Time Variation of Parameters Used in Electricity Demand Models

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Abstract

Many studies estimate the impact of temperature rise on electricity demand based on static regression models (SRMs). However, the assumption of constant parameters is too restrictive to explain electricity demand data containing complex temporal patterns. This study develops a dynamic linear model (DLM) of monthly electricity demand in Japan and demonstrates that the coefficients of cooling and heating degree days (CDD and HDD) stochastically change with time. The estimation result indicates that electricity use for cooling is decreasing while electricity use for heating is increasing.

Introduction

The assumption of constant parameters is too restrictive to explain electricity demand data.

- Time series data of electricity demand contain stochastic trends (Dilaver and Hunt 2011: Energy Economics).
- Price and income elasticities of electricity demand stochastically change with time (Arisoy and Ozturk 2014: Energy).

We develop a dynamic linear model (DLM) of electricity demand in Japan and demonstrate that the coefficients of cooling and heating degree-days (CDD and HDD) are time varying.

Data

➢ **Industrial and residential electricity demands in Japan (Figure 1)**

- The data source is Electricity Survey Statistics published by Agency for Natural Resources and Energy.
- The data period is January 1988—March 2016 (N = 339).

➢ **Degree-day indices (CDD and HDD)**

- We use the population-weighted means of the degree-day indices in the central cities of the 47 prefectures.
- The base temperatures of the degree-day indices are determined through the model selection based on AIC.

Model

The DLM consists of an observation equation and state equations.

- The observation equation describes the relationships between electricity demand and explanatory variables (e.g. CDD, HDD, production, wage, electricity price, and the earthquake dummy).
- The state equations describe the dynamics of parameters. This study assumes that parameters follow Gaussian random walk.
- Unknown parameters are estimated by combining the maximum likelihood estimation and the Kalman filter.
- By the model selection based on AIC, we check whether each parameter is time varying or not (i.e. the state variance is positive or zero).

Observation equation

$$\log E_t = \sigma_t + \mu_t + \sum_{i=1}^{m} \theta_t^i X_t^i + v_t, \quad v_t \sim N(0, V)$$

E_t	Electricity demand	σ_t	Seasonal factor
μ_t	Intercept	$\theta_t^1, \ldots, \theta_t^m$	Coefficients
$X_t^1, \ldots, X_t^m$	Explanatory variables	v_t	Observation error
V	Error variance		

State equations

$$\sigma_{t+1} = -\sum_{j=1}^{s-1} \sigma_{t+1-j} + s_t, \quad s_t \sim N(0, S)$$

$$\mu_{t+1} = \mu_t + w_t, \quad w_t \sim N(0, W)$$

$$\theta_{t+1}^i = \theta_t^i + z_t^i, \quad z_t^i \sim N(0, Z^i)$$

$s_t, w_t^1, \ldots, w_t^m, z_t$ State errors $S, W^1, \ldots, W^m, Z$ Error variances

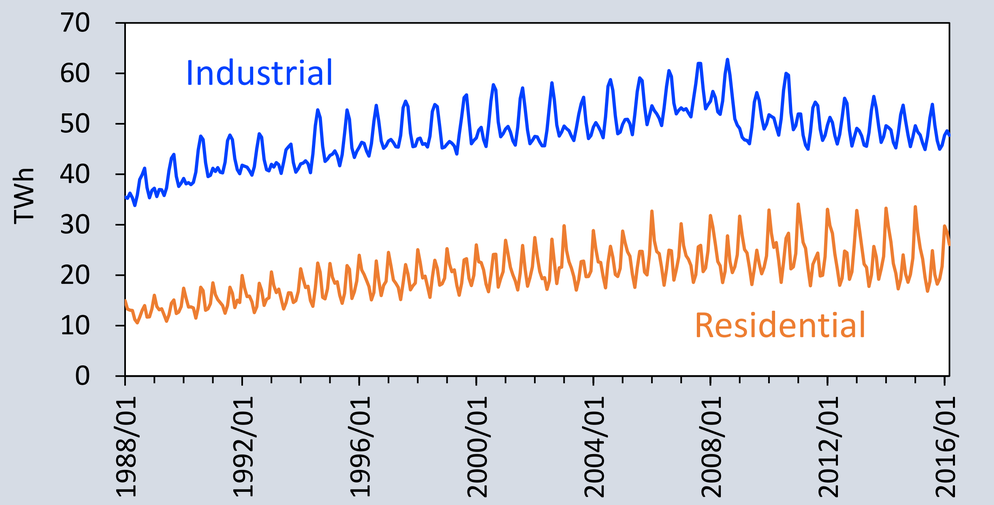

Figure 1: Industrial and residential electricity demands in Japan.

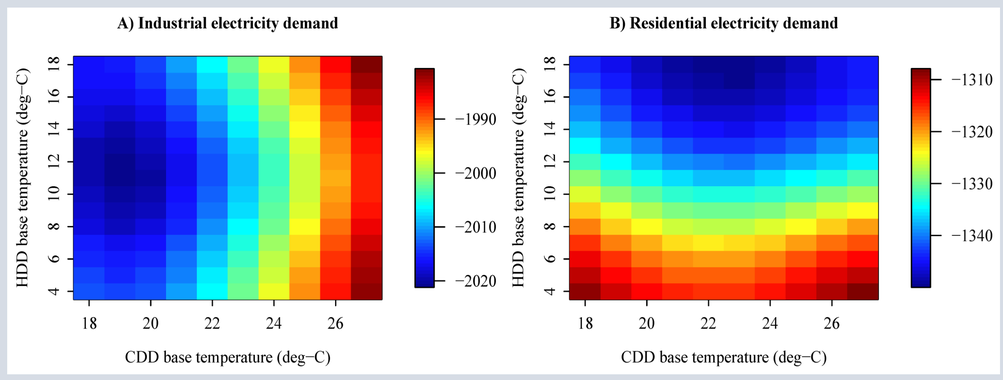

Figure 2: AIC of the electricity demand models under various combinations of the base temperatures.

Results

- In the industrial sector, the base temperatures of CDD and HDD were estimated at 19°C and 11°C, respectively (**Figure 2A**).
- In the residential sector, the base temperatures of CDD and HDD were estimated at 23°C and 18°C, respectively (**Figure 2B**).
- In the industrial and residential sectors, the coefficients of CDD and HDD are time varying (**Figure 3**).
- The CDD coefficients showed increasing trends but began to decrease in the 2000s.
- The HDD coefficients showed increasing trends throughout the period.
- The estimation result indicates that electricity use for cooling is decreasing while electricity use for heating is increasing.

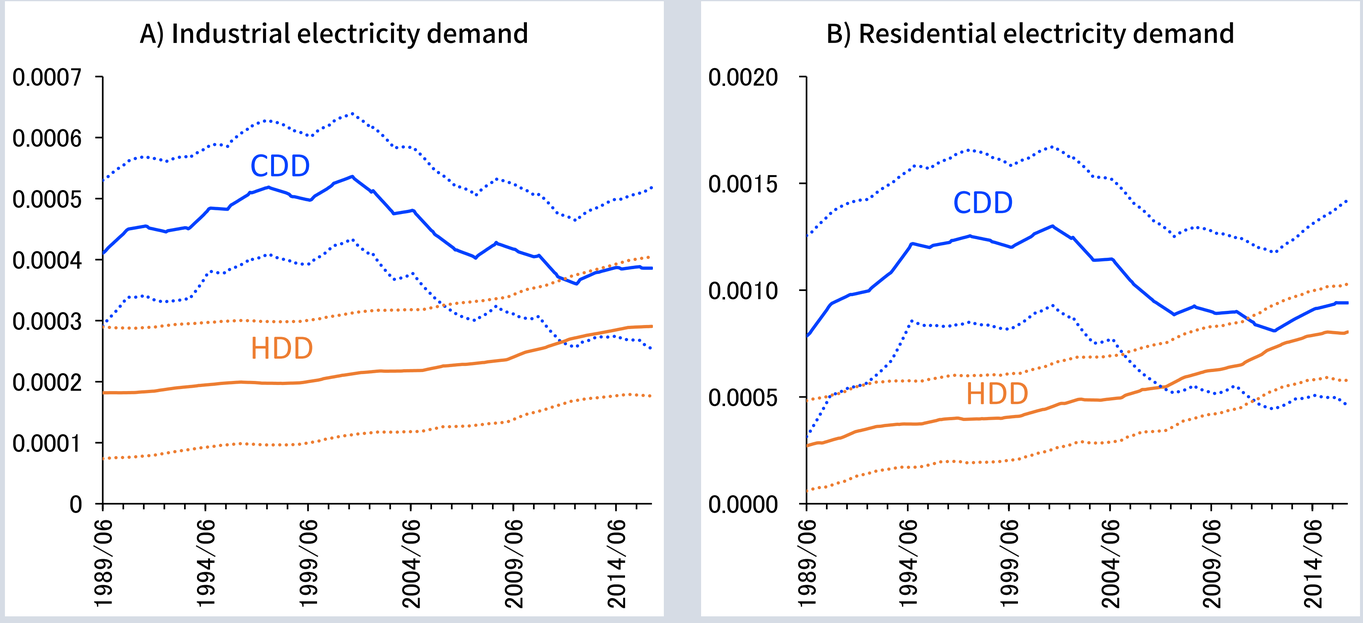

Figure 3: Time-varying coefficients of the CDD and HDD. The broken lines indicate 95% confidence intervals.

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