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RESIDENTIAL DEMAND FOR ELECTRICITY IN DASMARINAS, CAVITE, PHILIPPINES

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ABSTRACT

Recent unstable oil prices and continuing concerns of global warming have reignited interest in understanding the demand for residential electricity consumption by households. Given the declining tariff block that characterizes electricity demand, understanding households' responsiveness to electricity price changes can help both utility companies and policymakers predict future energy needs and design appropriate policy responses to future conservation needs.

This study identifies the factors affecting the demand for electricity of 403 households in the province of Cavite, Philippines. It also calculates appliance specific price and income elasticity's of their electricity demand. The reciprocal least square estimation and probity model were employed.

The findings show that number of TVs, number of fans, floor area, number of bedrooms, member of household not working, gross income, and refrigerator size increase electricity consumption. On the other hand, number of households and electricity consumption practices tend to reduce electricity consumption. Overall, household price elasticity of demand for electricity is low. Evidently, appliance specific price elasticity's differ across appliance portfolio. These differences reflect both the mean monthly consumption of the appliance and the coefficient of the appliance price used in the point elasticity computation. Overall, household income elasticity with respect to electricity demand is low and positive. This implies low responsiveness of residential electricity demand with respect to changes in income. Additionally, lower income households have greater elastic demand for electricity than higher income level households.

Keywords: Residential demand for electricity, electricity consumption, tariff block, appliance portfolio, price elasticity of electricity demand.

1.0 INTRODUCTION

The residential sector heavily relies on electricity as the most convenient form of household energy source. During the past few decades, electricity consumption in the Philippines has grown faster than any other fuel. The growth rate of per capita household electricity consumption in the Philippines has exceeded the growth rate of per capita income. While the Philippine per capita electricity consumption has been lower relative to other Asian countries (United Nations Economic and Social Commission for

Asia and the Pacific [UNESCAP], 2001) the national demand for electricity is at an all-time high. Rapid population growth and an expanding digital economy will drive electricity demand even higher within the next 25 years. Meeting this demand will be a challenge for the Philippine electric companies requiring them to make major investments in power plants, as well as the transmission and distribution systems used to deliver electricity where it is needed.

Differences in energy consumption between urban and rural households are more distinct with electricity. Electricity consumption by households in the National Capital Region and other urban areas has increased by an average of 27.8 per cent whereas consumption of electricity in rural areas continued to stagnate (UNESCAP, 2001). Electricity consumption in the Philippines grew by 10.6 percent in 2003, then by a lower 3.2 percent in 2004, and then by an even lower 2.5 percent in 2005. In 2006 electricity consumption grew by only 1.1 percent. In general, it is residential and commercial users who hold a bigger share of total consumption. The thing is, residential and commercial consumers have peak hours when their demand for electricity is strong (Freedom from Debt Coalition, 2008).

The Philippine electricity consumption shows a consistent trend over the years. Annual growth rate is four percent for Luzon and six percent for Visayas and Mindanao. However, during the past five years, the demand for electricity of residential sector has been noticed. Electricity consumption of residential consumers is greater than that of commercial and industrial sectors. Based on the Philippine Power Statistics report of Department of Energy (DOE), commercial sector is the lowest consumer among the three sectors (DOE, 2008). From 1986 to 2001, industrial sector is the highest consumer of electricity. However, in 2001 up to 2005, the highest demand for electricity has been shifted to residential sector. In 2006, the electricity consumption of residential sector in Luzon was 28 percent while that of commercial and industrial were 26 percent and 25 percent, respectively. Industrial sector got the highest share in both Visayas and Mindanao. Overall, the electricity consumption for both residential and industrial sector has a slight difference in 2006.

In 2005, Manila Electric Company (Meralco) has about 3.9 million residential customers. During the same year, Cavite has 515,707 residential customers (Meralco, 2008). This is about 13 per cent of the total residential customers within the service area of Meralco, most of the customers being served are in Metro Manila. In Cavite, however, the electricity consumption of residential customers was 868,178 MWh. Dasmariñas, being its biggest municipality in terms of population, has 109,040 residential customers with an electricity consumption of 162,306 MWh. This is about 21 per cent of the total residential customers and about 18.7 per cent of the total electricity consumption in Cavite.

Much has been written about the determinants of demand for electricity in developing and developed countries (eg. Holtedahl & Joutz, 2000; Ubogu, 2002; Reiss & White, 2002; Lin, 2003; Department of Energy, Philippines, 2001; Khanna & Rao, 2009; and ishi & Joutz, 2009). These studies differed only in the specification of price variable; time period covered (whether short-run or long-run); sector included (whether commercial or residential); performance outcomes of economic policies affecting the electricity sector, including institutional reforms such as privatization and regulation; and the proxy variables used for urbanization to indicate economic development. Other works attempted to include other variables such as environmental variables and price of electricity-consuming equipment (Francisco,1988) while others considered the stock of electrical equipment and rate of utilization (DOE, Philippines, 2001).

The effectiveness of pricing policy is dependent on how responsive the consumers are on changes of electricity prices. Intuitively, households may adjust their electricity consumption based on prices, income, and how efficient their electrical appliances are. The objectives of this paper are to identify the factors affecting residential demand for electricity; determine the responsiveness of residential demand for electricity to changes in electricity prices and income; and calculate the marginal effects for a portfolio of residential appliances.

The estimation of consistent and stable price and income elasticity estimates is important. The study will benefit the electric utilities, the residential consumers, and government planners and private investors who need to be well informed regarding privatization programs in restructuring the industry. Electric utilities will have a relevant basis in explaining to consumers their electricity consumption behavior and possibly suggest how to efficiently use their appliances and conserve electricity. In effect, if consumers are well informed on their electricity consumption, the country as whole will benefit in terms of optimizing the resources. This study may also be used as a reference in designing a rate structure and forecasting of energy sales. Moreover,ith proper and effective communication channels, residential consumers will be informed on how to efficiently use their appliances and conserve electricity. In effect, if consumers are well informed on their electricity consumption, the country as whole will benefit in terms of optimizing the resources.

2.0 LITERATURE REVIEW

In the past years, a number of studies on electricity demand has been documented and published. It has been one of the interests of economists and environmentalists across nations. According to Holtedahl and Joutz (2000), the short-run and long-run residential electricity consumption in Taiwan are affected by the price of electricity, household disposable income, population growth, and degree of urbanization. Urbanization, as a measure of economic development, was used to capture economic development characteristics and electricity-using capital stocks not explained by income. Urbanization implies greater access to electricity. The study did not include weather variables. In the estimation of residential electricity demand in Seoul, family size, size of house, household income, and dummy for a plasma television and air conditioner have a positive effect on residential electricity demand (Yoo, Lee, & Kwak, 2007). However, the price of electricity has a negative relation with residential electricity demand.

Ubogu (2002), however, in his analysis of the Nigerian electricity demand found that average price of electricity, though rightly signed, was found to be insignificant. The findings showed that per capital income, previous level of electricity consumption and urbanization are the most significant explanatory variables for the residential sector's electricity consumption. As regards the commercial sector, the significant explanatory variables were previous level of electricity consumption, income, average price of electricity and urbanization.

Mayer and Horowitz (2003) analyzed the demand for electricity and its relationship with the price of electricity using monthly consumption statistics of a community of owner-occupied, almost identical townhouses. A simple statistical model was used to split the cooling season demand for electricity into air-conditioner demand and the demand for lights and appliances. The noncooling portion of the demand decreased, but otherwise increased each year. It was found that, although the marginal price has doubled, these changes in price have had little effect on demand.

Reiss and White (2002) used a sample of California households and variation in electricity demand in both the short run and long run. Tariff design was considered to have energy conservation, raise additional revenues for utilities, and minimize expenditure changes in lower-income households. In the short-run, electricity demand is a factor of utilization of existing appliance stock, while in the long-run, changes utilization behavior and changes in stock of electric appliance are the significant variables. However, the study focused only on short-run effect because of limitations in the data and difficulty in the appliance replacement decisions. Appliances were categorized as space heating, water heating, air conditioning, refrigeration, pools, and other appliance. The effect of seasonal use of electricity and weather were not considered in the study.

Lin (2003) estimated the electricity demand in China by including GDP, price of electricity, population, structural changes, and efficiency improvement in the model. The study revealed that electricity demand is negatively related to changes in infrastructures and efficiency improvement. The weather condition was not integrated in the model because of difficulty in assessing its effect on electricity consumption. Structural changes such as construction of buildings, homes, and other infrastructures were considered as significant factors to contribute to the electricity consumption of the country. However, structural changes like new homes and commercial establishment were not considered. The study concluded that the GDP, energy prices, and structural changes are significant determinants in the short-term electricity consumption.

In the Philippines, the demand for electricity was estimated using the short-run and long-run models (Department of Energy, 2001). The short-run residential demand for electricity model was based on the demand for electricity-usage appliances while the long-run considered the variation of stock of appliances. In the short-run model, electricity consumption is a function of stock of electrical equipment and the rate of utilization. Moreover, the rate of utilization depends on the household size, price of electricity, household budget, and household class (urban or rural). It was found that the residential demand for electricity is a function of household budget per capita, price of electricity, household size, household class (urban or rural), entrepreneurial activities, electrical appliances, and interaction between price of electricity and the electrical appliance. The long-run demand for electricity of residential consumers depends on the changes or variation of the electrical appliances. The electricity consumption is a function of income, price of electricity, prices of competing fuels, and household characteristics. The empirical model is represented by the average household electricity consumption, average household expenditure per capita (adjusted for provincial price differences), average price of electricity, percent of households located in urban areas, and percentage of households with refrigerators.

Francisco (1988) also tried to include other variables such as own price variables, income, price of substitutes for electricity, price of electricity-consuming equipment, and environmental variables to explain the demand for electricity in the Philippines. The price considers the block pricing and the demand charge applied to the consumption of electricity. His paper focused on the demand elasticities of the Philippines concentrating the franchise area of Manila Electric Company (Meralco). The segments include residential, commercial, and industrial customers. For the demand model of residential customers, the problem in block pricing was mentioned. The price of liquefied petroleum gas (LPG), price of firewood, and level of employment were found to be insignificant factor. The price of LPG was a good substitute for electricity for commercial and industrial customers, but not for residential customers. Firewood was not a significant substitute for all customer class. The price of electricity-consuming appliances like the flat iron and refrigerators has small effects on the demand for electricity of residential customers while the price of air conditioners has a significant effect.

The Energy Information Administration (1998) revealed that in the US, the principal determinants of short-term demand variations in the residential sector are weather factors, although a significant trend in consumption per household persists in raising demand from year to year. For weather, nonzero parameter values for heating degree-days or cooling degree-days are allowed only during the season in which particular weather impacts are meaningful for the aggregate data. Thus, heating degree-days affects residential demand only from October through April. This technique is designed to improve the credibility of the separate estimates of heating and cooling degree-day effects on electricity demand, which might otherwise be confounded due to a close (negative) correlation between aggregate cooling and heating degree-days. In addition, growth in the total number of households in the US adds proportionately to electricity demand, other things being equal.

Meralco (2006) employed an econometric model to forecast residential energy sales. The residential energy sales used by Meralco from 1991 to 2005 varied over time. In 1991, an electricity sale is a function of Personal Consumption Expenditure per capita (PCE/n), number of customers, and the price of electricity. From 1992 to 1997, the model was a function of Gross National Product per capita (GNP/n), price of electricity, number of customers, and percent system loss plus an autoregressive variable. In 1998, the autoregressive variable was removed from the model. In 2005, percent LOSS was dropped from the model and other variable was considered. Notwithstanding these changes in variables, residential electricity consumption is positively affected by GNP per capita and total number of customers.

Khanna and Rao (2009), likewise, quantified the determinants of electricity demand and supply efficiency in developing countries. They postulated the causal relationship between electricity consumption and economic growth, price and income elasticities of demand, and the barriers to adoption of energy-efficient equipment. They also examined the performance outcomes of economic policies affecting the electricity sector, including institutional reforms such as privatization and regulation. Results showed that electricity demand is driven by GDP, prices, income, the level and characteristics of economic activity/urbanization, and seasonal factors. The magnitude of their effects differs across countries, time periods, and studies even for the same country.

Several studies also attempted to measure the change in electricity demand due to a change in price and model and forecast short-term and long-term peak half-hourly demand (Fan & Hyndman, 2008, 2010). They found that there is a nonlinear relationship between electricity demand and price which implies that the price elasticities vary with both the time and the day of the year. Similarly, Taylor, Schwarz, and Cochell (2005) found substantial variation in own price elasticity values among customers when they estimated the average hourly own price and substitute elasticities in the United Kingdom.

These results were supported by that of Danao's (2001) and Yoo, Lee, and Kwak's (2007) studies which revealed that the short-run residential demand for electricity is income and price inelastic. The results also showed that household size, urban location, age and educational level of the household head have significant positive effects on household electricity consumption. In a separate study in Bombay, the elasticities of residential demand for electricity in terms of price and income are -0.70 and 0.34, respectively (Tiwari, 2000).

Ishi and Joutz (2009) modeled the residential and industrial electricity demand in the Philippines. The results indicate a long run cointegrating relationship among residential electricity consumption, income, and the stock of electric appliances. In the industrial sector there is a long-run relationship between industrial electricity consumption and GDP. The lack of significant price responses appears to be the result of government development policies. Llanto et al. (1988) also estimated the demand elasticities of Philippine electricity focusing on the Manila Electric Company franchise area. Long-run price and income elasticities are found to be generally larger in magnitude than short-run elasticities and environmental variables have varying degrees of effects on demand for electricity.

In the case of urban Indian households, 30,000 households were surveyed to find out the relationship between seasonal price and income elasticities of residential demand for electricity. Electricity demand function was estimated in three seasons, such as winter, monsoon, and summer. The factors such as price, income, household size, and other household characteristics were studied to see its effect on electricity demand. The study found that the demographic and geographical characteristics have a significant effect on electricity demand. Also, the electricity demand is price and income inelastic in all three seasons (Filippini & Pachauri, 2003),

In Pakistan, using time series data from 1979 to 2006, Nasir, Tariq, and Arif (2008) estimated electricity demand model to investigate income and price elasticities of electricity demand. Their results showed that electricity demand is price inelastic in both short run and long run. Moreover, income elasticity is almost unitary in short run as well as in long run. In addition, household size has a strong positive impact on electricity demand in Pakistan.

Wills (2002) estimated the short- and long-run responses by households to changes in the price of electricity using data which permit measurement of the marginal price of electricity, the inframarginal demand charge, and estimates of household appliance stocks. The price elasticities of high- and low-level users of electricity were compared. The theoretical bias in price elasticity estimates resulting from neglect of the inframarginal demand charge was found to be empirically insignificant. Taylor (1975), likewise, tried to analyze the residential demand for electricity using both the marginal and average prices as predictors in the demand function.

The residential, industrial, and total electricity demand was also estimated by Kamerschen and Porter (2004) using partial adjustment and simultaneous equation approaches. Flow-adjustment models yielded positive price elasticity estimates. The simultaneous equation approach suggests that residential customers are more price sensitive than industrial customers. Weather was found to have the greatest impact on the residential sector, and cold weather appears to affect demand more than hot weather.

Ubogu (2002) in his attempt to determine the short and long-run income elasticities in Nigeria found the figures to be below unity, while those of urbanization were above unity. Urbanization was, however, found to be the most sensitive variable with respect to changes in the sector's electricity demand. Previous level of industrial electricity consumption and degree of urbanization were the main explanatory variables for changes in the industrial sector's demand for electricity. Industrial output and income were not found to be significant variables in explaining changes in the industrial sector's demand for electricity.

Holtedahl and Joutz (2000) tried to separate the short and long-term effects through the use of an error correction model. In the long run, the income elasticity is unitary elastic. The own-price effect is negative and inelastic. In an error correction framework, the short- run income and price effects are small and less than the long-run effects.

Llanto et al., (1988) also recognized that the price response is vital to the allocation of electric resources in peak demand periods. Unfortunately, many end-customers currently face a complex nonlinear pricing scheme and lack the necessary information to take advantage of incentive structure. An important distinction can be made about the ability of customers to react to pricing signals. In the short-run, customers must use their existing infrastructure, technologies and resources to react to changes in prices. Thus, their ability to react to the price changes is lower in the short-run than in the more distant future or "long-run," when customers can adapt with technologies and future innovation. As such, it can be expected that given the proper price signals, demand responsiveness should increase over time as customers are given the opportunity to react to them (Lafferty et al., 2001).

Based on the related literatures, it can be summarized that the short-run residential electricity demand is affected by household disposable income, population growth, price of electricity, degree of urbanization, household size, urban location, age, educational level of the household head, previous level of electricity consumption, weather, stock of electrical equipment, and the rate of utilization.

3.0 MODEL FOR ENERGY DEMAND

Electricity demand is characterized by two important dimensions: that electricity consumption is a derived demand and residential households face unusual pricing structure. The derived nature of electricity allows for a distinction in what households can do in the short run and in the long run. Additionally, the declining nature of block tariff structure implies that the large consumers may be subsidized unintentionally by low electricity consumers which introduces equity problems and raises concern for incentives to conserve. The equity issue raised by the declining block tariff stems from charging various groups of household different prices at the margin. For instance, it is generally known that the cost of generating or distributing extra kilo-watt hour electricity at peak hours (when system is loaded) exceeds the cost of generating same quantity of electricity during less peak hours (in Figure 1 between 0 and q1). On the other hand, the major criticism of a two-part tariff is that the constant charge for quantity of electricity consumption between 0 and q1 in Figure 1 may exceed the reservation wage of low-income consumers (a case prevalent in low income countries) and, therefore, violate the efficiency criterion of competitive market. Arguments along the efficiency criterion have given impetus to regulatory interventions by government. In the Philippines, such an intervention may take the form of restructuring pricing scheme to include time-of-day or peakload pricing. In such a scheme, pricing will increase beyond qi. This type of increasing block or tiered pricing scheme was used by Weiss & White (2005) to model household electricity pricing by California utilities. Under increasing block price scheme, the consumer pays a lower price pi for quantity between 0 and qi and p2 beyond qi (Figure 1). In contrast, in the Philippines, albeit pricing scheme allows for an increase in price (generation charge per kWh) beyond qi, but average price beyond qi may show a decreasing function and thus skewing price in favor of large consumers.

4.0 HOUSEHOLD DEMAND DECISIONS FOR ELECTRICITY

Electricity consumption belongs to a class of demand known as "derived demand" which means that electricity is not consumed directly by households but are dependent on the flow of services provided by a portfolio of household's durable energy-consuming appliances (Reiss & White, 2005). In a typical household setting, appliances such as air conditioning, microwave, refrigerator, washing machine, computer, and the like use varying quantities of electricity to render some degree of utility to households. The relationship between the decision process of electricity use and appliance is similar to when households make the decision to supply certain amount of labor in the labor market. For instance, when a household decides to work for 10 hours instead of 40 hours a week, constraint has been placed on how much they can purchase with a given income. In other words, the decisions to work and how much to buy are interdependent. In the same manner, when a household buys an appliance, electricity consumption per kilowatt hour is specified and, therefore, the appliance and electricity consumption are interdependent.

This phenomenon allows for a basic distinction between what households can do immediately to curtail electricity consumption and what might not be possible given the nature of appliance. Appliances, once purchased, constitute a fixed stock. The timeframe within which a household can replace or buy a new one is regarded as long run while that time period within which a household faced with budgetary constraints cannot afford to buy another appliance is known as short run. Consequently, own price of electricity will tend to play an important role in electricity demand in the short run. Given the nature of appliances, it is useful to model a household decision as to whether it is in the short run or long run. Following economic theory, it is expected that households may possess greater degree of flexibility to changes in electricity demand in the long run rather than in the short run. What has not been sufficiently explored in the literature is whether households possess some degree of control over electricity consumption in the short run. If replacing household appliances in the short run is impossible due to huge cash outlay involved, then conservation practices may offer reasonable options to control electricity use. This paper models a short run household decision.

In the short run, household appliances are fixed so that the intensity of use will be affected by electricity prices, gross monthly income, and other noneconomic factors. In a typical demand modeling, the quantity desired of electricity can be augmented with adjustment of electricity demand which satisfies both conditions of linear and nonlinear pricing scheme. Following Action, Mitchel & Mowill (1976), this demand function can be represented as

$$Qe_i = U_1(P_{e_i}, Y_i, Z_i) * A_{e_i} \qquad (1)$$

where Qe_i is quantity of electricity consumed by household, P_{e_i} is the price of electricity of an individual electricity consumer, Y_i is income of an individual electricity consumer, and Z_i is other variables that influence the consumption of electricity, A_{e_i} individual consumer's electricity adjustment due to stock of appliance; and $U_1(\cdot)$ represents variation in utility and intensity of electricity. Assuming continuous differentiability of functions, adjustment process for variables in equation 1 can be represented in mathematical notation as

$$\left[\frac{\partial Qe}{\partial Pe} = \frac{\partial U}{\partial Pe} + \ldots + \frac{\partial U_m}{\partial X_m}\right] * A_{e_i} + \frac{\partial A_{e_i}}{\partial Pe} * U_{e_i} + \ldots A_m + \frac{\partial A_m}{\partial X_m} * U_m \quad for\ m = 1,..M \qquad (2)$$

Since we are modeling short run electricity demand, no changes in the stock of appliance of the consumer is expected. Therefore, the relevant terms are those enclosed in the bracket as A_e term is essentially equal to zero.

In the case of typical goods sold under competitive markets, consumers' face single pricing scheme in which aggregated demand function will equal $D(p) = \sum_i D_i(p)$, while aggregated supply function will equal $S(p) = \sum_i S_i(p)$. Given marginal price, p^* , equilibrium will occur at $D(p^*) = S(p^*)$. In the case of electricity demand, consumers of electricity face price schedule which is a function of quantity of electricity consumed. This price schedule produces $Qe(p_1, p_2)$ where a constant price, p_1 & p_2 there

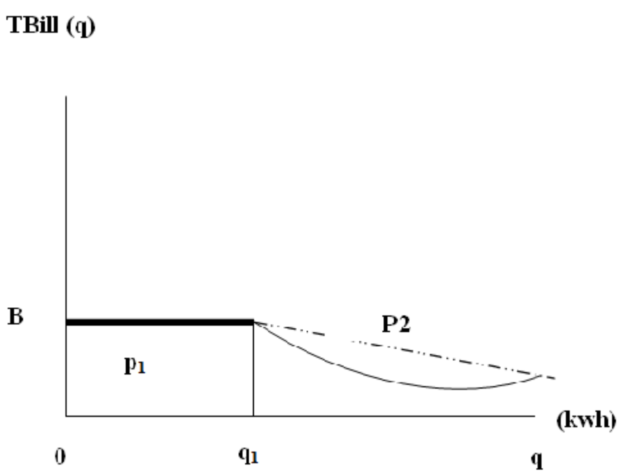
p_1

after prevails. Under declining block tariff rate, residential electricity consumption allows for a constant price, , fixed at a given level of electricity consumption and series of additional charges represented by p_2 as consumption of electricity increases. The total tariff bill for a given residential consumer is given as

$$Tbill(q) = B_1 + B_2 \begin{cases} B_1 = p_1 q_1 & if\, 0 \le q_1 \le q, \\ B_2 = B_1 + p_2 q & if\, q > q_1, \end{cases} \qquad (3)$$

where TBill (q) is a consumer's total bill for consumption level q. B_1 is the bill for category one consumers, p_1 is generation charge per kWh for quantity not exceeding q_1 B_2's bill for category two consumers, p_2 generation charge per kWh for quantity of electricity exceeding q_1 ,quantities as shown in Figure 1.

It is helpful to model appliance specific demand function to incorporate the varying nature of household appliances. This heterogeneous nature of appliances implies that different factors will affect appliances across households. For econometric specification, the categories of appliances considered are air conditioning, computer, microwave, washing machine, and refrigerator. Given these appliances, the total electricity used by household would equal electricity consumption by each category of appliance. The number of appliances a household owns can be defined in terms of L uch as l 1, 2 ..., L . The quantity of electricity demanded by households depends on the number of



appliance in use. Following Reiss and White (2005), total portfolio of electricity demanded can be expressed as

$$QE = \sum_{l=1}^{L} d_l q e_l \qquad (4)$$

where QE is total residential electricity consumption of all categories of appliance specified above; while

$$d_l = \begin{cases} 1\ if\ \ household\ owns\ category\ l\ appliance \\ 0\ if\ \ otherwise \end{cases}$$

Electricity demand in equation 4 can take a linear form as

$$QEl = \alpha_0 l + \alpha pl \ + \alpha yl + \alpha zl + \varepsilon l \qquad (5)$$

where QE is quantity of electricity consumed, p is the price of electricity, y is household income, z is other variables that influence electricity consumption, and ε is unobservable characteristics. The l term indicates that equation (5) may be specified for each of the five appliances mentioned above.

The declining tariff block rate shown in Figure 1 implies that the additional discharge rate charged (p2) as electricity consumption exceeds q1, is on average less than (p1). Reciprocal functional form on the p variable is more appropriate for the independent variables. Schmidt (2005) recommends reciprocal relationship when a downward sloping demand curve is assumed and $\alpha_2 > 0$ in equation 6 is greater than 0. As long as the term $\frac{1}{p}$, remain non-negative, α_0 will be positive and the demand curve will stay above the horizontal line. The estimable equation for reciprocal functional form can be given as

$$Qel = \alpha_0 l + \alpha_1 l \frac{1}{p} \ + \alpha_2 yl + \alpha_3 zl + \varepsilon l \qquad (6)$$

where $\alpha's$ are simply the estimated coefficients of $p, y,$ and z variables.

The challenge of our estimation process is to estimate non linear regression model with a demand function relating response predictor variables to household consumption of electricity under declining tariff price schedule faced by households. This model is ideal in the context of household electricity demand where tariff schedules are nonlinear and marginal price of electricity consumed by household is more relevant than average price. Following Reiss and white (2005) and Schmidt (2005), nonlinear regression model can be written as

$$y^* = f(\alpha, x_i') + \varepsilon_i \qquad (7)$$

where α is a vector of parameters to be estimated, x_i' is a vector of predictor variables, and $\varepsilon_i \sim N(0,1)$ is normally distributed random error with mean 0 and variance 1.

The relationship between the latent, y^* and the observed y can be written as

$$\begin{Bmatrix} y = 1 if\ y_i^* > 0 \\ y = 0 if\ y_i^* < 0 \end{Bmatrix} \tag{8}$$

the binary dependent variable takes the value 1 in case an individual household owns one type of appliance l from equation 4 and 0 if otherwise. We define standard normal distribution function as

$$P(y=1) = F(\alpha, x_i') \tag{9}$$

Equation (9) can be written as

$$p = \alpha_0 + \alpha_1 X_1 + ... + \alpha_k X_k \tag{10}$$

Equation (10) simply tells us that if $\alpha_k > 0$, increase in X_k will increase the chance that $p\ (y=1)$. The reverse is true if $\alpha_k < 0$.

Alternatively, equation (7) can be written (Schmidt, 2005 p. 369) so that the probability that a household owns l appliance is $\Phi(x'\alpha)$ and the joint probability or likelihood function of all residential household electricity consumers can be expressed using a standard probit model as

$$\text{Prob}(Y_{1_{l=1,2.....L}} \mid x) = \prod_{y_{1l=1}} \Phi(x'\alpha) . \prod_{y_{1l=0}} \left[1 - \Phi(x'\alpha)\right] \tag{11}$$

The $\Phi(.)$ term is the cumulative distribution function, which is the level of X corresponding to the Z score on a standard normal curve (Schmidt, 2005 p. 403). The probability that an individual household owns a given type of appliance can be written as $\Pr(Y=1)$ and the probability that an individual household choose not to own a given type of appliance can be written as $\Pr(Y=0)$ .Equation (11) simply implies that given a reasonable sample size, maximum likelihood approach allows for observing both values 1 and 0 that maximizes the value of the log likelihood function. The sign of log likelihood will turn out be negative since the chance that each household owns a category of appliance or does own the category of appliance is less than one.

When all X's are evaluated at the sample means, we can estimate marginal effects which reflects the chance that the electricity consumption of a household who owns a certain category of appliance changes as one unit of X variable changes. Essentially, the marginal effect allows us to capture by how much households' electricity consumption changes as the X's change which can be described as

$$\frac{\partial p}{\partial X_k} = \Phi(\mathrm{x}'\alpha_k) \qquad (12)$$

Equation (12) simply tells us that the probability derivative with respect to X variable is equal to $\Phi(.)$ cumulative distribution function multiplied by α_k .Following Schmidt (2005), we implement this through calculating estimated values of probability derivatives.

The conventional point price elasticity formula for price elasticity in the short run as in Epsey and Epsey (2004) can be written as:

$$\eta_{PE} = \frac{\partial E}{\partial PE} \frac{\overline{PE}}{\overline{E}} = \left(\alpha_1 + \alpha_2 \overline{AE}\right)\frac{\overline{PE}}{\overline{E}} \qquad (13)$$

where the estimated α 's are price coefficients of electricity and $\overline{AE}$ is the mean appliance stock. As discussed earlier, the price elasticities estimates are expected to be small or less responsive in the short run. On the other hand, long run elasticities are expected to be higher than short run because households can make replacement decisions on the type of appliance to use. Equation (13) is treated as generic for the five appliances in use by households.

In the case of income elasticity of demand, we are interested in the elasticity of quantity of electricity demanded with respect to income of household. Thus we can modify equation (13) to incorporate income as

$$\eta_{YE} = \frac{\partial E}{\partial Y} \frac{\overline{Y}}{\overline{E}} = \left(\alpha_1 + \alpha_2 \overline{AE}\right)\frac{\overline{Y}}{\overline{E}} \qquad (14)$$

where the estimated α 's are income coefficients of electricity and $\overline{AE}$ is the mean appliance stock. Equation (14) is treated as generic as well for the five appliances in use by households.

5.0 THE DATA

The study was conducted in 10 barangays in Dasmarinas, Cavite, Philippines. The barangay is the basic unit or the lowest level of political and governmental subdivision in the Philippines. Every barangay is under the supervision of municipalities and cities. Among the municipalities in the province of Cavite, Dasmarinas has the highest number of households and with the highest number of residential electricity consumers totaled at 112,010 customers (Meralco, 2008).

Primary data were gathered through personal interview with the housewives. Only the legally connected residential customers were interviewed. The electric bill validated the legality of customers and the rate class. The rate class was identified and confirmed the type of customer as residential. The monthly price of electricity, monthly electricity demand, and the number of residential customers in Cavite were sourced out from Meralco.

A sample size of 403 households was drawn from the complete list provided by the NSO using systematic sampling method. Every 5^{th} household was interviewed until the sample size was met. Accessibility, safety, and security of the area during data gathering were also considered. Personal interview with the housewives, who were believed to be the most knowledgeable persons in the household about electricity consumption, was employed. However, there were respondents, other than the housewives, who entertained and answered the personal interview. Segmentation of respondents was primarily based on their electricity consumption.

6.0 RESULTS AND DISCUSSION

6.1 Estimates of Electricity Demand

Estimates of electricity demand coefficients using reciprocal functional model are shown in Table 1. It shows the monthly estimated demand parameters for all households and for the five appliances modeled in the study. Considering that this study is concerned with price and electricity demand elasticity's, we focus on price and electricity demand interpretations. Generally, parameter signs of the variables carry the expected signs. The first column in Table 1 shows the explanatory variables commonly used in electricity consumption demand equations. The second column shows the electricity consumption demand estimates for all households in the study. Columns 3 to 7 show the parameter estimates for the five appliances considered in the study. For all households, the price parameter estimate implies that a one Peso (Philippine currency) increase on average price of electricity would, on average, reduce monthly electricity consumption by approximately 19,739 watts or 19.7 kWh per month (or 236.86 kWh per year). Given that average monthly electricity consumption for all households in the study is 139 kWh, 19.7 kWh reductions due to price would amount to 14 percent of average household consumption. Fourteen percent reduction in electricity consumption implies that

Table 1. Estimate of electricity demand model using reciprocal functional form

VARIABLE	ALL	REF	COMP	AIRCON	MICROWAVE	WASHMACH
Constant	-228.657721***	12.478641	-0.947973	1.714223	-1.315612	0.537762
PRICE	-19739.22002**	-2310.76012**	37.422081	-3.565891	354.845101	-109.931401
NTVs	14.535341***	6.243997***	0.898318*	1.542468**	7.361433***	0.678231*
NFANs	1.103322	2.007461**	0.202041	1.423145***	1.428851	0.526336**
FLRAREA	0.044435	0.012128	0.000423	0.019314	-0.024711	0.000113
NOBRMS	4.793631	0.134206	0.047781	0.159427	1.015144	0.012658
MHHNW	-0.562147	-0.866431	-0.136733	0.052268	-0.451152	-0.239728
GROSSINC	0.001858***	0.000021	0.000011	-0.000022	0.000106	-0.000006
NOHH	-0.376748	-0.528063	0.047721	-0.112489	0.205945	0.113272
REFSIZE	0.636835	0.004412	0.020238	-0.046968	0.527111**	0.101312*
ECP	-1.026676	0.414972	-0.046716	-0.031105	-0.209721	0.070029
Income level						
Php2000-11000	-144.633311***	-3.726291	-0.094471	-6.041528**	-9.060712	-0.529113
Php12000-50000	-104.179512***	-0.191549	0.102214	-6.465606***	-9.598033*	-0.068734
R-squared	0.832763	0.225562	0.173997	0.135409	0.166642	0.080461

*** 1%; **5%; *10%

household may possess some control on electricity consumption in response to slight price changes, in the short run if the right incentives are applied. All appliances, except computer and microwave, carry the expected negative sign, according to theory.

Under some circumstances, positive price sign may be justified when regulation rules on tariff allow utility companies to charge additional price either due to peak hours or marginal cost considerations in providing additional power supply to a substation to buffer electricity supply. In the Philippines, illegal electricity tapped by "squatters" is rampant and may necessitate extra cost being passed on to other consumers.

The explanatory variables used in this study are generally consistent with mainstream literature on electricity consumption demand. The number of TVs (NTVs), number of fans (NFans), floor area (FLRAREA), number of bedrooms (NOBRMS), member of household not working (MHHNW), gross income (GROSSINC), and refrigerator size (REFSIZE) are estimated to increase electricity consumption. On the other hand, number of household (NOHH), electricity consumption practices (ECP), and income levels are estimated to reduce electricity consumption. The unexpected sign of NOHH is surprising in the sense that one would expect households with more members to consume more electricity. One could also interpret the negative parameter to imply that poorer household tends to have more family members and fewer appliances (which should under normal circumstances affect electricity consumption through use). Either way, NOHH is not statistically significant. Additionally, degrees of variation across appliances, in terms of goodness of fit, level of significance, and signs of coefficients of explanatory variables are evident. For instance, the overall goodness of fit is weakest in the case of washing machine followed by air conditioner. One may surmise that in terms of electricity consumption, this may have less to do with the behavior of household consumption patterns than say choice of appliance used in the model.

6.2 Marginal Effects

Table 2 indicates the estimated price effects of different appliances. The estimated coefficients of the probit model on individual appliances (not shown here, because the coefficients of probit are not directly interpretable) have been used to compute the marginal effects. The marginal effects can be interpreted as the estimated change in monthly appliance electricity consumption due to a unit change in the explanatory variable. All appliances, except ref. and computer are statistically significant and showed varying degrees of price sensitivities. The price parameter estimate of REF (−32.4) implies that a one peso per kilowatt hour increase in the marginal price of electricity would reduce a household's monthly consumption by approximately 0.0324 kWh (-32.4 watt/1,000 watt per kilowatt) per month (Table 2). Given that on average a typical household's refrigerator and microwave appliances contribute 29 kWh and 46 kWh, respectively of electricity consumption every month (total average electricity consumption for one month for the sample household using all appliances is 139 kWh). A PhP100.00 increase in the price of electricity would represent an 11 percent (0.0324 kWh X Php100.00) reduction in electricity consumption or 3.24 kWh reductions per month or about 39 kWh annual reductions. Faced with this demand structure, it is not expected that households would discontinue a universal appliance like a refrigerator in the short run. Reduction in electricity consumption in the short run may occur through electricity consumption practices (ECP) such as turning lights off or discontinuing the use of airconditioner. Estimated coefficients of the other appliances such as air conditioner, microwave, and.

Table 2. Estimate of marginal effects of household appliances, Dasmarinas, Cavite, Philippines

VARIABLE	REF	COMP	AIRCON	MICROWAVE	WASHMACH
Constant	0.0426376	51.203948	-0.184019	-0.008718	0.066791**
PRICE	-32.405071	-345.206862	-552.64521**	-317.70580**	-30.864079*
NTVs	0.060228**	-0.540803	0.249057**	0.196695**	0.056858*
NFANs	0.038801***	0.068145	0.080081*	0.038911	0.034811**
FLRAREA	0.000001	-0.003287	-0.000701	-0.001116*	-0.000603**
NOBRMS	0.002464	0.153694	0.061145	0.024211	0.043466**
MHHNW	-0.012084	0.062336	0.012499	0.001548	-0.027932**
GROSSINC	-0.000001	-0.000021	-0.000001	-0.000002	0.000001
NOHH	-0.010607	-0.195731	-0.023501	0.015697	-0.008671
REFSIZE	0.004293	-0.075156	0.015425	0.018000**	0.007571*
ECP	0.006308	0.010230	-0.016344	-0.029166***	0.003145
Income level					
Php2000-11000	-0.026377	-0.166552	-0.078747	-0.126170	-0.049311
Php12000-50000	0.042637	0.114204	-0.187124	-0.315292***	-0.072993

*** 1%; **5%; *10%

washing machine may be interpreted in the same manner. Electricity consumption practices show a positive sign (albeit, not significant) which suggests that very few options are available for households to conserve electricity consumption using refrigerator. In the case of Microwave, it is expected that conservation practices will reduce electricity as the negative and statistically significant coefficient (-0.029166) indicates.

6.3 Price and Income Elasticities

It is assumed that the stock of appliances is relatively fixed in the short-run. Given that households may adjust their consumption of electricity patterns in the future through the use of more efficient appliances, short-run price and income elasticities should differ from long-run elasticities. Estimates of appliance-specific price and income elasticities presented in Table 3 are percentage change in a household's monthly electricity consumption due to one percentage change in the marginal price and income. The estimates indicate very limited (i.e., inelastic demand) price responsiveness to households' electricity consumption. This implies that a one percent increase in the marginal price of electricity is estimated to have a less than one percent change in electricity consumption of households. Evidently, appliance-specific price elasticities differ across appliance portfolios. These differences reflect both the mean monthly consumption of the appliance and the coefficient of the appliance price used in the point elasticity computation. All appliances, except computer and Microwave, carry the expected negative sign. This is not unexpected since under declining block tariffs, high volume consumers of electricity who are more likely to afford appliances such as microwave and computer may have less incentive to conserve. In other words, benefits of low rates are conferred to high volume consumers while low volume consumers seem to pay higher rates on average.

The positive income elasticity with respect to electricity demand for refrigerator, computer and microwave reinforces the fact that due to the declining block tariffs, increase in income would tend to produce a normal good effect. Additionally, this low response to electricity demand as income changes may the fact that appliance stocks are fixed in the short run and income is not expected to change dramatically within a short horizon. On average, modest income increase may induce more electricity consumption. Another way to look at this is that household demand response may change less proportionately than income change producing positive or very small responses.

Table 3. Price and income elasticities of household by appliance

Mean Elasticity of Electricity Demand	Price	Income
Household Appliance		
Refrigerator	-0.090	1.30
Computer	0.028	0.15
Aircon	-0.0006	-0.08
Microwave	0.009	0.048
Washing machine	-0.026	-0.02
All households	-0.0175	0.0018

Table 4 shows a greater degree of less elastic price demand for household monthly income group of PhP12,000 - PhP50,000 than for households in income group PhP2,000 - PhP11,000. This result is not surprising since lower income households are more likely to react to electricity price increases. One may argue that when appliance is bought, the lower income households are less likely to buy more efficient appliance in the short run.

Table 4. Price elasticity by household income, Dasmarinas, Cavite, Philippines

Mean Elasticity of Electricity Demand	Price
Household monthly income level (PhP)	
2, 000 – 11, 000	-0.0022
12,000 – 50,000	-0.00065

7.0 CONCLUSIONS AND POLICY IMPLICATIONS

The results of price elasticity of demand are both interesting and surprising. Despite the unstable energy prices, responses to energy demand remain low. In the case of appliance-specific price elasticities, air conditioner appears to be the most price-unresponsive of the five appliances while refrigerator and microwave turn out to be elastic. This is not surprising given the nature of humidity during summer season or the general humid condition in tropical countries. The increasing use of microwave and refrigerator may reflect in large part, avoidance of food spoilage and food poisoning.

The price variable of the marginal effects provides very relevant and intuitive understanding of households' appliance response to changes in energy price. The price variable for all appliances is of the expected negative sign and significant, except for refrigerator and computer. The findings on the price variable suggest that there are potential benefits in the awareness and opportunities for load reduction. The current declining block tariff of the utility company seems to be sending the wrong price signals and could reflect long-run possibilities for less market participation to provide efficient appliances. In other words, if high volume consumers of electricity face lower rates, incentives to replace portfolio of appliance for efficient use of electricity will diminish.

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