30.6	29.1	29.1	30.4	31.2	30.7	30.8	32.2	32.5	31.8
% Spouse with primary level education (up to 5 class)	12.0	18.7	19.5	20.0	4.9	6.4	4.7	15.5	18.5	15.3
% Spouse up to secondary level education (5-8 class)	12.2	11.6	11.6	13.7	13.0	14.0	13.0	12.5	13.4	12.5
% Spouse with secondary and above level education (9 and above)	27.9	16.3	13.9	21.3	30.3	18.8	31.3	30.5	21.3	31.4
Monthly per capita total expenditure (Rs./real)	1996.9	403.7	388.0	450.2	1806.3	1327.8	1888.1	2628.1	1928.1	2719.4
%Households in the first 25% expenditure quartile Q1 (poorest)	25.0	26.0	28.4	18.9	25.6	41.1	22.5	25.5	38.4	23.3
%Households in the second 25% expenditure quartile (Q2)	25.0	25.7	26.9	26.1	25.2	27.6	25.5	25.3	29.4	25.3
%Households in the third 25% expenditure quartile (Q3)	25.0	24.9	24.5	27.5	24.9	20.1	25.9	24.9	20.2	25.7
%Households in the fourth 25% expenditure quartile (Q4)	25.0	23.5	20.2	27.6	24.2	11.3	26.1	24.3	12.0	25.8
%Schedule caste and or schedule tribe	0.490	15.8	17.0	12.7	50.2	60.3	48.6	60.4	68.0	59.5
% Sample from west India	16.1	15.8	15.7	18.4	16.2	12.4	16.8	15.8	11.4	16.2
% Sample from north-east India	10.0	10.2	10.7	10.2	7.6	9.9	7.7	11.5	13.8	11.9
% Sample from central India	6.9	7.8	7.7	8.1	7.2	7.9	7.1	6.5	7.0	06.4
% Sample from east India	15.1	15.5	17.3	11.3	16.0	26.4	14.9	14.6	22.9	13.6
% Sample from south India	23.7	20.5	20.9	21.0	23.4	21.5	24.2	24.5	24.5	25.1
% Sample from north India	23.0	27.4	25.8	27.8	24.1	20.2	23.3	21.5	19.4	21.0
No. of households	87,069	13,698	11,838	10,933	28,977	14,131	28,928	40,222	20,581	40,423

Sources: Authors' based on NSSO 46th, 63rd and 68th round surveys.

(dummy) is 1 if the family belongs to schedule tribe or schedule caste or backward caste, and 0 otherwise. Finally, Region is the five dummies for six regions of India, in which the West Indian States are set as the base (= 0). In the estimation process, three multiplicative independent dummy variables are constructed and included by multiplying the caste dummy, marginal, and smallholder household dummies by the log of the per capita per month consumption expenditure.

In Eq. (3), α_0 is a scalar and λ_i, β_i, γ_i, φ_s, θ_h, ψ_i and γ_d are the parameters to be assessed, and ζ_{im} is the random error term. Because a household may simultaneously use different types of fuels, we applied the multivariate probit estimation procedure in estimation Eq. (3).

3.3. Seemingly unrelated regression (SUR) estimation for the intensity of consumption

After estimating the Eq. (3), we examine the factors that affect the intensity of a particular energy source used by households. The intensity of a particular energy source is measured by dividing the expenditure for each energy source by total energy expenditure per household. This dependent variable also explains the degree of dependency on a particular energy source. In the case of independent variables, in addition to all of the independent variables specified in Eq. (3), to capture the unobserved households' characteristics that might affect consumption of three energy sources, we calculate a generalized inverse Mill's ratio (GIMR) applying the method of Vella (1998). After that, we estimate fuel consumption intensity for three fuel sources, as shown in Eq. (4), which includes the calculated GIMR. As the usage of different energy sources by a single household is mutually inclusive (simultaneous), the Seemingly Unrelated Regression (SUR) estimation procedure is applied to estimate the energy consumption intensity of the three energy sources as follows:

$$
\begin{aligned}
C_{im} &= \alpha_0 + (HCI)_{im}\lambda_i + \sum_{i=1}^{3}\varphi_s(SEDU)_s + \sum_{i=1}^{3}\theta_h(HEDU)_h \\
&+ \beta_1 \ln(MPXP)_{im} + \sum_{i=1}^{3}\psi_i(Exp\ quartile)_{im} + \beta_2(M\arg inal)_{im} \\
&+ \beta_3(Small)_{im} + \beta_4(Caste)_{im} + \sum_{i=1}^{5}\gamma_d(\text{Region})_d \\
&+ \sum_{i=1}^{2}\theta_i(Year)_i + \delta_i GIMR_{im} + \zeta_{im}
\end{aligned} \tag{4}
$$

Where, C_{imt} is the dependent variable of the ratio of a household's expenditure on different sources of energy (kerosene oil, firewood and electricity, and LPG) to total household expenditure on energy. It should be noted that in the case of some households, expenditure on a particular fuel is zero (no expenditure). Thus, the share of particular energy expenditure in total energy expenditure is zero for some households.

Since the 90s, India's economic achievement in terms of poverty alleviation and surges in per capita income has been extraordinary. Considering this and anticipating structural changes in the economy, Eq. (3) is estimated separately for 1990–91, 2000–01, 2006–07, and 2011–12.

Table 2
Estimated functions applying multivariate probit models explaining choice of fuel at the household level for household chores by the years sampled.

Dependent variables	Firewood	Kerosene oil	Electricity and LPG	Firewood	Kerosene oil	Electricity and LPG	Firewood	Kerosene oil	Electricity and LPG
NSS rounds	46th (1990-91)			63rd (2006–07)			68th (2011–12)		
Female headed household dummy (yes=1)	0.10 (0.06)	0.03 (0.05)	0.41*** (0.05)	0.22*** (0.05)	-0.002 (0.03)	0.26*** (0.06)	0.09** (0.04)	-0.0012 (0.03)	0.19*** (0.05)
Age, household head	0.01*** (0.00)	-0.0002 (0.00)	0.02*** (0.00)	0.01*** (0.00)	0.0004 (0.00)	0.01*** (0.00)	0.017*** (0.00)	0.0048*** (0.00)	0.01*** (0.00)
No. of family members	0.08*** (0.01)	0.07*** (0.01)	0.13*** (0.01)	0.08*** (0.01)	-0.003 (0.00)	0.12*** (0.01)	0.076*** (0.01)	0.019*** (0.00)	0.12*** (0.01)
Dummy for household head is educated up to primary level (yes=1)	-0.19*** (0.06)	-0.19*** (0.04)	0.33*** (0.04)	0.05 (0.14)	0.09 (0.06)	-0.02 (0.09)	-0.17*** (0.04)	-0.022 (0.02)	0.27*** (0.04)
Dummy for household head is educated up to middle school level (yes=1)	-0.29*** (0.06)	-0.23*** (0.05)	0.42*** (0.04)	-0.10** (0.04)	-0.22*** (0.03)	0.37*** (0.04)	-0.16*** (0.04)	-0.078*** (0.02)	0.48*** (0.05)
Dummy for household head is educated secondary and above level (yes=1)	-0.44*** (0.06)	-0.46*** (0.04)	0.59*** (0.04)	-0.14*** (0.04)	-0.41*** (0.02)	0.40*** (0.05)	-0.20*** (0.04)	-0.35*** (0.02)	0.49*** (0.04)
Age, spouse	0.01*** (0.00)	0.01*** (0.00)	0.002* (0.00)	0.01*** (0.00)	0.002*** (0.00)	0.004*** (0.00)	0.0038*** (0.00)	0.0010* (0.00)	0.0023** (0.00)
Dummy for spouse is educated up to primary level (yes=1)	0.18*** (0.06)	0.14*** (0.04)	0.40*** (0.04)	0.15 (0.15)	-0.04 (0.07)	0.25** (0.10)	0.26*** (0.05)	0.061*** (0.02)	0.32*** (0.04)
Dummy for spouse is educated up to middle school level (yes=1)	0.26*** (0.07)	0.09* (0.05)	0.70*** (0.05)	0.27*** (0.05)	0.034 (0.03)	0.31*** (0.06)	0.34*** (0.05)	0.066*** (0.02)	0.40*** (0.06)
Dummy for spouse is educated secondary and above level (yes=1)	0.10* (0.06)	-0.15*** (0.04)	0.99*** (0.06)	0.26*** (0.04)	-0.19*** (0.02)	0.65*** (0.08)	0.23*** (0.03)	-0.13*** (0.02)	0.64*** (0.06)
ln(monthly per capita expenditure in Rs.)	-0.05 (0.15)	0.27** (0.12)	0.64*** (0.15)	-0.01 (0.15)	-0.55*** (0.09)	1.33*** (0.24)	-0.018 (0.12)	-0.36*** (0.07)	1.14*** (0.19)
Dummy for a household in the second expenditure quartile Q2 (yes=1)	-0.13** (0.07)	-0.17*** (0.05)	0.35*** (0.05)	-0.14** (0.06)	-0.20*** (0.03)	0.100* (0.06)	0.038 (0.05)	-0.11*** (0.03)	0.027 (0.05)
Dummy for a household in the third expenditure quartile Q3 (yes=1)	-0.30*** (0.08)	-0.35*** (0.06)	0.36*** (0.07)	-0.12* (0.07)	-0.24*** (0.05)	0.003 (0.09)	-0.063 (0.06)	-0.27*** (0.04)	-0.067 (0.08)
Dummy for a household in the third expenditure group Q4 (yes=1)	-0.45*** (0.12)	-0.60*** (0.08)	0.15 (0.10)	-0.17* (0.10)	-0.28*** (0.07)	-0.46*** (0.11)	-0.073 (0.08)	-0.33*** (0.06)	-0.44*** (0.11)
Dummy for schedule cast or schedule tribe household (yes=1)	-1.29*** (0.44)	-1.56*** (0.37)	-0.24 (0.33)	-0.16 (0.34)	-0.39* (0.22)	-0.90* (0.47)	-0.54* (0.30)	-0.46** (0.19)	-1.03** (0.44)
Dummy for schedule cast or schedule tribe household X ln (monthly per capita expenditure Rs.)	0.24*** (0.08)	0.31*** (0.06)	0.003 (0.06)	0.05 (0.05)	0.09*** (0.03)	0.099 (0.07)	0.082** (0.04)	0.087*** (0.02)	0.11* (0.06)
Dummy for a households from a north east Indian state (yes=1)	0.32*** (0.07)	0.38*** (0.05)	-0.47*** (0.05)	0.02 (0.06)	0.80*** (0.03)	-0.29*** (0.07)	-0.51*** (0.04)	0.60*** (0.02)	-0.44*** (0.06)
Dummy for a households from a central Indian state (yes=1)	-0.01 (0.07)	-0.001 (0.05)	-0.25*** (0.06)	0.07 (0.06)	0.33*** (0.03)	0.14* (0.07)	-0.023 (0.06)	0.35*** (0.03)	-0.17** (0.07)
Dummy for a households from an east Indian state (yes=1)	0.18*** (0.05)	0.60*** (0.05)	-0.89*** (0.04)	0.19*** (0.04)	1.32*** (0.03)	-0.62*** (0.05)	0.11** (0.04)	1.31*** (0.02)	-0.72*** (0.05)
Dummy for a households from a south Indian state (yes=1)	-0.027 (0.05)	0.10** (0.04)	-0.26*** (0.04)	-0.03 (0.04)	0.18*** (0.02)	0.20*** (0.06)	-0.059* (0.04)	0.44*** (0.02)	0.059 (0.06)
Dummy for a households from a north Indian state (yes=1)	0.19*** (0.05)	-0.05 (0.04)	-0.23*** (0.04)	0.35*** (0.04)	0.16*** (0.02)	-0.36*** (0.05)	0.073* (0.04)	0.29*** (0.02)	-0.48*** (0.05)
Constant	1.60* (0.93)	-0.48 (0.70)	-4.36*** (0.86)	1.03 (1.10)	4.03*** (0.65)	-8.25*** (1.63)	1.00 (0.96)	2.20*** (0.52)	-7.15*** (1.34)
atrho21	0.44*** (0.02)			0.18*** (0.01)			0.18*** (0.01)		
Atrho31	0.11*** (0.02)			-0.18*** (0.03)			0.08*** (0.02)		
Artho32	-0.10*** (0.02)			-0.34*** (0.02)			-0.27*** (0.02)		
No. of households	14,734			30,368			41,967		
Wald chi^2 (75)	4879.18			9839.20			12,605.36		
Prob > chi^2	0.00			0.00			0.00		
Log pseudolikelihood	-15687.28			-24862.13			-34239.91		

Note: Standard errors in parentheses are calculated based on clustering the standard error at the household level. ***, **, and * indicate significance at the 1%, 5%, and 10% levels.

Table 3
Correlation coefficients among three fuel that households used for household's chores in India.

Fuel items used	46th round	63rd round	68th round
Firewood and kerosene oil (rho21)	0.41*** (0.02)	0.17*** (0.01)	0.18*** (0.01)
Firewood and electricity & LPG (rho31)	0.11*** (0.02)	-0.18*** (0.02)	0.08*** (0.02)
Kerosene oil and electricity & LPG (rho32)	-0.07*** (0.02)	-0.33*** (0.02)	-0.27*** (0.02)
Likelihood ratio test of rho21 = rho31 = rho32 = 0: $\chi 2$ (3)	595.07	458.79	477.16
Prob> $\chi 2$	0.00	0.00	0.00

Source: Derived from Multivariate probit model estimation.
Note: ***, **, and * indicate significance at the 1%, 5%, and 10% levels.

4. Findings and discussions

4.1. Descriptive results

Table 1 summarizes the basic characteristics of the urban households used in the study. In general, the sampled urban households in India were mostly headed by males (88%), with an average age of 45 years and nearly four members in their families (Table 1). The average age of a spouse was 31 years old. Among the sampled households, nearly 14.7% of the household heads had below primary level of education, nearly 15.5% had up to a secondary level of education, and 46.7% had above the secondary level education. In contrast, 12% of the spouses of the household head had up to a primary level of education, 12.2% of them had up to a secondary, and 27.9% had a secondary or higher level of schooling (Table 1). A closer scrutiny of Table 1 reveals that the level of education of the head and spouses were higher in the groups that reported the consumption of electricity and liquid petroleum gag (LPG) compared to the group that reported the use of firewood. This supports the previous findings on the existence of a strong and positive association between education and consumption of clean categories of fuel.

The average per capita per month expense of a urban household in India was INR1996.9. The average per capita per month expense was higher for families that reported electricity and LPG consumption than for the families who reported the consumption of firewood (Table 1). This finding also supports the proposed association between income and the consumption of cleaner fuels. We further divided the households into four quartiles based on monthly per capita consumption expenditure. It shows that the households from the richest expenditure (Q4), mostly used electricity and LPG and less of firewood and kerosene. In contrast, the sampled households in the poorest expenditure quartile (Q1) mostly used firewood and rarely used electricity and LPG. This demonstrates the positive assertion between the level of income and the consumption of cleaner fuels and vice versa.

Table 1 illustrates that 49% of households were from the schedule tribe, schedule caste, or backward caste. In the econometric model, the caste, small and marginal farm household categories are used directly in the model to examine their influence on fuel choice and expenditure patterns. Table 1 also highlights the distribution of the samples across Indian states by fuel usage, showing that a significantly less percentage of households in central, north-east, and east India use electricity and LPG. Thus, access to clean fuels by urban households is highly heterogeneous across regions in India.

4.2. Trend in the incidence of energy use

To capture the temporal variation in the use of dirty and clean fuels, we developed Fig. 1, which displays the pattern of household energy consumption across the time periods. In the last two decades in urban India, the percentage of families consuming firewood and other biomass as a fuel source remained consistent, with almost every household using firewood and other biomass as a fuel source. The percentage of families consuming kerosene and charcoal was 80% in 1990–91, which gradually declined to 49% in 2011–12, whereas the percentage of families consuming electricity and LPG increased steadily from 74% in 1990–91 to 96% in 2011–12, which highlight the significant progress achieved in urban India with regards to clean energy transition.

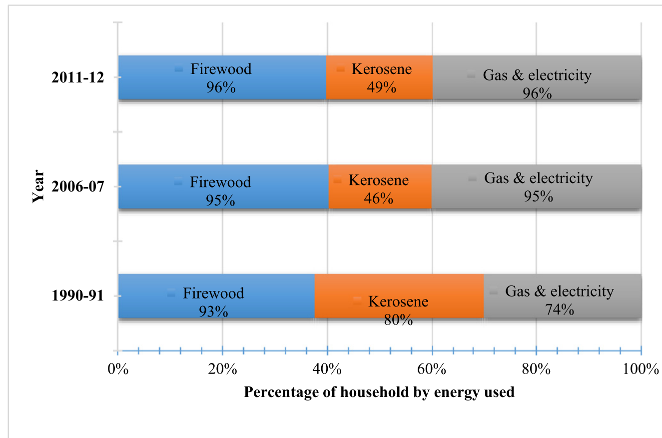

Fig.1. Energy use by sources across by households by years (percentage of household).

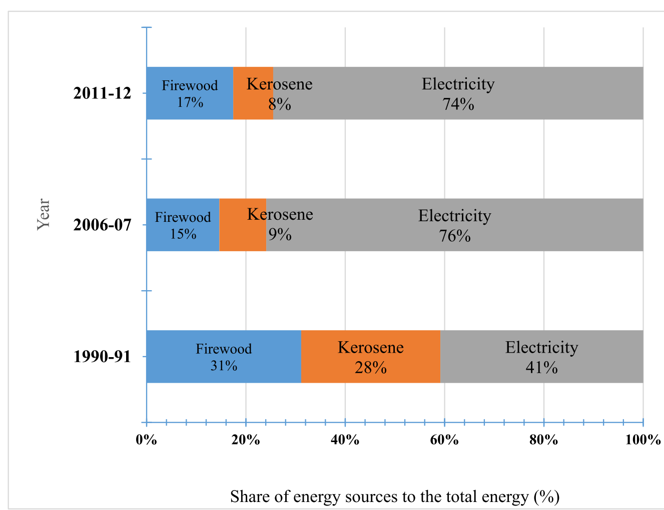

Fig.2. Share of energy sources to the total energy expenditure across years.

4.3. Trends in the reliance on fuels

During the periods sampled (1990–91 to 2011–12), the share of firewood expenditure to total energy expenditure declined while the share of expenditure on electricity and LPG has been increased significantly. The expenditure share of firewood to the total fuel expenditure among urban households dropped from 31% in 1990–91 to 17% in 2011–12 while the share of electricity and LPG to total fuel consumption increased from 41% in 1990–91 to 74% in 2011–12 (Fig. 2). The share

Table 4
Estimated functions applying SUR estimation method explaining monthly expenditure on different types of fuel at the household level by the years sampled in India.

NSSO rounds	46th (1990-91)			63rd (2006–07)			68th (2011–12)		
	Firewood	Kerosene oil	Electricity and LPG	Firewood	Kerosene oil	Electricity and LPG	Firewood	Kerosene	Gas & electricity
Female headed household dummy (yes=1)	-2.25* (1.20)	2.06** (0.90)	14.3*** (1.59)	0.24 (2.02)	-10.8*** (1.49)	105.0*** (6.59)	-1.07 (3.10)	-14.9*** (2.03)	134.1*** (8.20)
Age, household head	-0.15*** (0.03)	-0.16*** (0.02)	0.74*** (0.04)	-0.36*** (0.05)	-0.31*** (0.04)	3.32*** (0.17)	-0.33*** (0.08)	-0.31*** (0.05)	3.90*** (0.20)
Dummy for household head is educated up to primary level (yes=1)	-8.73*** (1.06)	1.93** (0.75)	4.00*** (1.02)	-0.69 (5.18)	0.73 (4.08)	-19.6* (10.68)	-13.5*** (3.18)	-1.61 (1.89)	-5.42 (5.73)
Dummy for household head is educated up to middle school level (yes=1)	-13.4*** (1.25)	4.24*** (0.95)	6.24*** (1.21)	-24.5*** (2.03)	-5.56*** (1.53)	29.8*** (4.54)	-35.3*** (3.31)	-7.31*** (2.05)	8.92 (6.22)
Dummy for household head is educated secondary and above level (yes=1)	-21.5*** (1.07)	-1.86** (0.87)	18.6*** (1.39)	-39.1*** (1.76)	-11.6*** (1.35)	36.2*** (5.41)	-54.2*** (2.73)	-10.2*** (1.54)	33.5*** (6.55)
Age, spouse	0.18*** (0.03)	0.047** (0.02)	0.15*** (0.04)	0.34*** (0.05)	-0.060* (0.03)	1.36*** (0.16)	0.51*** (0.07)	-0.17*** (0.04)	2.78*** (0.19)
Dummy for spouse is educated up to primary level (yes=1)	-3.76*** (1.12)	1.10 (0.84)	10.1*** (1.19)	-11.8** (5.24)	1.51 (4.35)	36.9*** (11.28)	-27.4*** (3.12)	-1.28 (2.01)	54.0*** (5.65)
Dummy for spouse is educated up to middle school level (yes=1)	-7.40*** (1.35)	2.61** (1.11)	18.7*** (1.59)	-13.4*** (1.90)	-3.74** (1.49)	80.3*** (4.74)	-27.8*** (2.98)	-9.06*** (1.95)	89.8*** (6.33)
Dummy for spouse is educated secondary and above level (yes=1)	-12.3*** (1.06)	-5.55*** (0.96)	38.7*** (1.83)	-17.5*** (1.53)	-7.76*** (1.09)	146.6*** (5.84)	-40.0*** (2.25)	-11.8*** (1.34)	158.6*** (6.10)
No. of family members	4.34*** (0.24)	3.07*** (0.18)	7.12*** (0.28)	8.29*** (0.57)	3.40*** (0.26)	77.1*** (1.83)	16.7*** (0.74)	5.14*** (0.39)	87.0*** (1.66)
ln(monthly per capita expenditure in Rs/real.)	-0.49 (3.31)	5.60 (3.81)	16.0*** (4.74)	-14.8** (6.15)	27.8*** (3.01)	365.8*** (36.21)	11.7 (13.99)	28.4*** (7.11)	359.2*** (28.31)
Dummy for a household in the second expenditure group Q2 (yes=1)	-3.27*** (1.15)	7.24*** (0.85)	5.99*** (1.34)	-38.2*** (2.29)	0.91 (1.82)	24.4 (15.73)	-39.3*** (3.75)	4.74** (1.98)	47.2*** (7.96)
Dummy for a household in the third expenditure group Q3 (yes=1)	-4.22*** (1.45)	7.84*** (1.12)	16.8*** (2.10)	-37.5*** (2.85)	-7.71*** (2.45)	3.30 (26.38)	-57.2*** (5.28)	6.08** (2.74)	57.9*** (13.39)
Dummy for a household in the third expenditure group Q4 (yes=1)	-6.22*** (2.03)	4.32*** (1.49)	28.0*** (3.29)	-24.4*** (3.88)	-14.1*** (3.41)	-21.2 (36.25)	-43.1*** (8.00)	2.54 (3.85)	64.5*** (20.40)
Dummy for schedule cast or schedule tribe household (yes=1)	12.1*** (1.24)	1.58** (0.68)	-6.00*** (0.80)	20.9*** (1.17)	-1.02 (0.88)	-50.5*** (3.09)	38.0*** (1.77)	-2.02* (1.20)	-86.6*** (3.93)
Dummy for a households from a north east Indian state (yes=1)	38.8*** (1.70)	-1.79* (1.01)	-33.4*** (1.61)	38.8*** (3.00)	-15.6*** (1.77)	-125.4*** (5.32)	43.1*** (3.66)	-14.7*** (2.37)	-153.3*** (5.95)
Dummy for a households from a central Indian state (yes=1)	15.1*** (1.27)	-6.60*** (1.04)	-20.4*** (1.83)	8.85*** (2.31)	-24.9*** (1.40)	10.9 (7.14)	22.8*** (4.19)	-22.8*** (2.51)	-22.1*** (8.29)
Dummy for a households from an east Indian state (yes=1)	10.4*** (0.99)	10.3*** (1.08)	-19.4*** (1.77)	15.5*** (1.62)	-1.16 (1.74)	-95.1*** (5.23)	12.3*** (2.57)	14.8*** (2.24)	-140.8*** (6.49)
Dummy for a households from a south Indian state (yes=1)	13.5*** (0.75)	-3.77*** (0.73)	-22.0*** (1.54)	4.67*** (1.37)	-8.18*** (1.20)	-112.9*** (4.95)	7.99*** (2.11)	-24.4*** (1.47)	-208.8*** (5.74)
Dummy for a households from a north Indian state (yes=1)	14.8*** (0.80)	-5.05*** (0.67)	-13.8*** (1.49)	25.5*** (1.59)	-17.6*** (1.11)	-17.0** (8.14)	24.8*** (2.62)	-19.7*** (1.54)	-14.1** (6.94)
Generalized inverse Mill's ratio	13.0*** (0.62)	27.7*** (0.47)	27.5*** (0.81)	33.6*** (1.24)	86.5*** (1.71)	55.2*** (9.09)	72.8*** (2.05)	109.4*** (1.81)	112.7*** (9.07)
Constant	24.3 (18.99)	-22.6 (21.06)	-112.1*** (26.66)	213.6*** (45.47)	-125.8*** (21.18)	-2707.9*** (254.41)	74.4 (105.92)	-128.1** (51.51)	-2706.2*** (210.34)
No. of households	14,734			30,368			41,967		
Chi2	4338.2	3742.1	11,603.9	8836.7	11,722.7	19,275.3	8724.3	10076.1	32823.6
Prob > chi2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
R2	0.23	0.21	0.44	0.23	0.28	0.39	0.17	0.19	0.44

Note: Values in parentheses are standard errors calculated applying bootstrap estimation method replicating 1000 times. ***, **, and * indicate significance at the 1%, 5%, and 10% levels.

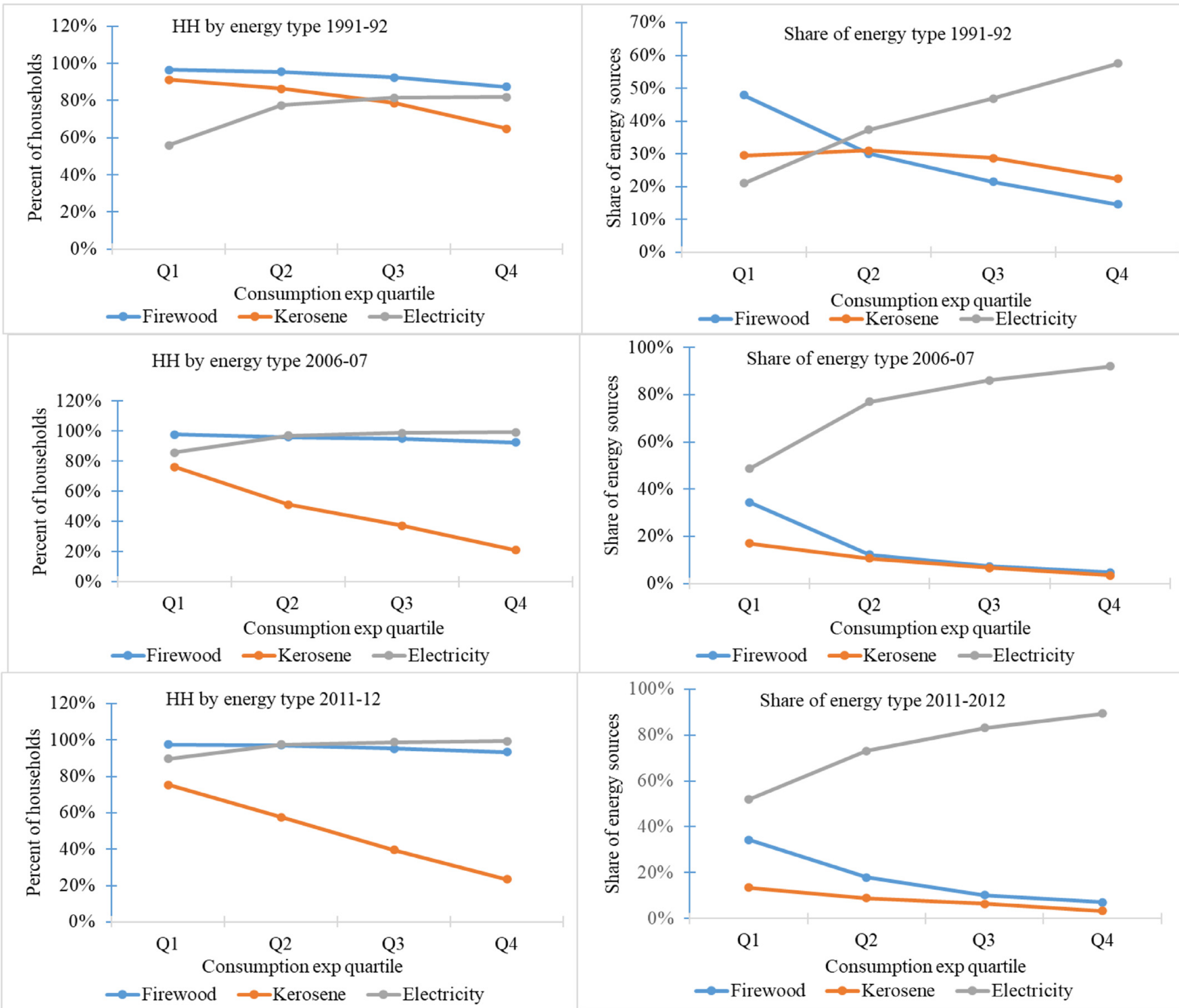

Fig.3. Percentage of households and share of energy sources to the total energy expenditure across income quintile by years.

of the kerosene to total fuel consumption fell from 28% in 1990–91 to 8% in 2011–12. Overall, although the sampled urban households significantly depend on clean fuel such as electricity and LPG, the use of firewood is still prevalent. At the same time, the use and reliance on kerosene and coal has been declining.

4.4. Relationship between income level and fuel consumption

Fig. 3 shows the percentage of household by fuel types and share of fuel consumption across income quartiles (Q1–Q4) over the periods sampled. The result shows that the percentage of households using kerosene oil decreased significantly across the income quintile while the percentage of households using firewood decreased marginally for all the survey years. The percentage of households using electricity and LPG increased across the income quintile, indicating that poorer households are less likely to use electricity. Interestingly, the decline in the percentage of households using electricity and LPG across the income quintile is steeper in 1991–92. In the subsequent survey year, it becomes less stepper, indicating that access to clean energy has improved over time in urban India.

In general, the proportion of expenditure on firewood, dung, and kerosene has decreased sharply over the years sampled, while the share of expenditure on electricity and LPG increased. In 1990-91 (NSS 46th round), the share of expenditure on firewood and dung was 48% among Q1 and 15% among Q4. In 2011–12, it dropped from 34% for the households from Q1 consumption expenditure group to 7% for the households in Q4 expenditure group. Similarly, the share of electricity and LPG increased by income quartile in 1990-91, 2006–07, and 2011–12. In 1990-91, the share of expenditure on electricity and LPG increased from 21% among quartile 1 to 58% in quartile 4, while in 2011–12, it increased from 52% in quartile 1 to 89% in quartile 4. In addition to the supply-side expansion, the income also played a positive role in transitioning from dirty to clean fuels in urban India.

4.5. Econometric findings

4.5.1. Exploring fuel choice: multivariate probit model estimation approach

The results from the multivariate probit approximation procedure is summarized in Table 2. Relatively older household heads and spouses tended to choose clean fuels. Interestingly, families headed by females favored liquified petroleum gas (LPG) and electricity for cooking over kerosene and coal. This finding is similar to the findings from other studies (Behera et al., 2015; Farhar, 1998; Parikh, 1995; Viswanathan and Kavi Kumar, 2005). Females may be more apprehensive about the detrimental effects of consuming polluting fuel. Households with large families tended to adopt biomass because they were able to allocate surplus labor to gather biomass, which is available for free, and the opportunity costs of gathering or preparing biomass tended to be lower.

Education level has a positive and significant association with clean energy and a negative and significant association with biomass and kerosene (Table 2). Notably, the effect of education on the choice of clean energy is progressive. These results strongly confirm the findings from other studies that relatively more educated household heads and spouses prefer using clean energy (Behera et al., 2015; Gregory and Stern, 2014; Hou et al., 2017; Huang, 2015; Mensah and Adu, 2015; Rahut et al., 2017d; Reddy and Srinivas, 2009).

The economic status of the family has a retrogressive effect on the use of firewood and kerosene as fuel. The coefficient of the log of per capita per month family consumption expenditure is positive and highly significant for all three rounds, while it is negative for kerosene. The wealth status of households, as presented by the expenditure quartile dummies (Q2–Q4), are positive, significant, and progressively increasing for the consumption of electricity and LPG for all three periods (Table 2). This demonstrates that comparatively well-off families prefer clean fuel over solid fuels such as biomass for cooking, which supports previous research findings (Baiyegunhi and Hassan, 2014; Cayla et al., 2011; Huang, 2015; Khandker et al., 2012; Kwakwa et al., 2013; Lhendup et al., 2010; Mensah and Adu, 2015; Mensah et al., 2016).

The caste dummy is negative and significant for the use of kerosene in all three rounds, while it is negative and significant for the adoption of electricity and LPG only in the 63rd round (2006–07) and 68th round (2011–12). Interestingly the coefficient of the interaction of the caste dummy with the monthly per capita expenditure dummy is positive for the use of clean energy, indicating that backward or schedule caste and relatively economically affluent households are more likely to use electricity and LPG for household purposes. To control for the regional effect, we used the regional dummy and found that compared to western India, households in North-East India, Central India, East India, South India, and north India were less inclined to consume electricity and LPG.

The suitability of the application of the Multivariate Probit estimation procedure is presented in Table 3. The correlation of coefficients of the error terms of three fuel functions specifies the robust and inclusive association among three broad categories of fuel that are used by the sampled households. This inclusiveness behavior of fuel use patterns allows the application of the Multivariate Probit model in elucidating the choice of fuels by urban families.

4.5.2. Examining intensity of use and reliance on particular fuels: seemingly unrelated regression (SUR) estimation

Table 4 highlights the SUR estimation procedure's result, which explains the factors influencing the dependency on three broad categories of fuel over the sampled years. The education of the head and spouse, and the economic status of the family progressively, positively, and significantly affect the share of expenditure on electricity and LPG (Table 4). The coefficient for families in quartiles Q2, Q3, and Q4 in the year 1991–92, 2006–07 and 2011–12 are positive and progressively increasing for electricity and LPG consumption while it is negative and progressively decreasing for the share of consumption expenditure on coal and kerosene (Table 4). This demonstrates that well-to-do families were less dependent on biomass and kerosene oil for fuel for domestic purposes. Similar to our findings, other research has established a direct relationship between wealth and the consumption of clean fuel (Baiyegunhi and Hassan, 2014; Cayla et al., 2011; Huang, 2015; Khandker et al., 2012; Kwakwa et al., 2013; Lhendup et al., 2010; Mensah et al., 2016).

Our findings also present some regional heterogeneity in the dependence on a specific source of energy among urban households. Compared to West Indian states, households from Northeast India, Central India, East India, and North India tended to rely more on biomass and kerosene and coal, and less on gas and electricity.

5. Conclusion and policy implications

The importance of clean energy for cooking and lighting cannot be over-emphasized, given the adverse effects of the use of dirty fuels like biomass, kerosene, and coal on human health and the environment. With rapid urbanization, households in urban India, in general, have had greater access to clean fuels and have been able to afford it. However, a significant number of urban households use and rely on dirty such as firewood and kerosene for domestic purpose. This study confirmed that almost large number of the urban households in India are still using solid fuels (biomass, dung cake, and firewood) and kerosene for cooking. Although biomass and firewood are renewable source of fuel, over-extraction of biomass and firewood can lead to deforestation and environmental degradation and thus can generate significant negative impacts on sustainable development.

Our econometric analysis found that the education of the head of the family and their spouse and the economic status of families, considerably governs a household's decision on the choice of fuel and extent of dependency on it. Based on the findings, this research recommends increasing investment to enhance human capital, mainly in women, which can augment the income of female members of urban households. This will increase the opportunity cost of using biomass and firewood by female family members, and thus will force households to use fuels other than biomass and firewood. In addition, lucrative income from the employment can also influence switching from dirty to clean fuels. Changes in family fuel consumption behaviors from environmentally unfriendly fuels to less harmful ones in developing nations will help improve health, the environment, and achieving sustainable development goals.

In addition, as significant number of urban families of India depend on firewood for cooking, designing, and scaling up improved cooking stoves in India on a priority basis could lessen pollution inside the house considerably. To encourage the use of LPG, subsidizations should be made available, but it is important to take into account the moral hazard problem and improper targeting while implementing such programs. The government of India should also harness and scale out renewable energy facilities in urban areas to expand the provision of clean energy.

To enhance electricity production and distribution capacities, particularly in the urban areas, India should co-finance the development of hydropower projects in Nepal and Bhutan, which are lying dormant in the Himalayas. In addition, India, Bangladesh, Nepal, and Bhutan should build South Asian regional grid lines and pipelines to trade electricity and LPG, which could enhance regional cooperation and go long way in reduring global GHG emission.

Disclaimer

The findings, interpretations, and conclusions expressed in this event are authors own and do not necessarily reflect the views of institutions of the authors.

Declaration of Competing Interest

We (Khondoker Abdul Mottaleb and Dil Bahadur Rahut) would like to confirm that we do not have any conflict of interest.

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