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The impact of Singapore's residential electricity conservation efforts and the way forward. Insights from the bounds testing approach

Tian Sheng Allan Loi *, Soh Leng Loo

Energy Studies Institute, National University of Singapore, 29 Heng Mui Keng Terrace, Block A #10-01, Singapore

HIGHLIGHTS

- We estimate an electricity consumption model for Singapore's residential sector.
- Aging negatively affects electricity consumption in the short run.
- Energy efficiency policies seem effective for residential electricity consumption.
- There is still potential for more electricity reduction in Singapore.
- Future conservation measures should account for the role of 'Hassle costs'.

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ABSTRACT

This article provides fresh empirical evidence of residential electricity demand in Singapore over the period of 1980–2014, using the bounds testing procedure to cointegration. The residential electricity demand comprises of income, price, temperature, rainy days, old-age dependency and the impact of energy efficiency policies. Our results are consistent with previous studies, where income and price elasticities are inelastic. Hence, from a policy perspective, subsidies will not be effective in reducing electricity demand. We also found that old-age dependency is an important determinant that reduces electricity consumption at least in the short-run, suggesting that policies that target the younger population may bring more savings.

The model findings suggest that in general, energy efficiency interventions introduced after 2007, which comprises of both informational strategies and efficiency standards, were effective in reducing household electricity consumption. However, in order to realise greater electricity reduction potential, policy efforts have to intensify into the future, with the main objectives being to permanently change energy habits, and consider the role of hassle 'costs' when rolling out energy saving measures.

1. Introduction

The residential sector is an important composition of the total electricity demand in Singapore. According to the Energy Market Authority of Singapore(EMA, 2015), residential consumption comprises 15% of the total electricity demand in Singapore at 6.9 Terawatt hours (TW h) in 2014. During the period between 1980 and 2014, total electricity use increased by a growth rate of 5.8%, which is around a 6.8 times increase. With increasing energy consumption and the need for environmental stability, the Energy Policy Group was formed in 2006 (Putra and Han, 2014) to accelerate Singapore's efforts towards the creation of a more energy efficient, low-carbon and sustainable nation. In conjunction with this establishment which led to increased focus on energy efficiency, there are several other developments pertaining to population characteristics as well. From 1980 to 2014, the elderly population (aged 65 years old and above) has increased nearly threefold. During the same period, real income levels per resident have also increased, while real energy tariffs have remained relatively constant.

There are two main objectives of this paper. First, the elasticities of the determinants for residential electricity consumption in the short-run and long-run during the period of 1980–2014 for Singapore will be estimated. This will be done by constructing an electricity demand model based on temperature, prices, income, old age dependency and policy changes. These determinants have evolved considerably for Singapore during this period, and could possibly affect electricity demand. This will be done by using the recently advanced autoregressive distributed lag model (ARDL)

* Corresponding author.
E-mail addresses: esiltsa@nus.edu.sg, tianshengallanloi@gmail.com (T.S.A. Loi), sohlengloo@gmail.com (S.L. Loo).

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introduced by Pesaran et al. (2001).

Secondly, we discuss the implications of these determinants on their influence on electricity demand, and how should public conservation efforts be geared towards in order to realise greater savings potential for the future. This should be examined in light of households' evolving electricity needs as aging and rising income levels lead to different energy lifestyles, which ultimately determines how residents perceive and adopt energy conservation practices encouraged by policy makers.

Our paper will also contribute to the academic literature in three novel ways. Firstly, to our knowledge there have only been two existing papers that attempt to model electricity demand in Singapore. Ang et al. (1992) estimated the residential demand for electricity between 1972 and 1990 using stepwise regression. However, this method requires a large number of predictor variables, which can be challenging in the presence of data constraints. Goh (2010) specified some residential demand models based on Johansen (1988) approach. However, doing so will make the model vulnerable to spurious co-integrating interactions if some variables used are stationary. Both of these methods have their limitations. We feel that the ARDL bounds testing approach is more reliable in terms of producing both short and long-run estimates, especially when small sample sizes are involved.

Secondly, with the current shift in demographics, developed nations face the trend of growing elderly population and this will have an impact on electricity consumption. According to Singapore's population white paper (National Population and Talent Division, 2013), by 2030 the number of citizens aged 65 years and above will triple to 900,000. This means that a larger share of electricity consumption taken up by the elderly in Singapore's residential sector. There is currently no known literature that focuses on the estimation of electricity demand based on aging dynamics in Singapore. Hence, this paper aims to fill up this gap as Singapore is currently in transition towards an ageing society, with its share of elderly consistently increasing over the years.

Thirdly, the additional parameter, an energy efficiency component, was added into our estimation of Singapore's electricity demand model were previously unexplored in ARDL modelling. These components are important to isolate the impacts of any behavioural or structural changes that could result from weather or energy efficiency policy measures from prices, income and temperature.

The rest of the paper is structured as follows. Section 2 provides an overview of the existing literature in residential electricity demand. Section 3 provides a brief overview of the data used, the empirical specification used for our model, and the bounds testing method. Section 4 presents the results and interpretation of the specified model. Section 5 examines how effective are current electricity conservation efforts and what is required to realise greater savings, discussed in relation to public attitudes and observable household trends. It will also suggest some future policy directions to realise greater energy savings. Finally, Section 6 will conclude the study and highlight important topics for further research.

2. Literature review

Existing literature focuses on the use of cointegration analysis to model energy demand interactions focusing on determining long-run elasticities from cointegrating vectors. These studies typically involve the use of either the Engle and Granger (1987) two-step method, or the Johansen's maximum likelihood (1988) and Johansen and Juselius' (1990, 1992) method for pretesting before specifying an error correction model (ECM). These methods has been used in Goh (2010) paper for Singapore's case, as well as studies such as Silk and Joutz (1997) for the US, Galindo (2005) for Mexico, Holtedahl and Joutz (2004) for Taiwan, and Jamil and Ahmad (2011) for Pakistan. A limitation is that these methods require all variables in the regression to be integrated in order one, $I(1)$ (Pesaran et al., 2001). This means that any inclusion of $I(0)$ stationary variables will lead to spurious cointegrating interactions with other variables.

Hence, there is a growing number of studies that use the bounds testing approach developed by Pesaran et al. (2001) to model household electricity consumption in several developed and developing countries such as the United States (Dergiades and Tsoulfidis, 2008), Australia (Narayan and Smyth, 2005), Turkey (Halicioglu,2007), Iran (Pahlavani et al., 2005) and South Africa (Ziramba, 2008). These studies focus on the use of the autoregressive distributed lag (ARDL) bound test to determine the long run elasticities and optimal number of lags to be used for each regressor, after which an Error-Correction Model (ECM) can be then specified to estimate short run elasticities and speed of adjustment to long-run equilibrium (Banerjee et al., 1993). Ghatak and Siddiki (2001) suggest that this approach can produce more statistically significant results to determine cointegrating relation in small samples, as compared to the Johansen (1988) approach, which restricts both the lagged dependent variables and regressors to possess the same lag orders during pre-testing for the best model. The ARDL avoids having such restrictions, and allows $I(0)$ variables to be included in the specification.

Studies that model electricity demand do so within the framework of household production theory. Ideally, this means electricity consumption should be modelled as a function of own price, price of a substitute fuel for energy, real income, capital stock of household appliances, and other possible determinants that affect household electricity usage patterns. Holtedahl and Joutz (2004) estimated their demand model based on own price, price of oil, population growth, disposable income, degree cooling days, as well as the degree of urbanisation for the period from 1955 to1996. Ziramba (2008) used annual time series data from 1978 to 2005, with only own price of electricity and per capita income as determinants. Dergiades and Tsoulfidis (2008) used per capita stock of housing as a determinant for electricity consumption in addition to own price, income, cooling and heating degrees-days, and the price of oil.

There are many quantitative studies that attempt to incorporate population dynamics such as age structure and household size into residential electricity or energy modelling. Most of them involve micro-level studies that typically comprise of a combination of methods utilising household surveys, such as Krishnamurthy and Kriström (2015), Longhi (2015), Brounen, Kok and Quigley (2012), and Alberini et al. (2011). For macro-level analysis, not much have been found. Sa'ad (2009) uses a structural time series (STSM) approach for Korea, where an underlying energy demand trend is isolated from prices and income, being treated as a combination of structural population change, lifestyle factors, and other variables affecting electricity consumption. There is also one study that focuses on the impact of population ageing on energy use, as what Garau et al. (2013) have done for Italy. This study uses an overlapping generation general equilibrium model to explore the transitional impact of aging on energy use. No studies so far to our knowledge have used age as a regressor in the ARDL modelling of residential electricity demand.

3. Data, empirical specification and econometric methodology

3.1. Data

Electricity consumption per resident rose 4.32 times from

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