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ANALYSIS OF RESIDENTIAL ELECTRICITY DEMAND FOR DEMAND SIDE MANAGEMENT IN RAJASTHAN

Oum Kumari R* and Suhasini Verma**

Abstract: *Global economies now a days largely rely on energy for economic development, as energy is considered to be an indispensable force for driving all the economic activities. Electricity, among all the sources of energy plays a vital role in the progress of Nation. Increasing demand for electricity has created drastic problem of power deficit and has also resulted in severe budget deficit also in the state of Rajasthan. An attempt has been made in the present paper to calculate elasticity of power in short and long run using econometric tools in order to make some policy changes to overcome the problem of power deficit by curbing excess demand for power in residential sector.*

Keywords: *Economic development, power deficit, elasticity of power.*

1. INTRODUCTION

For a long time energy was not considered as a factor of production in the process of production but modern economist have included energy as a important factor of production. Electricity, among all the energy sources plays a vital role in the life of human beings and therefore electricity forms a greater share of energy consumption as countries grow. The econometric literature related to residential demand for electricity has mainly focused on identifying the relationship between the demand for electricity and changes in short and the long-run income and prices (*cf.* Silk and Joutz, 1997; Filippini, 1998; Halvorsen and Larsen, 2001; Reiss and White, 2005).

Most of these studies are related to developed countries, while studies relating to developing countries are limited. Regionally, the research on residential electricity demand has been extremely limited. In this research article the short-run dynamics and long-run equilibrium relationship between residential electricity demand and its determining factors in the state of Rajasthan have been attempted.

* Assistant Professor, Manipal University Jaipur.
E-mail: bhawani_1978@yahoo.com, oum.kumari@jaipur.manipal.edu

** Assistant Professor, TAPMI School of Business, Manipal University Jaipur.
E-mail: verma.suhasini@gmail.com, suhasini.verma@jaipur.manipal.edu

The present research deals with the theoretical specification of residential electricity demand model in section 1.1 in which residents of Rajasthan are allowed to be sensitive to their income, price of electricity, and prices of substitute energy products. Development of empirical version of residential electricity demand model is considered in section1.2, while the estimation and its interpretation have been presented in section 1.3. The summary and conclusions are reported in the last section.

1.1 Theoretical specification of residential electricity demand

In modeling the electricity demand function, concentration has centered around the economic factors like electricity prices, prices of substitute energy products (e.g. price of kerosene oil, price of diesel, price of liquefied petroleum gas etc.), real income; while demographic factors like population, urbanization and environmental factors like climatic condition are often included as additional explanatory variables.

The residential electricity demand can thus be expressed in mathematical terms as follows:

ELDP = *f*(RINRESP, RPEL, PSEP, RPOP, ELAPP, TEM)

Where ELDP = per capita residential electricity demand

RINRESP = per capita real income of the residential sector

RPEL = residential electricity prices

PSEP = prices of substitute energy products

RPOP = residential population

ELAPP = stock of electricity appliances

TEM = average temperature of the area

The above model can be rewritten in a linear form by transforming variables into natural log, expressed with prefix "LN" as:

$$\text{LNELDPt} = \alpha 0 + \alpha 1\ \text{LNRINRESPt} + \alpha 2\ \text{LNRPELt} + \alpha 3\ \text{LNPSEPt} + \alpha 4\ \text{LNRPOPt} + \alpha 5\ \text{LNELAPPt} + \alpha 6\ \text{LNTEMt} + \text{Ut} \quad \ldots(1.1)$$

Where

$\alpha 1$ to $\alpha 6$ represents the slope coefficients

$\alpha 0$ is the intercept

Ut is the stochastic term or the error term at time *t*

t is attached to each variable as subscript denoting time series (value of concerning variable at time *t*)

1.2 Development of Empirical Model of Residential Electricity Demand

The empirical version of the theoretical model can be specified on the measured variables that are available in the data set. Data for the period 2000-2013 was collected from the various secondary sources as given below. The period chosen for analysis was post unbundling of Rajasthan State Electricity Board (RSEB).

In this research study the demand for electricity is represented by per capita consumption of electricity by the residential population or households also termed as domestic consumers. The data on residential income is not available so per capita income based on 2004-2005 (new series) of Rajasthan is taken as a proxy variable. The corresponding population figure (total population of Rajasthan) is also used as the proxy variable for the residential population.

The sensitivity of electricity demand to alternative fuel prices is also allowed in the model specified in this study. Although alternative fuel (energy products) is considered as substitutes but it will not be wrong if these are also used as complements of electricity for generation of electricity.

The time series data related to stock of household electricity appliances are not available so discarded from this empirical model. The variable temperature is not being considered in this study because temperature is a seasonal phenomenon with regard to electricity consumption that could only be captured in monthly or quarterly data. The macro level analysis has utilized the annual data, so it is out of scope of the present study.

The macro data analysis has been done using computer software Gretl and E views. The Table 1.1 specifies the variables and their acronyms used in the study.

Table 1.1
Variables and their source

Variable	*Acronym*	*Units*	*Data Source*
Per capita residential electricity consumption	LNPKTEL	KWh (units)	Distribution companies
Per capita income (at 2004-2005 prices)	LNPCY	Rs.	Directorate of Economics and Statistics
Average domestic price of electricity	LNDF_PEL	Rs. per KWh	Distribution companies
Price of kerosene	LNDF_PKRO	Rs per litre	Collectorate, Jaipur
Price of LPG	LNDF_PLPG	Rs per kg	Oil companies
Price of fire wood	LNDF_PFVUD	Rs per kg	Forest department
Total Population	LNTPOP	In lakh	Directorate of Economics and Statistics

Prefix LN represent natural log and DF represent deflated by CPI for agricultural laborers.

1.2.1 Empirical model

Theoretical model as contained in equation (1.1) can be transformed into the empirical form as follows:

$$LNPKTELt = \alpha 0 + \alpha 1\ LNPCYt + \alpha 2\ LNDF\_PELt + \alpha 3\ LNDF\_PKROt + \alpha 4\ LNDF\_PLPGt + \alpha 5\ LNDF\_PFVUDt + \alpha 6\ LNTPOPt + Ut \quad ...(1.2)$$

where

$\alpha 1$ to $\alpha 6$ represents the slope coefficients

$\alpha 0$ is the intercept

Ut is the stochastic term or the error term at time *t*

t is attached to each variable as subscript denoting time series(value of concerning variable at time *t*)

1.2.2. Estimation of Empirical Model of Residential Electricity Demand

1.2.2.1. Descriptive statistics of the data set

The descriptive statistics of the data set for raw, deflated and transformed in natural log form used for this research are reported in the Tables 1.2, 1.3 and 1.4 respectively.

Table 1.2
Data (Raw) Summary Statistics

Variable	*Mean*	*Min*	*Max*	*Std. Dev.*	*CV*	*Skewness*	*Kurtosis*	*Shapiro-W. Test*
PKTEL	759.40	712.11	932.14	91.140	0.12002	0.87389	–0.696	0.8387P = 0.027
PCY	20867	15011	27421	3957.5	0.18965	0.19651	–1.021	0.969P = 0.89
PEL	3.2610	2.4000	3.6970	0.48122	0.14757	–0.7077	–0.924	0.830P = 0.02
PKRO	10.750	10.000	15.250	1.7806	0.16564	1.9159	1.8762	0.487P = 0.00
PLPG	20.365	16.000	27.550	3.8778	0.19041	0.50431	–0.974	0.921P = 0.295
PFVUD	4.6250	1.50	10.00	2.8073	0.60697	0.59792	–0.906	0.913P = 0.237
TPOP	627.10	551.62	706.86	50.959	0.08126	0.06728	–1.219	0.966P = 0.862

Table 1.3
Data (Deflated) Summary Statistics

Variable	*Mean*	*Min*	*Max*	*Std. Dev.*	*CV*	*Skewness*	*Kurtosis*	*ShapiroW. Test*
PKTEL	759.40	712.11	932.14	91.140	0.12002	0.87389	–0.696	0.8387P = 0.027
PCY	20867	15011	27421	3957.5	0.18965	0.19651	–1.021	0.969P = 0.89
DF_PEL	0.0079	0.0048	0.01031	0.00165	0.20764	–0.6036	–0.668	0.937P = 0.47
DF_PKRO	0.0262	0.0175	0.0329	0.005103	0.19474	–0.2556	–1.237	0.946P = 0.575
DF_PLPG	0.0488	0.0378	0.0545	0.00575	0.11777	–0.8530	–0.889	0.806P = 0.011
DF_PFVUD	0.00991	0.0049	0.0137	0.00328	0.33061	–0.2762	–1.481	0.896P = 0.141
TOTPOP	627.10	551.62	706.86	50.959	0.08126	0.06728	–1.219	0.966P = 0.862

DF_P: Price data are deflated by CPI of Agricultural Labourers

Table 1.4
Data (in Natural log) Summary Statistics

Variables	*Mean*	*Std. Dev.*	*Min*	*Max*
LNPKTEL	6.6263	0.11516	6.5101	6.8375
LNPCY	9.9293	0.19111	9.6165	10.219
LNDF_PEL	–4.854	0.22947	–5.3375	–4.575
LNDF_PKRO	–3.660	0.20469	–4.0483	–3.414
LNDF_PLPG	–3.027	–3.0270	–3.2743	–2.909
LNDF_PFVUD	–4.673	0.36952	0.36952	–4.288
LNTPOP	6.4381	0.081388	6.3129	6.561

The stationarity and the order of integration in the chosen series have been tested by adopting the ADF, ADF-GLS and KPSS unit root tests. The results for unit root tests as shown in Table 3.5 indicate that all the variables are not integrated at the same order and depict the different orders, either I(0) or I(1). When the variables are of different orders of integration, the cointegration techniques such as Engle and Granger, (1987); Johansen, (1988); Johansen and Juselius, (1990) become inapplicable, only the technique that is suitable is the ARDL or bounds testing approach proposed by Pesaran *et al.* (2001).

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Table 1.5
Unit Root Test Statistics

	ADF Test		*ADF-GLS Test*		*KPSS Test*		
Variable	*Levels*	*First difference*	*Levels*	*First difference*	*Levels*	*First difference*	*Order of Integration*
LNPKTEL	–1.8173	–3.56557**	–1.96729	–4.0853***	0.46807*	0.420	I(1)
LNPCY	–15.78***	–14.451***	–6.9468***	–9.4293***	0.504915**	0.17549	I(0), I(1)
LNDF_PEL	–0.49906	–4.08875**	–1.06584	–4.5535***	0.148508*	0.12031	I(1)
LNDF_PKRO	–2.23103	–4.5202***	–2.52831	–3.7627***	0.45864*	0.127115	I(1)
LNDF_PLPG	–1.29916	–3.17704**	–1.66233	–4.2232***	0.399987*	0.122571	I(1)
LNDF_PFVUD	–2.2171	–5.1095***	–1.91065	–5.7527***	0.144735*	0.116819	I(1)
LNTPOP	–7.97***	–4.3094***	–3.70506**	–4.47451**	0.150409**	0.124058	I(0), I (1)

*= 10%, **= 5%, ***= 1% level of significance

The results of unit root tests (Table 1.5) indicate that the variables are integrated I(0) and I(1). For this reason ARDL approach is applied for the cointegration of the model.

Due to insufficient observations the short-run ARDL model could not be estimated and therefore finite distributed lags model (re-estimated on differenced data) as

Table 1.6
Finite distributed lags model (re-estimated on differenced data)
Dependent Variable: Per Capita Residential Electricity Consumption D(LNPKTEL)

Method: Least Squares				
Variable	*Coefficient*	*Std. Error*	*t-Statistic*	*Prob.*
D(LNPCY)	0.279762	0.023500	11.90485	0.0003
D(LNDF_PEL)	–0.142155	0.038795	–3.664281	0.0215
D(LNDF_PKRO)	0.349381	0.032960	10.60014	0.0004
D(LNDF_PLPG)	0.406360	0.029923	13.57997	0.0002
D(LNDF_PFVUD)	0.121944	0.027880	4.373851	0.0119
D(LNTPOP(-1))	1.225140	0.170923	7.167789	0.0020
R-squared	0.989602	Mean dependent var		0.032734
Adjusted R-squared	0.976604	S.D. dependent var		0.030409
S.E. of regression	0.004651	Akaike info criterion		–7.619632
Sum squared resid	8.65E-05	Schwarz criterion		–7.438081
Log likelihood	44.09816	Hannan-Quinn criter.		–7.818793
Durbin-Watson stat	1.355684			

Table 1.7
Long run ARDL model
Dependent Variable: Per Capita Residential Electricity Consumption (LNPKTEL)

Variable	*Coefficient*	*Std. Error*	*t-Statistic*	*Prob.*
C	–25.48620	0.182291	–139.8107	0.0046
LNPKTEL(-1)	–6.801802	0.044097	–154.2464	0.0041
LNPCY(-1)	2.304784	0.011484	200.6970	0.0032
LNDF_PEL(-1)	-0.508417	0.005713	-88.99311	0.0072
LNDF_PKRO(-1)	2.195067	0.014591	150.4389	0.0042
LNDF_PLPG(-1)	2.779225	0.017861	155.6017	0.0041
LNDF_PFVUD(-1)	0.715568	0.005591	127.9778	0.0050
LNTPOP(-1)	46.94792	0.315268	148.9143	0.0043
LNTPOP(-2)	56.11128	0.281234	199.5179	0.0032
R-squared	1.000000	*Mean dependent var*	6.646438	
Adjusted *R*-squared	0.999999	S.D. dependent var		0.115962
S.E. of regression	0.000110	Akaike info criterion		–15.89638
Sum squared resid	1.21E-08	Schwarz criterion		–15.62405
Log likelihood	88.48191	Hannan-Quinn criter.		–16.19512
F-statistic	1252264.	Durbin-Watson stat		2.058276
Prob(F-statistic)	0.000691			

reported in Table 1.6 is assumed as short-run model and Table 1.7 long run ARDL model and taken for comparison.

In the macro analysis of residential electricity consumption in the state of Rajasthan during the period 2000 to 2011-12, it has been seen that all the observed variables have influenced the electricity consumption pattern in the residential/domestic sector. The coefficients showing estimated elasticity of demand with respect to price, income and related goods in the short and long run are given in the Table 3.26.

Table 1.8
Estimated Elasticities of Residential Electricity Demand inRajasthan.

Elasticity of electricity demand	*Short run*	*Long run*
Price elasticity	–0.1421	–0.5084
Income elasticity	0.2797	2.3047
Cross elasticity	0.3493(k)	2.195(k)*
	*0.406(lpg)	2.77(lpg)*
	*0.121(fw) *	0.7155(fw)*

*k-Kerosene, lpg-LPG, fw-Fuel wood
Source: calculated

The results show that the variable LNDF_PEL (price of electricity) show a negative impact on electricity consumption. It is also clear from the results of short and long run analysis that price elasticity is < 1 for both short and long period which means a rise in electricity price would not effectively curb residential demand for electricity.

It is seen that per capita income has a significant positive impact on electricity demand. Income elasticity of demand for electricity is less than one in the short run which means that electricity is a necessity and therefore a change in the income of the residents would not cause large changes in the consumption of electricity in the short run as the residents are tied to particular stock of electrical appliances. However, in the long run income elasticity is > 1 which shows electricity becomes a luxury in long run as the income of the people increase, they prefer to lead a more convenient and comfortable life, which increase the stock of residential electrical appliances resulting in greater demand for electricity in the long run.

Cross elasticity values for all the three related goods are positive and <1 in the short run representing their substitutability with electricity. Though, in the long run the coefficients of cross elasticity in the case of LPG and kerosene are greater than one. Therefore, it is clear that any change in the prices of these related goodsviz, kerosene, LPG and fuelwood in the upward direction would increase the residential demand for electricity at the macro level in the State. The findings also show that the population growth of the State has positively affected the demand for electricity.

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