Analyzing the Open Electricity Market in Singapore using Data Science Approaches

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Abstract

The Open Electricity Market in Singapore (OEM) was soft launched in April 2018 by the Energy Market Authority (EMA). As a form of further deregulation in Singapore's electricity industry, the OEM was established to further promote competition and innovation in the power industry. Apart from the default retailer, SP Services Ltd, households are given the opportunity to select their preferred electricity retailer. With the increasing competition from growing retailers, this study analyses and predicts the market shares of the available retailers using descriptive statistics and creating a multiple linear regression model. Out of the identified six retailers, this study is able to obtain predictive modelling equations for SP Services, Keppel Electric and Senoko Energy Supply's market shares through elimination of variables of no statistical significance.

Keywords
Open electricity market, market shares, prediction, multiple linear regression model

1. Introduction

With Singapore's high dependency on trade and foreign investments, coupled with the increased competition from neighboring developing countries, Singapore has identified the necessity of deregulation in the country's electricity industry. Defined as the removal process of restrictions in an industry, deregulation is perceived to be able to lower electricity costs due to efficiency gains from market competition and lower costs for consumers. Although the outcomes of deregulation in electricity markets differ (Arocena et al., 2002; Besant-Jones and Tenenbaum, 2001; Brennan et al, 2002; Cabral, 2002; Clark, 2001; Sioshansi, 2002), many countries such as the United States and Australia have taken steps towards reformation in the energy sector. As such, Singapore has taken cautious measures in attempts to deregulate the industry since 1995. Through deregulation, Singapore aims to lower costs of electricity and achieve greater efficiency in hope to remain attractive to foreign direct investments.

Prior to 2001, Singapore Power (SP) Services Ltd was the sole electricity supplier licensed to provide electricity at published tariffs to the residential and business sectors (Chang and Tay, 2004; EMA, 2010). As a result, the Energy Market Authority (EMA) was set up in 2001 to achieve greater liberalization and create competition in the energy and gas industries (EMA, 2015). To promote effective competition in the energy market for a dynamic energy sector in Singapore, the EMA introduced retail competition where the electricity market was opened up to new players (Liew, 2020).

At the initial stage of partial deregulation in July 2001, various electricity retailers first targeted to supply large-volume electricity consumers of maximum power requirements exceeding 2MW (Chang and Tay, 2004). Contestable consumers could choose between Singapore Power (SP) Services, the default Public Electricity Supplier (PES), or other retailers of their choice under the day-ahead market of Singapore Electricity Pool (SEP) (Chang and Tay, 2004).

Over the years, the liberalization of the electricity market was taken to the next level to reach out to the masses and into the household sector. Moving forward, the EMA initiated the launch of the Open Electricity Market (OEM) in Singapore. The OEM initiative was established to further encourage competition and innovation in the power industry (EMA, 2010; Liew, 2020). Apart from SP Services, more electricity retailers have been made eligible to supply electricity. Consumers are now able to enjoy more flexibility and select their electricity supplier based on their personal preferences. Through the online comparison tool launched by the OEM, consumers are able to determine the best price plan for themselves based on personal information such as the type of dwelling, preferred contract type and average household electrical consumption. Furthermore, competitive pricings and offers for the same electrical supply are to the consumers' benefit.

Likewise, the OEM was released gradually in phases after the official OEM announcement in October 2017. Kicking off with the soft launch in April 2018 in Jurong, the initiative progressively expanded to all other regions in Singapore since its official launch in November 2018 (Liew, 2020; SingSaver, 2020). By August 2019, 40% of Singapore households have tapped on one of the other electricity retailers to power up their homes. Electricity retailers offer prices that could reach as low as 75% of the default electricity tariffs offered by SP Services (Tang, 2018; Loi and Putra, 2018; Kuttan, 2018). In 2019, the top 3 OEM retailers aside from SP Services compromises of Tuas Power Supply, Seraya Energy and Keppel Electric, owning 15.1%, 14.5% and 14.1% of market shares respectively (EMA, 2019).

In this paper, we aim to first conduct a univariate analysis on the growth of electrical consumption, establish a relationship between variables contributing to the growth of electrical demand and the market shares of existing electricity retailers as well as form predictive modelling functions that can be used to estimate and predict the future market shares of the retailers.

2. Methodology

2.1 Descriptive Statistics

Descriptive statistics are known as brief descriptive coefficients that are often used to summarize a given data set. The use of descriptive statistics forms the foundation of any quantitative analysis of data, where it highlights the basic features based on the immediate data alone. Descriptive statistics compromises of three main characteristics, namely the measures of central tendency, measures of dispersion as well as distribution. Central tendency is defined as an estimated center of a distribution of values, mainly consisting of three types: mean, median and mode. On the other hand, dispersion measures the variability of the data, where the two most commonly used methods are the range and standard deviation.

In this study, distribution is the most prominently used measure. Often depicted in a form of a histogram or bar chart, distribution summarizes the frequency of individual values or ranges of values for an identified variable. Since this study revolves around the analyzing proportions of market shares and electrical consumption based on varying variables, retrieved data were mostly represented in bar and pie charts to conduct a univariate analysis by depicting the distribution of a certain variable.

2.2 Rationale and Calculation of the Herfindahl-Hirschman Index (HHI)

With the growing electricity market, it is important to depict the growth and identify the significance of key players in Singapore's electricity market. In order to better understand the level of competition in the industry over the identified time period, this study incorporates the use of the Herfindahl-Hirschman Index (HHI).

HHI is a common index used to measure the market concentration of an industry, where it gives an indication on how the distribution occurs in an industry (Hayes, 2020). A highly concentrated industry has a HHI >2,500, indicating a near-monopolistic market where there are only a few key players who are holding a large percentage of the market share. On the other hand, industries with a HHI <1,500 have low market concentration with many equivalent key players, implying a near-perfect competition scenario.

The HHI value of the electricity market was calculated using the formula below:

$$HHI = s_1^2+s_2^2+s_3^2+\ldots s_n^2, \quad (1)$$

where s_n stands for the market share percentage of firm n expressed as a whole number.

2.3 Multiple Linear Regression (MLR) Analysis

A regression analysis is typically used to describe a relationship between two identified variables based on an observed data set, where it predicts the values of the dependent variable based on the independent variable. However, multiple linear regression (MLR) is an extended statistical technique that requires two or more independent variables in order to predict the outcome of the response variable, on the assumptions that there is a linear relationship between the independent and dependent variables and variables are normally distributed. A dependent variable is modelled as a function of several independent variables with respective coefficients, along with the constant term.

The multiple regression equation is expressed as follows:

$$y = m_1x_1 + m_2x_2 + m_3x_3 + \ldots m_nx_n + c, \quad (2)$$

where the subscripts of m represent the corresponding regression coefficients calculated and c representing the y-intercept.

The use of a MLR model can allow the identification of the strength of the effect that the identified independent variables have on the market shares of electricity retailers. Furthermore, MLR forecasts effects of changes to predict future values. In this case, we want to be able to understand how much the market shares of the electricity retailers will change when the independent variables fluctuate.

Therefore, this study aims to build a multiple regression model with the market shares of each electricity retailer as the dependent variable, by considering a range of independent variables. The starting independent variables identified are the overall average housing electricity consumption, HHI, average electricity consumption in both private and public housing, as well as the average electricity consumption in individual regions.

In this prediction model, it is essential to ensure that the independent variables used for the final regression function are statistically significant. In order to do so, the resultant p-value of the default model is taken into account. The p-value is the probability of obtaining a result as or more extreme than the one obtained in a random distribution. In simpler terms, it is the probability of the estimated regression coefficient of the independent variable being unreliable. As such, only independent variables with p-values smaller than 0.05 are deemed as statistically significant to be used in the model.

Using the Data Analysis Tool in Microsoft Excel, the default regression model will be ran for each individual electricity retailers. Independent variables with p-value larger than 0.05 will be removed from the model. Through this stepwise elimination approach, this study will build final regression equations for each electricity retailer.

3. Data Collection

The data used in this paper was retrieved from the official Energy Market Authority website. (https://www.ema.gov.sg/Singapore_Energy_Statistics.aspx). The data used in this paper focuses on the time frame of 2005-2019, consisting of the current market shares of electricity retailers, total electrical consumption of sub-sectors as well as the average monthly electricity consumption in households by dwelling type and region.

Specifically, this paper focuses on the electricity retailers that are holding the six largest proportions of market shares as of 2019. Namely, they are SP Services, Tuas Power Supply, Seraya Energy, Keppel Electric, Senoko Energy Supply and Sembcorp Power.

4. Results and Discussion

4.1 Graphical Results

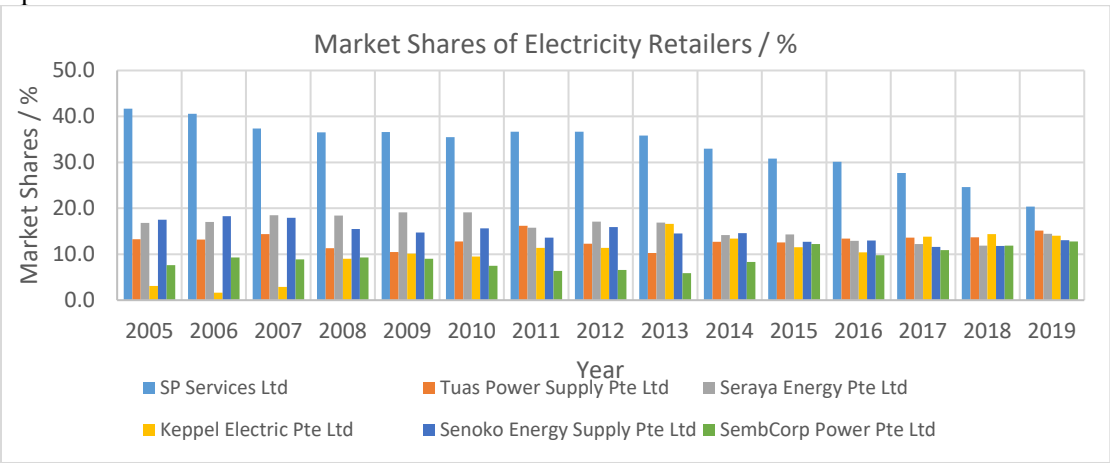

Figure 1: Market shares of respective electricity retailers from 2005-2019

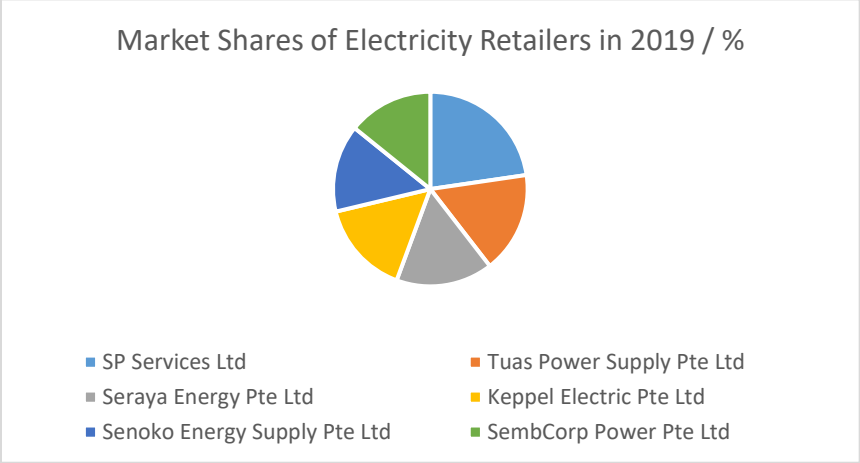

Figure 2: Market shares of respective electricity retailers in 2019

Over the 15 years, there has been a significant decrease in SP Services's market shares, as observed from Figure 1, dropping from the initial 41.7% in 2005 to 20.4% in 2019. There was a prominent sharp decline especially from 2016 to 2019. Despite this, SP Services managed to secure majority of the market shares even with the increased competition.

On the other hand, other market retailers' shares showed different fluctuations through the time period. Keppel Electric showed the largest increase in market shares from 2005, even experiencing sharp peaks in 2008 and 2013. In 2011, Tuas Power and Keppel Electric showed a significant increase in market shares while contrastingly, Senoko Energy, Sembcorp Power and Seraya Energy experienced a prominent dip. It is inferable that the change in market shares of other competing retailers greatly affects the extent of change in one's shares. Out of all retailers, Senoko Energy is noted to be the most sensitive retailer to competition. Specifically, Senoko Energy's market shares showed the most counter-changes depending on the fluctuations of that of the other retailers.

From 2017, the market shares of other retailers gradually became more evenly distributed, corresponding to the time period of the launch of the OEM. As observed in Figure 2, by 2019, all six retailers have a similar proportion of market shares, achieving an almost even distribution. With the growth of the electricity market being highly dependent on the overall electrical consumption, it is necessary for retailers to be aware of the breakdown in the country's electrical consumption.

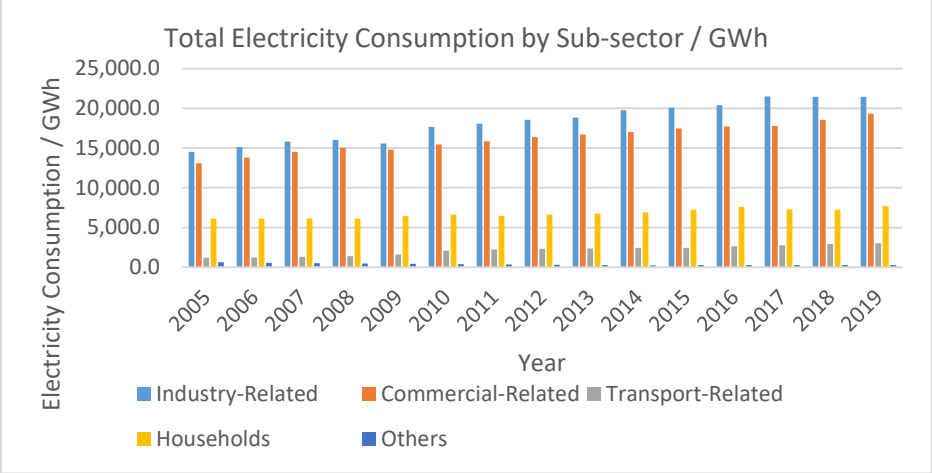

Figure 3: Total electricity consumption by respective sub-sectors

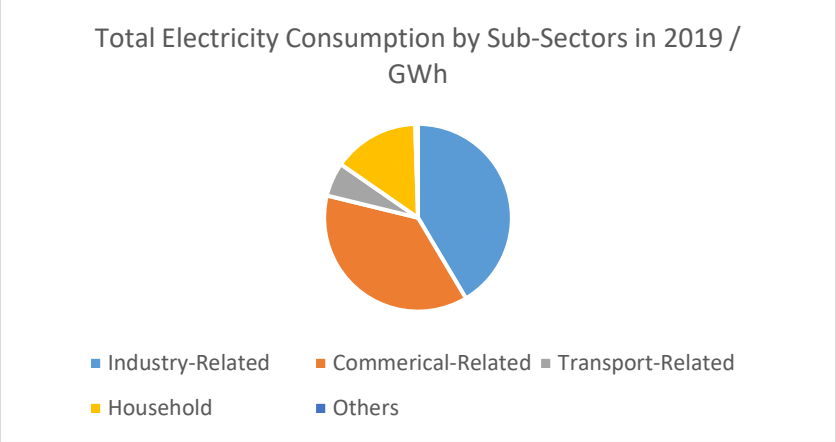

Figure 4: Total electricity consumption by respective sub-sectors in 2019

As observed in Figure 3, there has been a general increase in total electrical consumption in all sub-sectors. The increase in electrical consumption in the industrial and commercial related sub-sectors are particularly prominent, rising from the initial 14,509 GWh and 13,075 GWh in 2005 to 21,444 GWh and 19,315 GWh in 2019 respectively. The industrial and commercial-related sub sectors remain as the top two sub-sectors with the largest electricity consumption through the years.

On the other hand, the transport and household sub-sectors showed a more gradual increase. Specifically, compared to the other sub-sectors, the household sub-sector had the most consistent total electricity consumption, fluctuating in the 6092-7688 GWh range from 2005 to 2019.

Unlike the electricity market shares, the proportion of total electricity consumption of the different sub-sectors remained the same until 2019. In Figure 4, is depicted that the industrial and commercial-related sub-sectors both have

a relatively similar proportion and take up the majority of the total electricity consumption. The household sector remains as the third sub-sector in total electricity consumption, followed by the transport sub-sector.

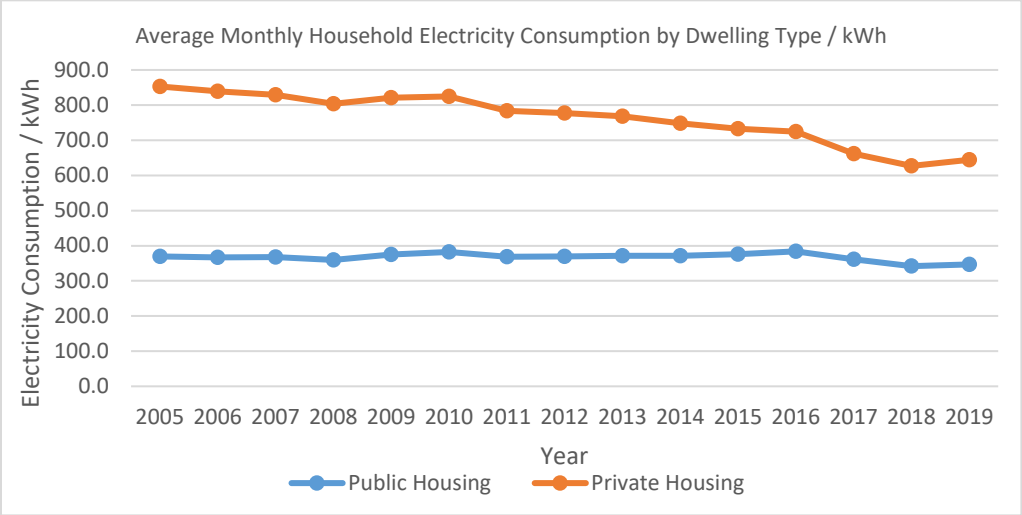

Figure 5: Average monthly household electricity consumption by dwelling type

Narrowing into the main target audience of the OEM, the household sub-sector, Figure 5 shows the changes in the average monthly household electricity consumption in both private and public housing. There has been a more significant drop in the average monthly consumption in private housing, dipping from the initial 853 kWh in 2005 to 644 kWh in 2019. Contrastingly, the average monthly consumption in public housing has remained consistent in the approximate 340-390 kWh range, without any prominent changes through the years.

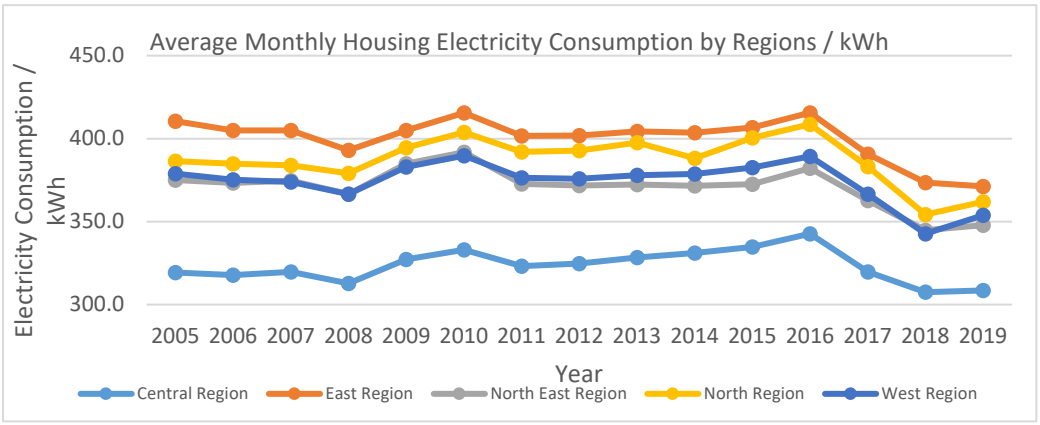

Figure 6: Average monthly electricity consumption by respective regions

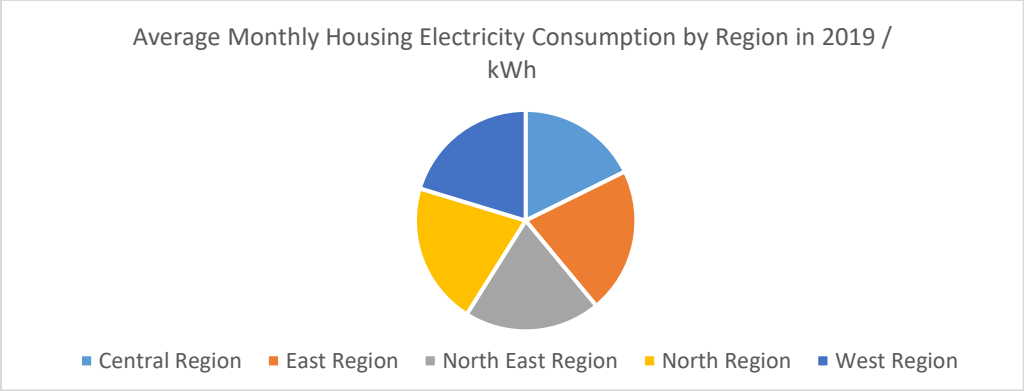

Figure 7: Average monthly electricity consumption by respective regions in 2019

Additionally, the household sub-sector can be further divided into separate regions: Central, East, Northeast, North and West Region. There is no doubt that the electricity consumption in the various regions are constantly differing. However, based on Figure 6, it is observed that the overall shape of all graphs are similar, where the electricity consumption in all regions exhibit similar up and down trends over the years. Particularly, from 2008 to 2010, all regions showed a significant rise in the amount of electricity consumed. Likewise, from 2016-2018, all regions too showed a prominent drop in electricity consumption.

Similar to the electricity consumption in sub-sectors, the proportion of average monthly electricity consumption by the regions remain consistent throughout. The east region consumes the most electricity, followed by the north region, west region, northeast region and finally the central region. The proportion of electricity consumed are also evenly distributed, as shown in Figure 7, where all regions consume a monthly average of around 300-370 kWh of electricity each in 2019.

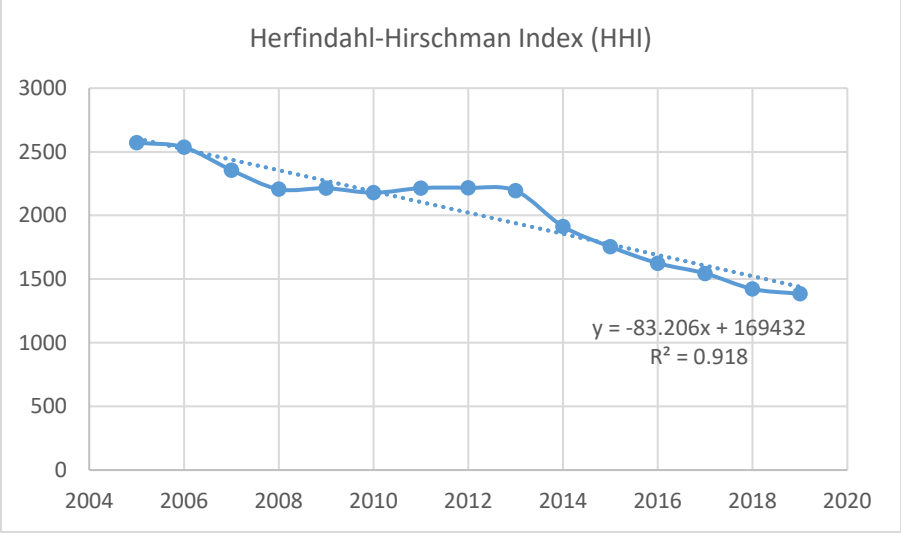

Figure 8: Calculated HHI of Singapore's electricity retail market

As observed from Figure 8, there has been a decrease in HHI from the initial 2,571 in 2005 to 1,384 in 2019. This indicates the immense growth in the electricity market, initially starting from a highly concentrated industry with a single retailer to a competitive market with many strong key players. This result corresponds with the earlier Figures 1 and 2 depicting the significant growth of non-default retailers.

Furthermore, it is observed that there was a drastic drop in HHI in 2014. This observation corresponds to Figure 1 where the market shares of other retailers begin to show a more even distribution in 2014. Since the HHI of the electricity industry is strongly dependent on the respective market shares of retailers, this indicates the increasing competition in the market, with more retailers becoming stronger contestants.

4.2 Multiple Linear Regression Results

4.2.1 Singapore Power Services Pte Ltd

Table 1: Singapore Power Services' Market Shares

Independent Variable	Coefficients
Overall average housing electricity consumption	.058 (.026)*
HHI	.013 (.001)*
Constant	-19.627
R^2	.963
Significant-F	2.8E-09*

* $p < .05$

As seen in Table 1, the results obtained indicate that the market shares of SP services are mainly affected by the overall average housing electricity consumption as well as calculated HHI. This result corresponds to the idea that SP Services is Singapore's default household electricity retailer. Rather than being affected by the more detailed variables, their predicted market shares will mainly be based on the country's overall consumption and the growth of the electricity market.

Based on Figure 8, the calculated HHI of Singapore's electricity market have been facing a consistent drop. It is noticeable that SP Services was the sole retailer that had a constant decrease in market shares over the years while the remaining retailers fluctuated over the same time span. This explains the on why HHI as an independent variable has proved statistical significance only to SP Services.

Therefore, the final modelling equation obtained is as follows:

$$\textit{Predicted market shares} = 0.058 * \textit{overall average housing electricity consumption} + 0.013 * \textit{HHI} - 19.627 \quad (3)$$

4.2.2 Keppel Electric Pte Ltd

Table 2: Keppel Electric's Market Shares

Independent Variable	Coefficients
Average housing electricity consumption in public housing	-4.004 (1.037)*
Average housing electricity consumption in Central Region	1.497 (.324)*
Average housing electricity consumption	.871 (.302)*

in North-east Region	
Average housing electricity consumption in North Region	.839 (.221)*
Average housing electricity consumption in West Region	.770 (.478)*
Constant	60.740
R^2	.856
Significant-F	.001*

* $p < .05$

Based on Table 2, unlike SP Services, Keppel Electric market shares show heavy correlation on detailed variables rather than the overall growth in the electricity market. Out of all six identified retailers, Keppel Electric's results show the heaviest reliance on average housing electricity consumption in regions, with 5 out of 6 allocated regions being statistically significant to Keppel. Furthermore, with Keppel being the first homegrown electricity retailer to join the OEM, it has successfully reached into the masses through its experience. As such, the model emphasizes that its market shares are too reliant on the average electricity consumption in public housing.

Therefore, the final modelling equation obtained is as follows:

$$\textit{Predicted market shares} = -4.004*\#\textit{public housing} + 1.497*\#\textit{central region} + 0.871*\#\textit{north-east region} + 0.839*\#\textit{north region} + 0.770*\#\textit{west region} + 60.740, \quad (4)$$

average housing electricity consumption in

4.2.3 Senoko Energy Supply Pte Ltd

Table 3: Senoko Energy Supply's Market Shares

Independent Variable	Coefficients
Overall average housing electricity consumption	.229 (.038)*
Average housing electricity consumption in Central Region	-.098 (.074)*
Average housing electricity consumption in North Region	-.161 (.077)*
Constant	2.923
R^2	.849
Significant-F	8.2E-05*

* $p < .05$

The result of the model implies that Senoko Energy Supply's market shares are most diversely affected, as seen from Table 3. Not only does the country's overall consumption prove as a statistically significant variable, targeted variables consisting of the average consumption in both central and north region have also indicated their significance. This

diverse range of affecting independent variables corresponds with Figure 1, where it has been previously noted that Senoko Energy's market shares have shown the most sensitivity over the years.

Therefore, the final modelling equation obtained is as follows:

$$\textit{Predicted market shares} = 0.229*\textit{overall average housing electricity consumption} - 0.098*\#\textit{central region} - 0.161*\#\textit{north region} + 2.923 \quad (5)$$

average housing electricity consumption in

4.2.4 Tuas Power Supply, Sembcorp Power & Seraya Energy

Unlike their counterparts, Tuas Power Supply, Sembcorp Power and Seraya Energy analysis result showed that the identified independent variables were of no statistical significance to them. A possible identified reason is due to their main consumers being larger audiences such as businesses. Unlike the other retailers, these three retailers are subsidiaries of Singapore's main power producers. Based on data obtained from EMA, Tuas Power holds the largest market share in electricity generation of 20.9% as of 2019. The parent organization of Sembcorp Power and Seraya Energy are also in the top five of electricity generation's market shareholders, owning 11.9% and 15.0% of shares respectively. Additionally, all three companies are part of Singapore's main power producers, owning large amounts of electricity generation capacity. Specifically, Tuas Power owns a total of 2,597 MWh, followed by YTL PowerSeraya owning 2,402 MWh and Sembcorp Cogen owning 1,188 MWh of generation capacity.

As a strong player in the electricity generation sector, this implies that the three retailers are focused on supplying energy to the country as a whole, rather than focusing on a single sub-sector. As such, it is viable that their electricity retail market targets the larger consumers such as small businesses, and market shares are not as easily affected by the consumption and trends identified in the household sub-sector.

5. Conclusion

With the heavy reliance on electricity in today's world, Singapore's electricity market is expected to grow and improve to keep up with this increasing demand. With the implementation of further deregulation in the household-targeted electricity retail market, the effects of liberalization are prominent. No longer being solely reliant on the default retailer (SP Services), new key players have entered and even dominated the market.

This study implements the use of descriptive statistics to explore the variables behind the growth of the electricity market. The results indicate that the launch of the OEM has catalyzed the growth of these new key players to such a large extent that it has resulted in an almost-perfect competitive market, with the HHI decreasing steadily over the years. The market shares of key players in the electricity market have also shown greater fluctuations and will definitely continue to change in the future.

Additionally, this study applies a multiple regression linear model for retailers to better identify the variables that are of most importance to their market shares. First, this model incorporates a large number of variables related to the electrical consumption growth in the household sub-sector as independent variables. Second, a stepwise elimination approach is applied for each retailer to identify only statistically significant variables. As such, a customized multiple regression equation is formed for each retailer.

Out of the six identified electricity retailers, this study managed to obtain predictive modelling equations for SP Services, Keppel Electric as well as Senoko Energy. Results from the multiple regression model have too corresponded to the trends identified in Figures 1-8. With the identified independent variables revolving around the electrical consumption in household sub-sectors, the variables have proved insignificant to the remaining three retailers, which targets larger consumers. However, this study precludes the consideration of external factors that could affect future electrical consumption in households such as the effects of the Covid-19 pandemic. A partial equilibrium analysis could be incorporated to better investigate the supply and demand in the electricity market. Nonetheless, this model has allowed the examination of the relationship between the market shares of electricity retailers and the electrical consumption within the household sub-sector.

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