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Dynamic models of residential electricity demand: Evidence from Switzerland

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ABSTRACT

We estimate the short- and long-run elasticities of electricity demand in Switzerland using a dynamic model of residential electricity consumption incorporating a correction introduced by Kiviet. We find that the short-run elasticity of residential demand for electricity in Switzerland is around −0.3 while the long-run elasticity is around −0.6. Our estimates indicate that pricing policy as a plan for energy strategy may have a moderate impact on residential customers in the short run but will have a stronger influence in the long-run. In view of the recent proposal in Switzerland to introduce a tax on electricity as part of its energy strategy plan, an increase in the price of electricity may result in a moderate decrease in electricity consumption.

1. Introduction

Reducing the emission of greenhouse gases (GHGs) is a major goal of nations to combat the impact of climate change. Electricity and heat production accounted for 25% of the total GHG emissions in 2010 [44].[1] Therefore, reducing GHG emissions in this sector is an important objective against climate change and pricing these emissions is one of the policy instruments that could be used to achieve this objective. The estimate of the responsiveness of electricity consumption to a price change is important to measure since it has an influence on the design for energy needs in the future and various policy instruments that include pricing and taxation. Obtaining the correct estimates of price elasticities is also crucial because of their importance for bottom-up and general equilibrium models used to understand the energy system and the impact of energy policy instruments.

Moreover, after the Fukushima Daiichi nuclear accident on 11 March, 2011, many countries have decided to phase out nuclear energy and are evaluating a tax on electricity to reduce consumption while also introducing policy measures to increase the level of energy efficiency and the amount of electricity generated from renewable sources. In the short-run, the possibilities for consumers are relatively limited. However, in the long run, the electricity demand may be stabilized using policies by, for example, providng incentives to consumers to switch to more energy efficient appliances.

In Switzerland, the Federal Council decided to suspend the approvals process for new nuclear reactors. It subsequently decided to make the ban on new nuclear reactors permanent. Furthermore, it was decided that the country's five existing nuclear reactors would continue producing electricity until they are gradually phased out with no replacements. The implications of a switch in electricity generation from nuclear to other sources are important for a country like Switzerland which is, at the moment, heavily reliant on

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[1] https://www.ipcc.ch/report/ar5/wg3/, website accessed 8 June, 2017.

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its nuclear reactors. In 2011, 40% of Switzerland's electricity was produced from nuclear power [62].[2] Therefore, the Federal Council has developed a long-term energy strategy plan, *Energy Strategy 2050*, that should be implemented in cooperation with the cantons and local utilities.[3]

The *Energy Strategy 2050* sets out the future for Switzerland very clearly by stating that it is focusing on increased energy efficiency, the expansion of hydropower and use of new renewable energy, and in a second step the Council "wishes to replace the existing support system by a management mechanism."[4] While the Federal Council had proposed, within the initial package of measures, mandatory efficiency goals for the utilities that sell more than 30 GWh as one way to reduce electricity consumption, switching electricity generation from nuclear to other sources would involve generating electricity from renewable sources and importing electricity from neighboring countries.[5] The *Energy Strategy 2050* also includes, in a later phase, a possible ecological tax reform. This will introduce an energy tax that is expected to bring about a more responsible use of resources and stabilize the consumption of electricity. In order to estimate the efficacy of an energy tax on electricity consumption it is crucial to obtain credible estimates of the responsiveness of electricity demand to changes in its price.

In this paper, we estimate the short- and long-run elasticity of electricity demand which will provide a measure of how an energy tax may affect the responsiveness of electricity consumption. In addition, this will provide policy makers and utility companies with estimates needed for forecasting electricity demand and enable them to plan for generation, transmission and distribution capacities. To do this we use information from a recent survey carried out on a sample of Swiss utilities by Boogen et al. [15]. Using information on residential electricity consumption, electricity prices, household characteristics and weather factors, we estimate a dynamic model of electricity consumption. We find that the short-run elasticity of residential demand for electricity in Switzerland is inelastic at around −0.3 while the long-run elasticity, while also inelastic, is reasonably high at around −0.6. Our results are in line with existing economic theory that the long-run elasticity should be higher than the short-run because households take into account the decision to adjust their stock of appliances. Therefore, they are more sensitive to price changes in the long-run. Since we use a dynamic specification of electricity demand we should note that Taylor [66] mentions that dynamic models with a lagged dependent variable impose a fixed relationship between short- and long-run elasticities but that estimates are not biased. Espey and Espey [25] find that short-run elasticities in dynamic models are generally smaller than those in static models while long-run models produce smaller estimates with a lagged dependent variable. Therefore, Espey and Espey [25] suggest that dynamic models should be estimated carefully to avoid any biases arising from lagged variables.

This paper contributes to the empirical literature on short- and long-run electricity demand by estimating the respective price elasticities using a new and short panel data set to estimate a dynamic electricity demand model. We use a correction introduced by Kiviet [48] and extended by Kiviet, Bun and Kiviet [18,49] and Bruno [17] for the least squares dummy variable method to account for the endogeneity of the lagged dependent variable in a dynamic demand model using aggregated data. As mentioned in Ref. [13], having dynamics in the underlying process is important for obtaining consistent estimates of parameters even when the coefficient on the lagged dependent variable may not be of direct interest. We also test for the equality of the estimates of the short- and long-run electricity price elasticities and find them to be statistically different. There have been very few recent papers on estimating the short- and long-run price elasticity of electricity demand using a short panel data. The estimation of total electricity demand is also rare for Europe while most studies for Switzerland have focused on time-of-use electricity demand estimation.

The structure of the paper is as follows. In the next section we provide a review of the existing literature relevant to our study. We then describe a model of electricity demand in section 3. The variables used in our model and their sources are described in section 4. Our estimating equation and results of the estimating procedure are provided in the penultimate section. The final section has concluding remarks.

2. Brief literature review

There is now a substantial literature that estimates the price responsiveness of residential electricity demand.[6] Studies of residential electricity demand can be at the aggregated level, e.g. at the state- or country-level. These exploit panel data [1,6,10,19,33,37,51,53,54,65] or, alternatively, for country studies, just the time-series nature of the data [3,9,22,26,29,40,47,55,58,61,70].

Other studies are at the disaggregated level, e.g. using household surveys, and usually use cross-sectional data. Among early works, Houthakker [42] looks at electricity demand using domestic two-part tariffs in 1937-38 for 42 provincial towns in Great Britain. Fisher and Kaysen [35] study residential and industrial electricity demand in the United States. They were the first to distinguish explicitly between short-run and long-run demand. A first wave of papers on residential electricity demand was published in the 1970s, as the concerns on the limits of growth were coming up (e.g., [37,41]).

More recently, Reiss and White [59] find considerable heterogeneity in the estimated price elasticities of Californian households across income and other demographic characteristics. Yoo et al. [69] find that a plasma TV or an air conditioner significantly increases residential electricity consumption. However, the electricity demand estimated by using the average price appears to be price and income inelastic. Fell et al. [30] use monthly data from a consumer expenditure survey collected between 2006 and 2008 and estimate the price elasticity to be close to −1 and rather high compared to other cross-sectional studies. They explain this with the fact that they use average price and not marginal price as used in most other studies. Krishnamurthy and Kriström [50] estimate price elasticity in a cross-country study using data from households in 11 OECD countries for 2011 and find a high price elasticity of between −0.27 and −1.4 in most countries.

Compared to these cross-sectional studies, Alberini et al. [2] find

[2] In 2011, apart from the 40% of electricity that was produced from nuclear power, 54% was produced from hydro power, while the rest was produced from other sources. Furthermore, Switzerland imported around 83 TWh of electricity and exported around 80 TWh of electricity [62]. Thus, there was only a small import excess in 2011, which is characteristic of Switzerland's electricity market.

[3] To note, Switzerland is a federal state consisting of 26 cantons and the design and implementation of energy policy instruments are divided between the federal government, cantonal governments and electric utilities (approximately 650 electric utilities) involved in the production, distribution and supply of electricity.

[4] http://www.bfe.admin.ch/energiestrategie2050/06445/index.html?lang=en, website accessed 14 June 2017.

[5] Switzerland voted for the first package on 21 May, 2017 but mandatory efficiency goals was removed from it.

[6] Heshmati [39] provides an overview of the numerous studies. Espey and Espey [25] use a meta-analysis to quantitatively summarize 126 previous studies, from 1971 to 2000, of residential electricity demand while [2] contains a survey of some more recent studies.