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Measuring public understanding on Tenaga Nasional Berhad (TNB) electricity bills using ordered probit model

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Abstract. In 2016, Tenaga Nasional Berhad (TNB) had introduced an upgrade in its Billing and Customer Relationship Management (BCRM) as part of its long-term initiative to provide its customers with greater access to billing information. This includes information on real and suggested power consumption by the customers and further details in their billing charges. This information is useful to help TNB customers to gain better understanding on their electricity usage patterns and items involved in their billing charges. Up to date, there are not many studies done to measure public understanding on current electricity bills and whether this understanding could contribute towards positive impacts. The purpose of this paper is to measure public understanding on current TNB electricity bills and whether their satisfaction towards energy-related services, electricity utility services, and their awareness on the amount of electricity consumed by various appliances and equipment in their home could improve this understanding on the electricity bills. Both qualitative and quantitative research methods are used to achieve these objectives. A total of 160 respondents from local universities in Malaysia participated in a survey used to collect relevant information. Using Ordered Probit model, this paper finds respondents that are highly satisfied with the electricity utility services tend to understand their electricity bills better. The electric utility services include management of electricity bills and the information obtained from utility or non-utility supplier to help consumers manage their energy usage or bills. Based on the results, this paper concludes that the probability to understand the components in the monthly electricity bill increases as respondents are more satisfied with their electric utility services and are more capable to value the energy-related services.

1. Introduction

Tariff charges are commonly used to source power company's revenue, return on its investment and recovery of its operating costs. Hence, these rate charges need to be assigned carefully to its customer based on their distinctive characters. For TNB customers, there are sixteen different tariff rate being offered, excluding tariff for Top-up and Standby Services [1]. For the purpose of the study, this paper focuses on electricity bills based on tariff rates for Residential Customer, also known as Domestic Tariff. These residential customers include those who occupy a private dwelling, which is not used as hotel, boarding house or used for carrying out any form of business, trade, professional activities or services. Their electricity bills are based on meter reading that shows the amount of electricity they are consuming in a particular month and related to consumption charge [2][3]. This charge is also known as a usage charge, variable charge or energy use charge. The charge is based on the amount of electricity usage and in cents per kilowatt hour (cent/kWh). Another charge being included in the bills is service fees or also known as access to electricity charge. The fee is a fixed amount and it is charged regardless of the amount of electricity being used by the customers. This fee is charged based on cents per day or ringgit

per billing period and covers costs that do not depend on actual energy usage, for example those associated with maintaining poles and wires, and customer administration.

For the past few years, TNB electricity bills have undergo several layout changes to make it to be more transparent and informative to their customers [4]. The recent one was on 21 July 2016, where the Billing and Customer Relationship Management (BCRM) is being upgraded as TNB long-term aim is to provide customers with greater access to information on their power consumption, usage and bills [5]. The BCRM programme involves an upgrade of TNB's billing system to 8.5 million customers across Peninsular Malaysia, a change from 14 to 12 digits account numbers and safety tips. Moreover, the annual report in [6] claim that via BCRM, TNB aims to deliver a more personalised service for customers through better analysis and utilisation of customer information. The system includes new billing features, customer information, enhanced credit control management, efficient financial operations and business process automation. With BCRM, TNB can respond to customers quickly and efficiently via their preferred channel or device.

To the best of the authors' knowledge, currently there is no study being done on measuring public understanding on TNB electricity bills. The closest to such study is conducted by [7] that investigates the public opinion on electricity-related issues such as knowledge on pricing details included in the electricity bill, attitudes and opinion about various features in the electricity bill and the desired changes on the information in current electricity bill. In the study, they found that only 4 percent of consumers claimed they are 'very knowledgeable' on the determination of the electricity pricing. However, these consumers tend to be more dissatisfied with the price they are paying for electricity. The study also found that many of the residential and business consumers have a lack of understanding on different charges in their bills and its purposes. The study suggested that majority of the consumers interested to see more information that explains on various charges on their bill, how electricity prices are being determined and how much electricity they consumed.

However, most of the studies in this area relates to public understanding on energy efficiency and its effect on their energy consumption. In energy consumption analysis conducted by [8], they found that there is a positive correlation between knowledge and awareness. This correlation means an increase in awareness on energy efficiency resulted to an increase in the practice of saving energy. Both awareness and knowledge on energy efficiency are important to motivate the consumers to practice energy efficiency in using their electrical appliances. The study by [8] also shows that an increase in residential energy consumption are mainly caused by several factors such as the usage pattern of electrical appliances are not consistent (time of use), the lack of awareness on the practice of efficient energy and the use of electrical appliances that are not energy efficient. In another study by [9], the effect of knowledge of energy efficiency labels on electrical appliances and household characteristics on the adoption of energy efficient household appliances in Germany is being analysed. They find energy labelling seems to help improve the energy efficiency of appliances. This means consumers who choose the products will use less energy.

A study by [10] argued that household will have to bear the negative impacts on energy savings if they are not given proper education and guidance on energy saving practice. Similarly, in a study by [11], they claim that there is a major opportunity for electricity providers to educate consumers on the environmental interconnection between their usage, the impact on the environment and the value of available options and program. Without the basic understanding of this relationship, many customers will not be able to engage in a positive manner and, if not carefully managed, their reactions might create a detrimental perception.

Using ordered probit model [12], the study measured whether the respondent satisfaction towards energy-related services, electricity utility services, and their awareness on the amount of electricity consumed by various appliances and equipment in their home could improve the level of the respondents understanding on the electricity bills.

2. The methodology of ordered probit model

In this paper, the dependent variable is defined as, understanding on components of the monthly electricity bill received and it is denoted as $Y_{1,i}$ and the set of covariates is the value of the energy-related services, $x_{1,i}$; the consumer's satisfaction with the electricity utility service, $x_{2,i}$; the products and services that the customers interested, $x_{3,i}$; and customer's awareness on the amount of electricity consumed by various appliances and equipment in their home, $x_{4,i}$. This model follows a cross-sectional ordered probit model and the ith respondent is based on a latent variable Y_i^* which is related to a $(k\times1)$ vector of explanatory variables $x_{k,i}$ via the following linear relationship

$$Y_i^* = \mu + \gamma_k' x_{k,i} + \varepsilon_i \tag{1}$$

where μ is a scalar constant, γ_k is a $(k\times1)$ coefficient vector and ε_i is assumed to be normally distributed. For ease of notation we subsume the constant into $\boldsymbol{x}_{k,i} = (1\ x_{k,i}')'$ and define $\boldsymbol{\beta}_k = (\mu\ \gamma_k')'$ and hence

$$Y_i^* = \boldsymbol{\beta}_k' \mathbf{x}_{k,i} + \varepsilon_i \tag{2}$$

The latent variable Y_i^* and Y_i in turn are related via

$$Y_i = \begin{cases} 4 & \text{if } Y_i^* > \rho_3 \\ 3 & \text{if } \rho_3 \geq Y_i^* > \rho_2 \\ 2 & \text{if } \rho_2 \geq Y_i^* > \rho_1 \\ 1 & \text{if } \rho_1 \geq Y_i^* > \rho_0 \\ 0 & \text{if } \rho_0 \geq Y_i^* \end{cases} \tag{3}$$

with ρ_0, ρ_1, ρ_2, ρ_3 and ρ_4 being threshold parameters, which are collected in $\boldsymbol{\rho} = (\rho_0\rho_1\rho_2\rho_3\rho_4)'$. Each ordinal value in equation (3) means the respondents could either understand *not very well at all* ($Y_i = 0$), understand *not well* ($Y_i = 1$), *neutral* ($Y_i = 2$), understand *well* ($Y_i = 3$) and *very well* ($Y_i = 4$). The set of independent variables also are taking categorical values as defined in table 1. Hence, all of these variables are best modelled using ordered probit model.

Table 1. Definition of categorical values for all the variables in the model.

Variables	Categorical Values				
	0	**1**	**2**	**3**	**4**
Understanding on components of the monthly electricity bill received, $Y_{1,i}$	Not well at all	Not well	Neutral	Well	Very Well
Value of the energy-related services the capability to easily access detailed information pertaining to the energy use, $x_{1,i}$	Not Valued	Least Value	Neutral	Valued	Very Valued
Consumer's satisfaction with the electricity utility service, $x_{2,i}$	Very Unsatisfied	Unsatisfied	Neutral	Satisfied	Very Satisfied
Products and services that the customers interested device or application that would allow the customer to control their household appliances remotely, $x_{3,i}$	Very Not Interested	Not Interested	Neutral	Interested	Very Interested
Customer's awareness on the amount of electricity consumed by various appliances and equipment in their home, $x_{4,i}$	Very Unaware	Unaware	Neutral	Aware	Very Aware

To complete the model, it is necessary to specify the distribution of the error term ε_i. In the context of the ordered probit model, this is defined to follow a standard normal ($N(0,1)$) distribution. This is a standard modelling technique for ordered categorical variables. The specification allows pthe calculation of conditional category probabilities $P(Y_i = j|\boldsymbol{x}_{i,k})$, which in turn allow us to specify a log-likelihood function as follows:

$$\begin{aligned} llf_{\tau|j}(\boldsymbol{\beta}_k, \boldsymbol{\rho}) = I_4 \log\left[P\left(Y_i = 4\middle|\boldsymbol{x}_{i,k}; \boldsymbol{\beta}_k, \boldsymbol{\rho}\right)\right] \\ + I_3 \log\left[P\left(Y_i = 3\middle|\boldsymbol{x}_{i,k}; \boldsymbol{\beta}_k, \boldsymbol{\rho}\right)\right] \\ + I_2 \log\left[P\left(Y_i = 2\middle|\boldsymbol{x}_{i,k}; \boldsymbol{\beta}_k, \boldsymbol{\rho}\right)\right] \\ + I_1 \log\left[P\left(Y_i = 1\middle|\boldsymbol{x}_{i,k}; \boldsymbol{\beta}_k, \boldsymbol{\rho}\right)\right] \\ + I_0 \log\left[P\left(Y_i = 0\middle|\boldsymbol{x}_{i,k}; \boldsymbol{\beta}_k, \boldsymbol{\rho}\right)\right] \end{aligned} \tag{4}$$

where $I_j = \mathrm{I}(Y_i = j)$ is an indicator function which equals one in case $Y_i = j$ is true and 0 otherwise. The model parameters $(\boldsymbol{\beta}_k, \boldsymbol{\rho})$ that maximise that log-likelihood function are the Maximum Likelihood (ML) parameter estimates.

At the heart of the likelihood calculation is the calculation of the category probabilities. In the case of the respondents could understand *not well* ($\mathrm{Y_i} = 1$), the category probability of $P\left(Y_i = 1\middle|\boldsymbol{x}_{i,k}; \boldsymbol{\beta}_k, \boldsymbol{\rho}\right)$ is calculated as

$$\mathrm{P}\left(\mathrm{Y_i} = 1\middle|\mathbf{x}_{\mathrm{i,k}}; \boldsymbol{\beta}_{\mathrm{k}}, \boldsymbol{\rho}\right) = \mathrm{P}\left(\rho_1 \geq \mathrm{Y_i^*} > \rho_0\middle|\mathbf{x}_{\mathrm{i,k}}; \boldsymbol{\beta}_{\mathrm{k}}, \boldsymbol{\rho}\right) = \Phi\left(\rho_1 - \boldsymbol{\beta}_{\mathrm{k}}{}'\mathbf{x}_{\mathrm{i,k}}\right) - \Phi\left(\rho_0 - \boldsymbol{\beta}_{\mathrm{k}}{}'\mathbf{x}_{\mathrm{i,k}}\right) \tag{5}$$

where Φ represents the standard normal CDF. The log-likelihood function can be optimised by any standard nonlinear optimiser as long as ρ_0 is constrained to be smaller than ρ_1. Asymptotic standard errors for the estimated ML parameter estimates $(\widehat{\boldsymbol{\beta}_k}, \widehat{\boldsymbol{\rho}})$ are calculated based on the basis of the expected inverse Hessian Matrix of the variance covariance matrix

Hence, the mean marginal effect can be considered as the change in category probabilities as $x_{i,k}$ changes from j to $j + 1$

$$\mathrm{E}\left(\frac{\partial[P\left(Y_i = j\middle|\boldsymbol{x}_{i,k}; \boldsymbol{\beta}_k, \boldsymbol{\rho}\right)]}{\partial x_{i,k}}\right) = \mathrm{E}[P(Y_i = j|x_{tk} = j + 1) - P(Y_i = j|x_{tk} = j)] \tag{6}$$

where the category probabilities $P(Y_i = j|x_{tk} = j + 1)$, in the case of $Y_i = 1$ is using the defined in equation (5).

3. Result

The results of the mean marginal effects are estimated based on equation (6) using Stata software. They are shown in table 2. All the effects are statistically significant at 10% significant level.

Table 2. The mean marginal effects for all the covariates in the model.

Dependent variable	Independent variables	Significant coefficient, β_k	Mean Marginal Effect (%)				
			Not well at all	Not well	Neutral	Well	Very well
$Y_{1,i}$	$x_{1,i}$	0.4254	-2.86	-12.8	-1.3	7.53	**9.43**
	$x_{2,i}$	0.2354	-1.61	-7.11	-0.66	4.05	**5.33**
	$x_{3,i}$	0.31	-2.18	-9.22	-0.96	5.47	**6.89**
	$x_{4,i}$	0.2751	-1.62	-8.59	-0.75	4.83	**6.13**

Based on the positive coefficients of all covariates in the model, the respondent's values on the energy-related services, their satisfaction on electricity utility service, their interest on electricity-related products and services and their awareness on the amount of electricity consumed by various appliances and equipment in their home seem to give positive impact on their understanding on components of the monthly electricity bill received. These are consistent with the probability of marginal effect. Firstly, for the covariates, $x_{1,i}$, when a respondent gives more value to an energy-related services, the capability to easily access detailed information pertaining to their energy use, the probability of understanding *very well* on the components of the monthly electricity bill they received increases by 9.43 percent.

Secondly, for the covariates, $x_{2,i}$, the probability of understanding *very well* on the amount of the monthly electricity bill they received increases by 5.33 percent when the customer satisfied that the information obtains from their utility supplier seem to help them manage their energy usage or bills. The respondents seem to be most interested on a device or application that would allow the customer to control their household appliances remotely. Therefore, for the covariates, $x_{3,i}$, respondent that has more interest on such devices or application, the probability of understanding *very well* on the components of the monthly electricity bill they received increases by 6.89 percent. Finally, respondents that seem to be most aware about the amount of electricity consumed by various appliances and equipment in their home, their probability of understanding *very well* on the components of the monthly electricity bill they received increases by 6.13 percent.

This is consistent with the study by [13] that shows there is a positive relationship among the respondents of understanding of both the components of the electric bill and the pricing of electricity. This study collects several information such as the value of energy services, utility performance and customer choice, interest in new products and services and electricity awareness to get the percentage in each information and their impact towards the understanding of component of their electricity bills and electricity pricing.

4. Conclusion

In this study, ordered probit model is used to quantifying the understanding of customer on the components of the monthly electricity bill received and the pricing of electricity consumed. The result shows that the probability to understand the components of the monthly electricity bill received increases as the customer is more satisfied with their electric utility services. Moreover, a customer that has more awareness about the amount of electricity consumed have higher probability to understand the components of the monthly electricity bill and the pricing of electricity consumed. This study shows that the older the respondent is, the more likely they do not understand the pricing of electricity they consume.

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