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The structure of residential energy demand in Greece

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Abstract

This paper attempts to shed light on the determinants of residential energy demand in Greece, and to compare it with some other OECD countries. From the estimates of the short-run and long-run elasticities of energy demand for the period 1965–1999, we find that residential energy demand appears to be price inelastic. Also, we do not find evidence of a structural change probably because of the low efficiency of the energy sector. We find, however, that the magnitude of the income elasticity varies substantially between Greece and other OECD countries.
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1. Introduction

The recent high increase in oil prices has brought again to the attention of governments and citizens the important effects that energy price hikes may have on the economic activity and unemployment. The importance of these effects certainly varies from country to country, but there is no doubt that they will be more important on those that are highly dependent on oil. Greece is one such country since, with the exception of the electricity that is, to a large extent generated by coal, the non-oil sources of energy are very limited.

According to the data published by the International Energy Agency (IEA), residential energy consumption in Greece that comes mainly from oil and electricity, has increased by 5.5% per annum over the period 1965–1999, reaching the level of 3.43 million tones of oil equivalent (toe) in 1999. The main increase has taken place during the period 1991–1998, when final energy consumption grew by 4.8% annually. This evolution could be explained by the fall of the real energy prices and the high growth rate of real GDP that has been observed over this period.

It should be noted that residential energy consumption in Greece, as in other countries of Southern Europe, is lower than in most other European Union countries, a characteristic that is perhaps related to their climatic conditions. It is also worth mentioning that during the period 1985–1999 energy consumption declined or remained unchanged in Central and Northern European countries that have a high final energy consumption (e.g. France, Netherlands), while it increased in countries with low energy consumption (Greece, Ireland, Portugal). This is also confirmed by some studies which examine the structure of residential electricity consumption in Greece.[1]

Several authors have attempted to examine the demand for residential energy in Greece ,mainly of electricity.[2] This interest is mainly not only due to the

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[1]See, for example Donatos and Mergos (1991).

[2]Donatos and Mergos (1989), Donatos and Mergos (1991), Christodoulakis et al. (2000), Bentzen and Engsted (1993), Hondroyiannis (2004).

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fact that residential energy demand has been rising rapidly, but also because the Greek energy market had to be liberalized in the framework of the European Union (e.g European directive 2002/91/EU). The reliable estimates of price and income elasticities of residential energy demand become important factors for assessing proposals to revise electricity rates and for predicting the needs for residential demand in the future (Hondroyiannis, 2004).

The purpose of this paper is to examine the main factors that determine the residential energy consumption in Greece, and on the basis of our findings to attempt to draw some conclusions on the policy choices that the country has to make. The recent oil price hikes, brings again to the fore the need for a more determined and multifaceted approach if the country is to improve the efficiency in the consumption of the energy in the residential sector.

This paper differs from earlier works in the subject in two distinct ways. First, our approach in determining the residential energy pattern in Greece is quite different from that of some previous studies (Donatos and Mergos, 1989; 1991; Christodoulakis et al., 2000), by taking into account the impact of weather conditions in the estimation procedure and by giving emphasis to the properties of the estimated long and short-run equations. Secondly, we examine the existence of structural breaks that is an important element, to which rather scant attention has been paid by the earlier studies.

The paper is organized as follows. In Section 2, we present the empirical model that will be used in order to estimate the short-run and long-run elasticities of residential energy demand in Greece. In Section 3, we present the main results of the estimated model and analyze possible structural changes by applying the Chow-Test and several other tests based on recursive residuals. In Section 4, we attempt a comparison of our findings with those of some other studies for Greece, but we also make some comparisons with the finding for some other countries. Finally, in Section 5, we summarize our findings and attempt to draw some policy conclusions.

2. Modeling energy consumption

There are several studies estimating the demand for energy in the residential sector. In most of these studies the aim has been to measure the impact of real energy prices on the demand for energy, by estimating income and price elasticities.[3] The most popular approach has been the estimation of a single equation ad hoc demand functions.[4] Our empirical analysis uses a single equation model expressed in a log linear form. Total energy consumption (CON) is a function of real gross domestic product (GDP), a weighted real price of energy (PEN) and the number of heating degree days (HDD). So the residential energy demand function can be written as

$$\mathrm{CON_t} = f(\mathrm{GDP}_t, \mathrm{PEN}_t, \mathrm{HDD}_t) \tag{1}$$

Eq. (1) was estimated in log linear form using lagged variables in order to capture the dynamic effect of the energy demand. The use of lagged variables in a simple equation model or in a demand system implies that the estimated parameters are time invariant. (Chambers, 1990).

The data used in the empirical estimation of Eq (1) are national time- series data for the period 1965–1999. The range of the estimated period is chosen so that structural stability tests can assess the impact of the two energy crises (1973 and 1979) on energy demand. The energy consumption (CON) is measured in million tones of oil equivalent (toe) and is based on data provided by the International Energy Agency (IEA). The data for GDP are expressed at constant 1995 prices and are obtained from the National Statistical Service of Greece (NSSG). Energy prices for electricity and oil are taken from "Energy Prices and Taxes" (IEA) and have been deflated by the consumer price index (1994 = 100). Finally, the variable of HDD are taken from the database of IEA.

The linear Eq. (1) that refers to total energy demand was estimated using a partial adjustment model (Nerlove, 1958). The main reason for choosing this specific model is that its disturbance term does not autocorrelate as adaptive expectation model or the simple Koyck model. Moreover, with this model, we can estimate the short- run and the long-run elasticities of the energy demand.

The short-run energy demand equation can be written as follows:

$$\begin{aligned}\log \mathrm{CON}_t = {} & \delta \log \beta_0 + \beta_1 \delta \log \mathrm{GDP}_t \\ & + \beta_2 \delta \log \mathrm{PEN}_t + \beta_3 \delta \log \mathrm{HDD}_t \\ & + (1-\delta) \log \mathrm{CON}_{t-1} + \delta u_t,\end{aligned} \tag{2}$$

where CON_t is the energy demand in year t, GDP_t the real income (output), PEN_t the real weighted price of energy, HDD_t the heating degree-days in year t and δ is the coefficient of adjustment.

Long-run elasticities are calculated by dividing short-run elasticities by δ.

[3]See, for example, Bentzen and Engsted (1993), Fouquet (1995), Silk and Joutz (1997), Haas and Schipper (1998), Donatos and Mergos (1989), and Christodoulakis et al. (2000).

[4]See, in particular, Christodoulakis et al. (2000), and Silk and Joutz (1997). For a relevant survey of the literature see Pindyck (1977).

3. Econometric results

We estimate Eq. (2) by using the partial adjustment model in two ways. First we regress the dependent variable (CON) against the above independent variables, and, second, we do the same by adding two dummy variables to capture the effects of the two energy crises in 1973 and 1979.

Table 1 presents the results of our estimates, with column one presenting the estimate without dummies and column two with the dummy variables. As can be seen the short-run elasticities have the anticipated signs. According to the first column of the table, the short-run income (GDP) elasticity of demand is positive (0.79) and statistically significant. This means that if income rises by 1% total residential energy demand will rise by 0.79%.

The elasticity of demand with respect to the PEN is as expected, negative and less than one. It is also statistically significant. The coefficient of HDD is positive and significant in both specifications. The positive sign means that when the number of heating-degree days rises (decreases) households increase (decrease) total energy consumption[5]. Finally, total energy consumption (CON_t) is positively related to its lagged dependent variable (CON_{t-1}) implying a significant dynamic character in the residential energy demand.

The coefficient of adjustment δ, takes a small value of 0.51, implying that about 51% of the discrepancy between the desired and actual level of energy demand is eliminated within a year. This means that households slowly adjust their level of energy consumption in response to the changes of independent variables. The low value of δ could be partly traced in the lack of energy substitutes such as natural gas that might lead the level of short-run energy demand to greater flexibility.

Generally speaking, the above equation fits to the data very well, with high R^2 (97%). Also, the statistical tests reject the presence of autocorrelation of first or higher order and heteroscedasticity. The primary short-run energy demand Eq. (2) has been modified so that the impact of the two energy crises (1973 and 1979) could be also estimated. The introduction of the two dummy variables W_1 and W_2 in Eq. (2) showed that only the second energy crisis (1979) had a negative effect on residential energy demand (column 2).

We have also estimated the long-run elasticities of the model. Table 2 presents the short-run and the long-run elasticities of the model with respect to income and price respectively. As expected from the theory, the short-run elasticities are substantially lower than their long-run counterparts.[6] This means that the impact of an increase in the price of energy would be larger in the long-run than in the short-run. This is due to the fact that households in the longer term have a wider range of options for responding to higher prices, such as reorganization of their energy consumption, energy shifting, energy conservation measures, relocation, etc (OECD, 2001). Furthermore, the long-run income elasticity is higher than unity (1.54), which means that energy demand is quite income elastic. On the contrary, the price elasticity of energy demand is less than unity, but our estimate appears to be substantially higher in

Table 1
Short-run estimated elasticities

	Estimate without dummies (1)	Estimate with dummies (2)
C	$-6.45^{a)}$	$-6.54^{b)}$
	(−2.35)	(−2.41)
GDP	$0.79^{a)}$	0.80^{a}
	(3.37)	(3.48)
PEN	-0.31^{a}	-0.28^{b}
	(−2.89)	(−2.41)
HDD	0.17^{c}	0.10
	(1.83)	(0.44)
CON_{t-1}	0.49^{a}	0.48^{a}
	(3.60)	(3.58)
W_1	—	−0.008
		(−0.09)
W_2	—	−0.14
		$(-1.71)^{c}$
R^2	0.974	0.977
LM(5)	0.68	0.13
	[0.98]	[0.99]
White test	17.39	18.13
	[0.23]	[0.31]
J. Bera test	2.02	2.29
	[0.36]	[0.31]

Note: The numbers in parentheses and in the square brackets are *t* values and *p*-values, respectively.
Source: Authors' calculations.
[a,b,c]denotes significance at 0.01, 0.05 and 0.10, respectively. C denotes the constant term. LM (5) is a Lagrance multiplier test for fifth order autocorrelation.

Table 2
Short -run and long-run elasticities of the model

Elasticities	Short-run	Long-run
Income	0.79	1.54
Price	−0.31	−0.60

Source: Authors' calculations

[5]For the years 1978 and 1982 oil consumption has been boosted due to unusually cold winters.

[6]See also OECD (2000).

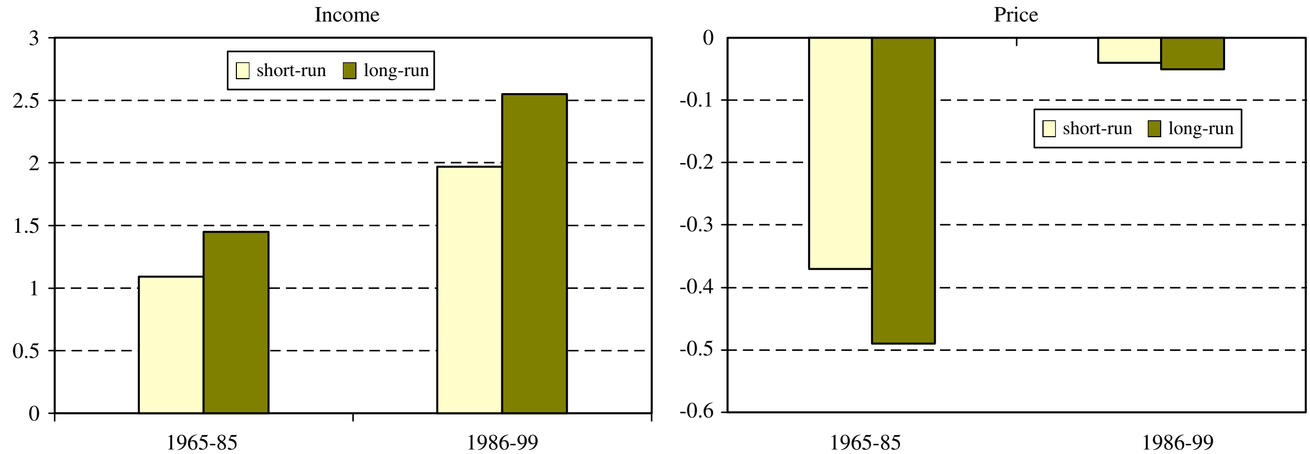

Fig. 1. Elasticities of energy demand in the two sub-periods.

comparison to the estimate found by Christodoulakis et al., 2000.

In order to get a better picture of the changes in the income and price elasticities, we can divide the period of our estimate into two sub-periods, namely 1965–1985, and 1986–1999.

As we see in Fig. 1, the income elasticities are higher in the period 1986–1999, when the energy prices did not fluctuate widely, than in the period of high price increases (1965–1985). This may be explained by the fact that energy demand is influenced strongly by the level of economic activity (GDP). More specifically, in the period of high energy prices (1965–1985) the level of energy demand fell as a result of the economic recession (Christodoulakis and Kalyvitis, 1997). This partly explains the low value of income elasticities in comparison with the next period where the relevant elasticities are estimated to be much higher. Also, the price elasticities of energy demand expressed in absolute terms seem to remain high in the period of high price increases (1965–1985). In order to explain this phenomenon, we must examine whether there are structural changes in the residential energy consumption as a result of the two crises (Haas and Schipper, 1998).

To investigate whether significant structural changes have taken place in the specific period we conducted several tests (Chow-test, dummy variables, recursive residuals tests). The results of this investigation are presented in Table 3.

Based on the results of the Chow-test, we observe that neither of the two energy crises alters the structure of the residential energy demand in Greece. In other words in the short-run, structural changes do not appear to have occurred in 1973 and 1979. According to the dummy variable approach, we note that structural change appears to have occurred in 1979.

It is interesting to mention the absence of structural break in 1986 when oil prices dropped. This can be probably explained by the low efficiency of the energy sector as a result of the low degree of substitutability between the sources of energy. It seems that Greece could not curtail the increasing needs of its economy for energy. Thus, after the crises the slowdown in energy consumption is related to the slowdown of the economic activity, rather than to changes in the structure of the demand in the (residential) energy sector.[7] Additionally, the tests on the recursive residuals demonstrate the absence of a structural brake during the whole period (Fig. 2).

Table 3
Testing for structural breaks

Years	Chow-F	Dummy- constant	Price-dummy
1973	2.32	−0.009	−0.0007
	[0.07]	(0.09)	(0.006)
1979	2.45	**−0.15**	**−0.011**
	[0.08]	**(0.08)**	**(0.006)**
1986	1.86	−0.08	−0.006
	[0.13]	(0.08)	(0.006)

Note: Figures in parentheses and square brackets denote the standard errors and the *p*-values, respectively, bold numbers indicate structural changes at 10% significance
Source: Authors' calculations.

4. A comparison with the results of similar studies

Let us now compare our findings for the short-run and long-run elasticities with those found by some other studies both about Greece, but also about some other countries. These results are presented in Table 4. The short-run elasticities are smaller than their long-run counter parts, implying that the LeChatelier principle is satisfied. This is not unusual in the case of large systems, whose long-term responses are more perceptible than the short-term responses.

[7] This is also confirmed by Donatos and Mergos, (1989).

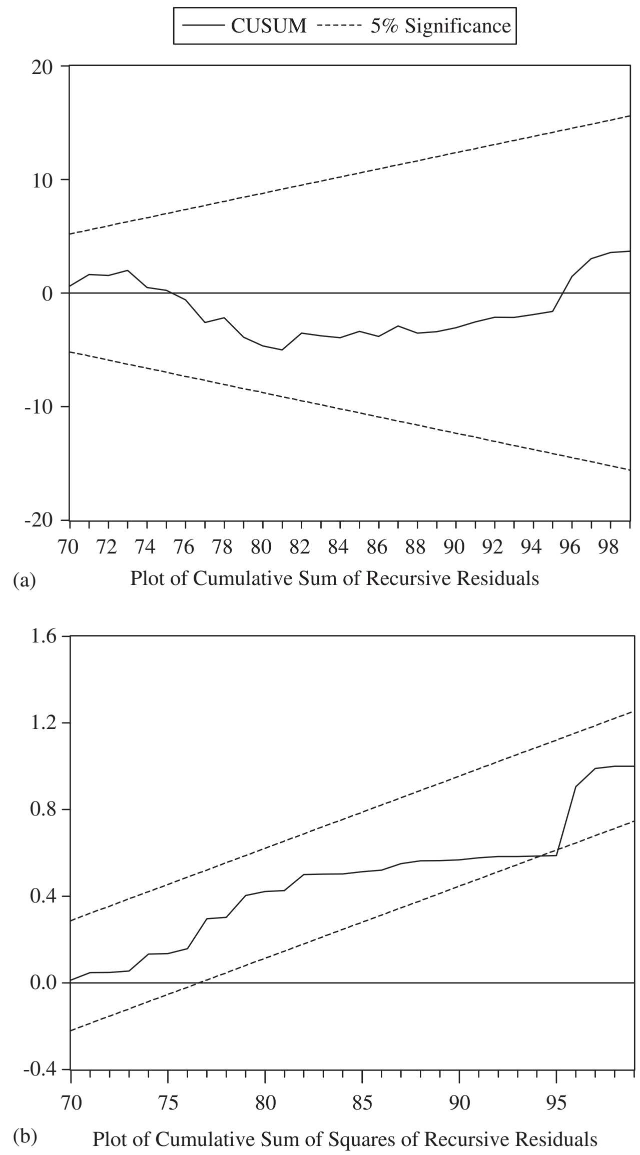

Fig. 2. Structural stability tests. (a) Plot of cumulative sum of recursive residuals. (b) Plot of cumulative sumof squares of recursive residuals.

Before making the comparison of the results reported in these studies, it is important to note the following basic differences among the models. The Greek data used by Christodoulakis et al. (2000), cover the period 1974–1994 and, therefore, do not capture the impact of the first energy crisis, whereas the data used in the present study cover 34 years, from 1965 to 1999, a period which includes some years prior to the first oil shock. As a result the price elasticities reported by the previous study are smaller than those reported in the present study. Also, the short-run income elasticity estimated by Christodoulakis et. al. (2000) is bigger than those reported in the present study.

Hondroyiannis (2004), estimated the residential electricity demand for Greece by using a vector error correction mechanism (VECM) with monthly data, taking into account changes in real income, price level and weather conditions that cover the period 1986–1999. The findings of this paper, suggest the presence of a stable residential demand for electricity in Greece both in the long- and short-run, with elasticities (income and price) that do not vary significantly from ours.

Arsenault et al (1995) consider energy demand as a function of the real disposable income per household, the price of energy and HDD. According to the findings of this paper, residential energy demand in Canada appears to be price and income inelastic both in the long- and short-run. Also the coefficient of heating degree days is positive and statistically significant implying that energy in households is mostly used for space heating. Finally, in the study by Haas and Schipper (1998) the income variable refers to real private final consumption expenditures. In this paper, an international comparison of price and income elasticities can be made.

As it is clear the elasticities reported in the studies vary widely, thus preventing any meaningful comparisons. From these results, we can conclude that Greece has an energy pattern similar to that of countries like Japan and Austria, where income elasticities do not vary substantially between the mentioned studies. We can also note that the income elasticities are smaller in high-income, developed countries than in less developed countries like Greece). In other words, the residential energy sector in Greece tends to be more sensitive to the changes of income (GDP) than it is in other more industrially advanced countries. The empirical finding that residential long-run income elasticity in Greece exceeds unity may imply that the Greek residential energy sector is still at a relatively low level of development and as a result the consumption of energy rises more rapidly than income (GDP). This may be explained by a number of reasons, such as different levels of per capita GDP, level of urbanization of the population, higher level of the underground economy, etc. An analysis, (Jones, 1992), showed that a 1% increase in the per capita GNP leads to an almost equal (1.03), increase in energy consumption. However, as reported, an increase of the urban population by 1% increases the energy consumption by 2.2%, i.e. the rate of change in energy use is twice the rate of change in urbanization. These data show clearly the impact urbanization may have on energy use.

However, according to a couple of recent empirical studies for Greece (RAE, 2003; Agoris et al., 2004), it is estimated that the magnitude of the income elasticity in the Greek residential sector will decline gradually for the next ten years approaching zero in the long-run.

Finally, it is worth mentioning that the high income elasticity of the energy consumption of the Greek households can be partly explained by the increase in

Table 4
A comparison of residential energy demand elasticities

Study and country	Estimation period	Elasticity Income	Price	Other variable(s)	Method	R^2	Remarks
1. This study	1965–1999	1.54[a]	−0.60[a]	0.33[b]	PAM	0.97	Other variables are lagged energy consumption and HDD
	1986–1999	0.79[b]	−0.31[b]	0.17[b]			
2. Hondroyiannis (2004), Greece	1986–1999	1.56[a]	−0.41[a]	−0.19[a]	VECM	0.84	The other variable is an index for temperature
		0.20[b]	—	—			
3. Christodoulakis et al. (2000), Greece	1974–1999	1.51[a]	−0.24[a]	—	ECM	0.98	—
		1.27[b]	−0.23[b]				
4. Arsenault et al. (1995), Canada	1962–1990	0.35[a]	−0.68[a]	0.59[b]	PAM	0.97	Other variables are lagged every consumption and HDD
		014[b]	−0.28[b]	0.29[b]			
5. Agostini et al. (1992), OECD countries	1978–1988	0.45[b]	−0.28[b]	—	OLS	na	—
6. Haas and Schipper (1998), OECD countries							
• USA	1970–1993	0.17[a]	−0.13[a]	0.41[b]	PAM	0.66*	The other variable refers to HDD
		0.12[b]	−0.09[b]				
• Japan	1970–1993	1.02[a]	−0.19[a]	—		0.99*	
		0.53[b]	−0.10[b]				
• Sweden	1970–1993	0.00[a]	−0.11[a]	046[b]		0.92	
		NS[b]	−0.11[b]				
• W. Germany	1970–1993	0.42[a]	−0.14[a]	0.75[b]		0.75*	
		0.27[b]	−0.09[b]				
• UK	1970–1993	0.40[a]	−0.13[a]	0.62[b]		0.90*	
		0.33[b]	−0.11[b]				
• Denmark	1972–1993	0.00[a]	−0.27[a]	0.59[b]		0.98*	
		NS[b]	−0.22[b]				
• Austria	1970–1993	1.11[a]	−0.33[a]	0.65[b]		0.95*	

Notes: (+) This paper refers to residential demand for electricity, NS = the coefficient is not significantly different from zero at the 25% level. (*) Adjusted R^2.
[a]Long-run elasticities.
[b]Short-run elasticities.

the use of air-conditioning especially in summer months) and the low level of energy conservation. In Greece, as in other Mediterranean countries (Italy, Spain and Portugal), room air-conditioners (RAC) sales have increased significantly over the last decade, and are expected to further increase in the coming years adding more loads to the electricity system and resulting in higher CO_2 emissions (Papadopoulos et al, 2003).

5. Concluding remarks

In this paper, we have attempted to determine the main determinants of the residential energy demand in Greece. For this purpose we have estimated the income and price elasticities of energy demand in Greece during the period 1965–1999. Our main findings are the following: first, in the long-run, residential energy demand is price inelastic and income elastic. In the short-run the elasticity of income (GDP) is less than unity (inelastic demand). None of the two energy crises (1973/79) had a positive and significant impact on energy demand. Therefore, no evidence is found of a structural change in energy demand, something that is probably due to the low efficiency of the energy sector as a result of the low degree of substitutability between the sources of energy.

It is worth mentioning that the magnitude of the income elasticities varies substantially between Greece and other OECD countries. The residential energy sector in Greece appears to be more sensitive to income variations than in other countries, where energy demand with respect to income is rather inelastic. This may be due to the different levels of growth between Greece and other OECD countries. Furthermore, the magnitude of income elasticities could be traced to exogenous factors such as the urbanization of the population which mainly occurred during the period 1965–1975. Finally, the high level of the underground economy in Greece which is estimated to be above 20% of GDP, may be another factor that partly explains the relatively high magnitude of income elasticity.

In order to better understand the reasons for the increase of residential consumption in Greece, and in other Mediterranean countries (Italy, Spain and Portugal) we may also have to take into account the expanded role of electric appliances and the extensive use of air-conditioning. Although in many countries the primary energy consumption of buildings is being reduced, because of the adoption of more effective measures for energy conservation, this refers mainly to the heating loads. In Southern Europe for example (Greece, Italy), the primary energy consumption continues to increase, mainly because of the propagation of air-conditioning appliances. This development leads to an increase in electricity consumption that is concentrated in the two or three summer months, and become therefore a dominant element in the energy balance of every power supplier. In Greece the increase in electricity consumption (peak load) is concentrated in summer months and especially in July.

The elasticities obtained in this study could be used for further policy analysis. The higher long-run income elasticity compared to the short-run income elasticity means that the response of energy demand to income will be larger in the long term than in the short term. High levels of long-run income elasticity indicate that energy demand in Greece is likely to increase quite sharply as GDP increases. Given the Greek GDP has been growing over the last eight years above the European Union average and this trend is expected to continue in the next few years, the energy demand will be rising unless the government takes measures for energy conservation. The problems of pollution and the compliance with the Kyoto protocol make it imperative for the government to implement a comprehensive policy strategy for more energy efficient houses and to give incentives for the use of environment friendly sources of energy.

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References

Agoris, D., Tigas, K., Giannakidis, G., Siakkis, F., Vassos, S., Vassilakos, N., Kilias, V., Damassiotis, M., 2004. An analysis of the greek energy system in view of the Kyoto commitments. Energy Policy 32, 2019–2033.

Agostini, P., Botteon, M., Carraro, C., 1992. A carbon tax to reduce CO2 emissions in Europe. Energy Economics 14 (4), 279–290.

Arsenault, E., Bernard, J-T., Carr, CW., Genest-Laplante, E., 1995. A total energy demand model of Quebec. Energy Economics 17 (2), 163–171.

Bentzen, J., Engsted, T., 1993. Short and long-run elasticities in energy demand: a co-integration approach. Energy Economics 15 (1), 9–16.

Chambers, M.J., 1990. Forecasting with demand systems: a comparative study. Journal of Econometrics 44, 363–376.

Christodoulakis, N.M., Kalyvitis, S.C., 1997. The demand for energy in Greece: assessing the effects of the community support framework 1994–1999. Energy Economics 19 (4), 393–416.

Christodoulakis, N.M., Kalyvitis, S.C., Lalas, D.P., Pesmajoglou, S., 2000. Forecasting energy consumption and energy related CO2 emissions in Greece: an evaluation of the consequences of the community support framework II and natural gas penetration. Energy Economics 22 (4), 395–422.

Donatos, G.S., Mergos, G.J., 1989. Energy demand in Greece: the impact of two energy crises. Energy Economics 11 (2), 147–152.

Donatos, G.S., Mergos, G.J., 1991. Residential demand for electricity: the case of Greece. Energy Economics 13 (1), 41–47.

Fouquet, R., 1995. The impact of VAT introduction on UK residential energy demand. Energy Economics 17 (3), 237–247.

Haas, R., Schipper, L., 1998. Residential energy demand in OECD-countries and the role of irreversible efficiency improvements. Energy Economics 20 (4), 421–442.

Hondroyiannis, G., 2004. Estimating Residential Demand for Electricity in Greece. Energy Economics 26, 319–334.

Jones B. G., 1992. Population growth, urbanization and disaster risk and vulnerability in metropolitan areas: a conceptual framework. In *Environmental Management and Urban Vulnerability*, World Bank Discussion Paper no. 168

Nerlove, M., 1958. Distributed lags and demand analysis for agricultural and other commodities, Agricultural Handbook no 141, US Department of Agriculture.

OECD, 2000. Behavioral responses to environmentally related taxes. Environment Monographs no 111.

OECD, 2001. Environmentally Related Taxes in OECD Countries: Issues and strategies. OECD, Paris.

Papadopoulos, A.M., Oxizidis, S., Kyriakis, N., 2003. Perspectives of solar cooling in view of the developments in the air-conditioning sector. Renewable and Sustainable Energy Review 7 (5), 419–438.

Pindyck, R., 1977. The Structure of World Energy Demand. The MIT Press.

Regulatory Authority for Energy. 2003. Long term energy planning of the Greek energy system. Draft proposal for Debate, January.

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