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# Modelling altered revenue function based on varying power consumption distribution and electricity tariff charge using data analytics framework.

W N R A Zainudin and N A Ramli

Faculty Science and Technology, Universiti Sains Islam Malaysia, 71800 Nilai, Negeri Sembilan, Malaysia

Email: [rahini@usim.edu.my](mailto:rahini@usim.edu.my)

**Abstract.** In 2010, Energy Commission (EC) had introduced Incentive Based Regulation (IBR) to ensure sustainable Malaysian Electricity Supply Industry (MESI), promotes transparent and fair returns, encourage maximum efficiency and maintains policy driven end user tariff. To cater such revolutionary transformation, a sophisticated system to generate policy driven electricity tariff structure is in great need. Hence, this study presents a data analytics framework that generates altered revenue function based on varying power consumption distribution and tariff charge function. For the purpose of this study, the power consumption distribution is being proxy using proportion of household consumption and electricity consumed in Kwh and the tariff charge function is being proxy using three-tiered increasing block tariff (IBT). The altered revenue function is useful to give an indication on whether any changes in the power consumption distribution and tariff charges will give positive or negative impact to the economy. The methodology used for this framework begins by defining the revenue to be a function of power consumption distribution and tariff charge function. Then, the proportion of household consumption and tariff charge function is derived within certain interval of electricity power. Any changes in those proportion are conjectured to contribute towards changes in revenue function. Thus, these changes can potentially give an indication on whether the changes in power consumption distribution and tariff charge function are giving positive or negative impact on TNB revenue. Based on the finding of this study, major changes on tariff charge function seems to affect altered revenue function more than power consumption distribution. However, the paper concludes that power consumption distribution and tariff charge function can influence TNB revenue to some great extent.

## 1. Introduction

Electricity supply industry is one of the components under the energy sector and plays a vital role in country's growth and development [1]. In Malaysia, there have been a few developments in electricity supply industry, one of them is incentive-based regulation (IBR) mechanism which started in 2010. The IBR aims to evaluate a regulatory framework and management processes of Energy Commission (EC) against best practice principles and policies. Throughout the IBR implementation, the supply industry is able to pursue economic efficiencies since IBR aims to ensure that electricity tariff setting is conducted in orderly and transparent manner with emphasis on more efficient utility performance [2]. Aligned with this objective, this paper presents a data analytics framework that presents altered revenue function based on varying power consumption distribution and tariff charge function. For the purpose of this study, the power consumption distribution is being proxy using proportion of household consumption and electricity consumed in Kwh and the tariff charge function is being proxy using three-tiered increasing block tariff (IBT). The altered revenue function is useful to give an indication on whether



any changes in the power consumption distribution and tariff charges will give positive or negative impact to the economy. These two inputs are chosen since the framework assumes both power consumption and tariff charges can be considered as an important determinant for Tenaga Nasional Berhad (TNB) revenue. This conjecture is based on that fact that a utility may need to increase the power consumption (per-kWh) rate to collect sufficient revenue to cover its fixed costs [3]. However, most distribution and customer service costs do not vary with the amount of kilowatt-hour (kWh) sales, even though these costs are recovered mainly through a per-kWh rate. A reduction in sales, therefore, leads to a greater reduction in revenues than in costs. In line with that, successful conservation and energy efficiency programs decrease sales, and since electric utility rates typically are based on sales volume, it also decreases utility revenues.

Additionally, the conjecture is also based on some reviews that tariff charges generate revenues for the government. This is because the charges benefit the government and producers of the importing country in the form of tax revenues and producer surpluses at the expense of its consumers in the form of higher prices [4]. In developing countries, tariffs also are used to achieve multiple goals such as raising public sector revenue, correcting market distortions, providing protection for local industry, improving terms of trade by attempting to influence world market prices and redistributing income [5]. Therefore, the tariff rates set for a utility's customers should allow for an opportunity to earn an overall revenue requirement deemed appropriate by the Commission [6].

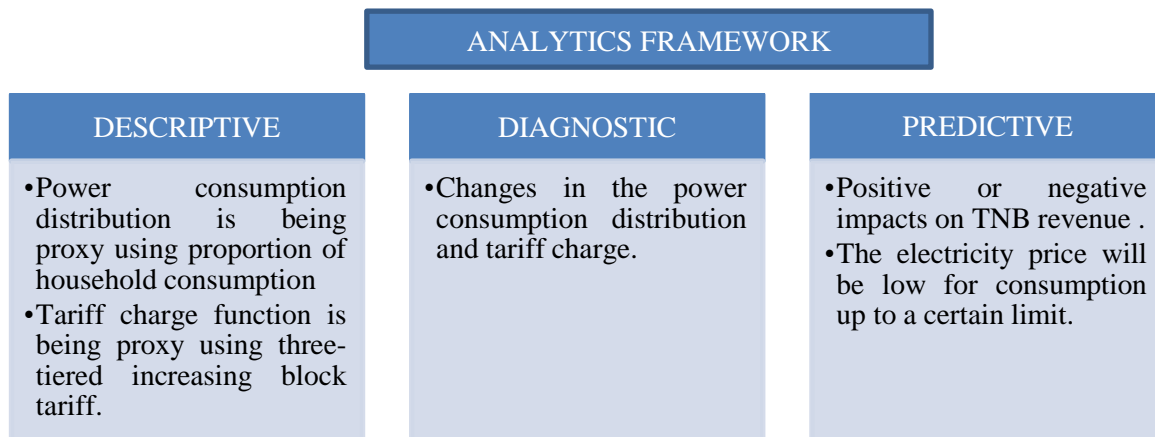
There are other inputs that could also influence the utility revenue function such as weighted average cost of capital (WACC), regulated asset base (RAB), operating expenses (OPEX), depreciation, tax and efficiency carryover amount [7]. For the purpose of this paper, only the effect of these two inputs which are power consumption distribution and tariff charges on the revenue function are being investigated. However, the effects of the other inputs could be used as potential research area in this topic.

## 2. Methodology

The methodology used for this framework begins by defining the revenue to be a function of power consumption distribution and tariff charge function. This paper is using proportion of household consumption and electricity consumed in kWh as a proxy for power consumption distribution and a three-tiered IBT as a proxy for tariff charge function. In a study by [8], they argue that the electricity consumption assigned in the first block of the IBT is used to maintain essential daily need and its electricity charge is 75% of the second block which almost equals the average cost of electricity. The price of the third block reflects an upward trend of marginal cost of generation which aims to promote energy conservation. The IBT's for electricity has been implemented in many developed countries or regions such as the United States, Japan, Korea, Malaysia and China.

Then, the methodology continues by deriving the proportion of household consumption and tariff charge function within certain interval of electricity power. Any changes in those proportion will contribute towards changes in revenue function. Thus, these changes are conjectured to give an indication on whether the changes in power consumption distribution and tariff charge function are giving positive or negative impact on TNB revenue. The methodology process is based on data analytic framework and best illustrated in Diagram 1.

**Diagram 1: Data Analysis Framework.**



Descriptive process are analytics that describe the past which refer to any point of time that an event has occurred. It is useful to allow information to be obtained from the past behaviours and to give better understanding on how this information might influence the future outcomes. Hence, based on Diagram 1, the process of using proportion of household consumption as a proxy for power consumption distribution and three-tiered increasing block tariff as proxy for tariff charge function can be classified as descriptive process in the framework. These approximation are being supported by various studies in [9][10][11] [12][13] that uses the same approach. Next, the framework uses diagnostic process which can be defined as identification of a condition or problem by systematic analysis on the background or history, evaluation on the research or test results and investigation on the assumes or probable causes. Based on this, the effect of power consumption distribution and tariff charge function on revenue function is considered as diagnostic process in the framework. Lastly, the predictive process completes the framework since it provides estimation on the likelihood of future outcome. In particular, the predictive process will give a conjecture whether the changes in power consumption distribution and tariff charge function are giving positive or negative impact on TNB revenue.

*2.1. Revenue of TNB*

Based on the assumption made at the beginning of the paper on the importance of power consumption distribution and tariff charges in determining a utility revenue, the function is defined as follows;

$$R(f, T) = N[\sum_w^{w+\Delta w} f(w).w.T(w)] \tag{1}$$

- R = Revenue function per year*
- N = Total number of households*
- f(w) = Proportion of household consumption*
- w = Electricity consumed in Kwh*
- T(w) = Tariff charge function*

The proportion of household consumption,  $f(w)$  is being derived based on the proportion of household consuming within certain interval  $(w_1, w_1 + \Delta w_1)$  of power. This proportion is being modelled using probability density function (pdf) of chosen distribution,  $g(w)$ . Let, first derive the probability density function (pdf) of proportion of household consumption based on a chosen distribution,  $g(w)$  as follows;

$$\Pr(w \in A) = \int_A g(w)dw \tag{2}$$

where  $A \in \mathbb{R}$

Next, the proportion of household consuming within certain interval  $(w_1, w_1 + \Delta w_1)$  of power,  $f(w)$  is derived as follows;

$$Pr(w_1 < w < w_1 + \Delta w_1) = \int_{w_1}^{w_1 + \Delta w_1} g(w) dw = f(w) \quad (3)$$

Based on the three-tiered increasing block tariff (IBT), the tariff charge function is defined in equation (4);

$$T(w) = \begin{cases} P_1, & 0 < w < \alpha_1 \\ P_2, & \alpha_1 < w < \alpha_2 \\ P_3, & w > \alpha_2 \end{cases} \quad (4)$$

Where  $\{\alpha_i\}_{i=1}^n$  denote the upper limits of consumption for the various block and  $\{P_i\}_{i=1}^N$  are the appropriate charges.

Finally, the data analytics framework assumes any changes in the proportion of household consumption,  $f(w)$  and tariff charge function,  $T(w)$  leads to new revenue function,  $R'(f, T)$ . The difference between these revenue function,  $R'(f, T) - R(f, T)$  can give an indication on whether the changes in proportion of household consumption,  $f(w)$  and tariff charge function,  $T(w)$  resulted to either negative or positive impact on revenue. In section 2.2 and 2.3, these changes are being discussed further. In order to implement this data analytic framework, information on the number of customer, demand profile and billing cost are in need. However, since this paper focuses on the design of the framework, its implementation is a fertile ground for future study.

### 2.2. The impact of changes in Proportion of Household Consumption, $\Delta f(w)$ on $R'(f, T) - R(f, T)$

Previous studies claim that households' electricity consumption is highly dependent on their income level [9][10][11][12][13]. For example, a study by [10] finds an increase in income leads to additional home appliances which increase electricity demand. This means the domestic electricity consumption is mainly characterised by household income variability and there exists a positive relationship between them. While in [12] a lower price elasticity is detected in higher electricity consumption households compared with that of the lower level, richer families compared to the poor, and in North China compared to the South. Therefore, as the economy grows there will be a as higher proportion of households who could afford to consume at high volume. This could potentially have resulted for the difference between revenue function,  $R'(f, T) - R(f, T)$  to be positive. This is based on previous conjecture that increment in power consumption could potentially resulted to more revenue to be collected [3]. However, empirical studies in [14] on household energy consumption in developing countries indicate that energy consumption in households rises at a small rate as household income increases, and may even decline. This is consistent with the growth in energy demand in Third World that seem to be mainly levels and largely dependent on ownership of appliances. Data from the Philippines suggests that the location of the household affects electricity appliance ownership and usage of the electricity and the growth in electricity seems to exist at nearly all income level. Among household in the same general socio-economic class, those living in the primary city, Manila, had more appliances and consumed more electricity than did households living in more provincial urban areas.

### 2.3. The impact of changes in Tariff Charge Function, $\Delta T(w)$ on $R'(f, T) - R(f, T)$

For this paper, the data analytics framework is based on three-tier IBT or also known as progressive tariffs. The IBTs divides household electricity consumption into several blocks, and certain price is applied to a defined block. In IBT, the price of electricity will be low for consumption up to a certain limit, whereby any consumption exceeding this limit will be charged a higher price. The volume of electricity consumption in each block represents an electricity demand of an income group. Generally, the initial block is designed to meet household needs for essential purposes, and the volume is higher in developed countries compared to in developing countries due to their high standard of living. The second

block is used to meet the basic demand of low income urban household which is not too high. While the third block focuses on the urban middle and upper middle-income household. The three-tier IBT is a pricing model that charges high rate per kWh at higher levels of energy usage and a low rate per kWh at lower level of energy usage [15]. Therefore, the changes in tariff charge function,  $\Delta T(w)$  are mainly influence by the structure of the IBT which include the number of block, the volume and price in different blocks. This also means based on previous conjecture the changes in tariff charge could generate revenues for the government. The number of block are theoretically considering the gaps between incomes and the tiers are set to ensure an efficiency of income redistribution. Hence, higher number of block could potentially have resulted for the difference between revenue function,  $R'(f, T) - R(f, T)$  to be positive. For example, considering the higher requirement on voltage equipment and administrative costs, the common structure of IBT's in developed countries usually consists of three to six tiers to ensure economic efficiencies. In addition, a larger gap of electricity price between the blocks can improve the efficiency of the tariff charge function. This is because the lowest rate in the initial block is determined at subsidized rate while the highest rate in tariff charge function is used to compensate for the subsidy. Hence, a larger price gap between the blocks could possibly resulted for the difference between revenue function,  $R'(f, T) - R(f, T)$  to be positive. However, [16] argued that the IBTs in developing countries might not achieve the goal of alleviating poverty, instead it might make the situation worse because of the lack of access to the network and larger number of poor household. Other than that, [16] also claimed that even though there are income distribution effect, the effect is still limited and might be less significant than expected.

### 3. Conclusion

With introduction of IBR mechanism in 2010, the electricity industry had to undergo several changes. These changes are important to ensure the supply industry could pursue economic efficiencies since IBR aims to ensure that electricity tariff setting is conducted in orderly and transparent manner with emphasis on more efficient utility performance [2]. With that motivation, this paper is interested to presents a data analytics framework that presents altered revenue function based on varying power consumption distribution and tariff charge function. The altered revenue function is useful to give an indication on whether any changes in the power consumption distribution and tariff charges will give positive or negative impact to TNB revenue. Based on the finding of this study, major changes on tariff charge function seems to affect altered revenue function more than power consumption distribution. Therefore, the paper concludes that power consumption distribution and tariff charge function can influence TNB revenue to some great extent.

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