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Energy demand and environmental taxes: the case of Greece

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Abstract

The purpose of this paper is to analyze the effects that energy taxes may have on reducing environmental pollution in Greece. We study the demand for residential energy for the period 1965–1998, and on the basis of these estimates we make forecasts for CO_2 emissions in the coming years. Furthermore we develop alternative scenarios for tax changes, and study their effects on CO_2 emissions. According to our findings the harmonization of the Greek energy taxes to the average European Union levels implies an increase of total CO_2 emissions by 6% annually. If taxes are raised, however, to the highest European Union levels, the CO_2 emissions are restricted significantly. These empirical findings may indicate that environmental taxation cannot be the unique instrument for combating pollution.

JEL classification: O38; Q48

Keywords: Environmental tax; Energy demand; CO_2 emissions

1. Introduction

The use of taxes as an instrument to control externalities and, in particular, environmental pollution has been always popular amongst economists. Recently, however, this instrument has gained popularity among policy makers, and we observe a growing number of countries adopting taxes for environmental purposes.[1]

The main reason for the preference of market-related instruments, like taxes, instead of the traditional ‘‘command and control’’ measures is that the former work through the market and are less costly in their administration than the latter. With the environmental pollution becoming a very serious problem, and with its effects affecting our social and economic life, governments have started searching for effective means of controlling and limiting pollution. Pollution and, in particular, air pollution is not anymore a problem of a specific region or country. It is a major global problem, which cannot be tackled effectively without the co-operation of all countries or at least of the major pollution producers. In this framework, several attempts have been made, mainly by the United Nations, so that an agreement is reached at the world level in order to limit pollution. Such an important event is the Kyoto agreement, which aims at reducing the emission of some harmful for the environment, substances, especially carbon dioxide.

The imposition of taxes on polluting products or polluting sources is also considered as a fair approach since the polluter pays for the pollution created. This has led to the well-known principle that the polluter should pay. Such an approach, however, may be considered as only partial, since it does not take into account the effects of these taxes on the distribution of income, which could be quite important.[2]

The Kyoto Protocol sets out certain commitments for the developed countries, in the United Nations Framework Convention on Climate Change (UNFCCC) for the period 2008–2012. The overall target agreed is a reduction of the six most dangerous gases that contribute to the greenhouse effect by at least 5% below the 1990 levels for the period 2008–2012. Greece will have to restrict the average growth of the emissions of all six gases, for the period 2008–2012, to +25% compared to 1990 levels. This target is to be achieved through a number of actions at national and European

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[1] For a recent review on the use of taxes for environmental protection in the OECD countries, see OECD (2001).

[2] For a first approach to the incidence of environmental taxes see Rapanos (1995).

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level that refer to all sectors of the economy and particularly to energy sector.

The purpose of this paper is to provide estimates for the residential energy consumption in Greece by type of energy form, and on the base of these estimates to make some forecasts of the demand for energy for the period 1999–2010. These forecasts will then be used to estimate CO_2 emission levels, which are closely related to energy consumption. Employing three alternative scenarios for tax changes, we attempt to estimate their impact on energy consumption and consequently on CO_2 emissions.

The paper consists of five sections. In Section 2 a brief overview of the residential energy sector in Greece is provided, together with a presentation of the CO_2 emissions that are generated by residential energy consumption. In Section 3, we present the model of the demand for residential energy consumption, while Section 4 reports the main results of the estimated models. In Section 5, we develop three alternative tax scenarios, and estimate their effects on energy consumption, on CO_2 emissions and their impact on tax revenues. Finally, in Section 6 the main conclusions of the paper are presented.

2. The structure of the residential energy sector in Greece

Residential energy consumption in Greece has increased by 5.4% annually within the period 1965–2001. Fig. 1 shows the composition of the two main sources (petroleum products and electricity) of energy used by Greek households during the examined period. It is evident that during this period the share of electricity in household energy consumption has increased steadily. In quantity terms the share of electricity has increased by 2% annually. A major part of the observed growth in the electricity share comes from an increase in the number of consumers (Tserkezos, 1992). On the other hand the share of petroleum products (light and heavy fuel oil, LPG, kerosene) seems to be slightly declining by 0.6% per annum, while the use of other sources either remained the same (fuel wood) or declined as for example coal.

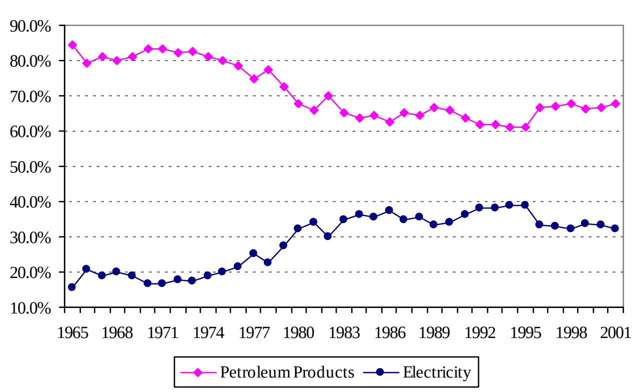

Fig. 1. Petroleum products and electricity shares in the residential sector (1965–2001). *Source:* IEA—Energy Balances in OECD countries various editions.

Electricity seems to be the main source of residential energy in Greece, except for heating where the share of electricity is below 10%, and the main energy source is diesel oil (Donatos and Mergos, 1991). This proportion may change significantly within the next few years because of the rapid introduction of natural gas, which can be used for both industrial as well as for residential consumption. The use of natural gas, which harms much less the environment, may lead over time to its substitution for traditional sources of energy (oil, electricity, etc.).

The tax on electricity—at constant 1988 prices—has increased, within the period 1965–1998, by about 0.4% annually, while the tax levied on light fuel oil has increased for the period 1974–1998 by 3.1% per annum. Energy taxation has varied during this period, since it was used by the Greek Government not only as an important source of state revenues, but in certain circumstances also as a means to contain inflation, which was quite high over this period.

In Greece, energy related activities including extraction, distribution and combustion of fossil fuels are responsible for approximately 76% of the total national greenhouse gases emitted each year (Christodoulakis et al., 2000). The polluter that contributes the most to the greenhouse effect is carbon dioxide (CO_2), which is generated mainly from the combustion of energy inputs like lignite, brown and coal, for electricity generation and fuel oil. During the period 1990–1995, CO_2 emissions from the energy sector accounted for approximately 90% of total CO_2 emissions in Greece (Christodoulakis et al., 2000). The CO_2 emissions that are generated from households contribute to total emissions by approximately 8.6%. Total per capita CO_2 emissions have also increased in the period 1990–98 by 13.6% (IEA, 2000).

Fig. 2 shows the estimated CO_2 emissions by type of energy (light fuel oil and coal) that is generated from households for the period 1960–2001. The emissions, which are generated from the consumption of light fuel oil, have increased for the examined period by 4.4% per annum. On the contrary, the household consumption of coal, for the period 1965–2001, declined and as a result it had a positive effect on the environment, as the related CO_2 emissions fell by 3.4% annually.

3. Modeling energy consumption

Energy demand has been the focus of numerous studies.[3] In most of these studies the purpose has been to

[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).

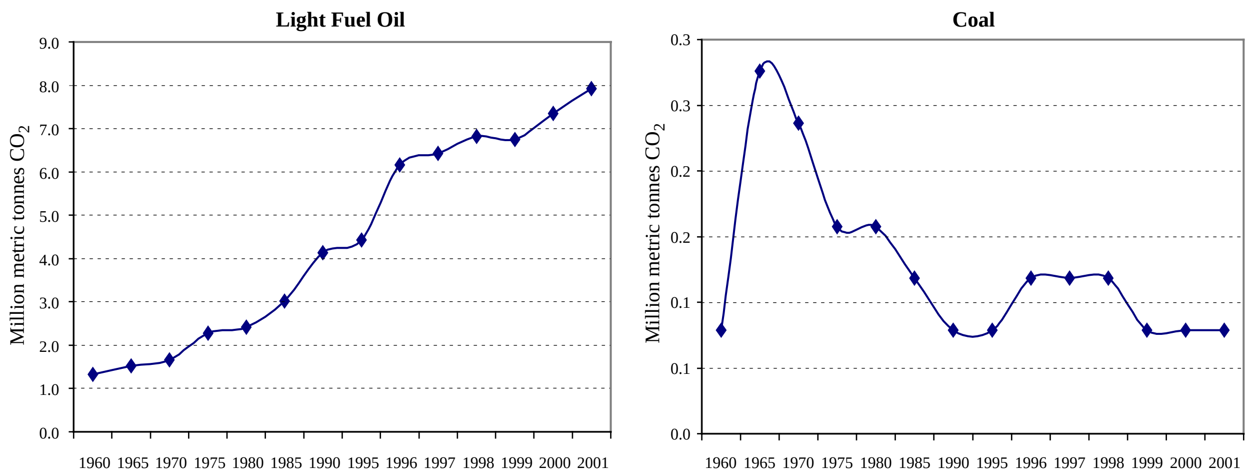

Fig. 2. Residential CO_2 emissions (1960–2001). *Source:* IEA—authors' calculations.

measure the impact of the economic activity and real energy prices on energy demand by estimating income and price elasticities. The most popular approach is the estimation of a single equation ad hoc demand functions using co-integration techniques (e.g. see Christodoulakis et al., 2000; Silk and Joutz, 1997 et al.). Although this approach has a number of disadvantages that have been discussed thoroughly by Pindyck (1977), the simplicity of estimation and the rather straightforward interpretation of the results is a strong advantage that cannot be overlooked. In this paper we will attempt to build a model designed specifically for investigating the impact of taxation on residential energy demand. Taxes have an indirect effect on residential energy consumption, since they act through the price mechanism. This approach differs from that of similar studies since their main objective is the interpretation of income and price effects on energy demand, without taking taxation explicitly into account.[4]

Our empirical analysis uses a single equation model for each type of energy (oil and electricity)[5] expressed in log linear form. Energy consumption (CON) for each source of energy (oil and electricity) is assumed to be a function of the real gross domestic product (GDP), the real price of energy (PEN), and the number of heating degree-days (HDD). It is worth mentioning that taxes do not enter the model as independent variables, because multicollinearity would appear. Hence, we do not estimate the relevant elasticities, but we assume instead that the magnitude of taxes is captured by prices. Also this model does not capture the effect of petrol consumption in total energy demand because of the lack of data.

The data used in the empirical estimation are national time series data for the period 1965–1998. The energy consumptions (CON) for oil and electricity, respectively, are measured in million tones of oil equivalent (toe) and are based on data available from the International Energy Agency (IEA).[6] GDP is expressed in constant 1988 prices and is 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 (1988 = 100). Finally, the variable of heating degree-days (HDD) is also available from the IEA database.

In order to estimate residential energy demand by source of energy (oil and electricity) we followed the error correction mechanism (Engle and Granger, 1987). The main reason for using this approach instead of using a VAR model is that the latter is more sensitive to the number of lags that can be used (Kremers et al., 1992). The basic statistical assumption underlying this approach is that the variables are stationary with the first two moments of the underlying data generation process not depending on time. In fact many time series are not well characterized as being stationary processes and so the first step is to examine the stationarity of the variables. In other words, we have to check for the presence of unit roots. If variables are non-stationary I(1) processes, then there may exist a linear combination which may well be stationary I(0) processes. If this is the case then the variables are cointegrated. Using an error correction model (ECM), short- and long-run effects can be captured by estimating the short- and long-run elasticities, respectively (Banerjee et al., 1993). Therefore, the long-run equation for the two energy sources is

[4] See, for example, Christodoulakis et al. (2000), Bentzen and Engsted (1993), and Haas and Schipper (1998).

[5] We do not include natural gas since its use in Greece is very limited and it is only recently that a distribution network has started been installed.

[6] The data on residential energy consumption comes from "Energy Balances in OECD Countries".

given by the following formula:

$$\log \mathrm{CON}_t(r,j) = c_{rj} + \theta_{rj} \log \mathrm{GDP}_t + \delta_{rj} \log \mathrm{PEN}_t(r,j) + \delta_{rjk} \log \mathrm{PENE}(r,j) + \mu_{rj} \log \mathrm{HDD}_t + u_t, \quad (1)$$

where CON(r,j) is the consumption for energy source j in residential sector r, θ_{rj} the income elasticity of energy source j in residential sector r, δ_{rj} the own-price elasticity of energy source j in residential sector r, δ_{rjk} the cross-price elasticity between the two energy sources (j and k) in residential sector r and HDD$_t$ the heating degree-days.

Next, we estimate the ECM, which is written as

$$\Delta \log \mathrm{CON}_t(r,j) = c_{rj} + \sum_{i=1}^{k} \alpha_{i,rj} \Delta \log \mathrm{CON}_{t-i}(r,j) + \sum_{i=0}^{l} \theta_{i,rj} \Delta \log \mathrm{GDP}_{t-i} + \sum_{i=0}^{m} \delta_{i,rj} \Delta \log \mathrm{PEN}_{t-i}(r,j) + \sum_{i=0}^{m'} \delta_{i,rjk} \Delta \log \mathrm{PENE}_{t-i}(r,j) + \sum_{i=0}^{n} \mu_{i,rj} \Delta \log \mathrm{HDD}_{t-i} + \gamma u_{t-1} + e_t, \quad (2)$$

where u_{t-1} is the lagged disturbance term of the long-run equation and the lag orders k, l, m, m' and n are chosen so as to make e_t white noise.[7] The coefficient of the error correction term γ measures the speed of adjustment towards the long-run equilibrium and is expected to have a minus sign.

Looking at the data over the examined period, we observe that our variables are probably non-stationary I(1). In order to examine the order of integration for these variables we have applied the Augmented Dickey–Fuller and Phillips–Perron tests.

The results of these tests are presented in Table 1. The 5% critical value for each test is −3.55. As it can be seen, none of the reported statistics for GDP, CELEC, COIL, PELEC and POIL are close to this value, which implies that the null-hypothesis of a unit root cannot be rejected for these variables. For HDD however, the unit root hypothesis is strongly rejected so that the variable is stationary or integrated I(0). By taking first differences of the non-stationary variables the hypothesis of stationarity cannot be rejected. Therefore, all the variables except for HDD are non-stationary I(1). This implies that there can be no long-run effect from the number of heating degree days (HDD) on energy demand,[8] but this does not preclude the existence of a short-run effect (Bentzen and Engsted, 1993).

Table 1
Tests for unit roots

Variable	Lags for ADF test	ADF test τ_τ	Phillips–Perron τ_τ
GDP	1	−2.04	−2.42
CELEC	1	−0.88	−1.72
COIL	1	−2.71	−2.17
PELEC	1	−2.51	−2.37
POIL	2	−1.40	−2.06
HDD	1	−3.63*	−4.72**
Δ(GDP)	1	−3.77*	−4.66**
Δ(CELEC)	1	−4.60**	−7.04**
Δ(COIL)	1	−3.58*	−6.59**
Δ(PELEC)	1	−4.75**	−5.64**
Δ(POIL)	2	−3.61*	−3.76**

Notes: The above tests are derived from the OLS estimation of the following equation for each variable involved: $\Delta x_t = \mu + \beta t - \delta x_{t-1} + \sum_{i-1}^{k} \phi_i \Delta x_{t-i} + u_t$, where τ_τ is the t-statistic for testing the significance of δ when a time trend is included in the above equation. The critical values for the relevant tests are obtained by Dickey and Fuller (1981). For the Phillips–Perron test we set the truncation lag equal to 3 consistent with the Newey–West correction. *, ** Denotes significance at $\alpha = 0.05$ and $\alpha = 0.01$, respectively.

Table 2
Tests for co-integration

Variables	ADF test: t-value (1 lag)
U_{OIL}	−4.61*
U_{ELEC}	−5.72**

Notes: U_{OIL} and U_{ELEC} denote the error correction terms of oil and electricity long-run equation, respectively. The t-values reject the null-hypothesis of no co-integration, indicating that the residuals are I(0). The critical values for the relevant tests are obtained by MacKinnon (1991). *, ** Denotes significance at $\alpha = 0.05$ and $\alpha = 0.01$, respectively.

The next step is to examine if there is one cointegrated relationship between the non-stationary variables. For this purpose, we applied the (augmented) Dickey–Fuller test (see Table 2) and found that at the 5% level of significance the disturbance term on each equation (oil and electricity) is stationary and integrated I(0). This means that according to the Granger representation theorem there is one cointegrating vector which corresponds to long-run equilibrium between the non-stationary variables of each model (Engle and Granger, 1987).

4. Estimation results

In this section we report the estimated results of the models that can be used in order to make forecasts on

[7] Because we have annual data, we set the lag orders equal to 1 (see Bentzen and Engsted, 1993).

[8] Therefore this variable is omitted from the long-run Eq. (1).

energy consumption for the next 11 years. Table 3 shows the long-run elasticities, by source of energy, that have been estimated from the cointegrated equations for oil and electricity. In the first column of the table we get the coefficients (elasticities) of the variables, whereas in the second column the long-run elasticities for electricity demand are presented. All independent variables have a statistically significant impact on residential energy demand. The residential demand for oil and electricity with respect to income (GDP) is estimated to be elastic, since the relevant coefficients exceed unity (1.08 and 1.38, respectively). The own price elasticities are negative and less than unity while the cross-price elasticities are positive. This implies a substitutability relation which appears only in the long-run between the two sources of energy. Note also that the cross-price effects are small, which may support the argument that the scope of energy switching in residential sector, is still limited.

Table 4 shows the results of estimating Eq. (2) for oil and electricity demand. Each coefficient of the variables denotes the short-run elasticity. All the coefficients of the variables for the oil demand equation have the anticipated signs (column 1) except for the price of electricity which is not statistically significant and has an opposite sign, due to the fact that electricity is not used for heating as light fuel oil. The short-run elasticities with respect to own price and income are estimated to be less than unity (inelastic demand). The coefficient of HDD is positive and has a statistically significant effect on residential oil demand. The error-correction term (γ) is strongly significant with an adjustment coefficient of -0.60, indicating that in the case we are off the long-run demand curve, oil consumption adjusts towards its long-run level, with about 60% of this adjustment taking place within the first year.

The estimation of residential electricity demand in the short-run gives similar results (column 2). The short-run own elasticities with respect to price and income are estimated to be less than unity.[9] Also there is a weak complementarity relationship of electricity with light fuel oil. This happens because oil is used mainly for space heating—its share is about 60%—where the share of residential electricity for heating is relatively low.[10] The HDD affect positively the electricity demand from households. Finally, the error-correction term is strongly significant with an adjustment coefficient of -0.39, indicating that in the case we are off the long-run demand curve, electricity consumption adjusts towards its long-run level with about 39% of this adjustment taking place within the first year.

Table 3
Long-run elasticities by source of energy

Variables	COIL (1)	CELEC (2)
GDP	1.08[a]	1.38[a]
	(6.0)	(4.80)
POIL	−0.39[a]	0.04[b]
	(−3.35)	(2.40)
PELEC	0.16[b]	−0.69[a]
	(2.10)	(−3.67)
R^2	0.89	0.69
Durbin–Watson	1.59	1.44
White test	13.62	5.66
J. Bera	1.89	0.74
ARCH test	0.54	0.10

Source: Authors' calculations. Note: The numbers in parentheses are *t*-values, [a,b,c] denotes significance at 0.01, 0.05 and 0.10, respectively.

Table 4
Short-run results of error-correction models*

Variables	Δ(COIL) (1)	Δ(CELEC) (2)
C		0.058[a]
		(6.59)
Δ(GDP)	0.64[c]	0.36[b]
	(1.34)	(2.20)
Δ(POIL)	−0.52[a]	−0.12[b]
	(−3.28)	(−2.06)
Δ(PELEC)	−0.36	−0.17[c]
	(−1.13)	(−1.61)
Δ(HDD)	0.33[c]	0.23[a]
	(1.52)	(3.13)
γ	−0.60[a]	−0.39[a]
	(−3.33)	(−3.55)
R^2	0.43	0.55
Durbin–Watson	1.64	1.73
LM (5)	3.87	1.37
	(0.56)	(0.92)
White test	17.74	20.53
	(0.60)	(0.42)
J. Bera	0.26	7.49
LMARCH (5)	1.78	1.57
	(0.87)	(0.90)

(*) The constant term for oil demand and the coefficients of the lagged dependent variables turned out to be insignificant and were therefore omitted from the models. Note: The numbers in parentheses are *t*-values, [a,b,c] denotes significance at 0.01, 0.05 and 0.10, respectively. C denotes the constant term. LM (5) and LMARCH (5) are Lagrance multiplier tests for fifth order autocorrelation and fifth order autoregressive conditional heteroskedasticity (ARCH), respectively.

5. Projections of energy demand

In this section, we use the estimated (error-correction) models to simulate the impact of introducing an

[9] This result is similar with findings by Donatos and Mergos (1991) who use data for the period 1961–1986 and estimate residential electricity demand as a function of prices, income and other relevant variables.

[10] This finding is also traced in Donatos and Mergos (1991).

(environmental) tax on energy consumption on CO_2 emissions, and on tax revenues in the period 1999–2010. We consider three different scenarios, which were developed by the European Commission:

(a) A most probable or medium tax (relative to the EU tax levels) scenario (MP).
(b) A high tax scenario (HT).
(c) A low tax scenario (LT), which also predicts 66% price increase in the period 2004–2005.

Table 5 presents all the relevant assumptions for the exogenous variables of the simulated model. The assumptions underlying the three scenarios are based on similar assumption about probable developments in energy prices, taxation and income from the OECD and EU reports (Energy in Europe, 1996). The simulation period is restricted to 1999–2010. The main reasons for this restriction is the scarce validity of long-run forecasts and the short-run structure of the model that does not take into account the possibility of technological innovations (Agostini et al., 1992).

5.1. Energy consumption and emissions

For the low tax scenario (LT), the level of energy consumption for oil and electricity is expected to decrease within the period 2004–2005 by 38.6 and 34.4%, respectively, as a result of a probable oil price shock in 2005 according to a scenario of the European Commission. Additionally we observe that in the high tax scenario (HT) oil and electricity consumption will increase by 1.8 and 3.1% annually within the period 1999–2010.

Next, using the above projections for the demand of the two sources of energy and the corresponding emission factors, CO_2 emissions for the period 1999–2010 are calculated and presented (Fig. 3). The emission growth rate is reduced by the imposition of high taxes on oil in the period 1998–2001. This corresponds to a level of pollution that is 16.1% lower compared to the 1998 levels. However, in the medium term, a high level of taxation on oil consumption leads to an increase in CO_2 emissions by 1.8% annually, within the period 1999–2010. On the other hand, in the most probable scenario, CO_2 emissions that are generated from residential oil consumption will increase by 4.6% per annum, whilst in the low tax scenario the level of emissions during the same period will increase by 7.6% annually.

CO_2 emissions from electricity consumption follow a similar pattern. More specifically, the introduction of higher taxes on electricity consumption, for the simulated period, corresponds to an increase in the level of CO_2 emissions by 3.1% per annum. This means that the imposition of a higher level of taxation does not have any noticeable impact on pollution. Finally, it might be worth mentioning that no simulated policy reduces the CO_2 emissions below the 1998 level.

The above growth rates of CO_2 emissions that are generated from households are substantially higher from world forecasts. The growth rate of world CO_2 emissions is estimated to increase by 1.8% annually up to 2025 (Holtz-Eakin and Selden, 1995). On the other hand, estimates of the European Union, indicate an annual average increase of 1.1% for the period 1995–2000, which will come down to 0.5% for the next period up to 2020 (Energy in Europe, 1996). These variations may persist due to the fact that the effects of the introduction of natural gas (i.e. an expected reduction on the consumption of solid fuels) are omitted from the model.

5.2. Tax revenue

The tax revenue that can be collected (see Fig. 4) from the taxation of the two sources of residential energy is relatively high. The revenues from the high tax scenario (HT) for oil and electricity will increase annually by 12.8

Table 5
The structure of the three scenarios

Variables	Most probable (MP)	High tax (HT)	Low tax (LT)
GDP	2.5% increase per annum	3.5% increase per annum	1% increase in the period 1999–2005 and 1.8% increase in the period 2005–2010
Energy prices	2% increase in oil price and 1.5% decrease in electricity price	2% increase in oil price and 3.8% increase in electricity price	4.6% increase in the period 1999–2004, 66% increase in the period 2004–2005 and 14.7% decrease in the period 2005–2010 for the two sources of energy
Taxation	Harmonization to the European Union average tax level	Harmonization to the average tax level of the three countries with the highest tax rates	Harmonization to the average tax level of the three countries with the lowest tax rates
Period	1999–2010	1999–2010	1999–2010

Source: European Commission (1996).

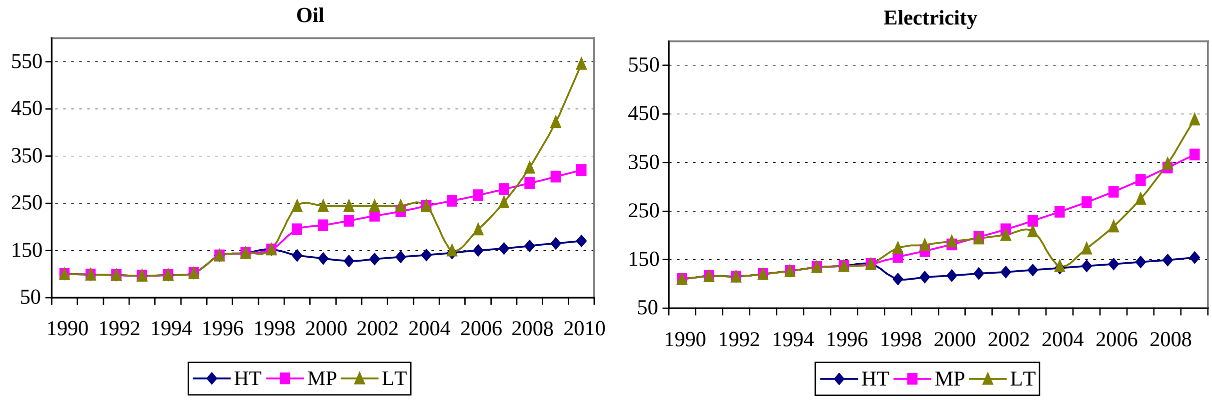

Fig. 3. CO_2 emissions for the three scenarios (1990 = 100).

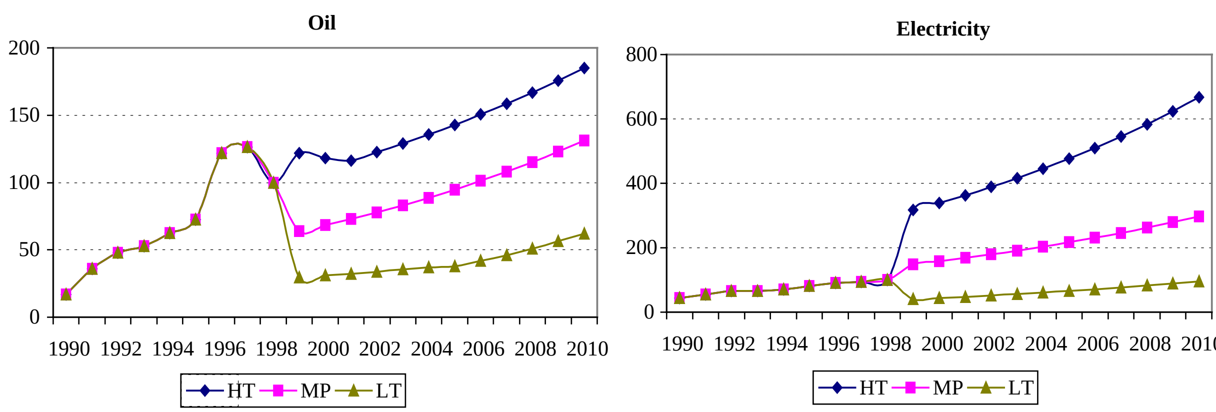

Fig. 4. Total tax revenues under the three scenarios (1998 = 100).

and 14.5%, respectively (1990–2010). The annual growth rate of revenues under the MP are 10.9 and 9.9%, respectively, while under the LT the increases are about 6.8 and 3.9%, respectively.

6. Concluding remarks

In this paper, we attempted to examine the effects of environmental taxation as a means to reduce residential energy consumption in Greece and restrict CO_2 emissions that are generated from the combustion of fossil fuels. In order to assess the effectiveness of an environmental tax levied on energy consumption, we estimated the factors that determine residential demand by source of energy (oil and electricity) for the period 1965–1998. To overcome the problem of non-stationarity of the variables we used co-integration and error-correction methods to estimate short- and long-run energy demand elasticities. The results of the error-correction models were used to make forecasts for the level of energy consumption (oil and electricity) for the period 1999–2010. Three policy scenarios have been simulated (high tax, medium tax and low tax).

Our main findings are the following: The resulting error-correction models had parameters with the expected signs and magnitudes. Therefore, in the long-run the (cross-price) elasticities of the two sources of energy imply a, statistically significant, substitutability relationship of electricity with diesel, while in the short-run this relationship does not exist (complementarity). In the short run the residential demand for electricity is less sensitive to changes in income and prices than oil demand. Furthermore, the households appear to adjust more rapidly their demand for oil in response to changes in income and prices than their demand for electricity.

When the estimated model is used to forecast residential demand by source of energy, it gives some valuable results that can be used for policy analysis. According to our findings, by the end of the next decade Greece may still be far from the 25% target compared to 1990 levels. This implies that an environmental tax cannot be the unique instrument to reduce emissions (Agostini et al., 1992). This means that additional measures should complement the tax policy in order to make the attainment of the target feasible. Greece could use effectively alternative sources of energy generation which are friendly to environment such as wind and solar energy. Additionally, the government could introduce more effective environmental regulations (e.g. strict standards for the residential heating system) that would enhance the overall energy efficiency of households and enterprises.

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