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Analysing households' responsiveness towards socio-economic determinants of residential electricity consumption in Singapore

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ABSTRACT

The research of household electricity use is still relatively new for Singapore, where apart from some government surveys and sparingly available papers, not much has been done to understand the underlying socio-economic determinants that affect residents' energy demand. Here, we seek to quantify price and income elasticities, as well as provide reasonable justification for price asymmetry in Singapore using a panel approach across dwelling types and geographical areas. We find that households do not react much to prices, and that price elasticities may decrease as income rises. There is also some evidence of price asymmetry, with surprising results putting responsiveness towards price decreases larger than price increases. This points towards similar behavioural patterns with the rebound effect for household energy efficiency, if found present in future studies. Our findings suggest that there will only be positive responses towards dynamic pricing and higher churn rates if more transparent information is provided on related cost savings, when households are exposed to retail choice in the electricity market after full retail competition is introduced in 2018. In addition, a large role will have to come from cultivating the young to engage in sustainable practices to achieve energy efficiency targets.

1. Introduction

In the past decade, Singapore's household income has risen at levels greater than that of its increase in Gross Domestic Product. This points towards both a more inelastic response towards price and income changes on electricity use, as household expenditure starts to rise disproportionately away into other consumer services. The demand for air conditioners (ACs) is already approaching saturation point, where the household penetration rate of AC has been around 75–80% (National Environment Agency (NEA), 2013. Euromonitor, 2016) for the past few years and show no signs of increasing. Population aging may be the reason for this, where elderly people prefer higher temperatures than their younger counterparts (Loi and Loo, 2016), hence do not require ACs in their homes. At the same time, as more people value personal freedom and hence start families later in life, the household size has been decreasing year by year.

There is also some observed heterogeneity in the electricity usage for households both across dwelling types and even across geographical boundaries, despite being a small nation-state. The latter is because of two reasons. Firstly, the income of households varies across different regions, where the proportion of richer households at and above the median income level are higher in specific areas (Table 1), such as Bukit Timah, Bishan, Pasir Ris and Punggol (Department of Statistics Singapore (DOS), 2016). The share of the wealthy[1] (household income above $10,000/month) also exceeds 30% in these areas. This points towards higher average electricity usage in these regions. Secondly, energy efficiency awareness programmes are promoted differently across districts, with varying levels of importance and scale. For example, the North-West and South-West districts have been comparatively more active in promoting reduced energy usage via activities in 2014-15, such as the Recycle-A-Bulb Challenge @ South-West, Eco-Living @ South-West, and the Green Homes @ North-West campaigns.[2] These campaigns may have led to comparatively greater reduction in electricity use for these regions, ceteris paribus.

Hence, in light of these observations and developments, and that not much has been done to model Singapore's residential electricity demand in recent years, it is important to provide reliable estimates on price, income, and demographics as suitable indicators of electricity demand in recent context. These estimates should account for differences due to geographical distribution and dwelling types.

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[1] $10,000/month corresponds to $120,000/year, which we deem as wealthy. Here, our definition of wealthy households is based on the classification of income deciles as provided in the household income statistics provided by the Singapore Department of Statistics (DOS). $10,000 & over' is classified as the highest possible decile we can use in our analysis. Please refer to http://www.singstat.gov.sg/statistics/browse-by-theme/household-income-tables for more information.

[2] More information about such district campaigns can be found at https://www.cgs.sg/news-awards.

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Table 1
Proportion of households earning $8000 or more in 2015* (Median Income = $8666).

Overall	35%
Central Region	
Bishan	48%
Bukit Merah	27%
Bukit Timah	67%
Geylang	26%
Kallang	27%
Marine Parade	44%
Novena	42%
Outram	15%
Queenstown	30%
Rochor	27%
Tanglin	69%
Toa Payoh	28%
East Region	
Bedok	36%
Pasir Ris	46%
Tampines	36%
North East Region	
Ang Mo Kio	28%
Hougang	33%
Punggol	43%
Sengkang	40%
Serangoon	44%
North Region	
Sembawang	38%
Woodlands	29%
Yishun	27%
West Region	
Bukit Batok	39%
Bukit Panjang	36%
Choa Chu Kang	40%
Clementi	34%
Jurong East	33%
Jurong West	30%

* Author's own calculations from EMA (2015).

This paper attempts to construct explanatory models for Singapore's household electricity demand, centred on two main focus areas. We will determine long-run elasticities for prices and income relative to electricity consumption before opening a discussion on how this matters for energy savings and retail competition in the future. In addition to this, price asymmetry and the rebound phenomenon will be discussed in Singapore's context, since consumers may choose to use more electricity when prices fall. How consumers respond to increased prices may be different from periods of price decreases. The rebound effect has been estimated with varying levels of magnitude in mostly temperate countries like the USA, the UK and China. However, tropical countries with fairly non-varying temperatures, such as Singapore, are still relatively unknown in terms of the phenomenon itself. In general, single country rebound studies are uncommon in the tropical regions. We aim to add on to this study with the introduction of a pure price rebound analysis for Singapore based on asymmetry in this context.

This work comes crucially at a period where retail market competition is still relatively new in Singapore for smaller consumers of electricity, with small-medium sized enterprises (SMEs) just getting used to having a choice for their electricity retailer since 2014. The final phase for liberalization will involve residential consumers in 2018. This means that the smallest electricity consumers in Singapore will soon be able to make their own decisions on the retailers to buy their power from. As such, understanding how households react to determinants that affect their energy behaviour is a necessary venture, as it will certainly have an impact on policy developments related to many issues, such as load shifting and dynamic pricing mechanisms for Singapore.

We find that in general, price elasticities[3] are no greater than −0.271, isolating the effect of less elastic income effects and energy efficiency policy initiatives. Household size is a large factor determining the size of average electricity demand (Vringer and Blok, 1995; Moll et al., 2005; Brounen et al., 2012; Kelly, 2011), whereas it is possible that electricity use becomes less price elastic as income rises. The presence of asymmetry is inconclusive in terms of estimated magnitudes, although it signals the possibility that consumers respond to price decreases more than price increases, which indicates the rebound effect may follow the same trend as well.

In our paper, we will first summarize relevant literature that provided the motivation for our study. We then describe the data sources and methodological structure, which we use for our regression specifications. Subsequently, we will display the results in the following section, which also are analysed with more existing literature and other statistics. In this section, we also present the asymmetric possibilities present in Singapore's electricity demand, and how it could be relevant to the rebound effect. We include a separate section for further policy discussion on their possible impacts on demand response and the constraints we face in the study. The conclusion will round up the details of our study and highlight important areas for future work.

2. Literature review

Here, we present a brief literature summary corresponding to previous studies that are conducted with respect to the panel regression of residential sector energy consumption focused primarily on single country analyses. We will also include analyses related to price asymmetry as it is related to an important objective of our research.

Studies that analyse energy consumption based on panel data are typically focused on disaggregated household survey data that are conducted by state governments, due to the amount of financial expense and work required to collect detailed private information from the homeowners and/or renters. The Residential Electricity Consumption (RECS) survey and American Housing Survey (AHS) in the US are two sources with very large datasets where authors like Reiss and White (2005), Poyer et al. (1997), Poyer and Williams (1993), as well as Albertini et al. (2011) have utilized to construct detailed demand models to explain energy consumption based on the influence from socio-economic variables and dwelling characteristics. Other countries, such as Netherlands (Brounen et al., 2012) and Canada (Bernard et al., 2010), use similar datasets in their respective countries to investigate price and income elasticities as well. In particular, Albertini et al. (2011) utilized AHS data over six years, using almost 75,000 households to identify determinants for electricity and gas consumption specifically focused on large cities in the US. They estimated price elasticities at −0.736 for electricity consumption and −0.572 for gas consumption, both larger than previous studies on the US, such as Reiss and White (2005) at −0.39 for California, and Garcia-Cerrutti (2000) estimates. A recent Swiss study (Boogen, 2017) used survey data collected from utility companies instead and conducted a stochastic frontier function approach to identify household inefficiency in electricity use.

Another large segment of research deal mainly with aggregated data across either states within a country, or across multiple countries. For example, Salari and Javid (2016) use yearly U.S. data across just nine years from 2005 to 2013 to model electricity consumption across 50 states, using both static and dynamic Generalized Method of Moment (GMM) models. Blázquez et al. (2013) also use similar models to determine short and long run elasticities with nine years of data as well

[3] Price elasticity is defined as (% change in electricity demanded)/(% change in electricity price). In general, elasticities tell us how much people change electricity consumption with respect to a variable, such as price or income when they change. This is denoted in percentage terms.