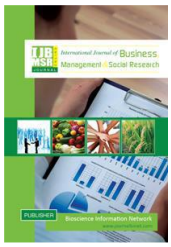
Published with Open Access at Journal BiNET
Vol. 11, Issue 02: 602-608
International
Journal of Business, Management and Social Research
Journal Home: www.journalbinet.com/ijbmsr-journal.html



Determinants of energy consumption in rural households of India

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Article Received: 04.02.2022; Revised: 29.03.2022 and Published online: 15 April, 2022.

ABSTRACT

The relation between rural household characteristics and household energy consumption demand and expenditures indicates a signal for continuous production and supply of energy to enhance rural development. This study was aimed to identify the determinants of energy consumption in rural households of India. A total of 7416 observations was used from the Indian household survey data 2018. In this study, Ordinary Least Square (OLS) method was used to attain the objectives. Findings of the study evident that the household principal decision maker, indebtedness of the household, household size and irrigation pump used by the household for cultivation purposes were the prime indicators that significantly affect the energy consumption expense of the rural household. Of the above-mentioned indicators, household principal decision maker, household size and irrigation pump used by the household positively affect the energy consumption expenditure, whereas indebtedness of the household had a negative effect. All those factors are essential to determine the energy consumption demand and ensure sustained energy production at the rural level to enhance rural development. This rural development, in turn, will contribute to alleviating poverty and brings up economic development of the country.

Key Words: *Energy policy, Household characteristics, Renewable energy and Rural development.*

Cite Article: Rasha, R. K., Kazal, M. M. H., Mondal, R. K. and Sujan, M. H. K. (2022). Determinants of energy consumption in rural households of India. International Journal of Business, Management and Social Research, 11(02), 602-608. **Crossref:** https://doi.org/10.18801/ijbmsr.110222.64

I. Introduction

Energy acts as the key element for alleviating poverty, fostering the wheels of economic development and accelerating the social and human life of urban and rural people (Miah et al., 2010). Besides, energy demand speeds up economic growth and positively related to each other (Pokharel, 2007; Perkins et al., 2019; Mao et al., 2020). However, with the increment of energy consumption expenditure, its demand has been growing faster as the digitalization of society brings up more dependence on the use of different electronic appliances all over the world. India is not an exception in this regard. Even energy

consumption and its demand in India is the highest among the South-Asian countries (Ekholm et al., 2010). This demand pours a signal to the government for producing and supplying an adequate amount of energy to control its market price (Nassen, 2014). This stabilising mechanism helps balance demand and supply of energy at the rural and urban levels. However, the energy consumption pattern of the household is different from rural to urban, region to region and even from country to country (Tso and Guan, 2014; Ahmad and Oliveira, 2015; Mao et al., 2020). For instance, rural households of Nepal, Bangladesh, Myanmar, and most of India consume over 70% of energy compared to their national level (Miah et al., 2010). Nevertheless, the government of India has been granting subsidies for fuel consumption in rural households (Ekholm et al., 2010; Rahut et al., 2017b; Ravindra et al., 2019). They are emphasising the use of most effective clean energy, including solar, rechargeable batteries, solar lanterns, etc. (Ekholm et al., 2010; Rahut et al., 2017b). It proves that rural household energy consumption pattern has a great implication for the public policy designed by the government of India.

Existing literature evident that, historically, there exist some significant relationship between household socio-economic characteristics and energy consumption pattern (Lenzen et al., 2006; Pokharel, 2007; Ekholm et al., 2010; Miah et al., 2010; Johnson and Bryden, 2012; Rahut et al., 2017b; Satish and Nagesha, 2018; Zou and Luo, 2019; Mao et al., 2020). Among those characteristics household income, location, having empowered women in household, household size, land ownership, primary decision-maker of the household, household indebtedness, use of different energy sources for electricity supply, water uplifting, cooking, and irrigation, etc. are mostly mentionable in rural households of India. Besides these, some personal traits of the household head like age, education, gender also had some effect on the household energy consumption, demand, and expenditures (Lenzen et al., 2006; Nassen, 2014; Zou and Luo, 2019).

Over time, many researchers attempted to explore different aspects of energy consumption in South-Asian countries. For instance, Pokharel (2007) investigated the energy consumption pattern in Nepal. Rahut et al. (2017a) endeavoured to identify the determinants of household energy consumption in Timor-Leste. Zou and Luo (2019) studied the household energy consumption pattern in China and explored household size, age, education, and health of the household head as the essential characteristics. Mao et al. (2020) explored the prime factors of energy consumption in China and found energy accessibility, costs, climatic conditions, household income and behavioral preferences as the main factors. However, most of these studies are confined to identifying the important factors of energy demand of urban and rural households. Besides, studies on identifying the factors affecting rural household energy consumption in India are rare (Zou and Luo, 2019; Mao et al., 2020). Although Ekholm et al. (2010) studied the determinants of household energy consumption all over India by using the data of the National Sample Survey Organization (NSSO) collected between 1999 and 2000, availability of newer data (Indian Household Survey, 2018) fosters the demand for a newer study on this regard. A rigorous study of existing literature reveals a serious dearth of recent literature that identified the factors affecting energy consumption pattern in rural households of India. To make a sound policy for ensuring continuous supply of energy at an affordable price and encouraging the adoption of renewable clean energy instead of traditional non-renewable, contemporary determinants of energy consumption should be explored. To contribute to this specific gap in the literature, the present study was taken to identify the determinants of energy consumption in rural households in India. Findings of the study will help the national as well as regional energy policymakers, energy suppliers, household energy consumers and other stakeholders to prepare and implement a sound and effective policy for the advancement of rural India. That policy will intervein to balance energy supply and consumption at the rural household level.

II. Materials and Methods

This study is primarily based on secondary cross-sectional data. The data has been taken from Indian Household Survey, 2018. The data is about rural household characteristics and energy consumption patterns in 2018 from different states of India. The data was collected in March, April, and June of 2018. The data has been organized, scrutinized and managed properly using the statistical software STATA and MS excel. After that, the required variables were identified for the study. Statistical Software Gretl was used to analyses the data. Both descriptive and statistical analysis was done to attain the objective of the study. The total number of observations used in this study was 7416.

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Several factors affect the choice of the rural household energy consumption pattern consisting of different energy supplying sources, including grid electricity connection, solar use, rechargeable battery, diesel generator use and solar lanterns. The total expenditure of energy consumption (Rupees/year) was calculated by adding the initial cost (Rupees) of adoption and yearly consumption cost (Rupees/year) of energy from different sources. The following list (Table 01) provides a clear definition and description of all the variables used in this study to fulfil the research gap.

Table 01. Definition and description of all the variables

Variables	Description
Dependent variable	
Energy consumption expenditure (log)	Natural log of the total energy consumption expenditure from a grid connection, solar, rechargeable battery, diesel generator and solar lantern (Rupees/Year).
Explanatory variables	
Income (log)	Natural log of the household's annual income (Rupees/Year).
Decision-maker	If the household head is principal decision-maker = 1, otherwise = 0.
Gender of the household head	If the gender of the household head is male = 1, otherwise = 0.
Marital status of the household head	If the household head is married = 1, otherwise = 0.
Empowered women of the household	If the household have empowered/working female = 1, otherwise = 0.
Indebtedness of the household	If the household is indebted = 1, otherwise = 0.
Household size	Size of the household in number
Use of Electric pump	If the respondents use electric pump for household use other than irrigation purposes =1, otherwise = 0.
Use of irrigation pump	If the household use irrigation pump for irrigation = 1, otherwise = 0.

Functional Analysis

Ordinary Least Squares (OLS) method was used to identify the impact of important variables on the household energy consumption expenditure in rural India. A multiple regression model was constructed to estimate the relationship between household energy consumption expenditure and household characteristics. Under the general assumption, the household total energy consumption expenditure function can be specified on several factors (Wooldridge, 2013).

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \beta_9 X_9 + u \quad (1)$$

Where, u is the error term. β_0 is the intercept and β_1, β_2, β_3…….. β_9 are the slope coefficient.

The model specification using variables used for the study can be written as follows:

$$\ln\_Energy\ expense = \beta_0 + \beta_1 \ln\_income + \beta_2\ decision\ maker + \beta_3 gender + \beta_4 marital\ status + \beta_5\ empowered\ women + \beta_6\ household\ indebtedness + \beta_7\ household\ size + \beta_8\ electric\ pump\ use + \beta_9\ irrigation\ pump\ use + u \quad (2)$$

Table 02. Sample summary statistics of all the variables (N=7416)

Variables	Mean	Standard deviation	Maximum	Minimum
Energy consumption expenditure (Rupee/year)	4838.13	5509.40	122000	20
Annual income (Rupee/year)	108789	265242	1350000	1500
Principal decision-maker	0.67	0.47	1.00	0.00
Gender of the household head	0.33	0.47	1.00	0.00
Marital status of the household head	0.92	0.27	1.00	0.00
Empowered women of the household	0.12	0.33	1.00	0.00
Indebtedness of the household	0.34	0.47	1.00	0.00
Household size	6.64	3.46	14.00	1.00
Use of electric pump	0.09	0.29	1.00	0.00
Use of irrigation pump	0.35	0.48	1.00	0.00

Source: Indian household survey data, 2018

Test of collinearity

There is always a relation between the independent variables. This relation may be positive or negative. To identify the degree of collinearity between the explanatory variables test of collinearity has been done using Gretl (Wooldridge, 2013). The errors should be normally distributed and homoskedastic in multiple regression analysis. Breusch-Pagan test for heteroskedasticity was done to identify the problem of heteroskedasticity for the distribution of error variance (Wooldridge, 2013). To identify the omitted variable biases Ramsey's Reset tests were done. The normality test of the residuals was done to check whether the errors were normally distributed or not. The result of the correlation matrix showed that none of the independent variables were strongly correlated to each other (Appendix A1). In addition, the value of the variance inflation factor (VIF) of all the explanatory variables were ranged from 1.02 to 1.34 (Table 03). Hence, multicollinearity is not an issue for this analysis (Alam et al., 2018; Rasha, et al., 2019).

The value of the test statistic (LM = 22.922, p-value 0.006) of the Breusch-Pagan test confirmed that heteroskedasticity was present in the model. Hence, robust standard errors are used in this study to remove the problem of heteroskedasticity. Since the value of the test statistic (F = 1.712) was insignificant (p-value = 0.181), the result of Ramsey's Reset test proved that there was no omitted variable bias in the model.

Table 03. Result of the variance inflation factor (VIF)

Variables	VIF values
Average annual income	1.03
Principal decision maker	1.34
Gender of the household head	1.30
Marital status of the household head	1.10
Empowered women of the household	1.02
Indebtedness of the household	1.02
Household Size	1.05
Use of Electric pump	1.23
Use of Irrigation pump	1.29

Source: Indian household survey data, 2018

III. Results and Discussion

The summary statistics of all the variables, including explanatory and explained variables, are shown in Table 02. Findings presented in Table 02 showed that the household average annual energy consumption expenditure was 4838.13 Rupees, and the average annual income was 108789 Rupees. Besides, 67% of the household head was the principal decision maker who had taken all major household decisions related to the consumption of energy expense in India. Moreover, 33% of the household head was male and 92% of the household head was married. Additionally, 12% of the women in the household were empowered and working outside to meet the household necessities (Table 02). Table 02 also reveals that 34% of households were indebted in rural India, significantly affecting household energy consumption expenses (Table 04). Furthermore, the average size of the rural household was 6.64, which was larger than the household size found by Gupta and Pelli (2021). Moreover, 9% and 35% of households use the electric pump for household use and irrigation pump for cultivating land purposes, respectively (Table 02). Thus, all the socio-economic variables related to the household energy consumption expense in rural India.

Table 04 represents all the estimated values of the coefficient and related statistics on rural household energy consumption in India. Result of the study reveals that several factors determine the energy consumption expenditure of rural households in India (Table 04). The critical determinants were the size of the household, indebtedness of the household, use of irrigation pumps for the irrigation of cultivable land and principal decision making by the household head (Table 04). The household size and use of irrigation pumps had a positive significant effect on the household energy consumption expenditure from different sources, including grid electricity connection, solar electricity, use of the rechargeable battery, diesel generator electricity and solar lantern (Table 04). Besides, the indebted

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household had comparatively lower energy consumption expenses from different sources than the household those are not indebted. Thus, this indebtedness of the household had a negative significant effect on the energy consumption expense of the rural household in India (Table 04). Furthermore, if the household head is the principal decision-maker, he had a significant positive effect on the energy consumption expenditure (Table 04). Thus, the household characteristics had a significant effect on the energy consumption expenditure in India.

Table 04. Estimated values of the coefficient and related statistics of rural household energy consumption

Explanatory variables	Coefficient	Standard error	t-ratio	p-value
Constant	7.640***	0.19	39.900	0.000
Average annual income	0.004	0.02	0.255	0.790
Principal decision-maker	0.070**	0.03	2.281	0.020
Gender of the household head	0.010	0.03	0.408	0.680
Marital status of the household head	−0.020	0.04	−0.502	0.620
Empowered women of the household	−0.040	0.04	−1.060	0.290
Household indebtedness	−0.060**	0.03	−2.550	0.011
Household Size	0.040***	0.00	12.850	0.000
Use of electric pump	0.006	0.05	0.133	0.890
Use of irrigation pump	0.080***	0.03	2.945	0.003
Mean dependent var.	8.010	S.D. dependent var.		1.030
Sum squared	7653.380	S.E. of regression		1.020
R-squared	0.030	Adjusted R-squared		0.030
F (11, 494)	23.860	P-value (F)		0.001
Log-likelihood	−10639.680	Akaike criterion		21299.350
Schwarz criterion	21368.470	Hannan-Quinn		21323.100

Source: Indian household survey data, 2018

It can be seen from Table 04 that the household principal decision-maker had a positive and significant association with the household energy consumption expenditure. The value of the estimated coefficient of household principal decision-makers was positive (0.07) and significant at 5% level of significance (p-value <0.02). Thus, if the household head was the principal decision-maker, that household had 7% higher energy consumption expense than the other household. This result is consistent with Ekholm et al., 2010; Miah et al., 2010. Besides, it was found from Table 04 that the indebted household had a negative and significant relationship with the household energy consumption expense. The value of the estimated coefficient of the indebted household was negative (−0.06) and significant at 5% level of significance (p-value <0.05). Thus, the energy consumption expenditure of the indebted household was 5% lower than the household those were not indebted (Table 04). Any researcher did not previously take this variable. It adds a new dimension to the research in this regard. It seems to be that the indebtedness of the household had a significant effect on household energy consumption expenses in India.

It was evident from Table 04 that household size had a positive and significant association with household energy consumption expenditure. The value of the estimated coefficient of the household size was (0.04) positive and significant at a 1% level of significance (p-value <0.01) implies that if one person increased the number of households size, then the energy consumption expenditure would be increased by 4% which was similar with the findings of Rahut et al. (2017b) and opposite with the results of Gupta and Pelli (2021) and Zou and Lou (2019). From Table 04, it can also be said that the use of irrigation pump by the household had a positive and significant relationship with the household energy consumption expenditure. The value of the estimated coefficient of the irrigation pump used by the household was positive (0.08) and significant at 1% level of significance (p-value <0.01), which implies that the energy consumption expenditure of the irrigation pump user's household was 8% higher compared to the other household. This finding is consistent with Satish and Nagesha (2018) results.

On the other hand, household income, gender, and marital status of the household head empowered women in the household and use of electric pumps by the household had no significant effect on the household energy consumption expenditure (Table 04). Some other researchers found that the household income significantly affected the energy consumption pattern of the rural household

(Ekholm et al., 2010; Miah et al., 2010). Some earlier researchers consider energy consumption expenditure from five different electricity supply sources. Thus, it seems to be that this study was specially added a new dimension for demonstrating the relationship between household socio-economic characteristics and energy consumption patterns in India.

The coefficient of multiple determination (R^2) indicates the goodness of fit of the regression model (Rasha et al., 2019). Since the value of the estimated R-square was 0.03 (Table 04), it implies that about 3% of the variations in the total energy consumption expenditure can be explained by all the explanatory variables included in the model. Moreover, adjusted R^2 means adjusted for the number of degrees of freedom (Rasha et al., 2018). The value of the adjusted R^2 was 0.03 (Table 04), which also indicates that about 3% of the total variations of energy consumption expense by rural households can be explained by all the independent variables included in the model.

IV. Conclusion

Rural household characteristics greatly impacted the rural household energy consumption expenditures in India. Household size was one of the most important determinants of energy consumption expense. Moreover, the household head also played an essential role in the energy consumption decision. Agricultural production is dependent on irrigation. Many households were using irrigation pumps for irrigating their cultivable land. The households using irrigation pumps had comparatively higher energy expenses than the others. Thus, the government should ensure continuous production and supply of electricity for rural households in India. It will increase agricultural production in rural areas and meet the energy demand at lower cost. It will also speed up the energy consumption by the rural households, generating a signal for enhancing the supply of energy from different sources to foster rural development. Nonetheless, this rural development will improve their socio-economic condition by alleviating poverty and running the wheels of economic development in India.

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Appendix A1. Correlation matrix of all the explanatory variables

Variables	Income	Decision maker	Gender	Marital status	Empowered women	Indebtedness Household	Household size	Electric pump	Irrigation pump
Household's annual income	1.00	-0.02	-0.03	-0.01	-0.02	0.00	0.02	0.05	0.03
Principal decision maker		1.00	-0.41	0.23	-0.02	-0.05	-0.00	0.03	0.01
Gender of the household head			1.00	0.09	0.11	0.00	-0.02	-0.00	-0.04
Marital status of the household head				1.00	0.02	0.00	-0.01	0.02	0.03
Empowered women of the household					1.00	0.09	0.01	-0.01	0.00
Indebtedness of the household						1.00	0.04	0.01	0.06
Household size							1.00	0.07	0.21
Use of electric pump								1.00	0.43
Use of irrigation pump									1.00

Source: Indian household survey data, 2018