UNIVERSITY OF CYPRUS
ECONOMICS RESEARCH CENTRE

Economic Analysis Papers

An empirical time series analysis of energy consumption in Cyprus

Theodoros Zachariadis

Economics Research Centre
University of Cyprus

No. 01-06

March 2006

Publication Editors: Costas Hadjiyiannis, Theodoros Zachariadis

ERC Sponsors (in alphabetical order)

Association of Cyprus Commercial Banks

Central Bank of Cyprus

Cyprus Tourism Organisation

Department of Economics, University of Cyprus

Ministry of Finance

Ministry of Labour and Social Security

Planning Bureau

University of Cyprus

An empirical time series analysis of energy consumption in Cyprus

Theodoros Zachariadis*

Abstract

This report presents the first econometric analysis of energy consumption in Cyprus. Time series analysed were those of residential, commercial, industrial and agricultural electricity use, gasoline consumption as well as the aggregate non-electricity and total energy consumption using annual data from 1960 to 2004. The dynamic interaction between the corresponding energy form and appropriate income, price and weather variables was examined through the application 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. The validity of inferences made with such models has been re-established in the late 1990s thanks to the work of Pesaran-Shin-Smith.

Results from cointegration tests and VEC models show that a long-run equilibrium relationship between energy, income and prices exists for most energy uses. The long-term impact of income and prices on energy 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). Granger causality tests indicate that energy prices can be treated as purely exogenous, income and prices often Granger-cause energy use, and there is bidirectional causality between most energy forms and income or economic activity.

ARDL test results have to be interpreted in conjunction with those of the cointegration tests. In the cases of residential and commercial electricity consumption, elasticities are found to be similar with those of the VEC model, whereas results of the two methods are different for the long-term elasticities of gasoline and industrial electricity consumption.

Despite the quite small sample size, which poses limitations on the analysis, the evidence from both the VEC and ARDL models shows that results are meaningful and robust for residential, commercial and industrial electricity as well as gasoline consumption. This finding is important as it allows the corresponding income, price and weather elasticities to be used for forecasting purposes and policy analyses.

* This is part of a study being conducted in the framework of a Marie Curie Fellowship that I received from the European Community within its Sixth Framework Programme. The report reflects the author's views only; the European Community is not liable for any use that may be made of the information contained therein. I am grateful to Nicoletta Pashourtidou for numerous discussions as well as her suggestions and corrections. I would also like to thank Stelios Pashiardis from the Cyprus Meteorological Service, who has promptly provided the necessary information related to the weather variable that I used in the models. Remaining errors or omissions are obviously my own responsibility.

ΠΕΡΙΛΗΨΗ

Η παρούσα μελέτη αποτελεί την πρώτη οικονομετρική ανάλυση της κατανάλωσης ενέργειας που διεξάγεται στην Κύπρο. Χρησιμοποιώντας τις χρονοσειρές που είναι διαθέσιμες από τη Στατιστική Υπηρεσία της Κυπριακής Δημοκρατίας για την περίοδο 1960-2004, διερευνήσαμε τη δυναμική αλληλεπίδραση της κατανάλωσης διάφορων μορφών ενέργειας, της οικονομικής δραστηριότητας, των τιμών των αντίστοιχων καυσίμων και των καιρικών συνθηκών. Τα διαθέσιμα στατιστικά στοιχεία επέτρεψαν να αναλύσουμε την κατανάλωση ηλεκτρισμού στον οικιακό, εμπορικό, βιομηχανικό και αγροτικό τομέα, την κατανάλωση βενζίνης και τη συνολική τελική κατανάλωση ενέργειας (με ή χωρίς την κατανάλωση ηλεκτρισμού).

Η ανάλυση διενεργήθηκε με δύο μεθόδους: αφενός με τη χρήση ελέγχων μοναδιαίας ρίζας για τις εμπλεκόμενες μεταβλητές, μεθόδων συνολοκλήρωσης και μοντέλων διανυσματικής αυτοπαλινδρόμησης, και αφετέρου με την εφαρμογή μοντέλων μίας εξίσωσης με αυτοπαλινδρόμηση και κατανεμημένη υστέρηση. Η πρώτη μέθοδος είναι ευρύτατα διαδεδομένη σε εφαρμοσμένες οικονομετρικές αναλύσεις. Η δεύτερη μέθοδος χρησιμοποιούνταν εκτεταμένα μέχρι τη δεκαετία του 1980 και πρόσφατα οι εργασίες των Pesaran-Shin-Smith επαναβεβαίωσαν την αξιοπιστία της, υπό την προϋπόθεση ότι χρησιμοποιούνται συγκεκριμένες μη τυπικές (non-standard) κατανομές για τους ελέγχους υποθέσεων.

Τα αποτελέσματα των δύο μεθόδων συμφωνούν σε μεγάλο βαθμό και οδηγούν στο συμπέρασμα ότι υπάρχει στατιστικά σημαντική μακροχρόνια σχέση μεταξύ της ενεργειακής κατανάλωσης, του εισοδήματος/οικονομικής δραστηριότητας, των τιμών των καυσίμων και των καιρικών συνθηκών, ιδίως στις περιπτώσεις της κατανάλωσης ηλεκτρισμού στον οικιακό, εμπορικό και βιομηχανικό τομέα, της κατανάλωσης βενζίνης και της συνολικής κατανάλωσης ενέργειας. Όπως στις περισσότερες χώρες του κόσμου, οι εκτιμώμενες μακροχρόνιες εισοδηματικές ελαστικότητες είναι συνήθως μεγαλύτερες της μονάδας, ενώ οι αντίστοιχες ελαστικότητες των τιμών κυμαίνονται σε επίπεδα χαμηλότερα του 0,5 (σε απόλυτες τιμές). Σε ό,τι αφορά τη βραχυχρόνια συμπεριφορά των μεταβλητών, τα μοντέλα διανυσματικής αυτοπαλινδρόμησης δείχνουν ότι οι καιρικές συνθήκες επηρεάζουν σε μεγαλύτερο βαθμό την κατανάλωση ηλεκτρισμού από ό,τι το εισόδημα ή οι τιμές.

Οι διαγνωστικοί έλεγχοι που διενεργήθηκαν για όλα τα επιμέρους μοντέλα δείχνουν ότι ειδικά οι εξισώσεις για την κατανάλωση οικιακού, εμπορικού και βιομηχανικού ηλεκτρισμού καθώς και για τη συνολική κατανάλωση βενζίνης παρουσιάζουν πολύ ικανοποιητικές ιδιότητες. Κατά συνέπεια, τα μοντέλα αυτά μπορούν να χρησιμοποιηθούν περαιτέρω για τη διεξαγωγή μακροχρόνιων προβλέψεων της μελλοντικής κατανάλωσης ενέργειας και την προσομοίωση μέτρων πολιτικής, συμβάλλοντας έτσι στην κατάστρωση ενός συνεκτικού ενεργειακού σχεδιασμού για την Κύπρο.

CONTENTS

1. INTRODUCTION

Energy demand on a national and international basis has been analysed extensively since the early 1980s. Initially, the oil price shocks of 1973 and 1979 were the primary cause of interest for energy analyses with the purpose of determining the impact of income and prices on energy use. In the 1990s the issue of climate change was added to the policy agenda, and new concerns about the security of energy supply in view of increasing oil prices from 2000 onwards have made these studies extremely topical both in developed and developing countries. The primary exercise in most energy analyses is to determine income and price elasticities of energy consumption so that meaningful forecasts or policy simulations can be performed.

These studies typically analyse the long-term and short-term impact of energy prices and GDP (or another aggregate income variable) on aggregate consumption of one or more fuels, in individual sectors or over the whole economy. Atkinson and Manning (1995) provide an overview of elasticities estimated mainly for developed countries, whereas De Vita et al. (2005) summarise elasticities reported until recently for developing countries. In general, in the long run income elasticities are estimated to be around unity and often higher, and price elasticities vary from about -0.2 to -1, while short-term income and price elasticities are reportedly about half the levels of their long-term counterparts[1]. Of all the individual sectors, transportation has been found to be the most income elastic and price inelastic.

Over the last two decades, a major challenge has been to explore the time series properties of the examined variables in order to conduct meaningful statistical tests and inferences. Since the seminal work of Engle and Granger (1987), Phillips and Durlauf (1986) and others, it became clear that inferences from autoregressive equations are only meaningful if the variables involved are stationary i.e. fluctuate stochastically with constant unconditional means and variances. As most economic (and energy) variables contain stochastic time trends, hypothesis tests and inferences had to be revisited. As a result, unit root tests became commonplace and cointegration methods, such as the Engle-Granger (1987) or the Johansen (1988, 1991) approach among others, were employed in order to test for the existence of stationary long-run relationships among the (non-stationary) variables that would allow the implementation of standard regression methods.

[1] Silk and Joutz (1997) argue that these values would be much lower if the analyses included the stock of energy-consuming appliances as an additional explanatory variable.

It was in the late 1990s, however, that Pesaran and Shin (1999) and Pesaran et al. (2001) showed that, under specific assumptions that hold quite often, autoregressive distributed lag (ARDL) equations, which had been dismissed as inappropriate since the unit root / cointegration 'revolution', may well be valid and are more rigorous in small samples than cointegration techniques. Still, Bentzen and Engsted (2001) note that ARDL and cointegration methods should be viewed as supplements rather than substitutes, as the use of ARDL presupposes that i) no variable is integrated of order 2 or higher and ii) there is only one cointegrating relationship among the variables; this implies that unit root and cointegration tests may still be necessary under the ARDL approach unless one accepts the above assumptions on the grounds of economic theory.

Cyprus is an island in the Eastern Mediterranean with an area of 9 250 square kilometres and a population of about 750 000, which became a member of the European Union (EU) in 2004. The need for long-term energy analyses for Cyprus was mainly realised in the last decade as a result of growing concerns about the security of energy supply and in view of the requirements for reporting and forecasting energy use and greenhouse gas emissions within the EU. Two recent studies in this context were a so called "Strategic Plan for the Limitation of Greenhouse Gas Emissions in Cyprus" (Mirasgedis et al. 2004) and a White Paper for the exploitation of renewable energy and the rational use of energy in Cyprus (Zervos et al. 2004). Still, those studies employed models that had been developed for other countries or regions, so that model parameters had not been derived from national data.

The study presented here is the first one to conduct an econometric analysis of energy consumption in Cyprus[2]. In the absence of appropriate seasonal economic indicators for the island, the analysis had to rely on annual data dating back to 1960 when Cyprus became an independent country. A consequence of these constraints was that the analysis had to be carried out with 40 to 45 observations for each variable. In view of the quite small sample, it was considered necessary to conduct hypothesis tests with several methods in order to check the robustness of the conclusions drawn. Therefore, after an overview of the energy sector in section 2, the paper continues with an overview of the general model formulation (section 3) and a description of the data used (section 4) and then presents the results obtained through unit root tests and cointegration analysis (section 5) as well as through the application of ARDL models (section 6). Finally, section 7 provides some conclusions and outlines future work.

[2] The only analysis of this kind I am aware of is that of Narayan and Smyth (2006) who performed a unit root test of one variable (primary energy consumption) in 182 countries, among which was Cyprus.

2. THE ENERGY SECTOR IN CYPRUS

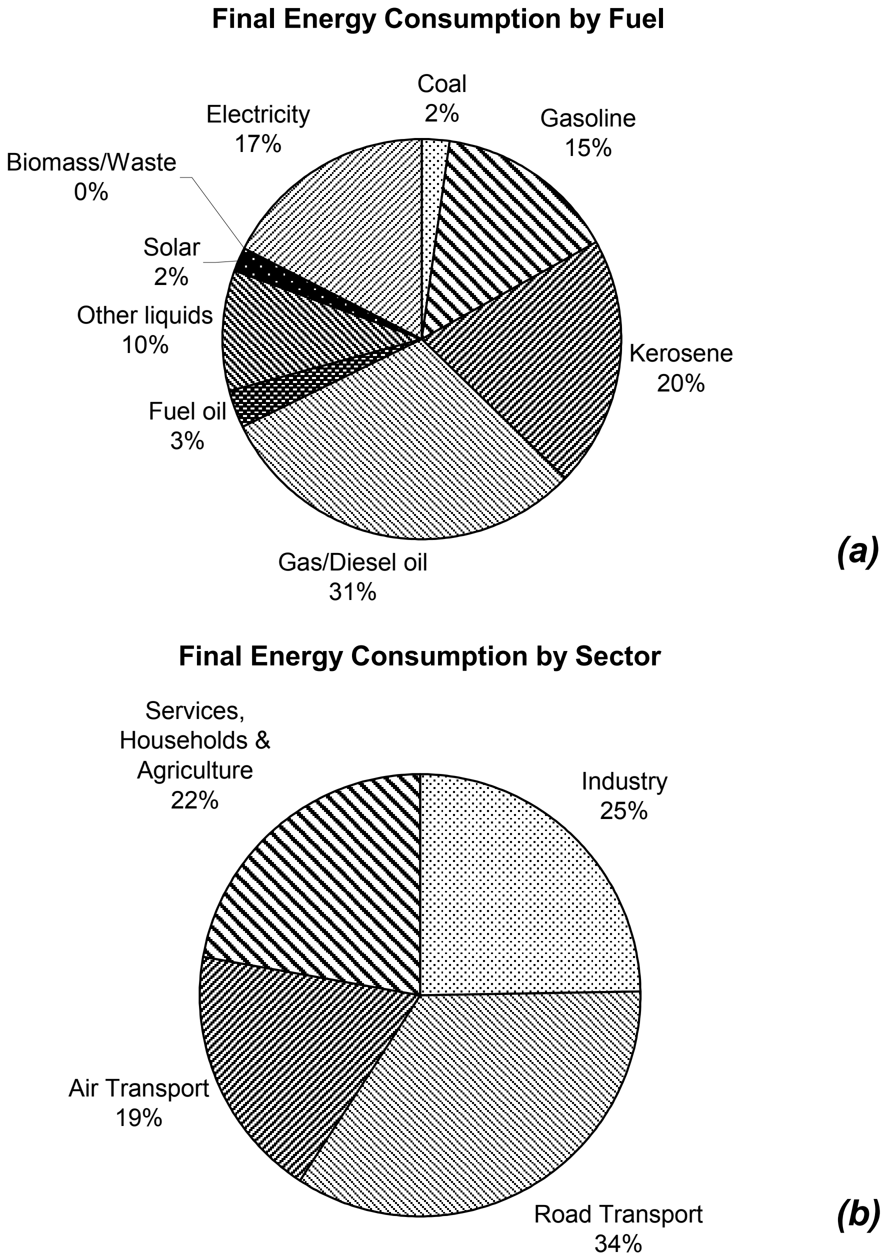
The basic characteristics of the Cypriot energy system have been described several times before (see e.g. Koroneos et al. 2005, Mirasgedis et al. 2004, Zervos et al. 2004). In short, the island possesses no indigenous energy resources apart from ample solar and some wind and biomass energy potential 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 988 MW in 2005) are mainly powered by fuel oil; from 2009 onwards 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 and despite an invasion of Turkish troops (still keeping hold of 38% of the island's territory) in 1974. Its per capita Gross Domestic Product was close to 17 000 Euros in 2004, or 75% of the EU average.

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 a slowdown since the mid-1990s (2.7% annual growth after 1995). Predictably, electricity consumption increased even faster (by 7.1% and 5.5% annually in the last 30 and 10 years respectively). Energy intensity, the amount of energy consumed per unit of GDP, is higher than that of any other Mediterranean EU country and has not shown any clear signs of receding yet (Eurostat 2005). Oil products currently account for 97% of primary energy demand, with coal and solar energy sharing the rest.

Figure 1 displays the shares of final energy demand in Cyprus in the year 2003 by fuel and sector. Road transport consumes more than a third of final energy, with the rest being shared in almost equal parts by industry, the residential/services sector, and aviation. Gas/Diesel oil has the highest share in final energy as it is used in road transportation, in buildings for heating purposes and in the industry. Electricity, gasoline and kerosene account for 15-20% of final demand each. Fuel shares have remained essentially stable since 1990, only with electricity clearly gaining share. In the sectoral breakdown, industry has lost share (from 33% in 1990 it fell to 25% in 2003, reflecting a similar decrease in industrial economic activity as a fraction of GDP), and its share was taken up by the other main sectors.

Figure 1: Final energy consumption in Cyprus in 2003
***(a)* by fuel and *(b)* by sector. Source: Eurostat (2005).**



3. THE GENERAL MODEL FORMULATION

The most common way to analyse energy use in a time series framework is through an 'ad hoc model', a term being used to acknowledge the limited theoretical basis of such a formulation as opposed to other models (consumer demand systems such as the translog model) that have some foundation in economic theory (Zarnikau 2003). A usual 'ad hoc' model of energy use involves estimating an equation or a system with the following three variables (mostly in linear double logarithmic form in order to derive elasticities directly from the estimated coefficients):

- energy consumption (as an aggregate over all fuel types and economic sectors or disaggregated by fuel and/or sector)

- economic activity or income (expressed as GDP, disposable income, value added, production index etc.) in real terms

- the real price of the corresponding energy form; usually the end-user price is used except in cases with data availability problems, where an international price (e.g. Brent oil price) is used.

In a single-equation framework the energy variable will be the only dependent one, with economic and price variables taken as exogenous. In a multivariate analysis all three variables are treated as endogenous. Reviews of such studies have been published several times before (see e.g. Bentzen and Engsted 1993). Many recent studies include additional explanatory variables:

- a weather-related variable such as average temperature or heating/cooling degree-days (see section 4 for an explanation of the degree-day concept) in order to account for weather fluctuations that affect energy used for heating and cooling purposes;

- relative fuel prices or the fuel price of at least one major 'competing' fuel so as to account for substitution effects between different energy forms.

In a few cases the analysis includes additional variables based on additional detailed information e.g. about the stock of energy-consuming appliances or the number and average size of new dwellings built in a country. Despite the obvious advantages of including such variables which describe important technical and demographic effects and may thus lead to more realistic estimates of income and price elasticities, this information is often difficult to find or may not be of appropriate quality – see e.g. the related discussion of Micklewright (1989) and Silk and Joutz (1997).

To strike a balance between available data and requirements for a robust energy analysis for Cyprus, the models that will be described in the following sections of this report have utilised 4 variables for each sector and fuel that were addressed: energy consumption (e_t), real economic activity or income (y_t), real fuel price (p_t) and total (heating + cooling) degree-days (tdd_t). In a single-equation framework such as the

ARDL model described in section 6, this leads to the following general formulation in a linear double-logarithmic form:

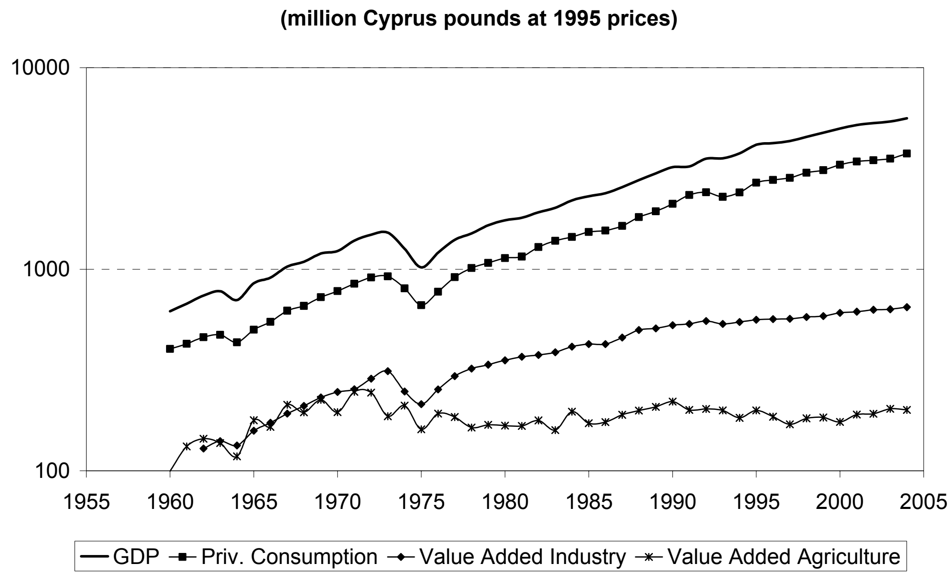
$$e_t = f\,(y_t,\ p_t,\ tdd_t) \qquad (1)$$

In the VAR analysis of section 5 all three basic variables will be treated as endogenous. The inclusion of relative fuel prices (or prices of competing fuels) has also been tested, and whether the results legitimate the use of these variables is stated in the corresponding sections. The use of variables in levels or in their first differences is determined on the basis of their time series properties and will also be described in the following sections of the report.

4. AVAILABLE DATA

Energy, economic and price data were taken from various publications of the Statistical Service of the Republic of Cyprus (CYSTAT 2005). Most of them are annual data series from 1960 to 2004. Non-electricity energy consumption is not available in the form of long time series for each economic sector but only in aggregate form and does not include small amounts of coal used by cement industries. On the other hand, electricity consumption data are available in some disaggregated form (for the main economic sectors, i.e. residential, commercial, industrial and agricultural consumption). Hence the analysis that follows is as detailed as the available information allows.

Figure 2: Evolution of GDP, final consumption expenditure and value added of selected sectors in Cyprus, 1960-2004. The scale is logarithmic. Source: CYSTAT (2005).



For those categories where energy consumption data are available, end user prices are also provided by official sources. Current prices per tonne of oil product (or per kilowatt-hour of electricity) were first transformed to current prices per tonne of oil equivalent (toe) and then into constant prices per toe with the aid of the GDP deflator. Economic data used were total GDP, private final consumption expenditure and the value added (VA) of industry, services and agriculture (see Figure 2). VA data in current prices were turned into constant 1995 price data through the GDP deflator.

Weather conditions may critically affect energy use, although not all energy studies account for this variable explicitly. In the case of Cyprus, with hot summers and mild winters, it is both low temperatures (inducing energy use for heating) and high temperatures (causing air conditioner operation for cooling) that matter for energy analyses. Therefore, the appropriate climate variable could not be an average annual temperature, but rather the sum of heating and cooling degree-days over each year. Heating (cooling) degree days are meant to measure the severity and duration of cold (hot) weather: 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.

Table 1: Energy data available for Cyprus and the corresponding economic and climate time series that were used in the regressions of each energy series.

Energy consumption variables	*Economic variables*	*Climate variable*
Electricity, total	Real GDP Average weighted electricity price	Cooling+heating degree-days
Electricity, residential	Real private consumption expenditure Residential electricity price	Cooling+heating degree-days
Electricity, industry	Real value added of industry Industrial electricity price	-
Electricity, commercial	Real value added of services Commercial electricity price	Cooling+heating degree-days
Electricity, agriculture	Real value added of agriculture Agricultural electricity price	-
Gasoline	Real GDP Gasoline price	-
Total non-electricity final consumption	Real GDP Average weighted non-electricity price	Cooling+heating degree-days
Total final energy consumption	Real GDP Average weighted energy price	Cooling+heating degree-days

Despite relatively mild winters in Cyprus, energy use for heating is not negligible because of inefficient heating systems (often characterised by poor insulation and the lack of central heating systems in many buildings). Therefore, in this case the sum of cooling and heating degree-days seems to be the proper variable for use in energy demand relationships, as it reflects those weather conditions that typically cause energy-using heating and cooling appliances to operate. The Meteorological Service of Cyprus recently computed this information for the first time in their history, and provided us with data from two meteorological stations located in the two largest Cypriot cities of Nicosia and Limassol. I selected 18°C and 22°C as realistic reference temperatures for calculating heating and cooling degree-days respectively.

Figure 3: Evolution of final energy consumption of selected fuels in Cyprus, 1960-2004. Other petroleum products do not include aviation fuel. Source: CYSTAT (2005).

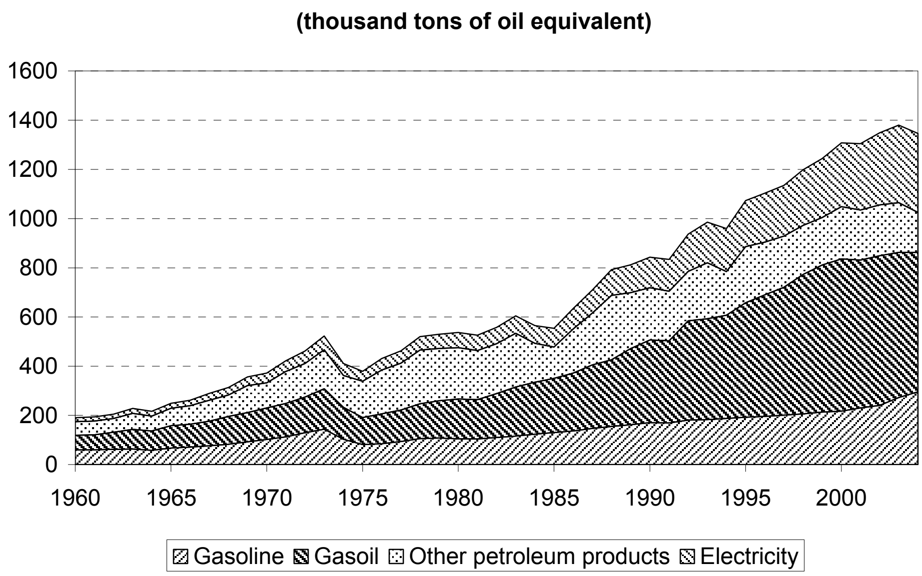


Figure 4: Sectoral shares of electricity consumption in Cyprus, 1960-2004. Source: CYSTAT (2005).

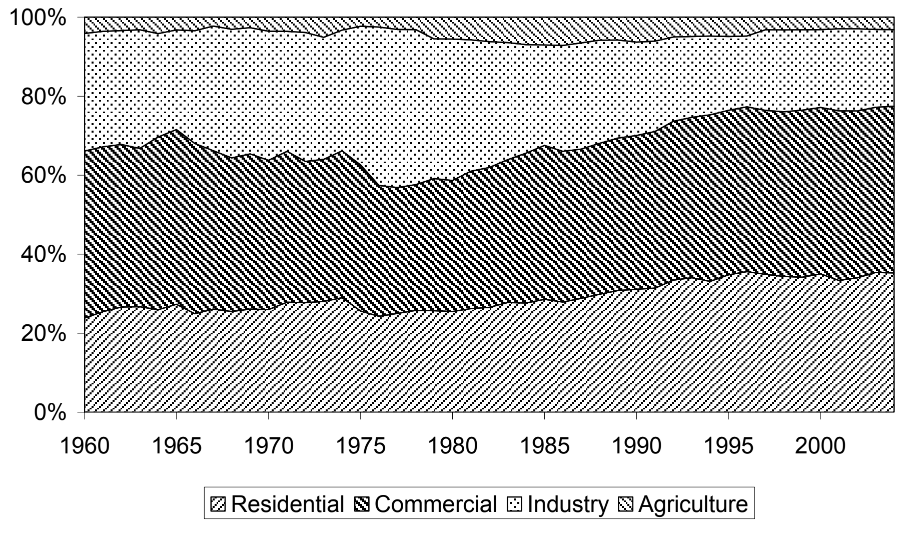
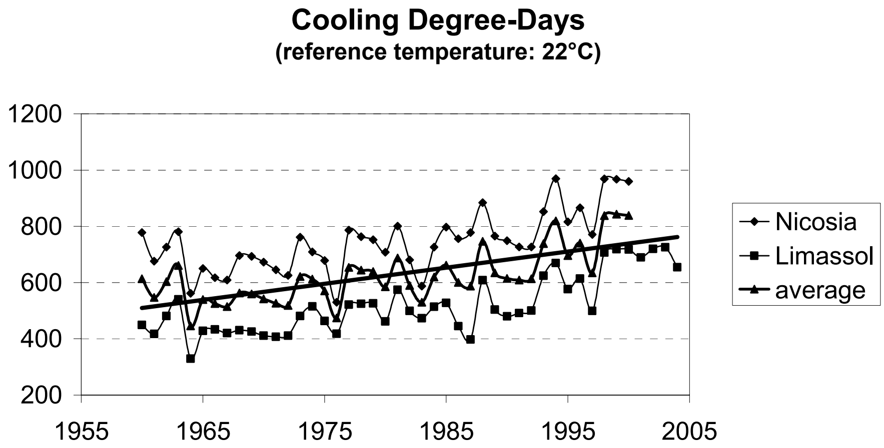
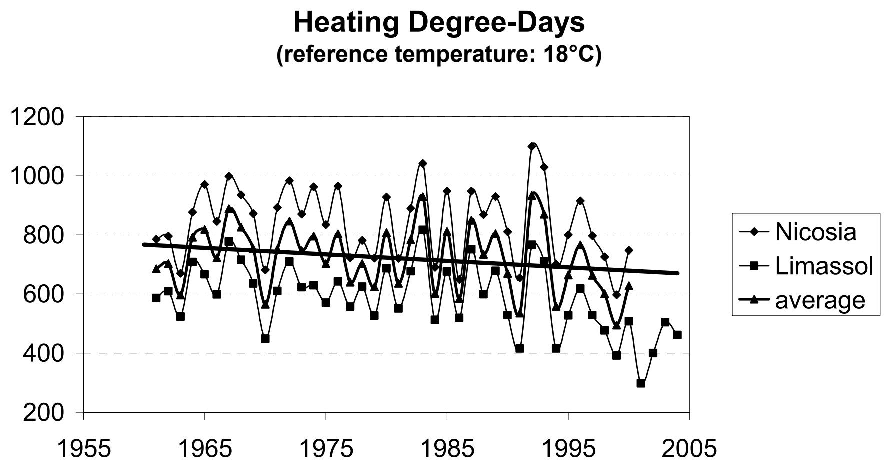


Figure 5: Evolution of degree-days as calculated from temperature measurements in meteorological stations in the two largest Cypriot cities of Nicosia and Limassol, 1960-2004. The average of two stations is also indicated, together with an indicative trendline. Source: Meteorological Service of Cyprus.





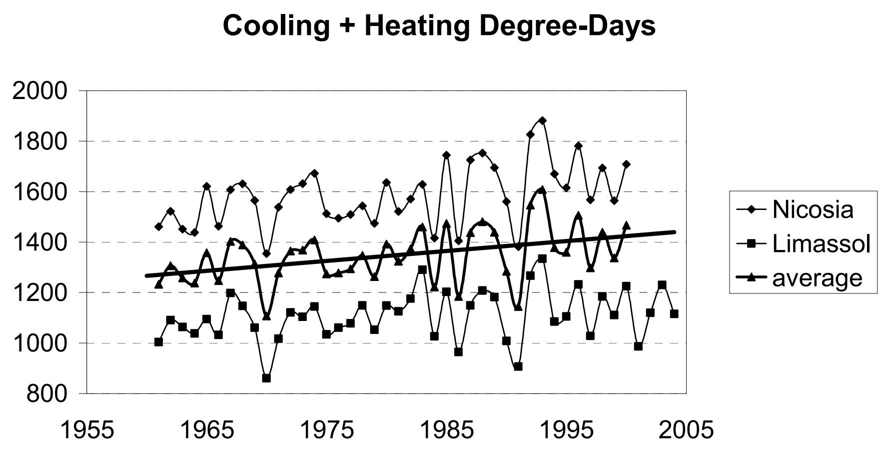


Figure 6: Evolution of real fuel prices in Cyprus, 1960-2003. The price of heating and automotive gasoil were identical up to 2000 and have deviated very little since then. Electricity price is the sales-weighted average of all sectors. Source: CYSTAT (2005).

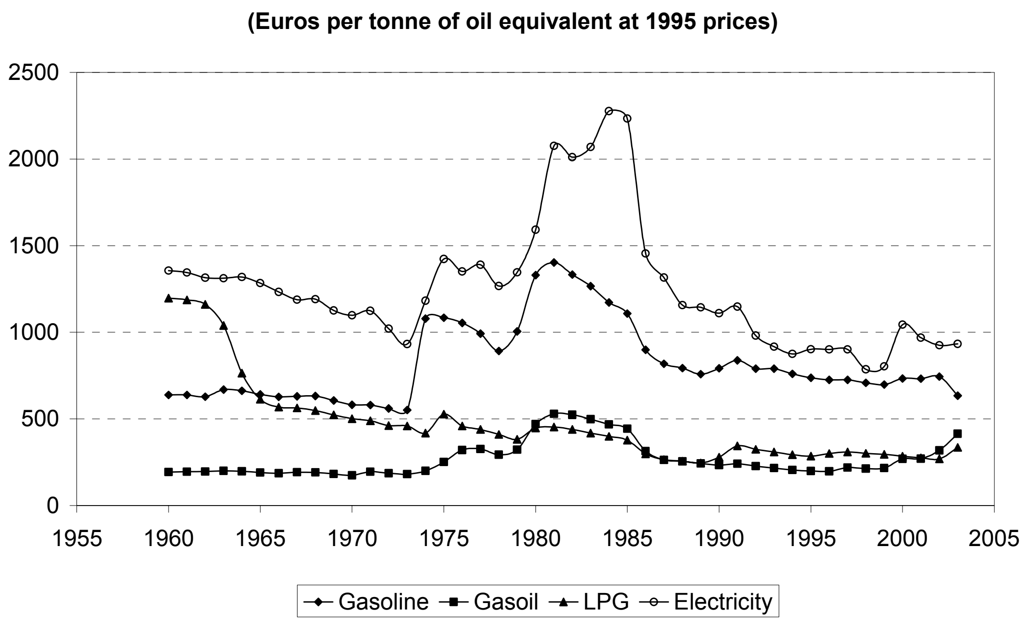
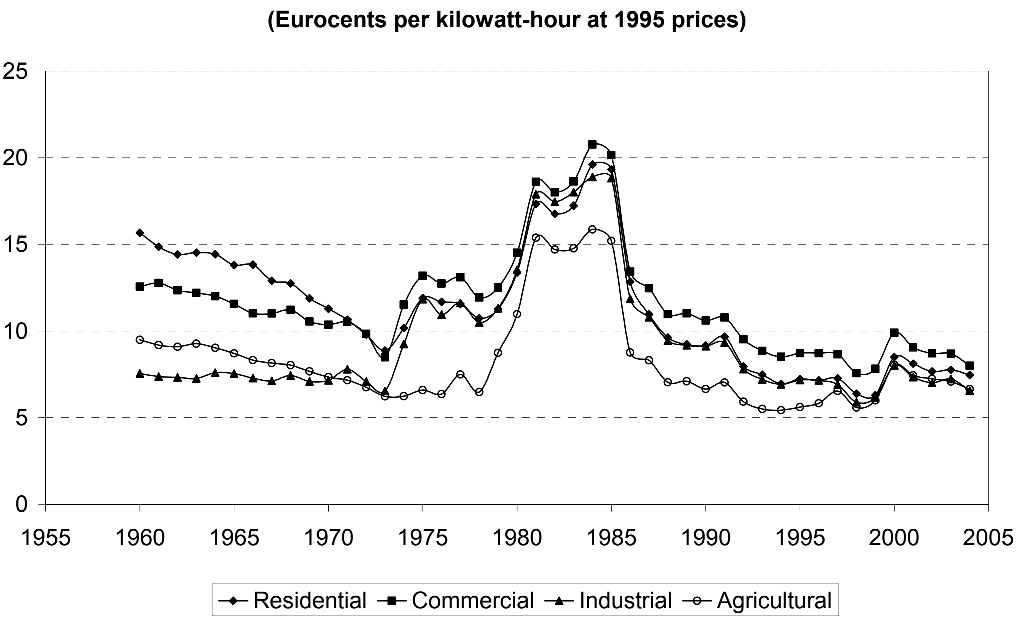


Figure 7: Evolution of real electricity prices in Cyprus, 1960-2004. Source: CYSTAT (2005).



Figures 2 to 7 show the evolution of the basic economic, energy and weather variables explained in the previous paragraphs. Table 1 summarises the energy time series data and the corresponding economic and weather variables used in the regressions to be described in the following sections.

5. APPLICATION OF COINTEGRATION TECHNIQUES AND VECTOR ERROR CORRECTION MODELS

Applied time series analysis usually proceeds by i) testing the stationarity properties of variables through unit root tests with and without structural breaks, ii) performing cointegration analysis if some variables are found to be non-stationary and iii) formulating Vector Error Correction models for the examination of short-run and long-run interactions between variables. On the basis of these models one can draw conclusions about Granger causality between variables and explore the dynamic model characteristics by analysing the responses of variables to impulses (or shocks) in the other variables of the system. Each one of these steps is described in the following sections.

5.1. Unit root tests

It is evident from Figures 2 and 3 that all economic and energy variables experienced an abrupt shift (reduction in their levels) in 1974-1975 as a result of the Turkish invasion in Cyprus in mid-1974. Most of these variables returned back to their 'normal' track by 1978-1979 without a significant change in their long-term trend. Since this event was by far the most important one in the history if the island during the 1960-2004 period, it is reasonable to take this as an exogenous structural break in the time series in the sense that, as Perron (1989) conveys referring to the 1929 Great Crash and the 1973 oil price shock, such events "… were not a realisation of the underlying data generating mechanism of the various series" and that the exogeneity assumption is used in order to remove the influence of this shock from the noise function[3].

As a result of this exogenous structural break, it is appropriate to perform a unit root test according to the Perron (1989) method because tests that do not account for structural breaks may falsely fail to reject the unit root null hypothesis against the trend-stationary alternative when the data generating process is trend-stationary with a one-time break. As this break in Cyprus involved a one-time change in level, Perron's model A was used:

$$y_t = \hat{\mu} + \hat{\theta} DU_t + \hat{\beta} t + \hat{d} D(TB)_t + \hat{a} y_{t-1} + \sum_{i=1}^{k} \hat{c}_t \Delta y_{t-i} + \hat{e}_t \quad (2)$$

[3] Although the 1974 events in Cyprus almost coincided with the 1973 world oil price shock, Perron's (1989) finding that some post-1973 macroeconomic variables reported by Nelson and Plosser (1982) in the U.S. experienced a change in their slope after 1973 is not supported for the case of Cyprus by Figures 2 and 3.

where *y* is the test variable, *DU* is a dummy variable having the value of 0 until 1974 and 1 from 1975 onwards, *D(TB)* is another dummy taking the value of 1 in 1975 and 0 in all other years and $\hat{e}_t$ is an (0, σ^2) innovation series. The lagged differences of *y* are added in order to eliminate possible nuisance-parameter dependencies in the limit distributions of the test statistics caused by temporal dependence in the disturbances (Zivot and Andrews 1992). The number of lags *k* is determined by a test of the significance of coefficients $\hat{c}_t$. Perron started with a maximum of *k=8* but in our case, due to the limited sample size such a high lag order would decrease the power of the test too much, therefore I applied a maximum *k=3*.

Table 2 reports the results of Perron's unit root test for all economic and energy variables, while Table 3 displays the Augmented Dickey-Fuller (ADF – see Dickey and Fuller 1979) test results for these variables and the weather variable. According to both tests, the unit root hypothesis cannot be rejected at the 5% level for any economic and energy variable in levels except agricultural value added[4], whereas the ADF test shows that degree-days is clearly a stationary (I(0), integrated of order zero) variable. Further investigation of unit root hypotheses in the first differences of variables is shown in Table 4[5]. Results reveal that the differenced variables are stationary; therefore, with the exception of agricultural value added, all other economic and energy variables are found to be I(1) (integrated of order 1).

It is necessary to note here that unit root test results should be treated with caution. For one thing, the size and power of unit root tests is typically low because it is difficult to distinguish between stationary and non-stationary processes in finite samples (Harris and Sollis 2003), and there is a switch in the distribution function of the test statistics as one or more roots of the data generating process approach unity (Cavanagh 1995, Pesaran 1997). Moreover, the sample size (less than 45 observations) is small in our case, thus limiting further the power of these tests. However, since both the ADF and the Perron test confirm the existence of a unit root in most energy and economic data used here, and as this is in line with findings from other countries (see e.g. Clements and Madlener 1999, Fatai et al. 2004, Narayan and Smyth 2006), the conclusion that the energy, macroeconomic and price data of Cyprus exhibit non-stationary properties seems to be valid.

---

[4] According to the ADF test, private consumption is also stationary but I prefer to rely on the Perron test result and regard it as an I(1) variable.

[5] ADF testing was used for this purpose as the weakness of this test is associated with over-accepting the unit root hypothesis in processes with structural breaks. As test results in this case show rejection of the hypothesis (see Table 4) it was not considered necessary to employ the Perron test as well.

Table 2: Perron unit root test results for all energy and economic variables examined in this study.

Variable	*k*	*μ*	t_μ	*θ*	t_θ	*β*	t_β	*d*	t_d	*α*	t_α
Electricity consumption, total	0	1.054	2.147	-0.046	-1.161	0.013	1.850	-0.200	-3.221	0.814	-1.970
Electricity consumption, residential	0	1.068	2.563	-0.110	-1.786	0.022	2.215	-0.273	-3.257	0.742	-2.320
Electricity consumption, industry	0	0.644	2.002	-0.012	-0.230	0.007	1.503	-0.076	-0.766	0.866	-1.741
Electricity consumption, commercial	0	1.307	2.347	-0.133	-1.918	0.024	2.171	-0.150	-2.309	0.708	-2.212
Electricity consumption, agriculture	2	0.693	3.541	0.236	2.247	0.012	1.428	-0.924	-4.190	0.707	-2.766
Gasoline consumption	1	1.610	3.137	-0.086	-1.583	0.015	2.845	-0.082	-0.710	0.608	-3.057
Total non-electricity final consumption	0	1.418	2.396	0.017	0.400	0.009	1.773	-0.122	-1.586	0.742	-2.283
Total final consumption	0	1.496	2.478	-0.001	-0.013	0.011	1.981	-0.124	-1.707	0.731	-2.366
Real GDP	0	2.374	3.137	-0.010	-0.248	0.017	2.553	-0.290	-5.110	0.643	-3.040
Real private consumption expenditure	0	1.870	3.072	0.020	0.614	0.015	2.448	-0.283	-5.380	0.698	-2.958
Real value added of industry	0	1.155	3.263	0.078	2.397	0.004	1.436	-0.253	-4.253	0.785	-3.028
Real value added of services	0	1.355	1.599	0.017	0.271	0.012	1.197	-0.282	-4.550	0.777	-1.518
Real value added of agriculture	3	3.288	4.785	-0.103	-1.689	0.002	0.962	-0.137	-1.299	0.380	-4.669 *
Average weighted electricity price	0	0.416	2.117	0.140	1.585	-0.006	-1.800	0.100	0.794	0.791	-2.181
Residential electricity price	1	0.501	2.433	0.112	1.514	-0.007	-2.026	0.025	0.202	0.770	-2.556
Industrial electricity price	0	0.303	1.794	0.139	1.171	-0.005	-1.397	0.174	1.208	0.831	-1.732
Commercial electricity price	0	0.501	2.301	0.155	1.734	-0.007	-1.993	0.047	0.384	0.759	-2.330
Agricultural electricity price	0	0.309	2.089	0.159	1.874	-0.006	-1.828	-0.079	-0.523	0.812	-2.262
Gasoline price	1	1.872	1.653	0.165	0.977	-0.005	-1.086	-0.344	-1.377	0.700	-1.622
Average weighted non-electricity price	1	1.166	1.743	0.056	0.558	-0.002	-0.466	-0.204	-1.332	0.786	-1.741
Average weighted energy price	1	1.278	2.000	0.092	0.884	-0.002	-0.684	-0.082	-0.525	0.764	-1.998

Notes: Regression formula is $y_t = \hat{\mu} + \hat{\theta} DU_t + \hat{\beta} t + \hat{d} D(TB)_t + \hat{a} y_{t-1} + \sum_{i=1}^{k} \hat{c}_t \Delta y_{t-i} + \hat{e}_t$.

See explanations under eq. (2) in the text. Sample size for all variables is 44 or 45, therefore the λ value for a structural break in the 15th observation (year 1974) is always approximately 0.3. *t*-statistics are reported for the hypotheses that the corresponding parameter is zero, except for α where t_α refers to the hypothesis $\alpha=1$. The critical value of t_α, taken from Table IV.B of Perron (1989) for $\lambda=0.3$ at the 5% and 10% level, is –3.76 and –3.46 respectively. * denotes rejection of the unit root hypothesis at 5% level.

Table 3: ADF unit root test results for all variables (in levels) examined in this study.

Variable	*Lags*	*Exogenous regressors*	*ADF test statistic*
Electricity consumption, total	1	Constant & linear trend	-2.810
Electricity consumption, residential	1	Constant & linear trend	-2.438
Electricity consumption, industry	0	Constant & linear trend	-1.955
Electricity consumption, commercial	1	Constant & linear trend	-2.278
Electricity consumption, agriculture	0	Constant & linear trend	-2.129
Gasoline consumption	1	Constant & linear trend	-3.517
Total non-electricity final consumption	1	Constant & linear trend	-2.729
Total final consumption	1	Constant & linear trend	-2.906
Real GDP	1	Constant & linear trend	-3.323
Real private consumption expenditure	1	Constant & linear trend	-3.915 *
Real value added of industry	2	Constant & linear trend	-2.859
Real value added of services	1	Constant & linear trend	-2.946
Real value added of agriculture	1	Constant	-3.206 *
Average weighted electricity price	0	Constant	-1.237
Residential electricity price	0	Constant	-1.242
Industrial electricity price	0	Constant	-1.232
Commercial electricity price	0	Constant	-1.221
Agricultural electricity price	0	Constant	-1.647
Gasoline price	0	Constant	-1.637
Average weighted non-electricity price	0	Constant	-1.605
Average weighted energy price	0	Constant	-1.632
Cooling+heating degree-days	0	Constant	-6.510 *

Notes: Lag length in the ADF test equations was selected on the basis of the Schwarz Information Criterion. Critical values at 5% level are around –2.93 and –3.52 if test equation includes a constant or a constant and a linear trend respectively (MacKinnon 1996). * denotes rejection of the unit root hypothesis at 5% level.

Table 4: ADF unit root test results for all variables (in first differences) examined in this study.

Variable	*Lags*	*Exogenous regressors*	*ADF test statistic*
Electricity consumption, total	1	Constant	-4.760 *
Electricity consumption, residential	0	Constant	-5.294 *
Electricity consumption, industry	1	Constant	-5.099 *
Electricity consumption, commercial	0	Constant	-3.820 *
Electricity consumption, agriculture	0	Constant	-6.478 *
Gasoline consumption	1	Constant	-4.986 *
Total non-electricity final consumption	0	Constant	-6.425 *
Total final consumption	0	Constant	-6.239 *
Real GDP	1	Constant	-5.018 *
Real private consumption expenditure	1	Constant	-5.381 *
Real value added of industry	1	Constant	-5.544 *
Real value added of services	1	Constant	-5.073 *
Average weighted electricity price	0	-	-5.274 *
Residential electricity price	0	-	-4.956 *
Industrial electricity price	0	-	-5.357 *
Commercial electricity price	0	-	-5.619 *
Agricultural electricity price	0	-	-5.731 *
Gasoline price	0	-	-5.582 *
Average weighted non-electricity price	0	-	-5.086 *
Average weighted energy price	0	-	-5.296 *

Notes: See explanations in Table 3. Critical value for rejection of unit root hypothesis at 5% level is –1.95 if test equation does not include any exogenous regressor (MacKinnon 1996).

5.2. Cointegration analysis

Since most variables are non-stationary, the model shown in Section 3 (see eq. 1) should not be estimated in their level form but in first differences. The obvious problem of such a solution, i.e. the loss of information on any long-run relationships between variables, can be resolved with the use of cointegration analysis. This involves, within a Vector Autoregression (VAR), checking whether a linear combination of non-stationary variables is stationary, which would imply that there exists a long-run equilibrium relationship between the variables. In our case, there are three I(1) variables involved in each system to be estimated; therefore, to allow for the theoretical possibility of up to two long-run relationships, cointegration analysis was carried out here with the widely used Johansen (1988, 1991) system approach.

Table 5 shows the results of the cointegration tests on all energy use relationships examined. In some cases the (stationary) degree-days variable has been included as exogenous to the cointegrating vector. By default, tests were conducted assuming an unrestricted intercept term, thereby allowing for a quite general specification without over-parameterising the system. In cases where the cointegration hypothesis was rejected for this scheme, a separate test was conducted including an intercept in the CE only. Table 5 displays the outcome of all these tests. In most cases, the analysis confirms the existence of one long-term relationship between an energy consumption variable and the corresponding income and price variables. Long-term income elasticities[6] are found to be very significant and around or above unity, with the highest ones being observed in the cases of industrial electricity (2.1) and gasoline (1.8). Long-term price elasticities are significant in electricity consumption only,

Table 5: Results of the Johansen cointegration analysis.

Model #	Equation	Rank, r	Eigenvalue	Max. Eigenvalue statistic	5% critical value	Trace test statistic	5% critical value	Exogenous	intercept	e_t	y_t	p_t	constant
1	Electricity consumption, total	0	0.273	13.72	21.13	21.52	29.80		CE & VAR	1	-1.387 *	0.237	3.364
		≤1	0.164	7.68	14.26	7.81	15.49				[-28.324]	[1.705]	
		≤2	0.003	0.13	3.84	0.13	3.84						
2	Electricity consumption, total	0	0.693	50.78 *	22.30	64.22 *	35.19		CE	1	-2.178 *	-0.424	13.272
		≤1	0.252	12.46	15.89	13.43	20.26				[-6.601]	[-0.452]	[3.580]
		≤2	0.022	0.97	9.16	0.97	9.16						
3	Electricity consumption, total	0	0.278	14.01	21.13	22.42	29.80	Δtdd	CE & VAR	1	-1.375 *	0.269	3.219
		≤1	0.172	8.11	14.26	8.41	15.49				[-28.167]	[1.927]	
		≤2	0.007	0.30	3.84	0.30	3.84						
4	Electricity consumption, total	0	0.720	54.67 *	22.30	67.04 *	35.19	Δtdd	CE	1	-1.641 *	-0.186	7.271
		≤1	0.245	12.09	15.89	12.37	20.26				[-11.532]	[-0.468]	[4.578]
		≤2	0.007	0.29	9.16	0.29	9.16						
5	Electricity consumption, residential	0	0.371	19.92	21.13	30.34 *	29.80	Δtdd	CE & VAR	1	-1.175 *	0.427 *	2.113
		≤1	0.199	9.53	14.26	10.41	15.49				[-20.299]	[3.175]	
		≤2	0.020	0.88	3.84	0.88	3.84						
6	Electricity consumption, residential	0	0.726	55.69 *	22.30	62.48 *	35.19	Δtdd	CE	1	-1.204 *	0.454	1.527
		≤1	0.119	5.44	15.89	6.80	20.26				[-10.057]	[1.613]	[1.181]
		≤2	0.031	1.36	9.16	1.36	9.16						
7	Electricity consumption, industry	0	0.586	36.15 *	21.13	39.35 *	29.80		CE & VAR	1	-2.089 *	0.468 *	6.011
		≤1	0.065	2.76	14.26	3.20	15.49				[-16.255]	[2.426]	
		≤2	0.011	0.44	3.84	0.44	3.84						
8	Electricity consumption, commercial	0	0.458	25.15 *	21.13	34.46 *	29.80		CE & VAR	1	-1.133 *	0.223 *	1.858
		≤1	0.200	9.16	14.26	9.31	15.49				[-77.878]	[4.726]	
		≤2	0.004	0.16	3.84	0.16	3.84						
9	Electricity consumption, commercial	0	0.450	24.48 *	21.13	33.61 *	29.80	Δtdd	CE & VAR	1	-1.132 *	0.235 *	1.828
		≤1	0.193	8.77	14.26	9.13	15.49				[-75.779]	[4.803]	
		≤2	0.009	0.36	3.84	0.36	3.84						
10	Electricity consumption, agriculture	0	0.162	7.59	14.26	7.69	15.49		CE & VAR	1	-	-0.276	-3.135
		≤1	0.002	0.10	3.84	0.10	3.84					[-0.184]	
11	Gasoline consumption	0	0.485	27.85 *	21.13	37.55 *	29.80		CE & VAR	1	-1.779 *	-0.873	14.154
		≤1	0.194	9.06	14.26	9.70	15.49				[-7.721]	[-1.463]	
		≤2	0.015	0.64	3.84	0.64	3.84						
12	Total non-electricity final consumption	0	0.381	20.15	21.13	34.73 *	29.80		CE & VAR	1	-0.916 *	-0.146	1.545
		≤1	0.235	11.28	14.26	14.58	15.49				[-31.532]	[-1.705]	
		≤2	0.076	3.31	3.84	3.31	3.84						
13	Total non-electricity final consumption	0	0.782	63.92 *	22.30	76.13 *	35.19		CE	1	-0.942 *	-0.218 *	2.402
		≤1	0.209	9.85	15.89	12.21	20.26				[-31.981]	[-2.408]	[4.265]
		≤2	0.055	2.36	9.16	2.36	9.16						
14	Total final consumption	0	0.369	19.33	21.13	30.50 *	29.80		CE & VAR	1	-0.970 *	-0.120	1.677
		≤1	0.201	9.45	14.26	11.18	15.49				[-34.700]	[-1.530]	
		≤2	0.040	1.73	3.84	1.73	3.84						

Notes: Rank *r* expresses the number of cointegrating equations according to each tested hypothesis. Tests included exogenous dummy variables for all or some of the years 1974, 1975, 1980, 1986 and 2000 because of too high (in absolute terms) growth rates during these years (see Figures 2, 3, 6 and 7). Lag length of all underlying VARs was set equal to 1. Column 'exogenous' displays whether total degree-days was included in the test VAR (in first differences) or not. Column 'intercept' shows whether an intercept was included in the cointegrating equation (CE) only or unrestrictedly in both CE and VAR. Critical values were taken from MacKinnon et al. (1999).

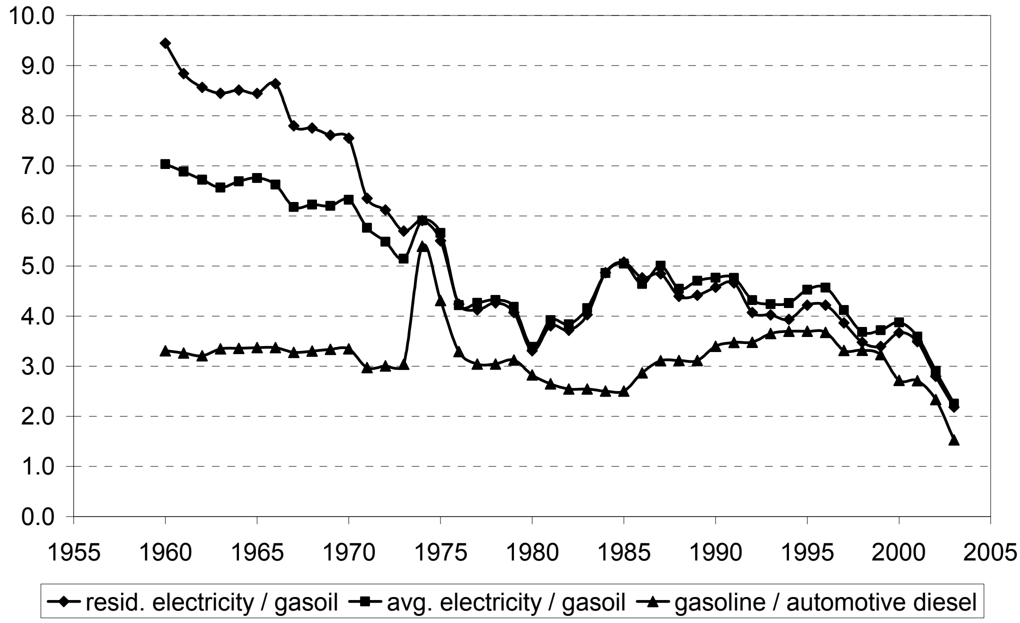
The right-hand side of the table shows the normalised coefficients of the cointegrating equations, with e_t, y_t and p_t denoting the coefficients of the corresponding energy, income and price variable respectively (see Table 1), with t-statistics in brackets. In agricultural electricity consumption, only energy and price are examined as the value added of the sector was found to be stationary (see Table 2). * denotes rejection of the corresponding hypothesis at 5% level.

[6] Since one cointegrating relationship is found in most models, it can be interpreted as the structural economic relationship between the variables; hence the use of the term 'elasticity' seems to be justified. It is reminded that e.g. an income elasticity of energy consumption of 0.8 implies that, if income rises by 10%, energy use will increase by 8%, whereas a price elasticity of -0.3 means that if the price doubles (increases 100%) energy use will decline by 30%.

ranging from 0.28 to 0.47, whereas they turn out to be insignificant for the other cases (consumption of gasoline, total energy and total energy except electricity). No long-term relationship was found for agricultural electricity consumption.

Although it might be appropriate to include relative energy prices in the above equations (which could explain potential substitution effects between e.g. electricity and gasoil in the residential and commercial sectors or between gasoline and diesel in transportation), all tests that were carried out[7] showed that the effect of competing fuels was insignificant. There may be at least two reasons for this behaviour: firstly, most electricity uses (e.g. home appliances, air conditioning systems, operation of motors and other processes in industry etc.) are hardly substitutable by another energy form (with space heating being the most important exception); secondly, as Figure 8 illustrates, the relative price of gasoline to automotive diesel has changed markedly only during the last few years, so that the analysis of the period 1960-2003 presented here cannot capture these effects.

Figure 8: Evolution of relative energy prices in Cyprus, 1960-2004.



[7] Two types of models were tested: one including, instead of the corresponding fuel price, the ratio of that price to that of a competing fuel and one including two prices: that of the corresponding fuel and that of its main ‘competitor’. For example, in the case of residential electricity consumption the former model included the ratio of residential electricity price over gasoil price and the latter model included both residential electricity price and gasoil price.

5.3. Vector Error Correction models

Once the cointegrating relationships (if any) have been determined, the next step is to estimate a Vector Error Correction (VEC) model, i.e. with the variables in first differences and including the long-run relationships as error-correction terms in the system. In our case the VEC equations take the form:

$$\Delta e_t = \alpha_{01} + \alpha_{11}\,\Delta e_{t-1} + \alpha_{21}\,\Delta y_{t-1} + \alpha_{31}\,\Delta p_{t-1} + \alpha_{41}\,\Delta tdd_t + \alpha_{51}(e_{t-1} + b\,y_{t-1} + c\,p_{t-1} + d) + u_{1t} \quad (3)$$

$$\Delta y_t = \alpha_{02} + \alpha_{12}\,\Delta e_{t-1} + \alpha_{22}\,\Delta y_{t-1} + \alpha_{32}\,\Delta p_{t-1} + \alpha_{42}\,\Delta tdd_t + \alpha_{52}(e_{t-1} + b\,y_{t-1} + c\,p_{t-1} + d) + u_{2t} \quad (4)$$

$$\Delta p_t = \alpha_{03} + \alpha_{13}\,\Delta e_{t-1} + \alpha_{23}\,\Delta y_{t-1} + \alpha_{33}\,\Delta p_{t-1} + \alpha_{43}\,\Delta tdd_t + \alpha_{53}(e_{t-1} + b\,y_{t-1} + c\,p_{t-1} + d) + u_{3t} \quad (5)$$

where e, y and p denote the corresponding energy, income and price variable respectively. The term in parenthesis is the error correction term, whose parameters were estimated in the cointegration analysis and are shown on the right-hand side of Table 5. Δtdd is the stationary variable of total degree-days in first differences. Residual terms u_{it} are independently and normally distributed with zero mean and constant variance. For each model, a sufficient number of dummy variables was used in order to filter out outliers in the time series and ensure normal distribution of residuals.

Table 6 presents the parameter estimates for each model that has displayed cointegration properties in the previous analysis (see Table 5)[8] along with a series of diagnostic tests. In general, the error-correction term is significant for both energy and income variables in almost all models. However, it is only in residential and commercial electricity consumption that the adjustment coefficient α_{5i} has the expected negative sign (which implies that it is indeed an error-correction mechanism that tends to bring the system closer to its long-run equilibrium – see e.g. Harris and Sollis 2003). As regards the short-term effects, most of them turn out to be insignificant, with a few exceptions, mainly on income variables: private consumption seems to be negatively affected by residential electricity consumption; non-electric energy consumption and price negatively affect GDP; gasoline consumption and gasoline price also affect GDP; and total energy consumption exhibits a short-term price elasticity of –0.22, while price and total energy consumption affect GDP with elasticities of –0.60 and –0.17 respectively. Finally, total degree-days are strongly significant, both for residential and total electricity consumption, with an elasticity of

[8] In the case of commercial electricity consumption I have chosen model #9, which contains degree-days as an exogenous variable, because it helps to enrich the analysis sicne the weather variable is significant as is shown in both Tables 5 and 6.

–0.21 and –0.13 respectively, which confirms the appropriateness of including this variable in the analysis.

Table 6: Results of the VEC analysis.

Model #	*Variables involved*	α_{0i}	α_{1i}	α_{2i}	α_{3i}	α_{4i}	α_{5i}
4	Electricity consumption, total	-	0.029	0.023	-0.059	0.107 *	0.060 *
			[0.182]	[0.180]	[-0.989]	[2.231]	[7.498]
	Real GDP	-	-0.311	-0.038	-0.049	0.031	0.073 *
			[-1.537]	[-0.236]	[-0.651]	[0.511]	[7.237]
	Average weighted electricity price	-	-0.216	0.214	0.003	-0.155	-0.015
			[-0.723]	[0.909]	[0.029]	[-1.741]	[-0.992]
5	Electricity consumption, residential	0.093 *	-0.042	-0.019	-0.103	0.209 *	-0.158 *
		[10.243]	[-0.377]	[-0.129]	[-1.722]	[3.647]	[-2.838]
	Real private consumption expenditure	0.089 *	-0.383 *	0.190	0.012	-0.038	-0.119 *
		[9.868]	[-3.450]	[1.337]	[0.195]	[-0.662]	[-2.150]
	Residential electricity price	-0.015	-0.141	0.235	0.249 *	-0.159	-0.103
		[-0.791]	[-0.623]	[0.809]	[2.049]	[-1.365]	[-0.916]
7	Electricity consumption, industry	0.060 *	0.233	-0.310	0.103	-	0.014
		[3.093]	[1.123]	[-1.066]	[0.752]		[0.334]
	Real value added of industry	0.056 *	-0.012	-0.122	-0.049	-	0.090 *
		[6.012]	[-0.121]	[-0.873]	[-0.750]		[4.614]
	Industrial electricity price	-0.022	-0.147	0.232	-0.079	-	0.055
		[-1.301]	[-0.798]	[0.901]	[-0.646]		[1.525]
9	Electricity consumption, commercial	0.080 *	0.068	-0.096	0.001	0.080 *	-0.254 *
		[7.960]	[0.531]	[-1.025]	[0.014]	[2.302]	[-2.793]
	Real value added of services	0.066 *	-0.003	0.062	-0.044	0.055	0.321 *
		[3.774]	[-0.012]	[0.382]	[-0.555]	[0.901]	[2.016]
	Commercial electricity price	-0.058 *	0.247	0.242	-0.038	-0.077	0.311
		[-2.293]	[0.760]	[1.026]	[-0.329]	[-0.882]	[1.351]
11	Gasoline consumption	0.057 *	0.208	-0.171	-0.068	-	0.026 *
		[8.097]	[1.314]	[-1.194]	[-0.787]		[3.809]
	Real GDP	0.082 *	-0.388 *	-0.012	-0.188 *	-	0.030 *
		[12.162]	[-2.569]	[-0.089]	[-2.286]		[4.550]
	Gasoline price	-0.018	0.210	-0.109	0.293	-	0.006
		[-1.455]	[0.754]	[-0.434]	[1.933]		[0.473]
12	Total non-electricity final consumption	0.062 *	-0.403	0.130	-0.237	-	0.241 *
		[4.373]	[-1.504]	[0.641]	[-1.825]		[2.007]
	Real GDP	0.082 *	-0.605 *	0.165	-0.226 *	-	0.349 *
		[8.752]	[-3.429]	[1.240]	[-2.649]		[4.417]
	Average weighted non-electricity price	-0.001	0.222	-0.181	0.357 *	-	-0.055
		[-0.037]	[0.792]	[-0.856]	[2.625]		[-0.434]
14	Total final consumption	0.068 *	-0.414	0.148	-0.216 *	-	0.245 *
		[5.117]	[-1.612]	[0.767]	[-2.268]		[2.153]
	Real GDP	0.083 *	-0.599 *	0.195	-0.166 *	-	0.357 *
		[8.274]	[-3.126]	[1.357]	[-2.341]		[4.211]
	Average weighted energy price	0.003	0.039	-0.073	0.172	-	0.027
		[0.128]	[0.099]	[-0.246]	[1.174]		[0.154]

Diagnostic tests

Model #	*Description*	*PAC(4)*	*LM(4)*	*J-B*	*WHn*	*WHw*
4	Total electricity	0.080	0.328	0.870	0.944	0.765
5	Residential electricity	0.523	0.896	0.374	0.976	0.338
7	Industrial electricity	0.081	0.350	0.700	0.473	0.536
9	Commercial electricity	0.119	0.498	0.128	0.953	0.767
12	Gasoline	0.400	0.878	0.283	0.933	0.692
13	Non-electricity	0.955	0.957	0.056	0.919	0.566
15	Total final energy	0.952	0.951	0.002	0.999	0.950

Notes: For explanation of parameters see equations (3) to (5). As indicated in the first column, results refer to the corresponding models used in the cointegration analysis of Table 5. The same dummy variables were used as for the cointegration analysis. * denotes significance of estimates at 5% level. The lower part of the table reports probability values for rejecting the hypotheses of the following diagnostic tests: adjusted Q-statistic for Portmanteau Autocorrelation test up to the 4th lag, Lagrange Multiplier (LM) autocorrelation test up to the 4th lag, Jarque-Bera normality test (orthogonalisation method: Cholesky of covariance) and White heteroskedasticity test without (WHn) and with (WHw) cross terms. Estimations were conducted with OLS.

The results shown in Tables 5 and 6 have implications on questions about exogeneity and Granger causality among variables. This issue is discussed in the next section. Note however that, as the VEC models yield meaningful results for models 5, 7, 9 and 11, (residential, industrial and commercial electricity and gasoline consumption respectively), causality and impulse response analyses that will follow focus on these models only[9].

5.4. Exogeneity and Granger causality tests

The existence of a cointegrating vector among energy, 'income' and prices in each one of the two systems to be examined (residential and commercial electricity consumption) suggests that there must be Granger causality in at least one direction in each system. However, the direction of causation is not evident, nor is it clear whether causality is observed in the short or in the long run (or both); to address these issues further analysis is required on the basis of the VEC model results.

Since the seminal paper by Granger (1969), the literature on Granger causality has grown considerably. A significant amount of work has been devoted to addressing the question of causality between energy and economic development (see e.g. Asafu-Adjaye (2000), Fatai et al. (2004) and Yoo (2006) for an extensive literature review). The results from research in this field worldwide are very mixed, with some studies finding unidirectional Granger causality from energy consumption to GDP or vice versa, others confirming the 'neutrality hypothesis' (i.e. no causality in any direction), and other studies finding bidirectional causality. Although it has been attempted to provide economic interpretations for all these results, it is interesting to note that some results varied for the same countries and with similar data sets, depending only on the estimation methods that were used.

To test for Granger causality in a time series analysis framework, most of the studies so far have used bivariate approaches (an energy variable and an income/employment variable). In the framework of the current study for Cyprus, a trivariate approach was employed (i.e. causality between energy, income and prices), similar to those of Asafu-Adjaye (2000), Glasure (2002) and Masih and Masih (1997, 1998), firstly because the necessary VEC model was already available from the previous analysis (see Section 5.3 above) and secondly because it is more appropriate to include energy prices in the analysis in order to overcome a potential omitted variable bias (Lütkepohl 1982).

[9] In models #5, #7, #9 and #11 the estimated coefficients of both the long and the short-run relationships (see Tables 5 and 6) have also passed the stability CUSUM and CUSUMSQ tests.

Having equations (3) to (5) as a reference, Granger causality was examined in three ways:

i) By observing the significance of the lagged differences of the energy, 'income' and price variables in the above mentioned equations; this is a measure of short-run (or weak Granger) causality. Note that, as the lag order of equations (3) to (5) is 1, significance of the differenced variables can be measured directly through the corresponding t-statistic.

ii) By reviewing the significance of the error-correction term in the above equations as a measure of long-run causality; the t-statistic is again sufficient for this purpose.

iii) By testing the joint significance of the error-correction term and the various lagged variables in each VEC variable through a F-test, sometimes mentioned as a measure of 'strong Granger causality' (Oh and Lee 2004).

Table 7: VECM-based Granger causality tests for select models.

		Short-run effects (t-statistic)			ECT effect (t-statistic)	Joint short- and long-run effects (F-statistics)		
Model #	*Variables*	Δe_t	Δy_t	Δp_t		*ECT* & Δe_t	*ECT* & Δy_t	*ECT* & Δp_t
5	Electricity consumption, residential							
	Δe_t	-	-0.129	-1.722	-2.838 *	-	4.504 *	7.292 *
	Δy_t	-3.450 *	-	0.195	-2.150 *	9.163 *	-	2.385
	Δp_t	-0.623	0.809	-	-0.916	0.682	1.175	-
7	Electricity consumption, industry							
	Δe_t	-	-1.066	0.752	0.334	-	0.582	0.510
	Δy_t	-0.121	-	-0.750	4.614 *	10.214 *	-	10.753 *
	Δp_t	-0.798	0.901	-	1.525	1.370	1.924	-
9	Electricity consumption, commercial							
	Δe_t	-	-1.025	0.014	-2.793 *	-	3.923 *	4.342 *
	Δy_t	-0.012	-	-0.555	2.016 *	2.759	-	2.038
	Δp_t	0.760	1.026	-	1.351	0.917	1.131	-
11	Gasoline consumption							
	Δe_t	-	-1.194	-0.787	3.809 *	-	8.032 *	7.585 *
	Δy_t	-2.569 *	-	-2.286 *	4.550 *	12.859 *	-	13.040 *
	Δp_t	0.754	-0.434	-	0.473	0.425	0.209	-

Notes: Symbols refer to equations (3) to (5). *ECT* stands for the error correction term in these equations.
* denotes significance at 5% level.

The results of these tests are displayed in Table 7 and allow one to draw the following conclusions:

- There is no indication of causality running from energy consumption or income to prices in any one of the four models; therefore electricity and gasoline prices can be treated as strongly exogenous within a trivariate VEC framework. This is reasonable since Cypriot electricity production comes from oil-fired power plants and hence power generation costs, similarly to gasoline prices, are mainly affected by international oil prices, which are obviously not influenced by oil demand in Cyprus – this is the case of a 'small open' economy as noted by Pesaran et al. (2000).

- Residential electricity consumption is Granger-caused by both private income and electricity prices in the long run. Conversely, there seems to be no short-term causality from income and prices; in fact, it is evident from the regression results of Table 5 that weather conditions seem to be the only significant cause of variation in electricity use of households in the short run. The same seems to be valid for commercial electricity too.

- Private income is Granger-caused by electricity consumption, both in the short and in the long run. On the other hand, the price of electricity does not seem to affect income: the significance level for rejecting the hypothesis of no causality is 11% (corresponding to the F-statistic of 2.385 in Table 6). This seems to be reasonable as the total electricity bill accounted for less than 2% of total expenditure of Cypriot households in the last two decades (CYSTAT, 2005). However, in view of bidirectional causality between income and electricity and the quite low probability value for rejecting the hypothesis of no causality from prices to income, one could argue that exogenous electricity prices may affect both electricity use and private income through the long- and short-run mechanism reflected in the VEC model. In case of a deviation from long-run equilibrium (e.g. through price fluctuations) electricity and income variables interact to return to the long-term path.

- In the industrial sector, value added is Granger caused by both electricity use and prices; these latter variables seem to be exogenous in this VEC framework.

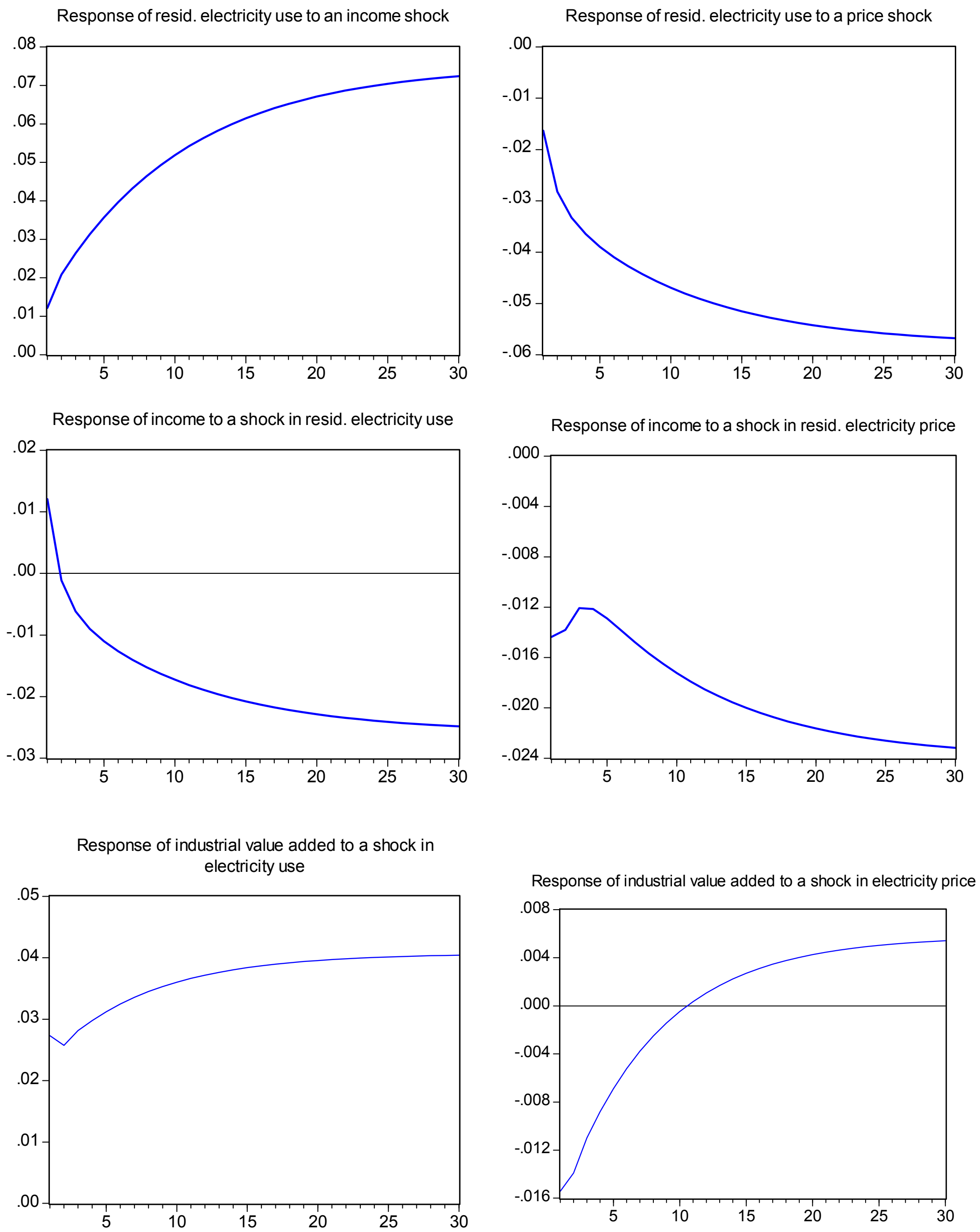
- In the case of commercial electricity, no Granger causality is detected among the three variables in the short run, whereas in the long run electricity consumption is affected both by economic activity and electricity prices. Moreover, long-term Granger causality is observed from electricity use and prices to economic activity (measured as value added of the tertiary sector); judging from the 8% significance level of the F-value of 2.759, one can infer that electricity use is responsible for this long-term causal relationship. This indicates that, as in the residential sector, prices are exogenous in this system; electricity use and economic activity adjust to potential disequilibrium error in order to restore long-run equilibrium.

- Similarly to residential electricity, a bidirectional causal relationship is found between gasoline consumption and GDP, which are both also Granger caused by gasoline prices.

5.5. Impulse responses

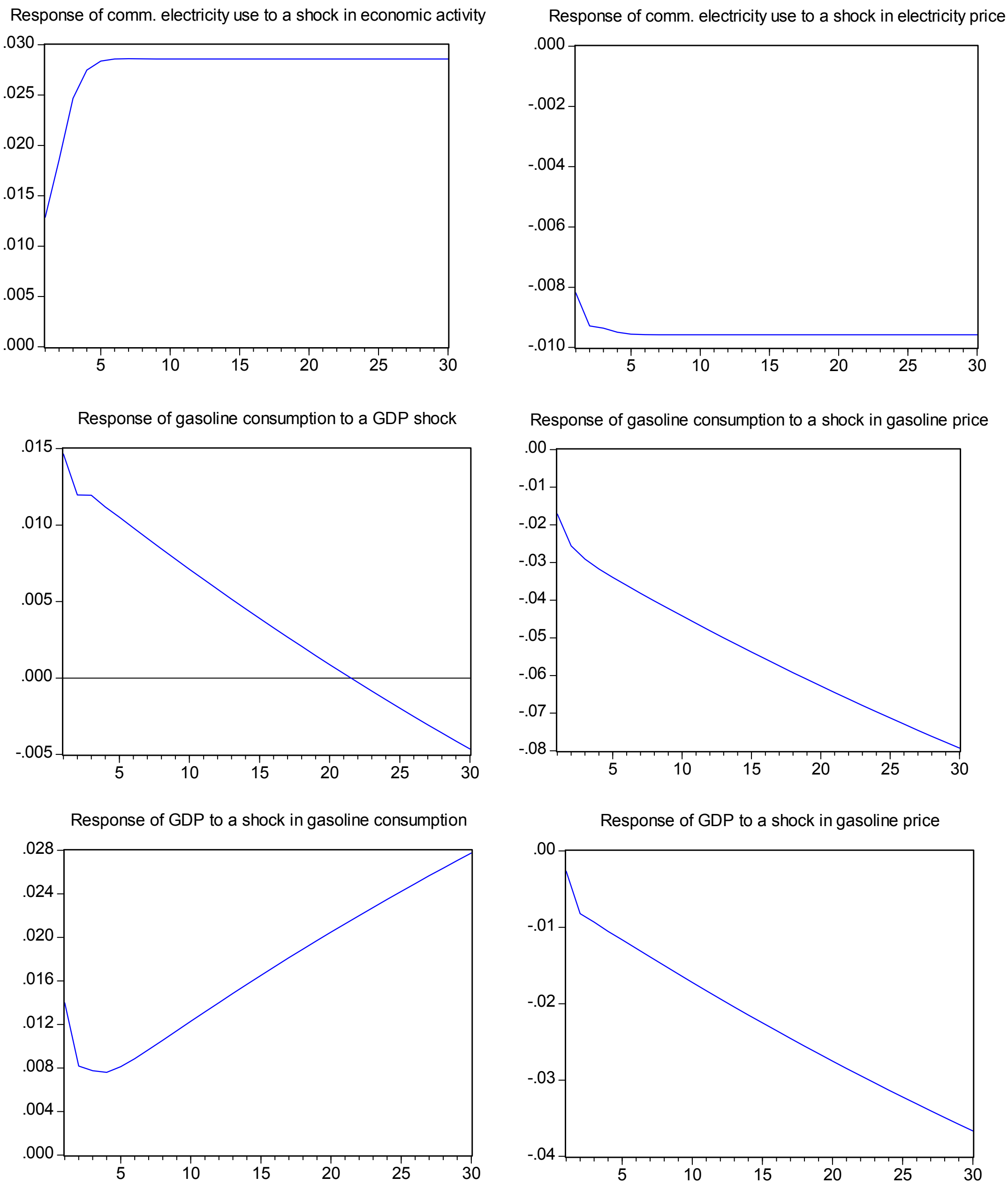
Figures 9 and 10 display the impulse responses of the VEC models, for those variables where Granger causality was detected as described in the previous section. Because of the existence of the cointegrating relationship, shocks do not fade away but leave a permanent 'trace' on the affected variables (see e.g. Lütkepohl and Reimers 1992).

Figure 9: Impulse responses to generalised one standard deviation innovations according to the VEC models of residential and industrial electricity.



- In the residential sector, variables approach their long-term equilibrium positions about two decades after the one-time innovation has occurred: shocks in private income and electricity prices significantly affect electricity consumption in a positive and negative way respectively. Less important is the (negative) impact on private income from shocks in the use and price of electricity.

Figure 10: Impulse responses to generalised one standard deviation innovations according to the VEC models of commercial electricity and gasoline consumption.



- Industrial economic activity ‘absorbs’ shocks in electricity use and prices somewhat faster than private income, with electricity use affecting it much more than prices.

- As regards the commercial sector, the effect of innovations stabilises after about 6 years; this is partly due to the greater (in absolute terms) error-correction coefficient α_{51} as shown in Table 6. The impact of a shock in economic activity is greater (in absolute terms) than that of a shock in the price of electricity.

- The near-zero error-correction coefficients of the gasoline model (see Table 6) cause very slow impulse responses of the corresponding variables. The effect of price shocks on gasoline use is much stronger then the effect on GDP. Moreover, gasoline consumption is influenced more by a price shock than by a GDP shock, whereas GDP is almost equally affected (but in opposite directions) by shocks in prices and in gasoline use.

6. APPLICATION OF ARDL MODELS

As noted in the introductory section, autoregressive distributed lag (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). In this chapter I will analyse the same energy, economic and weather variables as before, applying this method. As the ARDL approach is a single-equation method and thus presupposes that variables on the right-hand side of each equation are at least weakly exogenous, this issue is discussed among others in section 6.3.

The Pesaran ARDL approach involves two basic steps: firstly, the existence of a long-run relationship is tested through an appropriate F-test; secondly, depending on the outcome of the first step, the regression equation is estimated either in levels or in first differences. These procedures will be explained in the following sections.

6.1. Tests for the existence of a long-run relationship

In order to examine whether a long-run relationship exists among the variables involved in a model, an ARDL bounds testing approach has been developed (Pesaran et al., 2001). In accordance with that method, the energy-income-price-weather system is initially modelled with the following equation:

$$\Delta e_t = \beta_0 + \sum_{i=1}^{m} \beta_{1i}\, \Delta e_{t-i} + \sum_{j=0}^{n} \beta_{2j}\, \Delta y_{t-j} + \sum_{k=0}^{p} \beta_{3k}\, \Delta p_{t-k} + \sum_{l=0}^{q} \beta_{4l}\, \Delta tdd_{t-l} + \\ + \beta_5\, e_{t-1} + \beta_6\, y_{t-1} + \beta_7\, p_{t-1} + \beta_8\, tdd_{t-1} + \varepsilon_t \qquad (6)$$

where symbols denote the corresponding variables explained in the previous sections and ε_t is assumed to be a white noise error process.

The null hypothesis of 'no long-run relationship' is tested with the aid of an F-test of the joint significance of the lagged level coefficients of eq. (6):

$H_0: \beta_5 = \beta_6 = \beta_7 = \beta_8 = 0$ against $H_1: \beta_5 \neq 0, \beta_6 \neq 0, \beta_7 \neq 0, \beta_8 \neq 0$

Pesaran et al. (2001) have proved that the distribution of this F-statistic is non-standard irrespective of whether the regressors are I(0) or I(1), and have tabulated the appropriate critical values. Depending on the number of regressors and on whether an intercept and/or a time trend is included in the equation, a pair of critical values is provided, which constitute an upper and a lower bound respectively. If the F-statistic is greater than the upper bound, the null hypothesis is clearly rejected and a long-run relationship exists among the test variables. If the F-statistic is smaller than the lower bound, then the null cannot be rejected and estimation can continue assuming no long-run relationship. If the statistic falls between the two bounds, then the result is inconclusive; it is only at this stage that the analyst may need to conduct unit root tests in order to proceed (Pesaran and Pesaran, 1997).

In our case I applied eq. (6) choosing a maximum lag length of 1 (*m=n=p=q=1*) since data are annual and in order to avoid over-parameterisation of the model. In the cases of total, residential and commercial electricity as well as in total final energy consumption the existence of a long-run relationship was tested in two models: one including the degree-days variable and one without degree-days. Obviously, for all other energy uses degree-days were not included as a variable.

The results of these F-tests are shown in Table 8. The existence of a long-run relationship is confirmed at the 95% significance level only for gasoline and total energy consumption, the latter under inclusion of the degree-days variable. (It also seems to be confirmed for agricultural electricity, but there are indications for misspecification in that equation – see next section). At the other extreme, the null hypothesis is clearly rejected even at the 90% level for total electricity consumption, irrespective of the inclusion of the weather variable. In all other cases the results of the F-tests are inconclusive as the F-statistic lies between the boundary values at the 95% and/or 90% significance level. These results, in conjunction with those of the unit root / cointegration analysis presented in Tables 2 to 5, provide an indication for the existence of long-run relationships between energy use, income/economic activity and energy prices in all time series available for Cyprus, with the exception of agricultural and total electricity consumption. These exceptions seem to be justified in view of the particularities of the agricultural sector (where another explanatory variable such as the annual rainfall may be necessary for the model to be adequate) and since total electricity use is in fact an aggregate figure derived from the consumption of individual sectors.

Table 8: Tests for the existence of a long-run relationship with the ARDL model.

Dependent variable	*"Exogenous" variables*	*F-statistic*	*95% critical values*	*90% critical values*
Electricity consumption, total	*y, p, d*	2.403	3.219; 4.378	2.711; 3.800
	y, p	1.962	3.793; 4.855	3.182; 4.126
Electricity consumption, residential	*y, p, d*	3.254	3.219; 4.378	2.711; 3.800
	y, p	2.534	3.793; 4.855	3.182; 4.126
Electricity consumption, industry	*y, p*	4.100	3.793; 4.855	3.182; 4.126
Electricity consumption, commercial	*y, p, d*	3.019	3.219; 4.378	2.711; 3.800
	y, p	3.781	3.793; 4.855	3.182; 4.126
Electricity consumption, agriculture	*y, p*	6.396	3.793; 4.855	3.182; 4.126
Gasoline consumption	*y, p*	4.938	3.793; 4.855	3.182; 4.126
Total non-electricity final consumption	*y, p*	4.246	3.793; 4.855	3.182; 4.126
Total final energy consumption	*y, p, d*	6.183	3.219; 4.378	2.711; 3.800
	y, p	4.389	3.793; 4.855	3.182; 4.126

Notes: *y*, *p* and *d* denote the corresponding income, price and weather variable respectively according to Table 1. Critical values are those of Pesaran and Pesaran (1997) for equations with an intercept and no time trend.

6.2. Estimation of ARDL models in levels

Having tested the existence of a long-run relationship, the next step is to estimate the corresponding univariate model. This can be carried out either with an error-correction framework similar to that of the VEC system of eqs. (3) to (5) or by using directly all variables in levels:

$$e_t = \gamma_0 + \sum_{i=1}^{m} \gamma_{1i}\, e_{t-i} + \sum_{j=0}^{n} \gamma_{2j}\, y_{t-j} + \sum_{k=0}^{p} \gamma_{3k}\, p_{t-k} + \sum_{l=0}^{q} \gamma_{4l}\, tdd_{t-l} + \xi_t \qquad (7)$$

where ξ_t is assumed to be a white noise error process.

Since the aim of this analysis is to arrive at equations that will be used for long-term energy modelling purposes, where the ARDL model in level form is simpler and more straightforward to implement, I ran regressions of eq. (7) for all available energy variables. According to Pesaran and Shin (1999), the appropriate way to proceed is to select the lag length of each variable on the basis of the Schwarz or the Akaike Information Criterion. Since there are fewer coefficients to be estimated in eq. (7) than in eq. (6), I selected a maximum lag length of $m=n=p=q=2$ and ran all the ($(2+1)^4=81$) appropriate regressions for each model with OLS. I then selected that equation with the lowest Schwarz criterion as this criterion is consistent, performs better in small samples (Pesaran and Shin, 1999) and is more 'conservative' in lag length selection, which is convenient in our case because of the limited sample size.

Table 9 summarises the estimation results by displaying the order of each ARDL equation along with the short-run and long-run elasticities, where applicable, of the corresponding income, price and weather variables. It is reminded that short-run elasticities are the sum of the estimated lagged level coefficients of each variable in eq. (7), whereas the corresponding long-run elasticity is this sum divided by one minus the sum of the lagged coefficients of the dependent variable. For example, in the case of the price variable:

Table 9: ARDL model estimation results: short-run and long-run elasticities of income/economic activity (*y*), price (*p*) and degree-days (*d*) respectively.

		Short-run elasticities			*Long-run elasticities*		
Dependent variable	*Lag order*	*y*	*p*	*d*	*y*	*p*	*d*
Electricity consumption, total	(1,1,0)	0.310	-0.074	-	-	-	-
Electricity consumption, residential	(1,0,0,0)	0.435	-0.170	0.231	1.263	-0.495	0.671
Electricity consumption, industry	(1,1,1)	0.120	-0.083	-	1.243	-0.857	-
Electricity consumption, commercial	(1,0,0,0)	0.322	-0.078	0.098	1.123	-0.271	0.340
Gasoline consumption	(2,1,1)	0.060	0.003	-	0.615	0.026	-
Total non-electricity final consumption	(1,1,1)	0.070	0.001	-	0.833	0.012	-
Total final energy consumption	(1,1,1,0)	0.033	-0.075	0.065	0.733	-1.674	1.451

Diagnostic tests	*LM(2)*	*ARCH(2)*	*J-B*	*RESET*
Electricity consumption, total	0.365	0.371	0.231	0.123
Electricity consumption, residential	0.071	0.613	0.957	0.319
Electricity consumption, industry	0.415	0.611	0.975	0.234
Electricity consumption, commercial	0.679	0.980	0.832	0.088
Electricity consumption, agriculture	0.382	0.903	0.000	0.010
Gasoline consumption	0.160	0.669	0.624	0.177
Total non-electricity final consumption	0.280	0.527	0.000	0.007
Total final energy consumption	0.444	0.605	0.950	0.554

Notes: Estimation was performed with OLS and heteroskedasticity-consistent standard errors and covariance. All elasticity values reported are significant at the 95% level. Lag order refers to the values of *m*, *n*, *p* and *q* in eq. (7), selected with the Schwarz Information Criterion. Long-run elasticities are not reported for total electricity consumption, where the existence of a long-run relationship was clearly rejected (see Table 8). The lower part of the table reports probability values for rejecting the hypotheses of the following diagnostic tests: serial correlation Breusch-Godfrey LM test and ARCH LM test up to the 2nd lag, Jarque-Bera normality test and Ramsey's specification error (RESET) test with one fitted term.

short-run price elasticity = $\sum_{k=0}^{p} \hat{\gamma}_{3k}$ and

long-run price elasticity = $\sum_{k=0}^{p} \hat{\gamma}_{3k} \Big/ \left(1 - \sum_{i=1}^{m} \hat{\gamma}_{1i}\right)$

All equations of individual fuels (i.e. gasoline) or sectors (residential, commercial and industrial electricity) pass the diagnostic tests with the exception of agricultural electricity, which fails the normality and Ramsey RESET tests, thus indicating that the equation is misspecified. The aggregate models of total electricity and total non-electricity consumption do not display equally good properties.

Long-run income and price elasticities of residential and commercial electricity are similar to those resulting from the cointegration analysis (see Table 5). Short-run elasticities, which were found to be insignificant in the VEC models, are significant here but with values of less than 0.5 in absolute terms. The long-run effect of the weather, which could not be estimated with the Johansen cointegration approach, is estimated to be moderate (elasticities of about 0.7 and 0.4 for residential and commercial electricity respectively). However, long-run elasticity estimates for gasoline and industrial electricity consumption (0.6 and 1.2 respectively) are much lower in the ARDL than in the VEC models (1.8 and 2.1 respectively); this may be attributed to the fact the autoregressive coefficients in the corresponding ARDL equations approach or exceed unity, which may cause instability. Finally, the ARDL industrial electricity equation shows a significant long-run price effect, with an elasticity close to unity.

In those cases where the results have shown to be robust (i.e. residential, commercial and industrial electricity as well as gasoline consumption) the models also pass several stability tests such as the cumulative sum of the recursive residuals (CUSUM) test, the cumulative sum of the square of recursive residuals (CUSUMSQ) test and the N-step forecast test. As regards the stability of the estimated coefficients, recursive coefficient estimates display a noteworthy stability of all coefficients, particularly since the late 1980s. Consequently, the elasticities that have been estimated with these models can be treated with confidence and may be used for forecasts and policy simulations.

6.3. Discussion

The ARDL models pose several advantages over cointegration techniques such as the Johansen method that was applied in the previous chapter, mainly because they investigate the existence of a long-run relationship irrespective of whether the variables are I(0), I(1) or a mixture thereof. Thus one may avoid the need to pre-test for the existence of unit roots in variables, which is important in view of the power and size problems associated with unit root tests in small samples as outlined in section 5.1.[10] Additionally, the ARDL bounds test procedure allows to include a potentially stationary variable such as degree-days in the long-run relationship, which the Johansen cointegration approach would not allow, thus limiting the analysis. Moreover, Pesaran and Shin (1999) have shown that ARDL equations are more rigorous in small samples than cointegration methods; this is particularly relevant in the case of Cypriot energy data, with sample sizes of 40-45. Finally, as Clements and Madlener (1999) point out, the ARDL approach places more 'structure' on the issue of energy consumption than the purely atheoretical VAR-based cointegration approaches.

A major difference between ARDL and VEC models is how they treat exogeneity issues. While all variables in a VEC system are in principle treated as endogenous, the ARDL assumes that there is one dependent variable and the rest of the variables are at least weakly exogenous ('long-run forcing' variables as Pesaran and Pesaran (1997) note). As shown in Table 7 and explained in section 5.4, Granger causality tests of the trivariate energy-income-price VEC models show statistically significant bidirectional causality between energy use and income. This seems to be a strong indication that, at least within this trivariate framework, income should be treated as endogenous, which questions the validity of using a single-equation ARDL model with energy being the only endogenous variable.

As a counter-argument one could mention the conflicting results of Granger causality tests for the same countries and periods, depending on the methodology applied or the specific data set employed by different analysts.[11] Moreover, as Stern (1993) notes, neoclassical economic theory would not accept that energy use causes economic growth, while several empirical studies indicate that the opposite might be true. In the light of these contradictory views and inconclusive results, the endogeneity of income variables shown in Table 7 cannot be taken for granted.

---

[10] In our case, however, unit root tests cannot be avoided since most of the bounds test results of Table 8 are inconclusive about the existence of a long-run relationship.

[11] The papers of Lee (2006) and Yoo (2006) offer just two recent examples of Granger causality results that are in line with those of some other studies and in disagreement with others, depending on the exact sample period, the causality test method and the variables employed (e.g. GDP vs. GDP per capita).

Furthermore, in the context of long-term energy modelling the ARDL approach may be more appropriate, as VEC models are usually applied for short-run forecasts only. A similar single-equation approach is also followed by international organisations and energy-planning authorities (e.g. EC 2003, EIA 2004, IEA 2004): taking exogenous forecasts of population, GDP growth, international fuel prices and other parameters, they proceed with calculating future energy needs. For all these reasons, it was considered appropriate to apply the ARDL approach in this analysis, examine the robustness of its results and compare them with those of the VEC models.

The statement of Bentzen and Engsted (2001) that ARDL and cointegration methods should be viewed as supplements rather than substitutes is confirmed in our case. The first reason is that the ARDL technique presupposes that no variable is integrated of order 2 or higher and there is only one cointegrating relationship among the variables. The second reason is that the results of the bounds tests shown in Table 8 often do not provide a definite answer to the long-run hypothesis, which makes it necessary to resort to unit root and cointegration tests.

In any case, both approaches often arrive at similar income and price elasticities; this is particularly evident for some of the models which pass the diagnostic specification and stability tests outlined above, i.e. residential and commercial electricity.

7. CONCLUSIONS AND OUTLOOK

This report has presented the first empirical analysis of energy consumption in the Republic of Cyprus. Using annual data from 1960 to 2004, I 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. I analysed the dynamic interaction between the corresponding energy form and appropriate income, price and weather variables with the aid of widely used time series analysis techniques such as unit root and cointegration tests, Vector Error Correction 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. The validity of inferences made with such models, which offer additional advantages within the context of this work, has been re-established in the late 1990s thanks to the work of Pesaran-Shin-Smith (see e.g. Pesaran et al. 2001).

Results from the cointegration tests and the VEC models show that a long-run equilibrium relationship between energy, 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. GDP elasticities of gasoline and industrial electricity are the highest whereas the corresponding price elasticities are insignificant. Granger causality tests indicate 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 is 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 are mostly inconclusive as regards the existence of a long-run relationship, so that they have to be interpreted in conjunction with those of the cointegration tests. In the cases of residential and commercial electricity consumption, income, price and weather elasticities are found to be similar with those of the VEC model, whereas results of the two methods are different for the long-term elasticities of gasoline and industrial electricity consumption. Short-run effects estimated with this method are significant but small in absolute terms.

Despite the quite small sample size, which poses limitations on the analysis, the evidence from both the VEC and ARDL models shows that results are meaningful and robust for residential, commercial and industrial electricity as well as gasoline consumption. This finding is important as it allows the corresponding income, price and weather elasticities to be used for forecasting purposes and policy analyses; up to now this task was carried out in Cyprus either with simpler methods (such as extrapolations of past trends) or with less transparent approaches as part of energy or environmental studies commissioned by Cypriot authorities to foreign consultants.

Future work will focus on long-term energy forecasts that will be carried out by applying models and/or parameters estimated in this report for a ‘business as usual’ reference case as well as for a number of alternative scenarios.

REFERENCES

Asafu-Adjaye J. (2000), The relationship between energy consumption, energy prices and economic growth: time series evidence from Asian developing countries. Energy Economics 22 (2000) 615–625.

Atkinson J. and Manning N. (1995), A survey of international energy elasticities. Chapter 3 in “Global Warming and Energy Demand”, edited by Terry Barker, et al. London: Routledge, pp. 47–105.

Bentzen J. and Engsted T. (1993), Short- and long-run elasticities in energy demand: a cointegration approach. Energy Economics 15, 9–16.

Bentzen J. and Engsted T. (2001), A revival of the autoregressive distributed lag model in estimating energy demand relationships. Energy 26 (2001) 45–55.

Cavanagh C.L., Elliott G. and Stock J.H. (1995), Inference in models with nearly integrated regressors. Econometric Theory 11: 1131–1147.

Clements M.P. and Madlener R. (1999), Seasonality, cointegration, and forecasting UK residential energy demand. Scottish Journal of Political Economy, Vol. 46, No. 2, 185–206.

CYSTAT (Statistical Service of the Republic of Cyprus) (2005), various economic, industrial and energy statistical publications.

Dickey D.A. and Fuller W.A. (1979) Estimators for autoregressive time series with a unit root. Journal of the American Statistical Association 74: 427–431.

EC (European Commission) (2003), European Energy and Transport – Trends to 2030. Office for Official Publications of the European Communities, Luxembourg. Also at http://europa.eu.int/comm/dgs/energy_transport/figures/trends_2030/index_en.htm.

EIA (US Department of Energy, Energy Information Administration) (2006), Annual Energy Outlook 2006, Report DOE/EIA-0383(2006), Washington, DC. Also at http://www.eia.doe.gov/oiaf/aeo/index.html.

Engle R.F. and Granger C.W.J. (1987), Cointegration and error correction: representation, estimation, and testing. Econometrica 1987;55:251–76.

Fatai K., Oxley L. and Scrimgeour F.G. (2004), Modelling the causal relationship between energy consumption and GDP in New Zealand, Australia, India, Indonesia, The Philippines and Thailand. Mathematics and Computers in Simulation 64 (2004) 431–445.

Glasure Y.U. (2002), Energy and national income in Korea: further evidence on the role of omitted variables. Energy Economics 24, 355–365.

Granger C.W.J., Investigating causal relation by econometric and cross-sectional method, Econometrica 37 (1969) 424–438.

Haris R. and Sollis R. (2003) Applied Time Series Modelling and Forecasting. John Wiley and Sons, Ltd.

IEA (International Energy Agency) (2004), World Energy Outlook 2004, Paris, France.

Johansen S., Statistical analysis of cointegration vectors. Journal of Economic Dynamics and Control, vol. 12, 231–254.

Johansen S., Estimation and hypothesis testing of cointegrating vectors in Gaussian vector autoregressive models. Econometrica 1991;59:1551–80.

Koroneos C., Fokaidis P. and Moussiopoulos N. (2005) Cyprus energy system and the use of renewable energy sources. Energy 30(2005) 1889–1901.

Lee C.-C. (2006), The causality relationship between energy consumption and GDP in G-11 countries revisited. Energy Policy 34 (2006) 1086–1093.

Lütkepohl H. (1982), Non-causality due to omitted variables. Journal of Econometrics; 19; 367–378.

Lütkepohl H. and Reimers H.-E. (1992), Impulse response analysis of cointegrated systems. Journal of Economic Dynamics and Control 16, 53–78.

MacKinnon J. G. (1996) Numerical Distribution Functions for Unit Root and Cointegration Tests. Journal of Applied Econometrics, 11, 601–618.

MacKinnon J. G. Haug A. A. and Michelis L. (1999) Numerical Distribution Functions of Likelihood Ratio Tests For Cointegration. Journal of Applied Econometrics, 14, 563–577.

Masih A.M.M. and Masih R. (1997), On the temporal causal relationship between energy consumption, real income, and prices: some new evidence from Asian-energy dependent NICs based on a multivariate cointegration/vector error-correction approach. Journal of Policy Modelling 19 (4), 417–440.

Masih A.M.M. and Masih R. (1998), A multivariate cointegrated modelling approach in testing temporal causality between energy consumption, real income and prices with an application to two Asian LDCs. Applied Economics 30 (10), 1287–1298.

Micklewright J. (1989), Towards a household model of UK domestic energy demand. Energy Policy 17(3), 264–276.

Mirasgedis S, Sarafidis Y., Georgopoulou E., Lalas D.P. and Papastavros C., Mitigation policies for energy related greenhouse gas emissions in Cyprus: the potential role of natural gas imports. Energy Policy 32(2004) 1001–1011.

Narayan P.K. and Smyth R. (2006), Are shocks to energy consumption permanent or temporary? Evidence from 182 countries. Energy Policy (in press).

Oh W. and Lee K. (2004), Causal relationship between energy consumption and GDP revisited: the case of Korea 1970–1999. Energy Economics 26 (2004) 51–59.

Pesaran M.H. (1997), The Role of Economic Theory in Modelling the Long Run. The Economic Journal, 107, 178–191.

Pesaran M.H. and Pesaran B. (1997), Microfit 4.0. Oxford: Oxford University Press.

Pesaran M.H. and Shin Y. (1999), An Autoregressive Distributed Lag Modelling Approach to Cointegration Analysis. In: Strøm S, editor. Econometrics and economic theory in the twentieth century: the Ragnar Frisch Centennial Symposium. Cambridge: Cambridge University Press, 1999.

Pesaran M.H., Shin Y. and Smith R.J. (2000), Structural analysis of vector error correction models with exogenous I(1) variables. Journal of Econometrics 97 (2000) 293–343.

Pesaran M.H., Shin Y. and Smith R.J. (2001), Bounds Testing Approaches to the Analysis of Level Relationships. Journal of Applied Econometrics 16: 289–326 (2001).

Phillips P.C.B. (1991), Optimal Inference in Cointegrated Systems. Econometrica 59: 283–306.

Phillips P.C.B. and Durlauf S.N. (1986), Multiple time series regression with integrated processes. Review of Economic Studies 53; 473–495.

Silk J.I. and Joutz F.L. (1997), Short and long-run elasticities in US residential electricity demand: a co-integration approach. Energy Economics 19, 493–513.

Stern D. (1993), Energy and economic growth in the USA – A multivariate approach. Energy Economics 15, 137–150.

De Vita G., Endresenb K. and Hunt L.C. (2006), An empirical analysis of energy demand in Namibia. Energy Policy (in press).

Yoo S.-H. (2006) The causal relationship between electricity consumption and economic growth in the ASEAN countries. Energy Policy (in press).

Zarnikau J. (2003), Functional forms in energy demand modeling. Energy Economics 25 (2003) 603–613.

Zervos A. Caralis G., Diakoulaki D., Lins C., Crettaz J., Blanchard L., Charalambous A., Thoma Y., Kassinis S., Chryssis I. and Marin C. (2004), Towards a White Paper for RES and RUE Strategy and Action Plan for the Republic of Cyprus. Report of a study for the European Commission funded by the ALTENER research programme, Athens, Greece.

Recent Economic Policy/Analysis Papers

10-05 Michael M., L. Christofides, C. Hadjiyiannis, S. Clerides and M. Stephanides, “Economic implications of foreign workers in Cyprus”, December 2005 - in Greek.

09-05 Hassapis C., “The relationship between financial uncertainty and economic growth”, December 2005 - in Greek.

08-05 Hassapis C., “Stability in the relationship between the stock market and the real economy”, December 2005 - in Greek.

07-05 Haroutunian S. and P. Pashardes, “Projections of Potential Output and Structural Fiscal Balance for Cyprus”, December 2005 - in English.

06-05 Georgiou A., D. Komodromou and A. Polykarpou, “Unified Database of Family Expenditure Surveys of Years 1984/85, 1990/91, 1996/97 and 2002/03”, October 2005 - in Greek.

05-05 Clerides S., “The Impact of Used Car Imports in the Cyprus Market”, October 2005 - in Greek.

04-05 Mamuneas Th., P. Pashardes, N. Pashourtidou and G. Shiammoudis, “Sectoral Productivity Analysis of the Cypriot Economy”, July 2005 - in Greek.

03-05 Nicolaidou N. and S. Hajispyrou, “The Consumption Behaviour of Tourists in Cyprus”, June 2005 - in Greek.

02-05 Pashardes P., N. Pashourtidou and G. Shiammoudis, “The Effect of Actions, Decisions and Announcements on Cyprus Stock Exchange during the Period 1999-2000”, February 2005 - in Greek.

01-05 Pashardes P., N. Pashourtidou and G. Shiammoudis, “Investors Behaviour and the Effect of Institutional Investors on Cyprus Stock Exchange During the Period 1999-2000”, February 2005 - in Greek.

08-04 Hassapis C., “Longrun Effects of the Money and Capital Market on Economic Growth and Shortrun Effects on Stock exchange and Real Economic Activity”, November 2004 - in Greek (previously numbered 02-04 in “Economic Analysis Papers” series).

07-04 Mitsis P. and L. Christofides, “Macroeconomic Model of Cyprus: Estimation of Quarterly Time Series for the GDP and the Domestic Expenditure Components for the years 1990 – 2001”, October 2004 - in Greek (previously numbered 01-04 in “Economic Analysis Papers” series).