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Analysis and long term forecasting of electricity demand trough a decomposition model: A case study for Spain

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ABSTRACT

Proper planning for the dimensions of an electricity production and transmission system requires the availability of medium- and long-term electricity demand projections that are sufficiently reliable. Generally, these projections are directly linked to the estimated growth for the whole real GDP (gross domestic product), although an in-depth historical evolution of this demand, as that given in this article, advises the explicit consideration of several determinants. The aim of this paper is to present an alternative analysis of the demand for electricity based on a simple growth rate decomposition scheme that allows the key factors behind this evolution to be identified. It is possible, taking this scheme as a starting point, to develop a long-term forecasting model to obtain projections of electricity demand given the expected evolution of the key factors. The proposed methodology is illustrated using Spain as a case study to obtain demand projections till 2030.

1. Introduction

Electricity consumption, or energy consumption in general, and economic growth are intimately related. A considerable effort has been made to disentangle the causal relationship between energy consumption and growth. The direction of this causality remains an open debate to this day: from energy to economic growth, or vice versa, but no-one is discussing the necessary relationship between the two variables.

In this paper we aim to study this relationship, focusing on the sensitiveness of electricity consumption to economic growth in a long-term perspective for the case of Spain. In particular, we are interested in the changing nature of the electricity-economic growth nexus with the ultimate goal of developing a forecasting model for electricity demand in a macro-economic long-term scenario. Previous works, like [4] among others, have showed that the strong correlation between electricity consumption and economic variables like Gross Domestic Product, GDP per capita, population can be used to make reasonable long term forecasts.

To tackle this goal we provide a simple framework that allows us to understand how these changes can be related to the deep transformations experienced by the Spanish economy, and that are reflected in the changes undergone in the rate of GDP (gross domestic product) growth, in the economic sectoral structure, and in the intensity of electricity use.

All these features are frequently mentioned in the literature as the main causes of change in the elasticity of electricity consumption over time, but in an unstructured way. Our study, based on the index decomposition methodology (see Ang, 2004 [2], or Ang and Zhang, 2000 [1] among others), shows a simple but very effective way to show how these long-term drivers of the changing relationship between energy and economic growth can be revealed and analyzed. The Spanish case is a very interesting one, as within a thirty-year period its economic structure has experienced deep changes, from a highly energy-intensive industrial economy with high rates of GDP growth to a service economy with moderate economic growth and declining electricity consumption in the post-2012 crisis period.

Previous works Chang et al. (2014) [6], Huang et al. (2008) [7], Holtedahl and Joutz (2004) [8], Hondroyiannis (2004) [9], among others, have showed two interesting features with respect to the link between energy and growth. First, income elasticity or GDP elasticity are not constant over time or between countries. Second, there are significant differences in income elasticities among residential and industrial sectors. Huang et al. [9] analyzed the relation between energy consumption and GDP for 82 countries

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from 1972 to 2002. Their data are divided into four categories of countries, according to their income level (low-income group, lower middle-income group, upper middle income group, and high-income group). What these authors found is that the relationship between energy and economic growth depends on the country's degree of development. For low-income countries, these authors did not find any type of causal relation between the two variables; in the middle-income group, economic growth leads energy consumption positively; whereas in the high-income group countries, economic growth leads energy consumption negatively. From these results it can be deduced that the energy-output relationship changes with economic development.

Chang et al. [6]; with Korean monthly data, reveal increasing income/output elasticities in electricity demand over the 1985–2012 period in the residential, commercial and industrial sector. Their findings show that demand for electricity is income inelastic but is becoming more income elastic with time, possibly driven by the proliferation of electronic devices in firms' production and in household consumption.

This changing nature is also reflected in the high degree of dispersion of the estimated income elasticities in energy demand for different countries. For instance [7], in the case of Taiwan for the 1955–1996 period found the income elasticity of residential electricity demand to be unity in the long run, while in the short term it was smaller. However, [8]; who examined the demand for residential electricity for Greece for the 1960–1998 period, reported much higher income elasticity at 1565. Other authors, like [12] with 1949–1993 data of residential electricity consumption in the United States, also found income elasticities lower than the unity.

Yamaguchi [13] drew a comparison between the periods of 1986–1993 and 1993–2004 for Japan, and found that income elasticities increased from 1076 to 1679. This author's results also showed that the level of sensitivity towards income increased after 1993.

Zachariadis and Pashourtidou [16] used annual data for the 1960–2004 period to examine electricity consumption in the residential and service sectors in Cyprus. The results showed that long run income elasticities for electricity consumption were greater than unity.

Chang et al. [6] highlight the relevance of the methodology adopted, showing that income elasticities can be overestimated when unchanging elasticities are assumed, while under time-varying elasticities electricity demands become inelastic to variations in income.

In the case of Spain, the works by Refs. [5,10] analyze Spanish residential demand. In the former, they found an income elasticity value of 0.7, whereas in the latter, the researchers concluded that demand for electricity in Spanish households is responsive to income with a long-run income elasticity of 0.61–0.7 and a much lower short-run elasticity of 0.23.

With respect to sectoral differences in the income elasticity for energy consumption, [3]; for instance, reported a high correlation between GDP and non-domestic electricity consumption. In domestic consumption a more irregular behavior was detected, linked to population growth and to the increase in electricity intensity due to the increased diffusion of air conditioning. These authors found that in Italy the GDP elasticity of non-residential electricity consumption is high, 1.41 in the short-run and 2.20 in the long-run. On the contrary, they reported residential consumption income elasticity to be only 0.29. These differences, therefore, will lead to a changing aggregate GDP elasticity depending on the relative weight of residential and non-residential electricity consumption over time. But the estimated income elasticities reported in the literature do not lie in similar ranges.

Other studies, such as Holtedahl and Joutz [7] and Hondroyiannis [8]; found income elasticities in the residential sector were equal or higher than unity for such dissimilar countries as Greece and Taiwan.

A common feature of the above-cited works is that they are essentially descriptive. Irrespective of the methodological approach used therein, electricity income elasticity is basically determined from an analysis of the coevolution of electricity consumption and household income, sectoral GVA (gross value added) or GDP, without a rationale that could explain such an evolution. Usually, authors give some insights about the factors underlying the variations (proliferation of electronic devices, increasing use of air conditioning, relative price of electricity, etc.) but the main results are not accompanied by an in-depth analysis.

We present below a simple framework that allows changes in income elasticity to be analyzed from a long-term perspective applicable to Spain. In the following section we will describe the main features of electricity consumption in Spain. The index decomposition methodology followed, which is applied to the case of Spain, is described in Section 3 while in the fourth section the forecasting model is presented. Finally, Section 5 concludes the paper.

2. Long term evolution of electricity demand and consumption in Spain

An adequate analysis of electricity demand from a long-term perspective needs not only to have disaggregated data for the classical residential and non-residential uses, but also a more detailed breakdown among non-residential uses in different activity branches.

Although Eurostat provides some detailed information for electricity consumption breakdown by uses (16 categories), the length of the historical time series is not very large, as they start in 1990. Therefore, we tried to obtain a broader database from the reports published yearly by the Spanish Ministry of Energy, Commerce and Tourism which currently details 34 different uses.

On the basis of these annual reports, the Department of Statistics of REE (*Red Eléctrica de España*), the Spanish company in charge of high-voltage electricity transmission, created a homogeneous database that covers the period from 1970 to 2012 and includes a common breakdown of 22 non-residential uses plus the residential use for the full period.

In order to develop a proper analysis between electricity demand and economic activity, a new set of data was created containing Gross Value Added (GVA) with a sectoral disaggregation level compatible with the breakdown in electric uses.

These GVA values are provided by the Spanish National Institute of Statistics from 2000 onward, and are measured in terms of Chain Linked Volume Index (2008 = 100).

As we needed a set of data covering the same period as the electricity consumption data, it was necessary to backcast the GVA time series from 1999 to 1970 using data expressed in terms of the former measures “constant Euros” or “constant Pesetas”.

Once the set of GVA index series was completed for the full period, these indexes were transformed into Chain Linked Volume Euros which allow us to compute sectoral electricity intensities measured as the amount of MWh consumed for each million of GVA in constant terms (i.e. without the effect of prices).

Bearing in mind our main goal of forecasting the electricity demand conditioned to the expected evolution of economic activity, we started our historical analysis by looking at the evolution of aggregate GVA (i.e. GDP) together with total electricity demand.

The Spanish Economy registered between 1970 and 2012 a remarkable rate of economic growth, which allowed the GDP to