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Revisiting the residential electricity demand in the United States: A dynamic partial adjustment modelling approach

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ABSTRACT

In recent years, price policies and price changes derived from environmental regulations have played a more important role to promote residential energy conservation. Using recent annual state-level panel data for 48 states, we estimate a dynamic partial adjustment model for electricity demand elasticities on price and income in the residential sector. Our analysis reveals that in the short run, one unit price increase will lead to 0.142 unit of reduction in electricity use after controlling for the endogeneity of electricity price. Thus, raising energy price in the short run will not give consumers much incentive to adjust their appliances to reduce electricity use. However, in the long run, one unit price increase will lead to almost one unit consumption reduction, *ceteris paribus*. In addition, we find new evidence that for states of higher per capita GDP, raising the electricity price may be more effective to ensure a cut in consumption.

1. Introduction

In the United States, residential buildings account for roughly 22% of primary energy consumption and over 37% of total electricity use.[1] Their dominance in the total electricity use has made them a focus of efforts to reduce greenhouse gas (GHG) emissions[2] and improve energy efficiency.[3] During the last three decades, electricity demand in the residential sector has grown constantly,

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[1] According to the 2015 Monthly Energy Review data and 2015 Electric Power Monthly data by the EIA, in 2014, the residential, commercial, industrial and transportation sectors account for 37.68%, 36.46%, 25.66% and 0.21% of total electricity use, respectively.

[2] In the U.S., primary sources of GHG emissions include electricity production (approximately 67% of electricity comes from burning fossil fuels, mostly coal and natural gas), transportation (burning fossil fuel for cars, trucks, planes, ships and trains), industry, commercial and residential (burning fossil fuels for heat and other end uses), agriculture, land use and forestry. Among these factors, increasing residential demand for electricity, especially what people are using electricity for relative to what they used to use it for, e.g., moving to bigger houses, serves as an important component. For example, in 2014, the increase of GHG emissions was mainly due to cold winter conditions resulting in an increase in fuel demand, especially in residential and commercial sectors (EPA, 2016).

[3] Energy efficiency is recognized as one of the lowest-cost options to reduce emissions. Climate mitigation scenarios with higher levels of energy efficiency show lower total costs. In an analysis of the costs of climate mitigation, Fraunhofer ISI (2015) demonstrated that a scenario with significant energy efficiency adoption was at least 2.5 trillion US dollars less costly by 2030 than other more energy-intensive mitigation scenarios. This sets the stage for greater prominence of energy efficiency in the

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although the growth has slowed progressively since 1990's due to energy efficiency investments. The annual energy outlook by the EIA predicted that considering extended policies, which includes additional rounds of appliance standards and building codes in the future, residential electricity use will continue to grow, by 0.2% per year from 2012 to 2040, spurred by population growth and continued population shifts to warmer regions with greater cooling requirements (Energy Information Administration, 2015).

Aiming to reduce the GHG pollution and promote energy efficiency and conservation among consumers' energy use,[4] multiple policy instruments and stimulus projects have been implemented by government in recent years. In 2009, the Stimulus Bill urged by President Barack Obama allocated $27.2 Billion for energy efficiency and renewable energy research and investment. Moreover, as of June 2013, more than 25 states have fully-funded policies in place that establish specific energy savings targets (Energy Efficiency Resource Standard, EERS) that utilities or non-utility program administrators must meet through customer energy efficiency programs.[5]

Yet, in spite of cost-effective circumstances for energy saving improvements, projects and regulations are still far from being an obvious success. Proponents of government intervention believe that substantial market barriers prevent socially desirable levels of investment in energy efficiency, so it is unlikely that any future market structure for the utility industry will ameliorate these "market barriers to energy efficiency." Ideally, homeowners would spontaneously make energy-efficiency investments in their homes, were they aware of future energy savings. In practice, it is often observed that consumers give up opportunities to make energy-efficiency investments. The literature on the so-called "rebound effect" holds that efficiency improvements can paradoxically lead to higher energy use (Kriström, 2008). Potential explanations include consumers' budget constraints, their uncertainty about energy prices in the future, lack of information in the energy market, high rates of intertemporal preferences, distrust in engineering estimates of the cost savings, and misplaced incentives (Alberini, Gans, & Velez-Lopez, 2011; Golove & Eto, 1996; Jaffe & Stavins, 1994; Metcalf & Hassett, 1999).

Given the ambiguous effects of direct efforts for energy efficiency, more and more attention has been paid to price policies. Price changes derived from environmental regulations have played a more important role in energy conservation. Many previous studies find that policies aiming to promote renewable resources and reduce GHG emissions, including Renewable Portfolio Standards and emissions trading schemes, raise economic costs and electricity prices (Fischer, 2006; Frondel, Schimidt, & Vance, 2012). In addition, with more rigid air quality standards and environmental regulations for power plants, there have been more beliefs that the cost of electricity delivered to final consumers is expected to increase.

In general, the policy influence of increased electricity prices is twofold. Besides promoting energy conservation and reducing emissions, one other important effect of raising electricity rates is that it will inevitably affect the welfare of the household, with differentiated effects on different groups, such as consumers from states of relatively higher income levels versus from states of relatively lower income levels. Quantitatively assessing these policy effects requires good estimates of residential consumption responsiveness to the electricity price changes or price changes derived from regulation policies (for instance, the carbon emissions tax and the renewable percentage requirement).

In this paper, using recent state-level panel data on residential electricity retail sales, revenue, average retail prices and residential natural gas prices from the Energy Information Agency (EIA), we estimate a dynamic partial adjustment model for residential electricity demand elasticities on price and income. Specifically, we estimate our model by applying the Bias Corrected LSDV (Alberini & Filippini, 2011; Kiviet, 1995) and the system GMM procedures (Blundell & Bond, 1998), and further instrument for both the lagged consumption and the price of electricity with lags. We further explore the electricity elasticities across states of different income levels. This would allow a clearer characterization of the different effects of a price increase and a price increase derived from regulations such as a carbon tax, on electricity consumption for groups of different income levels.

Previous works have applied different methods to measure the responsiveness of residential electricity consumption to the price, and have produced a wide range of estimations (from zero to −1.30), with diverse types of data used (time-series, cross-sections and panel) in variant geographical levels and time periods covered. Existing studies can be broadly classified into one of three categories: (i) those based on national level time-series data (Dergiades & Tsoulfidis, 2008; Kamerschen & Porter, 2004); (ii) those using household-level data (Alberini et al., 2011) but typically involving imputed data or are constrained to geographically narrow regions or with some important information missing, and (iii) those based on state-level panel data or county-level panel data for a state (Alberini & Filippini, 2011; Bernstein & Griffin, 2005; Paul, Myers, & Palmer, 2009).

This paper on residential electricity consumption using state-level panel data with dynamic partial adjustment model differs in several ways from the existing literature. First, we are using a more recent data set, the state-level residential electricity retail sales, revenue, average retail prices and residential natural gas prices from the EIA. In Alberini and Filippini (2011), their data cover the time period of 1995–2007, which is the most recent data in prior studies with dynamic panel data models. However, there are a number of important changes in the U.S. electricity

policy mix as governments work to achieve their contributions to the Paris Agreement in December 2015 (IEA, 2016).

[4] According to the literature, policies for energy efficiency have been strengthened the most in the residential sector, suggesting this is a key factor driving improvements. From 2000 to 2015, increasing population and the move to larger dwellings have especially contributed to the increasing energy consumption in this sector (IEA, 2016).

[5] The EERS requires that electric utilities achieve a percentage reduction in energy sales from energy efficiency measures. The strongest EERS requirements exist in Massachusetts and Vermont, which require almost 2.5% savings annually.

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