ESTIMATING PRICE ELASTICITY OF ELECTRICITY FOR THE MAJOR CONSUMER CATEGORIES OF GUJARAT STATE

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Abstract: Price Elasticity estimates of various consumers of electricity have been presented considering the aggregate price of electricity faced by Distribution companies of Gujarat state. The results highlight the need of category specific rational and optimum pricing policy for the load profile management activities in the backdrop of Demand Side Management.

Key Words: Consumer category, Discom, Electricity, Price Elasticity

1. Introduction

The Price Elasticity (PE) concept has been integrated with electricity market operation (wholesale and retail), ancillary service, consumer demand and benefit function, demand profile improvisation, reliability study and generation scheduling [1-6]. Majority of the studies which have estimated price elasticity of electricity consumption are from the field of economics, energy and public policy [7-14]. Such estimations of demand elasticity are based on cross sectional data, time series data, panel data and time divisional market data. Except few like [5] who developed formula to estimate self and cross elasticity and [15] who referred annual report of Power Smart Pricing (PSP) [16], most of the studies dealing with load / demand profile modification have either "set / assumed" the Price Elasticity or "modified" the referred values. Reliability of such modifications / assumptions is limited to the simulations only as the factual estimation becomes necessary when it comes to the policy improvisation e.g. to have correction in the electricity consumption pattern by modifying the existing tariff mechanism. This is because of the fact that the load profiles of various consumer categories in different demographic areas differ due to the economic growth, tariff structure and availability of substitutes.

The studies for estimating Price Elasticity of electricity consumption in Indian context could be listed by [7], [9], [10], [11], [17]. The study presented herein resembles with [7] in terms of consumer selection and with [11] in terms of the price selection methodology. The purpose of tariff improvisation is common to all the studies except [17] as it is based on energy projections and greenhouse gas abatement. Lagged values of variables have been considered in [11] to incorporate the bearing of lagged values on aggregate consumption of Punjab state. The justifiable reasons for not estimating the cross elasticity of substitutes also has been stated in [11]. The results presented in [7] are at national level for all the major consumer categories without considering the lagged effect as the estimates even with one year lagged effect were found insignificant. The seasonal PE estimates presented in [9] are at national level and [10] are at state level. Both the studies are based on the regional data provided by National Sample Survey Organization (NSSO). The studies carried out till date are based on the data which is almost a decade older. Over this period, the Indian power sector has undergone a considerable change as a result of transitional economy. In this background, revaluation / re-estimation of Price Elasticity is required. Under the subtitle "Steps for increasing penetration of Time of Day (ToD) tariffs in existing consumer categories", the Price Elasticity is highlighted as one of the key parameters for predicting load profile modification based on tariff structure [18]. This paper presents estimates of Price Elasticity of electricity consumption at aggregate level for five major consumer categories using Regulatory Information Management (RIM) reports published by Gujarat Electricity Regulatory Commission (GERC) for the five Distribution companies (Discom) of Gujarat state namely MGVCL, PGVCL, DGVCL, UGVCL and TORRENT POWER. This would facilitate in improving the existing tariff system and

promoting Demand Side Management (DSM) activities as rationalizing of tariff structure, reduction in subsidies, bringing the tariff in line with purchase cost, modifying the load curve / consumption pattern etc have been highlighted as the existing challenges in [19].

This paper defines the concept of Price Elasticity, explains the mathematical model used for PE estimation, highlights the need of such estimation at "Discom level" considering recent Indian power scenario, presents the estimated results and ends with concluding remarks.

2. Price Elasticity

Price Elasticity of demand is the measure of the responsiveness of the demand to its price. It is defined as percentage change in the demanded quantity with respect to the percentage change in its price [20]. Negative sign of PE indicates that consumption will reduce with the increase in the prices and positive sign indicates the reverse case. If the absolute value of elasticity is less than one, demand is said to be inelastic. The Price Elasticity is formulated as,

$$PE = (dY/Y)/(dX/X) = (dY/dX)\times(X/Y) \quad (1)$$

Where X is the price of the commodity, Y is the demand and d symbolizes change in the variable.

The PE matrix (PEM) referred by the studies dealing with generation scheduling, load profiling etc is of $n \times n$ size where n is the number of divisions of the daily load profile. Such divisions are based on either peak-off peak periods or time block wise division of load / demand profile. The primary diagonal elements of PEM are termed as "self elasticity" elements representing change in demand with respect to change in price at the given instance itself. The off-diagonal elements are termed as "cross (cross temporal) elasticity" of demand as they represent change in demand at the given instance with respect to change in price at the other time instance [21].

The self-elasticity of demand is represented with negative sign except for the Giffen goods and the cross elasticity is represented with positive sign. The concept of cross elasticity is little different in the case of electricity and it has been elaborated in [16] by considering "spill over" events. If an event is of a longer duration to fall into two different time blocks, decision to forgo the event in the first block due to the higher prices subsequently reduces consumption in the second block as well. This means that if the duration of an event is of more than an hour, the load reduction due to price increase in the i^{th} hour may reflect load reduction in the $i+1^{st}$ hour also. So it can be stated that there exists a possibility of the cross elasticity of electricity consumption turning to a negative value.

3. Mathematical model

The double log / constant elasticity model used to estimate demand elasticity for the econometric studies is represented by (2) [20], [22].

$$\ln Y = \alpha + \beta_1.\ln X_1 + \beta_2.\ln X_2 + \beta_3 \ln X_3 + ... + \varepsilon \quad (2)$$

Where, Y is the dependent variable, in this case it is electricity consumption; X_1, X_2, X_3…. are the independent variables say price of commodity (electricity herein), income, price of substitution commodity and the β values are the elasticity co-efficients namely price elasticity, income elasticity and cross elasticity of substitution. As only the PE estimation is of concern for the study herein, two variable model as shown in (3) is considered.

$$\ln Y = \alpha + \beta.\ln X + \varepsilon \quad (3)$$

Considering the general drooping relation between consumption and price, it has been proven by [22] that the β value in (3) represents the PE of consumption (electricity herein) as shown by (1). The physical significance of the intercept "α" and the error term "ε" are not explained herein as the purpose of this paper is estimation of PE using available data and no other in depth analysis.

4. Need of Price Elasticity estimation at Discom level-Indian case

Electricity cannot be stored in bulk like other commodities. Consumption of electricity is considerably different than the other daily necessities having an extensive scope of substitution like food, clothing and even transportation to some extent. As the electricity consumption pattern has undergone a change in India, the demand of fuels like kerosene, gas and firewood as a substitute for electricity has

significantly reduced. This fact has been very well explained in [11].

The consumption of elasticity with respect to GDP has been less than 1 consecutively for 8th, 9th and 10th national electricity plans [23]. It can be inferred that there will be a less proportional rise in electricity consumption with respect to GDP. As GDP is the indicator of income and the corresponding elasticity at an aggregate level is less than 1, it indicates that electricity has become a necessity of life.

The above stated facts indicate that the estimations of income elasticity as well as the cross elasticity of substitution due to other commodities would not give an insight into change in load profiles. Thus, only the Price Elasticity remains to be estimated prior to evolving a methodology for load profile modification.

PE estimation for electricity consumption can be done at national level, regional level, state level, distribution level and at the feeder / consumer category level based on the requirement and availability of data. Studies dealing with the modification of demand / load profile can be segregated into state specific, Discom specific and consumer category specific as consumption at these levels varies based on various local factors. If heterogeneous feeder is present, it can be considered as the representative of the consumer category which has loading share of more than 80% [18]. Discom participates in energy market based on daily fluctuations except for the high end consumers who avail open access. It can sell electricity at a higher rate and purchase at lower rate so as to earn profit. To earn more profit, it is required to have accurate load estimation with least fluctuations. To avoid chances of purchase at high price at peak periods, tariff modification is needed to flatten the load profile at peak periods. As stated above, such possibility can be examined based on the knowledge of the Price Elasticity of electricity demand.

It is observed that the fully functioning real time market for electricity trading is absent. Although there exists few intra-day transactions, they are irregular in nature [24-25]. The open access transactions are limited to the consumers having capacity above 1MW [26]. Moreover, the frequency linked Unscheduled Interchange (UI) mechanism is to be used as the grid balancing mechanism and not as the mechanism for real time electricity transactions [27]. The ToD mechanism is present but limited to water works and High Tension (HT) consumers i.e. 3.3 kV and above voltage levels [28]. Considering the above mentioned facts, estimation of PEM might only be possible for the consumers having ToD tariff. With the readily available data, estimation of constant, more precisely unique, PE for every consumer category is possible.

5. Data and discussion on the results of Price Elasticity estimation

To estimate the Price Elasticity of major consumer categories, data are obtained from the quarterly RIM reports published by GERC for the period from 2006-07 to the first two quarters of 2012-13 for all the Discoms of Gujarat state [29]. Railways being the exceptional case, it is exempted from the analysis. Initial seven quarterly data for the agricultural category may not be in line with the rest as it is indicated that the connections are metered from the fourth quarter of 2007-08. The data for commercial and industrial consumer categories are available at individual level up to second quarter of 2011-12 for MGVCL and DGVCL as these categories were regrouped and rearranged from the next quarter as per the tariff order of GERC. Rests of the Discoms have provided the consumption details keeping the same categories in their RIM reports. The data at aggregate level i.e. for Gujarat state are obtained by averaging the Discom details. At few places, due to unavailability of data, the gap is filled using the data of previous and next year.

Due to consideration of quarterly data, estimates may get affected by seasonality. To avoid the said effect, Price Elasticity has been estimated considering the yearly lagged values of consumption in quarterly fashion. The modified econometric model with the inclusion of lagged consumption is represented by (4).

$$\ln Y = \alpha + \beta_1 \ln X + \beta_2 \ln Y_{pqy} \quad (4)$$

The variable Y_{pqy} represents yearly lagged values of consumption in quarterly fashion.

Table 1 shows the category specific price extremes for the time period considered and Table 2 to 7 indicate the intended PE estimates and correlation between consumption and price for all distribution companies and the state.

The coefficient of correlation "r" represents the degree of association between aggregate price realized at Discom end and electricity consumption. For the purpose of explaining the estimates, the values of "r" are divided in three ranges as 0 to 0.3 for no association, 0.4 to 0.6 for moderate association and 0.7 to 1 for considerable / fair association between the said variables. Except the eight values falling into little and moderate association category, remaining values predict that the consumption of electricity is fairly associated with the prices realized. The degree of freedom has reduced due to consideration of lagged values. As the number of samples are less than 30, the confidence interval to have significant PE co-efficient is considered as 90% and the threshold of t-value is considered as 1.714 [30]. t-value is the precision with which the regression co-efficient is measured. From the t-statistics of total 30 estimates of PE, 18 fall within the threshold limit.

The prices considered herein are the aggregate level prices obtained from the revenue realization of Discom. The studies by [9], [10] were limited to household consumers and based on unit values payable by the consumers. Such values introduce (an upward) bias [31] in the estimates as there is difference between aggregate level data and individual consumer specific data. The reason for getting upward biased results can be explained by considering a simple example. Say consumer A has 10 units of consumption and pays Rs. 100. Consumer B consumes 15 units and pays Rs. 200. Considering the loss of 5 units, the Discom supplies 30 units and realizes Rs. 300. Considering constant slope of the demand curve i.e. (dY/dX), the ratio of price to demand i.e. (X/Y) is higher at the consumer side i.e. 300/25 than the ratio at the Discom end i.e. 300/30. In addition to that the data considered by [9] and [10] are based on NSSO recall while the data used for analysis herein, are directly obtained from RIM reports of Distribution company.

The reason mentioned by [9] for considering unit values payable (average price) was that the period under consideration had the single part tariff structure. The two part tariff is present in India since 1992-93. Furthermore, the estimates were presented at national level while the case presented herein is at Discom level. The majority of the data used by earlier studies were based on the NSSO survey conducted prior to the restructuring of State Electricity Boards (SEBs). For the presented study, the data considered herein are of 6 years in a quarterly fashion for all the major consumer categories after the restructuring of SEB of Gujarat state.

Results from table 2 to 6 indicate that except nine highlighted estimates i.e. one from MGVCL, two from PGVCL, one from DGVCL, three from Torrent power and two from the state of Gujarat, sign of remaining PE estimates is negative. Electricity being a necessity it may have flatter slope of demand curve compared to other goods having substitutes. The categories having highlighted positive PE do not follow the inverse demand law for the current observations. Considering the absolute value of estimates, consumer categories pretend to be price inelastic except for five underlined estimates. For these five estimates, the absolute values of PE are greater than 1. The possible reason for such estimates can be stated as the scarcity value of commodity might not be reflected in the realized prices and / or alternatively, the propensity to consume electricity might be higher on account of income effects.

Though table 7 indicate the aggregate level estimates i.e. state level estimates, it is hard to comment on the nature of electricity consumption at this macro level for all consumer categories as no comparison can be made amongst various Discom and state results for a given category due to heterogeneous estimates. This indicates the need of data analysis at possible micro level instead of aggregate / state level.

TABLE 1. CONSUMER CATEGORY SPECIFIC PRICES

Consumer Category	DGVCL	MGVCL	PGVCL	Torrent Power	UGVCL	GUJARAT
High Tension (HT) (Industrial)						
Maximum price*	7.04	4.80	5.74	4.62	7.02	5.72
Minimum price	4.56	4.44	3.85	3.80	4.37	4.24
Average price	5.47	4.59	5.06	4.16	5.94	5.04
Standard deviation in price	0.59	0.11	0.48	0.28	0.71	0.37
Residential						
Maximum price	5.20	5.47	5.69	3.92	6.40	4.63
Minimum price	2.50	2.89	2.82	2.97	3.13	3.06
Average price	3.79	3.23	3.75	3.33	4.58	3.74
Standard deviation in price	0.68	0.48	0.62	0.26	0.90	0.46
Commercial						
Maximum price	6.61	4.98	6.01	5.01	7.48	4.73
Minimum price	4.66	4.07	0.59	2.97	4.37	3.87
Average price	5.39	4.76	5.06	4.40	6.59	4.35
Standard deviation in price	0.49	0.17	1.00	0.39	0.91	0.24
Low Tension (LT) 1 (Industrial)						
Maximum price	5.34	4.82	6.27	4.58	8.10	5.70
Minimum price	3.95	4.51	3.80	3.81	0.52	3.50
Average price	4.72	4.66	5.19	4.09	5.58	4.85
Standard deviation in price	0.41	0.10	0.66	0.26	2.29	0.65
Low Tension 2 (Agriculture)						
Maximum price	4.36	2.05	1.58	3.72	3.85	2.06
Minimum price	0.45	0.39	0.32	0.60	0.31	0.69
Average price	1.74	0.85	0.62	2.10	0.75	1.21
Standard deviation in price	1.21	0.49	0.31	1.25	0.79	0.37

*Prices are in Rs/kWh

TABLE 2. PRICE ELASTICITY ESTIMATES OF MGVCL

Consumer Category	Price Elasticity	Coefficient of determination (r2)	Correlation coefficient (r)	t-value*
High Tension (HT)	-0.55	0.05	0.23	-0.59
Residential	0.05	0.58	0.76	0.22
Commercial	-0.08	0.64	0.80	-0.17
Low Tension 1 (LT) (Industrial)	-0.44	0.73	0.85	-1.50
Low Tension 2 (Agriculture)	-0.13	0.45	0.67	-1.22

TABLE 3. PRICE ELASTICITY ESTIMATES OF PGVCL

Consumer Category	Price Elasticity	Coefficient of determination (r2)	Correlation coefficient (r)	t-value*
High Tension (HT)	-0.40	0.34	0.58	-3.08
Residential	0.93	0.48	0.69	3.85
Commercial	-1.47	0.69	0.83	-2.91
Low Tension 1 (LT) (Industrial)	-2.30	0.47	0.69	-2.98
Low Tension 2 (Agriculture)	0.02	0.47	0.69	0.08

TABLE 4. PRICE ELASTICITY ESTIMATES OF DGVCL

Consumer Category	Price Elasticity	Coefficient of determination (r2)	Correlation coefficient (r)	t-value*
High Tension (HT)	0.17	0.10	0.31	1.30
Residential	-0.10	0.43	0.65	-0.56
Commercial	-0.59	0.30	0.55	-1.83
Low Tension 1 (LT) (Industrial)	-0.28	0.17	0.41	-1.42
Low Tension 2 (Agriculture)	-0.09	0.73	0.86	-1.14

TABLE 5. PRICE ELASTICITY ESTIMATES OF UGVCL

Consumer Category	Price Elasticity	Coefficient of determination (r2)	Correlation coefficient (r)	t-value*
High Tension (HT)	-0.10	0.04	0.19	-0.36
Residential	-0.13	0.92	0.96	-1.49
Commercial	-0.15	0.74	0.86	-1.01
Low Tension 1 (LT) (Industrial)	-0.40	0.24	0.49	-1.82
Low Tension 2 (Agriculture)	-0.01	0.97	0.99	-0.56

TABLE 6. PRICE ELASTICITY ESTIMATES OF TORRENT POWER

Consumer Category	Price Elasticity	Coefficient of determination (r2)	Correlation coefficient (r)	t-value*
High Tension (HT)	-2.32	0.74	0.86	-3.19
Residential	0.58	0.85	0.92	1.82
Commercial	-0.36	0.64	0.80	-0.70
Low Tension 1 (LT) (Industrial)	6.64	0.66	0.81	4.42
Low Tension 2 (Agriculture)	0.97	0.69	0.83	5.10

TABLE 7. PRICE ELASTICITY ESTIMATES OF GUJARAT

Consumer Category	Price Elasticity	Coefficient of determination (r2)	Correlation coefficient (r)	t-value*
High Tension (HT)	-0.03	0.06	0.24	-0.22
Residential	-0.47	0.68	0.82	-2.02
Commercial	-1.52	0.85	0.92	-5.31
Low Tension 1 (LT) (Industrial)	0.12	0.08	0.28	0.90
Low Tension 2 (Agriculture)	0.13	0.66	0.81	1.04

*At 90% confidence interval with threshold at 1.714

6. Conclusion

The variations in the results highlight that for designing the tariff policy at state level, it is needed to treat every Discom separately based on the demographic and economic conditions. While doing the same, it is necessary to pay attention to the consumption pattern of every consumer category as well as the scarcity value of electricity to have rational and optimum policy implications.

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