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Estimating sectoral demands for electricity using the pooled mean group method

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HIGHLIGHTS

- We estimate sectoral electricity demand in the Northeastern U.S. using panel data.
- Cooling degree days have a positive effect in electricity demand in all three sectors.
- Long run own price elasticities are negative in residential and industrial sectors.
- Natural gas has long run substitution effect in residential and commercial sectors.
- Heating oil price has short run positive effect in residential and commercial sectors.

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ABSTRACT

This paper examines the demand for electricity in the residential, commercial, and industrial sectors of the Northeastern United States using state-level panel data over the period from 1997 to 2011. It applies panel unit root and cointegration tests and then estimates the parameters using the pooled mean group method. The panel unit root and cointegration tests show that the series are integrated of order one and cointegrated. The electricity demand for the residential sector is responsive to its own price in the long run, with own price elasticity being −0.11, but irresponsive to own price in the short run. The long run income elasticities of electricity demand for the residential, commercial, and industrial sectors are 0.93, 0.53, and 1.95, respectively. Higher income elasticity implies that energy efficient appliances and the regulation of housing structures might be effective policy tools to promote energy conservation. The short run impact of fuel oil price is significant in the residential and commercial sectors. Cooling degree days have significant positive effects on the demand for electricity in the residential and commercial sectors. The long run cross price elasticities for natural gas in the residential and commercial sectors are 0.095 and 0.105, respectively.

1. Introduction

Estimating the demand for electricity in the residential, commercial, and industrial sectors of the Northeastern United States over the period 1997-2011 is the primary focus of this study. Electricity is one of the major drivers of economic activities in the commercial and industrial sectors of the economy. Heating and cooling of buildings and homes is the single largest use of electricity, followed by water heating, lighting, and appliance use in the residential sector.

On the supply side, major determinants of electricity price are the price of fuel, power plant costs, costs for transmission and distribution, weather, and regulations; whereas, electricity demand is driven by own price, cross price, income, and weather factors. However, numerous studies related to the sectoral demand for electricity indicate a mixed intensity of price and income elasticities; such as electricity demand is highly price and income elastic [1–5], price inelastic [6], and income inelastic [7]. Thus, the estimation of price, income, and weather elasticities of electricity demand with an appropriate model specification would have greater policy implications regarding energy conservation and efficiency in different sectors.

Fell et al. [4] find residential electricity demand is price sensitive in the context of U.S. customers; Chang et al. [8] show that the variation in temperature affects electricity demand in the short run; and Lee and Chiu [9] demonstrate that the impact of temperature in electricity demand is more important compared to price and income effect. Many studies concerning sectoral energy consumption show mixed response to price and income over the time. In particular, electricity demand is price and income elastic as well as inelastic depending on geographical

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region, energy market structure, consumer type, estimation methods, type of data, and economic status of the study region. In our case, it would be reasonable to estimate the demand elasticities in new contexts so as to aid in policy formulation regarding the electricity demand-supply mechanism, energy conservation, and welfare implications. Although the same issue was previously studied for the Northeastern U.S. by Beierlein et al. [10], using the data over 1967–1977, much has changed concerning factors affecting electricity demand since last 40 years. This makes it imperative that we study this issue again in the changed context. Additionally, Beierlein et al. did not conduct unit root and cointegration tests and also did not incorporate the impact of cooling degree days, which is one of the most influential factors for electricity demand, as noted by many authors. For example, Shaik and Yeboah [11] find energy demand sensitivity to downside temperature in the Northeastern U.S; You et al. [12] note the significant impact of cooling degree days in household electricity demand in Singapore and Shanghai; and Gutiérrez-Pedrero et al. [13] find cooling degree days to be a major driver of electricity demand in the European region. While estimating with panel data, the possibility of unit roots and cointegration are important concerns, due to the fact that without addressing those, regression results could be spurious. This study uses the most appropriate techniques for panel unit testing, as proposed by Pesaran [14], and Maddala and Wu [15], cointegration testing as proposed by Pedroni [16] and Kao [17], and estimates the parameters using dynamic pooled mean group, mean group, dynamic fixed effect, and common correlated effect mean group methods.

Unique regional factors are often lost due to aggregation in panel data. The importance of regional effects on total energy consumption and cost has been noted by several authors. For example, Taylor [18] provides the guidelines while estimating sectoral electricity demand, and Balestra and Nerlove [19] explains the importance in the case of natural gas demand. Beierlein et al. [10] estimate the sectoral electricity and natural gas demand in the Northeasten U.S. using 11 years of data. Hsing [20] estimates residential electricity demand for five southern states using data over the period 1981-1990 and finds the natural gas price insignificant in residential electricity demand; and Kalashnikov et al. [21] analyze the problem of finding a pooled regression formula relating the price and consumption demand of natural gas for each state in the United States. A regime shift analysis conducted by Sun et al. [22] in the U.S. electricity market shows the evolution of electricity prices correlation in residential, commercial, and industrial sectors, taking into account the uncertain influence of the fuel market. Their results indicate that electricity price correlation increased continually in all three sectors. It decreased in 2012, indicating its sensitivity to fuel price. Due to weather variations, more economic activities, higher income levels, and growing energy use, the Northeastern U.S. is a unique region to consider for electricity demand estimation.

Intuitively, people use more electricity for cooling during hot days. Consumers tend to adjust electricity demand based on temperature variations. In that sense, the impact of cooling degree days (CDD) in electricity demand estimation cannot be ignored. Shaik and Yeboah [11] examine the effects of climate change on US sectoral energy demand using state level panel data from 1970 to 2014. They find that the Northeast, Central, and the Southern region of the U.S. are sensitive for energy demand to downside temperature. Residential and industrial energy use in these regions go up with the rise of downside deviation from the mean temperature. The commercial sector is least affected, because it uses the least energy due to improved technological change. They find technological advancement leads to significant saving in energy consumption. Monthly household electricity demand analysis in conjunction with temperature variation conducted by You et al. [12] in Singapore and China indicates that a one degree increase in monthly temperature is significantly associated with a 13.6% increase in the monthly electricity consumption for Singapore, and a 30 degree days increase in heating and cooling degree days is associated with a 24.9% increase in monthly electricity consumption in Shanghai in the long run. In this nexus, the inclusion of temperature variables is very important when estimating electricity demand. Okajima and Okajima [23] find a significant effect of severe weather on household electricity consumption in Japan.

The previous study in the Northeastern U.S. did not include the impact of CDD. Therefore, we include CDD to model the dynamics of electricity demand, especially to account for short run impact in energy demand as noted by Chang et al. [8] in the Korean electricity market. This study reveals new findings due to the fact that it incorporated an extended sample period, took into account an important variable, adopted the latest model specification methods, and used more effective estimation techniques. The finding concerning short run substitutability between electricity and heating fuel oil price has policy implications from the environmental perspective.

Numerous authors have estimated the demand for electricity using different approaches in different geographical regions. However, the results concerning price and income elasticities of electricity demand for a particular sector are not uniform. The elasticity of electricity demand varies from region to region. Paul et al. [24] estimate the demand for electricity in the U.S. using a fixed effect model, paying particular attention to regional, seasonal, and sectoral variations. The estimated results show that the electricity demand is price inelastic in the short run, but varying by region, season, sector, and customer classes in the long run. Alberini et al. [1] investigate the demand for electricity and natural gas for households/dwellings in the 50 largest metropolitan areas in the United States using data over the period 1997-2007. Their findings indicate that the household electricity demand is strongly responsive to its own prices both in the short run and long run. However, price elasticity of electricity demand declines with income. Jamil and Ahmad [25] estimate demand for electricity using an error correction model with annual data over the period 1961-2008. They find that the residential electricity demand is highly elastic to price and income in the long run. Gutiérrez-Pedrero et al. [13] analyze the drivers of the intensity of electricity consumption in non-residential sectors in Europe and find that the cooling degree days have a significant impact on increased electricity intensity. However, they find negligible price impact on electricity demand. Salari and Javid [26] estimate residential electricity demand in the U.S. using state level data over the period 2005-2013. Estimated results using both static and dynamic panel methods indicate that the sociodemographic information, such as per capita income, household size, and educational level, have a significant impact on electricity demand in the residential sector. Burke et al. [27] estimate aggregate short run and long run price elasticity of electricity demand in the U.S. using data over the period 2003-2015. Estimated results using the instrumental variable method indicate that the electricity demand is irresponsive to price in the short run, but the long run demand is highly responsive to price, with a maximum price elasticity around -1 in the industrial sector and a minimum value around -0.3 in the commercial sectors. These values are very high compared with most of the existing literature.

Wang and Mogi [28] estimate residential and industrial electricity demand in Japan using annual data over the period 1989-2014. The income elasticities in both sectors are stable over the study period. However, consumers become less sensitive to price after the electricity deregulation and financial crisis and more sensitive to price after the Fukushima Daiichi crisis. The price elasticity in the residential sector is much higher than in the industrial sector, so they suggested that price and environmental taxation can be better policy tools in the residential sector. Atalla and Hunt [29] estimate residential electricity demand in six Persian gulf countries and find that electricity demand is