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Forecast of electricity consumption in Cyprus up to the year 2030: The potential impact of climate change

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ABSTRACT

This paper provides a forecast of electricity consumption in Cyprus up to the year 2030, based on econometric analysis of energy use as a function of macroeconomic variables, prices and weather conditions. If past trends continue electricity use is expected to triple in the coming 20–25 years, with the residential and commercial sectors increasing their already high shares in total consumption. Besides this reference scenario it was attempted to assess the impact of climate change on electricity use. According to official projections, the average temperature in the Eastern Mediterranean is expected to rise by about 1 °C by the year 2030. Using our econometrically estimated model, we calculated that electricity consumption in Cyprus may be about 2.9% higher in 2030 than in the reference scenario. This might lead to a welfare loss of 15 million Euros in 2020 and 45 million Euros in 2030; for the entire period 2008–2030 the present value of costs may exceed 200 million Euros (all expressed in constant Euros of 2007). Moreover, we assessed the additional peak electricity load requirements in the future because of climate change: extra load may amount to 65–75 Megawatts (MW) in the year 2020 and 85–95 MW in 2030.

1. Introduction

Cyprus is an island in the Eastern Mediterranean with an area of 9250 square kilometres and a population of about 750 000, which became a member of the European Union (EU) in 2004.[1] The island possesses no indigenous energy resources apart from ample solar and some wind and biomass energy potential and is highly dependent (by about 95%) on imported petroleum products. Its power system is isolated, and power plants (with a total installed capacity of about 1200 MW in 2009) are mainly powered by fuel oil; by 2014 new plants are scheduled to operate on natural gas too, which is planned to be transported to the island in liquefied form.

Cyprus has enjoyed sustained economic growth in the last three decades (averaging 5.8% and 3.1% per year over the last 30 and 10 years, respectively) mainly due to tourist income and the development of financial services. Its per capita Gross Domestic Product exceeded 21 000 Euros in 2008. Because of economic growth and as energy conservation was not a priority for authorities and citizens, total final energy consumption rose by about 4.5% per year in the 1975–2004 period, with signs of slowdown since the mid-1990s. Predictably, electricity consumption increased even faster (by 7.1% and 5.5% annually in the last 30 and 10 years, respectively). The importance of the power sector in the Cypriot energy system is highlighted by the fact that electricity consumption has doubled between 1990 and 2003, and its share in final energy demand has climbed from less than 12% to 17.5% during that period (Eurostat, 2009).

A few years ago, Zachariadis (2006a) and Zachariadis and Pashourtidou (2007) conducted the first comprehensive empirical analysis of energy consumption in the Republic of Cyprus. Using annual data from 1960 to 2004, we examined the evolution of all energy forms for which data were available. The time series that were analysed were those of residential, commercial, industrial, agricultural and total electricity use, gasoline consumption as well as the aggregate non-electricity and total energy consumption. The dynamic interaction between the corresponding energy form and appropriate income, price and weather variables were analysed with the aid of widely used time series analysis techniques such as unit root and cointegration tests, Vector Error Correction (VEC) models, Granger causality tests and impulse response functions. Because of power and size problems associated with these methods in small samples, single-equation autoregressive distributed lag (ARDL) models were also employed for each energy variable.

Results from the cointegration tests and the VEC models showed that a long-run equilibrium relationship between energy,

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[1] The information provided here refers only to the area controlled by the government of the Republic of Cyprus.

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income and prices exists in the cases of residential, commercial and industrial electricity, gasoline and total final energy consumption. The long-term impact of income and prices on electricity use is significant, with elasticities similar to those reported for other countries (above unity for income, less than 0.5 for prices in absolute terms). Weather fluctuations seem to be the most significant cause of short-term variation in electricity use (albeit with small elasticity values), while the effect of income and prices is not significant in the short run. Granger causality tests indicated that electricity prices can be treated as purely exogenous, income and prices clearly Granger-cause electricity use, and there is bidirectional causality between most energy forms and income or economic activity. Overall, the services sector turned out to be less elastic to changes in income, prices and the weather, and after a one-time shock it tends to revert to equilibrium much faster than the residential and industrial sectors.

ARDL test results were similar to those of the VEC models, particularly in the cases of residential and commercial electricity consumption. Therefore, despite the quite small sample size that poses limitations on the analysis, the evidence from both the VEC and ARDL models showed that results are meaningful and robust for residential, commercial and industrial electricity as well as gasoline consumption. This finding was important as it allowed the corresponding income, price and weather elasticities to be used for forecasting purposes and policy analyses. In a subsequent study, Zachariadis (2006b) used the econometrically estimated elasticities and carried out forecasts of electricity consumption in Cyprus up to the year 2030 as a function of macroeconomic variables, electricity prices and weather conditions under different oil price scenarios.

In 2008 the econometric estimates were updated by using data for the years 1960–2007, and new forecasts of electricity consumption were performed on the basis of the newly estimated elasticities (Zachariadis, 2008). This paper summarises the econometric methodology, the assumptions and the basic findings of this forecast, which includes a reference ('business as usual') scenario and a climate change scenario; the latter uses climate forecasts published by the Intergovernmental Panel on Climate Change (IPCC) in order to simulate the future effect of warmer weather on electricity use in Cyprus.

2. Econometric methodology

The electricity forecasts to be reported here were based on econometric estimations carried out with single-equation autoregressive distributed lag (ARDL) models. A similar approach is also followed by international organisations and energy-planning authorities such as the International Energy Agency, the European Commission or the US Energy Information Administration, where forecasts of population, GDP growth, international fuel prices and other parameters are taken as exogenous and energy use is determined with single-equation models. ARDL models were commonplace in energy analysis until the 1980s. Then the introduction of unit root and cointegration methods, which found that some regressions may be spurious if the time series properties of variables are not examined, almost dismissed the ARDL model as inappropriate. The 'revival' of ARDL methods came in the late 1990s with the aid of work by Pesaran, Shin and Smith (see e.g. Pesaran and Shin, 1999). As explained in more detail by Zachariadis and Pashourtidou (2007), ARDL models pose several advantages over VEC and cointegration techniques because they do not require testing for unit roots in variables, which is important in view of the power and size problems associated with unit root tests in small samples. Moreover, ARDL equations

Table 1
Energy, economic and weather data that were used in the econometric estimations.

Energy variable	Economic variables	Weather variable
Electricity consumption, residential sector	Private consumption Retail electricity price for domestic consumers	Total degree-days
Electricity consumption, industry	Value added of industrial production Retail electricity price for industrial consumers	–
Electricity consumption, commercial sector	Value added of tertiary sector Retail electricity price for commercial consumers	Total degree-days

are more rigorous in small samples than cointegration methods; this is particularly relevant in the case of Cypriot energy data, with sample sizes of 40–50. Finally, as Clements and Madlener (1999) point out, the ARDL approach places more 'structure' on the issue of energy consumption than the purely atheoretical cointegration approaches.

Using all variables in levels, the ARDL equation is the following:

$$e_t = \gamma_0 + \sum_{i=1}^{m} \gamma_{1i} e_{t-i} + \sum_{j=0}^{n} \gamma_{2j} y_{t-j} + \sum_{k=0}^{p} \gamma_{3k} p_{t-k} + \sum_{l=0}^{q} \gamma_{4l} tdd_{t-l} + \xi_t \quad (1)$$

where e, y and p denote the natural logarithm of the corresponding electricity, income and price variable, respectively. tdd the logarithm of total (heating+cooling) degree-days.[2] Index t denotes time in years, and i, j, k, l denote the lags of each one of the exogenous regressors. Finally, the error term ξ_t is assumed to be independently and normally distributed with zero mean and constant variance. As the variables are expressed in logarithms, the econometrically estimated coefficients γ_{1i}, γ_{2j}, etc. express elasticities.

Table 1 displays the data that were used for these estimations. All data come from the Statistical Service of Cyprus except degree-day data that have been provided by the Cyprus Meteorological Service. Electricity consumption is expressed in million kilowatt-hours (GWh), prices are expressed in Eurocents at 2000 prices per kilowatt-hour and economic activity data are in million Euros at 2000 prices. Note that estimations of agricultural electricity use were not econometrically robust, hence forecasts for this sector – which has a low and diminishing share of energy consumption – were conducted in a simple way.

After conducting some initial estimations with the whole sample (period 1960–2007) and confirming the good statistical properties of these regressions, we then examined whether the estimated coefficients have changed significantly over the years. We thus performed rolling regressions for 20-year periods (1961–1980, 1962–1981, … 1988–2007) and found that the coefficients

[2] Heating (cooling) degree days are meant to measure the severity and duration of cold (hot) weather: for example, the colder the weather in a given month or year the higher the heating degree day value. One degree-day expresses the need for heating (or cooling) during a day caused by an average daily temperature that is one degree lower (or higher) than a reference temperature. In this case reference temperatures of 18 and 22 °C for heating and cooling degree-days, respectively.