Analysis of Monthly Power Demand in Korea Using Panel Model

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Abstract

The proper estimate of price elasticity is important to better understand the behavior of consumers in power market. It would also be interesting to estimate the cross energy price elasticity of power demand, such as of gas and petroleum product. This paper analyzes the monthly power demand in Korean by estimating the price elasticity of electricity demand and other variables using econometrics technique. The electricity consumer is divided into two groups based on the contract type: (1) service and education; (2) industrial and agriculture-street light. The estimation result shows negative price elasticity of electricity demand for all contract types. Meanwhile mixed results both in sign and size are observed for the cross price elasticity of electricity demand. These imply the substitution and complement relationship between electricity and other energy (gas and oil)

1. Introduction

The price elasticity of demand is defined as the measure of percentage change of demand when price changes in one percent. It is important to get the proper estimate of this price elasticity to better understand the behavior of consumers in power market.

Prior to this study, some researches on price elasticity of power demand estimation can be found in the literature. Fan and Hyndman (2011) summarizes a number of those studies. Most of the studies are conducted in developed countries where power market reformation takes place, such as US, Australia, and Europian countries. From these, the estimated price elasticity of power demand differs from one study to another. The most common numbers are ranging from -0.2 to -0.4 for the short run elasticity and -0.5 to -0.7 for the long run elasticity. The inconsistency of result might be caused by the difference of model used which is heavily depends on the availability of data. It is also reported that there is no significant difference between residential, commercial and industrial price elasticity of demand.

The difference of model and data type utilized in estimation of price elasticity of power demand can be seen in a study by Lijesen (2007). For estimation of long and short run elasticity, various types of model such as trans-log, log-linear, and error correction model are summarized. The range and type of data also varies, it can be quarterly or annual, time series or panel, with different period under study. In his summary, the price elasticity in general can ranges from -0.04 to -1.113 for short run and -0.009 to -1.76 for long run. The higher range could be attributed to the difference on sector disaggregation and the type of data and model utilized in a study. The author also suggests that the panel data yield higher (absolute) results than aggregated time series, which could be originated from the causality problem in measuring the demand reactions.

Patrick and Wolak (2002) analyzes the data from large and medium sized industrial and commercial customers purchasing electricity under half-hourly spot prices and demand charges from the England and Wales electricity market for the period of April 1991 to March 1995 (four years). This study shows that the day-ahead price elasticity estimates vary substantially by time-of-use, industry and firms within industries. The values of price elasticity are ranging from essentially zero to 0.89 in absolute value. Please note that the sign of price elasticity of demand is usually negative, since the higher would give incentive to reduce the demand.

KEEI (2004) estimated the price elasticity of electricity demand using OLS (Ordinary Least Square) and ARDL (Autoregressive Distributed Lag) model. The determinants of electricity demand in this report are income of consumers, price of electricity, price of substitutional or complementary energy and seasonal factor. Using OLS method, the price elasticity of power demand is around -0.285 for the overall industrial sector. When using ARDL method, the price elasticity is lower, around -0.171 for overall. Meanwhile the price elasticity for commercial and residential sector is not significant.

The purpose of this study is to analyze the monthly power demand in Korean electricity market using econometrics method so that the price elasticity of power demand can be estimated. In the case of Korea, although there are previous researches on the empirical estimation of the price elasticity of power demand such as those of KEEI (2004), recent empirical work on domestic power demand has not been reported since. This paper also attempts to analyze the cross price elasticity of power demand. The analysis of other energy prices (gas and petroleum product) in our study would greatly improve the understanding of Korean power market especially in relation with the energy market in general.

This paper is organized as follow: the second section elaborates the data gathering, data processing and the econometrics method applied to those data; the results of estimation process would be summarized in section three along with the discussion of the results; then section four would provide concluding remarks of insights from the study.

2. Data and Method

The data set used in our analysis is monthly electricity consumption for the period of 2004-2010 provided by KEPCO (Korean Power Electricity Company). Other than electricity consumption, the database is also equipped with the electricity sales, number of households, contract sizes, and other variables. The original raw data is still categorized into several dimensions—regions, contract types, and industrial codes—other than the time dimension.

There are fourteen regions in the KEPCO database, which are: Seoul, South Seoul, Incheon, North Gyeonggi, Gyeonggi, Gangwon, Chungbuk, Daejon-Chungnam, Jeonbuk, Gwangju-Jeonnam, Daegu-Gyeongbuk, Busan, Gyeongnam and Jeju. Further, the original samples are categorized into 99 industries with their respective industrial codes. These can also be combined into several industrial groups, which ranging from agriculture, forestry, and fishing to residential and street lights. The last dimension is the contract types, with main classification such as residential, educational, industrial, service, agriculture, and street light. Those sectors then would be divided further based on the contract size (the upper limit of electricity power in kW), their connection to the power grid (there are several Voltage levels), and base tariff option[1]. In total, there are 36 different contract types according to KEPCO's classification. The definition of each contract type can be found in the appendix.

[1] The option with a higher base tariff would have a lower level of hourly (Time-of-Use) price

Although the richness of the database is tempting to analyze the power market in detail, the complication of econometrics model needed is also equivalent with the complexity of the data. In addition to that, the data quality also shows that the analysis utilizing all dimensions available would be difficult and could not provide the expected result. The analysis in this paper is based on the contract type while the other two dimensions (region and industrial group) are aggregated.

Since our sample has a panel data structure with 36 different contract types for the period of Jan. 2004 to Dec. 2010, we use a panel model to fully utilize the data information. For the convenience of estimation process, all of the contract types are classified into two big groups, service and industrial group, respectively. Service group consists of 14 contract types including those of service and education sectors. Meanwhile industrial group is composed of 22 contract types including industrial and agricultural sector in addition to the contract type for street light. A least square dummy-variable panel model is applied for each group, following Hsiao (2003). The estimation models specified for this study are:

Service and Education Group

$$\hat{y}_{i,t} = \sum_{k=1}^{2} \hat{\beta}_{1k}\, y_{i,(t-k)} + \sum_{k=1}^{4} \hat{\beta}_{2k}\, PE_{i,(t-k)} + \sum_{k=1}^{4} \hat{\beta}_{3k}\, PG_{i,(t-k)} + \sum_{k=1}^{4} \hat{\beta}_{4k}\, PI_{i,(t-k)} + \sum_{k=1}^{1} \hat{\beta}_{5k}\, House_{i,(t-k)}$$
$$+ \hat{\beta}_6 PE_{i,t} + \hat{\beta}_7 PG_{i,t} + \hat{\beta}_8 PO_{i,t} + \hat{\beta}_9 PI_{i,t} + \hat{\beta}_{10} HDD_{i,t} + \hat{\beta}_{11} CDD_{i,t} + \sum_{j=1}^{2} \hat{\beta}_{12j}\, SD_j$$
$$+ \sum_{j=2}^{12} \hat{\beta}_{13j}\, MD_j + \sum_{j=2}^{14} \hat{\beta}_{14j}\, PE_{i,t}CD_j + \sum_{j=2}^{14} \hat{\beta}_{15j}\, PG_{i,t}CD_j + \sum_{j=2}^{14} \hat{\beta}_{16j}\, PO_{i,t}CD_j + \sum_{j=2}^{14} \hat{\beta}_{17j}\, PI_{i,t}CD_j$$
$$+ \hat{\alpha}_i$$

Industrial and Agriculture-Street Light Group

$$\hat{y}_{i,t} = \sum_{k=1}^{1} \hat{\beta}_{1k}\, y_{i,(t-k)} + \sum_{k=1}^{1} \hat{\beta}_{2k}\, PG_{i,(t-k)} + \sum_{k=1}^{1} \hat{\beta}_{3k}\, PO_{i,(t-k)} + \sum_{k=1}^{1} \hat{\beta}_{4k}\, PI_{i,(t-k)} + \sum_{k=1}^{2} \hat{\beta}_{5k}\, House_{i,(t-k)}$$
$$+ \hat{\beta}_6 PE_{i,t} + \hat{\beta}_7 PG_{i,t} + \hat{\beta}_8 PO_{i,t} + \hat{\beta}_9 PI_{i,t} + \hat{\beta}_{10} House_{i,t} + \hat{\beta}_{11} HDD_{i,t} + \hat{\beta}_{12} CDD_{i,t} + \sum_{j=1}^{2} \hat{\beta}_{13j}\, SD_j$$
$$+ \sum_{j=2}^{12} \hat{\beta}_{14j}\, MD_j + \sum_{j=2}^{22} \hat{\beta}_{15j}\, PE_{i,t}CD_j + \sum_{j=2}^{22} \hat{\beta}_{16j}\, PG_{i,t}CD_j + \sum_{j=2}^{22} \hat{\beta}_{17j}\, PO_{i,t}CD_j + \sum_{j=2}^{22} \hat{\beta}_{18j}\, PI_{i,t}CD_j$$
$$+ \hat{\alpha}_i$$

where

$y_{i,t}$	: Electricity consumption for contract type i at time t
$y_{i,(t-k)}$	: Electricity consumption at time t-k (k-th lag)
$PE_{i,t}$	: Price of electricity (real term) at time t
$PG_{i,t}$	: Price of gas (real term) at time t
$PO_{i,t}$	: Price of oil (real term) at time t
$PI_{i,t}$	: Production index at time t
$House_{i,t}$	: Number of household at time t

$HDD_{i,t}$	: Heating Degree Days
$CDD_{i,t}$	: Cooling Degree Days
SD_j	: Structure break Dummy (SD_j = 1 for specific structure periods)
MD_j	: Monthly Dummy (MD_j = 1 for month j)
CD_j	: Contract type Dummy (CD_j = 1 for contract type j)
α_i	: Fixed effect

The model for each group is unique in terms of independent variables. Although in general, the specified model for electricity consumption includes explanatory variables such as the price of electricity for each contract, the price of gas and oil products, producer price index, industry specific production index, the number of customers, and temperature (to calculate Heating Degree Days and Cooling Degree Days), which are gathered from various sources, such as Bank of Korea and Korea Meteorological Administration (KMA). Then by adding different combination of structure break, the lags of electricity consumption, the price of electricity, and production index, model estimation is conducted.

It should be noted that several lagged variables are used in the model, for both the dependent (electricity demand) and independent variables (price of gas, oil, production index and number of household). When lagged dependent variable is included as regressor (autoregressive model), the model becomes a dynamic panel linear regression model. Some econometrics studies argue that in this case, the LSDV model no longer works because it produces bias on the estimated parameters. Thus it must be solved by utilizing other method such as using simple instrumental variable estimator as proposed by Anderson and Hsiao (1982) or using the first-differenced GMM estimation as proposed by Arellano and Bond (1991). But it should be noted that the problem posited by Arellano and Bond is in the condition of short time series (T) and long cross section (N), T > N. A case where the autoregressive panel model could be a problem is the study by Filippini (2011). Since his data size is quite small (T = 6 and N =22) he undergoes two kinds of estimation, which is LSDV and corrected LSDV model proposed by Anderson and Hsiao (1982) and Kiviet (1995).

However, the time dimension in this study is quite long in comparison to the number of contract types (T = 84; N = 14 or 22). Given the results obtained from LSDV are quite acceptable, it can be argued that the within estimator $\hat{\beta}_{WG}$(LSDV) does not have asymptotic bias when $T\to\infty$. Accordingly, we can still use the LSDV covariance matrix, following Hahn and Kuersteiner (2002). A rigorous study by Alvarez and Arellano (2003) analyzes the econometrics model for a pure autoregressive (AR) process for y. It then shows that when $N/T\to 0$, the asymptotic bias 1/T (1+α) disappears. It can be seen that in this study the N/T is small enough, which is 14/84 ≈ 0.17 for service group and 22/84 ≈ 0.26 for industrial group.

To describe the consistency of within estimator, in general, the dynamic panel linear regression model can simply be described as below. The lagged dependent variable, $y_{i,t-1}$, is included as regressor:

$$y_{i,t} = \lambda\, y_{i,t-1} + x'_{i,t}\beta + u_{i,t}, \quad u_{i,t} = \alpha_i + \epsilon_{i,t}, \;\; i = 1, \cdots, N, \;\; t = 1, \cdots, T$$

$$y_{i,t} - \bar{y}_i = \lambda\left(y_{i,t-1} - \bar{y}_{i,t-1}\right) + \left(x_{i,t} - \bar{x}_{i,t}\right)'\beta + (\epsilon_{i,t} - \bar{\epsilon}_i)$$

The correlation between $(y_{i,t-1} - \bar{y}_{i,t-1})$ and $(\epsilon_{i,t} - \bar{\epsilon}_i)$ will decide the consistency of within estimator. The asymptotic covariance of $(y_{i,t-1} - \bar{y}_{i,t-1})$ and $(\epsilon_{i,t} - \bar{\epsilon}_i)$ is as below.

$$\mathrm{cov}\left(y_{i,t-1} - \bar{y}_{i,t-1}, \epsilon_{i,t} - \bar{\epsilon}_i\right) \approx -\frac{\sigma_\epsilon^2}{T^2}\frac{(T-1) - T\lambda + \lambda^T}{(1-\lambda)^2}$$

In the dynamic panel linear regression model described above, we assume ($|\lambda| \leq 1$) to assure the dynamic stability of the model. Then, as the size of T becomes large, the covariance converges to zero. Because of no correlation between ($y_{i,t-1} - \bar{y}_{i,t-1}$) and ($\epsilon_{i,t} - \bar{\epsilon}_i$), it can be concludes that within estimator satisfies the consistency. In the other words, the parameter estimators resulted from our LSDV model can be justified as unbiased estimators.

3. Result and Discussion

In this study, the estimation process is done using a program with Least Square Dummy Variable procedure written in GAUSS. This section will provide the summaries and analyses of main results generated from the LSDV for both contract type groups[2].

3.1. Service and Education Group

In the group of service and education, there are 14 contract types and 1076 observations (unbalanced panel data) with 975 degrees of freedom. The R-square is calculated as 0.691. Table 1 shows the main estimation results, which include all of the lagged variables, the price of electricity, gas and oil, the production index, HDD and CDD. Most of the lagged variables are significant, especially for the last lag components. The estimators for price of electricity and price of gas are significant both at 5% level, while the number of household and HDD are significant at 1% level.

Table 1 Main Estimation Results for Service and Education Group

Variable	Estimate	Standard Error	t-value	p-value
y(-1)	0.25103	0.03224	7.78567	0.00000
y(-2)	0.07174	0.03013	2.38101	0.01746
PE(-1)	0.73999	0.13180	5.61452	0.00000
PE(-2)	-0.17427	0.12988	-1.34179	0.17998
PE(-3)	0.50457	0.11391	4.42963	0.00001
PE(-4)	-0.24104	0.10891	-2.21313	0.02712
PG(-1)	-0.86561	0.41028	-2.10980	0.03513
PG(-2)	0.81238	0.41928	1.93758	0.05296
PG(-3)	-0.68011	0.41135	-1.65337	0.09858
PG(-4)	0.61216	0.30997	1.97490	0.04856
PI(-1)	-0.70813	0.80991	-0.87433	0.38215
PI(-2)	-0.93332	0.81806	-1.14090	0.25419
PI(-3)	-0.92225	0.77832	-1.18492	0.23634
PI(-4)	1.70045	0.76897	2.21134	0.02724
House(-1)	-0.41613	0.07443	-5.59063	0.00000
PE	-0.96715	0.41258	-2.34413	0.01927
PG	1.15595	0.52440	2.20433	0.02773
PO	-0.06363	0.24381	-0.26096	0.79418

[2] The complete results are available upon request

PI	1.31730	0.92816	1.41926	0.15614
House	0.76041	0.07413	10.25727	0.00000
HDD	0.00106	0.00031	3.46998	0.00054
CDD	0.00045	0.00055	0.82884	0.40740

It should be noted that since the econometrics model has components of partial elasticity (denoted as various variables times contract type dummies), some of the main estimators shown above are for the base contract type only. The base contract types set up in this study are different for each variable: group 7, 12, 12, and 2 are the base contract type for price of electricity, price of gas, price of oil and production index, respectively. The calculation of total estimator for groups other than base is as follow:

$$\text{Estimator}_{\text{total}} = \text{Estimator}_{\text{base}} + \text{Estimator}_{\text{partial}}$$

Table 2 shows the calculation of price elasticity of electricity demand and the cross price elasticity for all contract types in the group of service and education. Note that in the case of insignificant partial elasticity, the total price elasticity would be equal to the price elasticity of the base contract type. The reason is because the partial elasticity could not reject the null hypothesis and the partial estimator would turn to be zero. Special case of oil price elasticity of electricity demand happens due to the fact that the elasticity for the base contract type is not significant, so do all of the partial elasticity. In this case it can be said that the change of oil price would have insignificant effect to the electricity demand.

It can be seen that the price elasticity of electricity demand is negative for all contract types, which means that the increase in electricity price would result in decreasing demand. The size of elasticity price is -0.967 for most of the contract types and -2.276 for contract type 12. As for the gas price elasticity (cross price elasticity), mixed response is observed. Exactly half of service and education sector exhibits positive cross price elasticity while the other half has negative sign. The positive sign of cross price elasticity means that when the other energy price (gas or oil) increases, the electricity demand would increase. Meanwhile negative sign shows that the increase in other energy price (gas or oil) would result in decreasing demand for electricity. The sign of cross price elasticity implies the substitution or complementary effect of other energy (gas or oil) to electricity. Both the positive and negative gas price elasticity has quite wide range of magnitude, from 0.07 to 1.15 and from -0.02 to -1.00. Meanwhile the oil price elasticity of electric demand is insignificant for all contract types.

Table 2 Own and Cross Price Elasticity of Electricity Demand for Service and Education Group

Contr. No.	Price Elasticity of Electricity Demand		Gas Price Elasticity of Electricity Demand		Oil Price Elasticity of Electricity Demand	
	Partial	Total	Partial	Total	Partial	Total
1	-0.01517	-0.96715	-0.95090	1.15595	0.06723	0.00000
2	-0.59059	-0.96715	-2.18312^{***}	-1.02717	-0.39364	0.00000
3	-0.19801	-0.96715	-1.08110^{*}	0.07484	0.01534	0.00000
4	-0.13949	-0.96715	-0.99296^{*}	0.16299	0.01767	0.00000
5	-0.86466	-0.96715	-0.89396	1.15595	-0.09904	0.00000
6	-0.39810	-0.96715	-1.45672^{**}	-0.30078	-0.16817	0.00000
7	-	-0.96715	-1.40848^{**}	-0.25253	0.05603	0.00000
8	-0.08968	-0.96715	-1.17998^{**}	-0.02404	0.14068	0.00000

9	-0.27563	-0.96715	-1.74607***	-0.59012	-0.36984	0.00000
10	-0.53564	-0.96715	-0.88292	1.15595	0.07046	0.00000
11	-0.54319	-0.96715	-2.15949**	-1.00354	0.02547	0.00000
12	-1.30971***	-2.27686	-	1.15595	-	0.00000
13	-0.59482	-0.96715	-2.16458***	-1.00863	-0.21732	0.00000
14	-0.04521	-0.96715	-1.11173**	0.04422	-0.18483	0.00000

Note: *, **, *** : significant at 10%, 5%, and 1% level, respectively.

3.2. Industrial and Agriculture-Street Light Group

In the group of industrial and agriculture-Street Light, there are 22 contract types and 1769 observations with 1637 degrees of freedom. The R-square is calculated as 0.979. Table 3 shows the main estimation results, which include all of the lagged variables, the price of electricity, gas and oil, the production index, number of household, HDD and CDD. Except for the lagged price of gas and price of oil, all lagged variables are significant. Also, the estimators for price of electricity, price of gas, production index, number of household and HDD are significant.

Table 3 Main Estimation Results for Industrial and Agriculture-Street Light Group

Variable	Estimate	Standard Error	t-value	p-value
y(-1)	0.35550	0.01161	30.62773	0.00000
P_G(-1)	-0.07059	0.15358	-0.45967	0.64581
P_O(-1)	-0.16133	0.12823	-1.25808	0.20854
Prdx(-1)	0.19543	0.10877	1.79678	0.07256
Hous(-1)	-0.30734	0.01534	-20.03677	0.00000
Hous(-2)	0.17493	0.01036	16.87779	0.00000
P_Elec	-0.52285	0.15978	-3.27235	0.00109
P_Gas	0.65310	0.32737	1.99497	0.04621
P_Oil	-0.04519	0.21447	-0.21069	0.83316
ProdIndx	0.54485	0.32137	1.69538	0.09019
House	0.70295	0.01055	66.65198	0.00000
HDD	0.00056	0.00019	2.95705	0.00315
CDD	0.00037	0.00038	0.98106	0.32671

Similar to the result of service and education group, the model for industrial group also utilizes partial estimators. Thus the estimators for price of electricity, price of gas, price of oil and production index shown above are only for the base contract type, which are the group 9, 4, 15, and 9, respectively. Meanwhile, the prices elasticity for any group other than base contract type is calculated by adding the base contract type elasticity with the respective group's partial elasticity.

Table 4 shows the price elasticity of electricity demand, gas price elasticity of electricity demand and oil price elasticity of electricity demand for all contract types within industrial and agriculture-street light group. Similar to the analysis in the service group, the partial elasticity which cannot reject the null hypothesis would turn to zero so that the total price elasticity of that group would be equal to the base contract type's price elasticity.

Table 4 Own and Cross Price Elasticity of Electricity Demand for Industrial and Agriculture-Street Light Group

Contr. No.	Price Elasticity of Electricity Demand		Gas Price Elasticity of Electricity Demand		Oil Price Elasticity of Electricity Demand	
	Partial	Total	Partial	Total	Partial	Total
1	-2.06981***	-2.59266	-0.50886	0.65310	0.07783	0.00000
2	-4.24714***	-4.76999	-0.55417	0.65310	0.00724	0.00000
3	-0.76440	-0.52285	-0.95615**	-0.30305	0.06389	0.00000
4	-1.91158***	-2.43443	-	0.65310	0.75188***	0.75188
5	-1.97593***	-2.49878	-0.54707	0.65310	0.46573*	0.46573
6	0.00710	-0.52285	-0.67832	0.65310	0.01332	0.00000
7	0.28912	-0.52285	-0.71209*	-0.05899	-0.02872	0.00000
8	0.38215	-0.52285	-0.51898	0.65310	-0.01096	0.00000
9	-	-0.52285	-0.79692**	-0.14383	0.13092	0.00000
10	0.03919	-0.52285	-0.41227	0.65310	0.13795	0.00000
11	0.13648	-0.52285	-0.87684**	-0.22374	-0.03307	0.00000
12	0.18227	-0.52285	-0.85142**	-0.19832	-0.03049	0.00000
13	0.33851	-0.52285	-0.94643**	-0.29334	-0.10304	0.00000
14	0.33216	-0.52285	-1.05143**	-0.39833	-0.03566	0.00000
15	-0.59077***	-1.11362	-1.51040***	-0.85730	-	0.00000
16	0.22141	-0.52285	-1.67590***	-1.02280	-0.47477*	-0.47477
17	-1.01314***	-1.53599	-0.02641	0.65310	-0.26253	0.00000
18	-0.10800	-0.52285	-0.27495	0.65310	0.14342	0.00000
19	0.30916	-0.52285	-0.77375*	-0.12066	0.04014	0.00000
20	-0.68122***	-1.20407	0.26718	0.65310	-0.44130	0.00000
21	-0.71798***	-1.24083	-0.93607**	-0.28297	-0.65651**	-0.65651
22	-1.14483***	-1.66767	1.31122***	1.96431	0.55120**	0.55120

Note: *, **, *** : significant at 10%, 5%, and 1% level, respectively.

The price elasticity of electricity demand has negative sign for all contract types in this sector's group, with magnitude ranging from -0.52 (base contract type) to -4.76 (contract type 2). Meanwhile for gas price elasticity of electricity demand, there are mixed results of complementary and substitution. Almost half of the contract types in this group posit positive gas price elasticity, which means that when gas price rises (and gas demand goes down) the electricity demand would go up. This shows a substitution relationship between gas and electricity. Meanwhile the other contract types show negative gas price elasticity, which implies complement relationship between gas and electricity demand. The size of gas price elasticity of electricity demand ranges from -0.05 (contract type 7) to -1.02 (contract type 16) and 0.65 (base contract type) to 1.96 (contract type 22).

Mixed results also can be seen in oil price elasticity of electricity demand. Around half of the contract types have negative sign; the same goes for the positive sign. The gas price elasticity for the base contract type is insignificant (and small magnitude to begin with) and most of the contract types in this sector's group is also insignificant. The size of significant oil price elasticity ranges from 0.46 to 0.75 and from -0.47 to -0.65.

4. Concluding Remarks

This study analyzes the monthly power demand in Korea. Among various dimensions available from the main raw data provided by KEPCO, the regions and industrial codes are aggregated. The LSDV type of model is utilized to estimate the price elasticity of electricity demand and other variables. All the contract types are classified into two groups: (1) service and education group; (2) industrial and agriculture-street light group.

The estimation result shows negative price elasticity of electricity demand for all contract types from both groups. The magnitude ranges from -0967 to -2.267 for service group and -0.522 to -4.769 for industrial group. As for the cross price elasticity of electricity demand, mixed results are observed for both groups. In overall, the gas price elasticity of electricity demand can range from -0.02 to -1.02 and from 0.0.7 to 1.96. Meanwhile the oil price elasticity of electricity demand has a range of -0.47 to -0.65 and 0.46 to 0.75. These show the substitution and complement relationship between electricity and other energy (gas and oil product), which is varied among different contract types.

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Appendix—List of Contract Types

- Contract Type (A, B, C) shows the power limit or the contract size (kW) of the costumer
- Voltage type (Low, High A, High B, High C) shows the voltage level of power grid connection
- Subcontract type (Option I, II, III) shows the variation of base tariff; higher base tariff yields lower hourly Time-of-Use price

Service and Education

Contr. No.	Code	Contract Type	Voltage Type	Subcontract Type
1	2110	General Service A	Low-Voltage	-
2	2130	Education	Low-Voltage	-
3	2211	General Service A	High-Voltage A	Option I
4	2212	General Service A	High-Voltage A	Option II
5	2231	Education	High-Voltage A	Option I
6	2232	Education	High-Voltage A	Option II
7	2261	General Service B	High-Voltage A	Option I
8	2262	General Service B	High-Voltage A	Option II
9	2311	General Service A	High-Voltage B	Option I
10	2312	General Service A	High-Voltage B	Option II
11	2331	Education	High-Voltage B	Option I
12	2332	Education	High-Voltage B	Option II
13	2361	General Service B	High-Voltage B	Option I
14	2362	General Service B	High-Voltage B	Option II

Industrial and Agriculture-Street Light

Contr. No.	Code	Contract Type	Voltage Type	Subcontract Type
1	0410	Agriculture A	-	-
2	0420	Agriculture B	-	-
3	0430	Agriculture C	-	-
4	0600	Street Light A	-	-
5	0610	Street Light B	-	-
6	3110	Industrial A	Low-Voltage	-
7	3211	Industrial A	High-Voltage A	Option I
8	3212	Industrial A	High-Voltage A	Option II
9	3311	Industrial A	High-Voltage B	Option I
10	3312	Industrial A	High-Voltage B	Option II
11	7211	Industrial B	High-Voltage A	Option I
12	7212	Industrial B	High-Voltage A	Option II
13	7261	Industrial C	High-Voltage A	Option I
14	7262	Industrial C	High-Voltage A	Option II
15	7311	Industrial B	High-Voltage B	Option I
16	7312	Industrial B	High-Voltage B	Option II
17	7361	Industrial C	High-Voltage B	Option I
18	7362	Industrial C	High-Voltage B	Option II
19	7363	Industrial C	High-Voltage B	Option III
20	7461	Industrial C	High-Voltage C	Option I
21	7462	Industrial C	High-Voltage C	Option II
22	7463	Industrial C	High-Voltage C	Option III