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Empirical assessment of the determinants of road energy demand in Greece ☆

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Abstract

This paper attempts to cast light on the determinants of road energy demand in Greece. For this purpose, we used cointegration techniques and vector autoregression (VAR) analysis in order to capture short-run and long-run dynamics for gasoline and diesel demand, respectively. From the empirical analysis that covers the period 1978–2003, we find that in the long-run gasoline energy demand appears to be price and income inelastic while diesel demand appears to be price inelastic and income elastic. We also found that the absence of close substitutes in the road sector denotes the low level of energy switching in Greece.

JEL classification: Q41; Q48; C32

Keywords: Road demand; Cointegration techniques; Vector autoregression analysis; Energy switching

1. Introduction and survey of the literature

Within the last decade, road energy demand has shown relatively high growth rates compared to other uses of energy in the Greek economy. It is estimated that within the period 1990–2002 road energy demand has increased by 44.3%. The main drivers that accelerated gasoline and diesel consumption are closely connected to the growing level of economic activity especially after Greece has joined the European Monetary Union (EMU) and the increasing number of automobiles (passenger cars and commercial vehicles). Transport sector

☆ The views expressed in this paper are those of the author and not those of the Hellenic Competition Commission.

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in Greece is also one of the major polluting ones. The share of road Greenhouse gas Emissions (GHG) in total transport emissions has increased from 77% in 1990 to 84% in 2002 (MINENV, 2004). Road transport is a key category of CO_2 and N_2O emissions. CO_2 emissions in 2002 increased by approximately 44% compared to 1990 emissions, while N_2O emissions tripled from 1990 due to the increase of new technology (catalytic) passenger cars (MINENV, 2004).

The issue of analyzing and predicting the evolution of road demand is crucial for a sound energy policy though it is a rather complicated topic. This paper approaches the problem on a scientifically solid base and it is timely with respect to the new European directives on the evaluation of energy performance in this field. Despite the importance of the subject in the development of energy policy in Greece towards full liberalization of the electricity and natural gas markets, no study has been done on road demand. Previous studies have examined various energy sectors (mostly residential and industrial sector) and policy issues (see Donatos and Mergos, 1989; 1991; Christodoulakis et al., 2000; Christopoulos, 2000; Hondroyiannis et al., 2002; Hondroyiannis, 2004; Rapanos and Polemis, in press) but they have neglected road demand. This paper aims to cover this lacuna.

Road energy demand has been of interest to economists for a long time and there is a substantial body of literature estimating its main determinants. In most of these studies, the purpose was to measure the impact of certain exogenous variables (GDP, energy prices, fleet vehicle, etc.) on road demand by estimating income and price elasticities. The majority of these studies apply cointegration techniques and especially Engle–Granger methodology in order to estimate the relevant elasticities (price, income).[1] More specifically, Bentzen (1994) uses an error correction model in order to estimate short-run and long-run Danish gasoline demand elasticities for the period 1948–1991. He found that the main determinants of gasoline demand were the price of petrol and the fleet of vehicles (PARK). The magnitude of price elasticities in the short- and the long-run is -0.32 and -0.41, respectively. According to his findings, taxing gasoline may show up to be much more positive concerning tax revenues, but if the purpose is to take care of environmental matters, other policy initiatives may be needed. Samimi (1995) also uses cointegration techniques in order to examine the impact of prices and GDP to road demand in Australia.

In order to estimate long-run gasoline demand equation, the researchers use annually data (e.g. Bentzen, 1994; Eltony and Al-Mutairi, 1995; Ramanathan, 1999) for a number of countries (i.e. European Union, OECD countries, etc.). The papers of Baltagi and Griffin (1983) and Dunkerley and Hoch (1987) estimate petrol demand for OECD countries and the developed countries, respectively. The study of Garbacz (1989) examines the relationship between gasoline demand and various macroeconomics variables in Germany.

McRae (1994) uses econometric models in order to capture the main determinants of gasoline demand in the Asian developed countries, while Ramanathan and Geetha (1998) apply single equations functions to measure the impact of price and income in gasoline demand in India.[2]

A different approach is followed in the study of Nicol (2003) who uses an empirical model to estimate the main determinants of petrol demand in Canada and USA, respectively. This study employs a simultaneous system of equations and use cross-section data per household

[1] See, for example, Bentzen (1994), Eltony and Al-Mutairi (1995) and Ramanathan (1999).

[2] For an extensive survey of gasoline demand elasticities see Dahl (1986) and Dahl and Sterner (1991).

(micro-data). According to the main findings, gasoline demand for USA and Canada appears to be price and income inelastic while the magnitude of various structural parameters is taking into account (size of household, type of ownership, etc.). In the study of Sharma et al. (2002), an alternative methodology is applied. In order to estimate the specific factors that affect gasoline and diesel demand in India, two equations in log-linear form are estimated using OLS for the period 1970–1998. Gasoline demand was found to be negatively affected by changes in the wholesale price of petrol and positively affected by variations in the population. Belhaj (2002) employs a 3-stage least squares (3SLS) technique in order to define the main determinants of vehicle and fuel demand in Morocco for the period 1970–1996. In light of the results, gasoline and diesel demand depend strongly on fluctuations in real prices, income and the vehicle stock.

The contribution of Alves and Bueno (2003) to the interpretation of gasoline demand in Brazil is rather important since an error-correction model is used. This study extents the current literature by measuring the impact of alcohol in final gasoline demand. According to the findings of their study, gasoline demand appears to be price and income inelastic both in the short and the long-run, while cross-price elasticity is positive implying that alcohol and gasoline are gross substitutes.

An interesting approach to examine the main determinants of road energy demand is the one followed by Fouquet et al. (1997). In the above mentioned study that covers the period 1960–1994, total energy demand in the United Kingdom is disaggregated into seven major energy sectors (road, residential, industry, etc.) according to the type of fuel they use (diesel, natural gas, gasoline electricity and coal). One of the main findings of their study is that long-run income elasticity for diesel ranges from 1.95 to 2.05 (income elastic demand). In contrast, long-run fluctuations in the real price of the above-mentioned fuel leave diesel demand unaffected since the relevant variable found to be stationary. Finally, in the study of Wohlgemuth (1997), the magnitude of long-run income elasticities lies within the bounds of 0.89 and 1.10, respectively, while price elasticities have a negligible impact to diesel demand.

The purpose of this paper is to examine the main factors that determine the road energy demand 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, the compliance with the Kyoto target for the increase of the greenhouse gases (+25% compared to 1990 levels), brings again to the fore the need for a more determined approach if the country is to improve the efficiency in the consumption of the energy sector (Rapanos and Polemis, in press). This paper differs from earlier works in the subject in two ways. First, our approach in determining the road energy pattern in Greece is quite different from that of some previous studies (Eltony and Al-Mutairi, 1995; Ramanathan, 1999; Alves and Bueno, 2003; Bauer et al., 2003), by taking into account the impact of vehicle stock and by giving emphasis to the responses of the related variables to relevant shocks (impulse response functions, variance decomposition). Secondly, we try to analyze diesel demand, to which has been paid rather scant attention by the earlier studies.

This paper consists of six sections. In Section 2 a brief overview of the transport energy sector in Greece is provided, together with a short presentation of the level of taxation by type of fuel. Section 3 offers a detailed description of the model, while Section 4 reports the main results of the cointegration techniques. In Section 5 short-run dynamics are presented through the estimation of VECMs as well as the impulse response functions and variance decomposition analysis. Finally, Section 6 encapsulates the main points of the paper presented together with some policy implications.

2. The structure of the transport sector in Greece

Transport sector constitutes one of the most energy-intensive sectors in Greece with a total final consumption of 7.2M tonnes in 2002. Total transport energy demand is divided into five distinct categories or sub-sectors (road, rail, international aviation and domestic navigation). According to the International Energy Agency (IEA), road demand absorbs around 80% of total final transport demand and this share has gradually increased since 1985. International civil aviation has a share of 10.8%, while internal navigation consumes only 9% of total transport demand. Finally, rail demand has the smallest share (approximately 0.6% for 2002).

Since the mid 1970s, a rise of energy consumption in transport sector has been observed, faster than that of total energy consumption, mostly reflecting a general improvement of the standard of living in Greece (i.e. increase of private cars, etc.). Energy transport sector in Greece mainly consumes oil products (gasoline, diesel, LPG) and to a lesser extent electricity. This proportion may change significantly within the next few years due to the rapid increase of public transportation that uses electricity (i.e. subway, railway, tram, sub-urban). The biggest share of energy transport consumption corresponds to motor gasoline (47%) followed by diesel (32%) which is mainly used by the road sector as a propellant for commercial vehicles (trucks, taxis, etc.). Jet fuel gasoline holds the 16% of the total final consumption while the share of heavy fuel oil in the total demand of the sector does not exceed 5%.

The tax on leaded gasoline has increased within the period 1978–2003, by about 10.7% annually, while the tax levied on unleaded gasoline has shown an increase for the period 1988–2003 by about 7% per annum. In addition, total taxation (VAT and excise tax) on automotive diesel oil has increased within the time period 1987–2003 by 9.3% annually reaching 342 euros/1000 l in 2003. Energy taxation has varied significantly during the previous mentioned periods, since it was used by the Greek Government not only as an important source of state revenues, but in certain circumstances also as an anti-inflationary tool, which was quite high over the previous decades (Rapanos and Polemis, 2005).

Total gasoline consumption in Greece has increased by 4% annually within the period 1988–2001 reaching 3.3M tonnes in 2001. A major part of the observed growth is attributed to the increase of the catalytic passenger cars that use advanced technology. This evolution is connected with the successful implementation of the “withdrawal” measure that Greek Government brought into force in 1991 (Bikos, 2004). With this initiative, the state gave specific motives to customers (i.e. tax exceptions, subsidies for new catalytic cars) who replaced their old-technology passenger cars with new more environmental friendly vehicles.

Unleaded gasoline (95 RON) has shown tremendous increase by 74.2% over the examined period (1988–2001). This type of fuel has entered the market in 1988 with a small consumption of 3000 tonnes reaching 2.3M tonnes in 2001. During the first 3 years (1988–1990), the consumption of unleaded gasoline was small because the number of circulating catalytic cars in Greece was negligible. Besides, the necessary infrastructure for the production (refineries), storage and supply of this quality to the retail hubs (petrol stations) was lacking. The increasing number of the catalytic vehicles from 1991 onwards and the gradually expansion of the oil companies network in order to meet the high demand accelerated unleaded gasoline consumption.

In contrast to the above development, leaded gasoline which comprises of two different blends has decreased by 6% per annum within the examined period. This evolution is mainly observed within the years 1998–2001 where leaded gasoline consumption fell by 37.1%. The main reasons for this decrease are attributed to the implementation of the "withdrawal" measure and the subsequent replacement of old leaded-petrol vehicles with catalytic ones that consume unleaded gasoline (Bikos, 2004).

Finally, a comparison between Greece and other EU countries is employed in order to provide additional policy information about the road energy sector. Greece has the lowest total final consumption per capita within the European union, reaching the level of 0.52 tonnes of oil equivalent (toe) in 2002, which is bellow the European average (0.70). In contrast, the relevant magnitude in Ireland exceeds the European mean reaches the level of 0.92 toe. A major conclusion that can be drawn is that countries with high growth rates such as Ireland, Finland, Sweden and Belgium consume more energy (well above the European average) in the road sector than the less-developed countries like Portugal and Greece. This may be attributed to the fact that developed countries have more energy needs to cover than the less developed ones due to the different level of growth and road infrastructure. However, in recent years, the level of road energy demand in Greece has grown significantly. The Community Support Framework III, the preparation for the Olympic Games of 2004, the gradually expansion of road network, the development of public infrastructure, are some of the main reasons that boosted road energy demand.

Another interesting issue is that Scandinavian countries (Denmark, Sweden and Finland) where the level of environmental taxation is highly developed (i.e. revenue collective mechanism, high taxes on fuels) can be characterized as road energy-intensive countries within the EU. This evolution is in tune with similar conclusions (see Bentzen, 1994). More specifically, taxing fuels (e.g. gasoline, diesel) in order to comply with environmental goals (e.g. mitigating CO_2 emissions) may show up to be a less efficient measure than raising tax revenues due to the low sensitivity (elasticity) of consumers to changes in fuel prices combined with the absence of substitution effects (fuel switching).

3. Description of the empirical methodology

Following the specification of Bentzen (1994), Samimi (1995), Eltony and Al-Mutairi (1995), Ramanathan (1999), and Alves and Bueno, 2003, two log-linear forms using per capita income (GDP), real energy price of gasoline and diesel and per capita vehicle fleet as independent variables were used in the empirical analysis. Therefore, the following specifications for the long-run road demand for gasoline and diesel are employed:

$$\ln(\mathrm{GASOL}_t) = a_0 + a_1\ln(\mathrm{GDP}_t) + a_2\ln(\mathrm{RPGASOL}_t) + a_3\ln(\mathrm{RPDIESEL}_t) + a_4\mathrm{TREND} + u_t \tag{1}$$

$$\ln(\mathrm{DIESEL}) = b_0 + b_1\ln(\mathrm{GDP}_t) + b_2\ln(\mathrm{RPDIESEL}_t) + b_3\ln(\mathrm{RPGASOL}_t) + b_4\ln(\mathrm{PARKD}) + u_t \tag{2}$$

where GASOL_t is the per capita gasoline road consumption at time t, GDP_t is real per capita income at time t, $\mathrm{RPGASOL}_t$ is the real price of gasoline (leaded and unleaded), $\mathrm{RPDIESEL}_t$ is the real price of diesel, TREND is a time trend which is included in the gasoline demand model (1) in order to capture possible technological advances (i.e. catalytic cars, use of cleaner and more efficient fuels, etc.), DIESEL_t is the per capita diesel consumption at time t and finally

$PARKD_t$ is the per capita diesel-engined fleet and finally u_t stands for the disturbance term in both equations.

The data used in the empirical estimation are national time series data for the period 1978–2003. The main reason for not using an extended data set is that the only reliable source (International Energy Agency) provides statistical data for road demand in Greece from 1978 onwards. However, we tried to estimate road energy demand in Greece using a data set from the Greek Ministry of Development running from 1970 with non-satisfactory results.[3] The main reason is attributed to the fact that the two data sets differ significantly in two ways. First, in the data set provided by the Ministry of Development, the necessary information for some of the relevant variables does not refer to Greece as a whole but only to specific geographical regions whereas some observations for gasoline prices are missing. Second and more important the data for the construction of the variable $DIESEL_t$ (per capita consumption of diesel oil) do not cover road sector but total transport sector (including rail and internal navigation). Therefore, the results obtained by the use of the extended data set, almost biased, are incorrect and lack of theoretical basis.

The per capita consumption for gasoline (GASOL) and diesel oil (DIESEL), respectively, is measured in litres. These data are available from the IEA.[4] Per capita GDP is expressed in constant 1995 prices and is obtained from the Eurostat Database (Newcronos – Theme 2). Energy prices for gasoline (RPGASOL) and diesel (RPDIESEL) are taken from “Energy Prices and Taxes” (IEA) and have been deflated by the consumer price index (1999 = 100). Finally, the variables that measure the per capita fleet (PARKD) of diesel- (buses, heavy commercial vehicles) and petrol- (passenger cars, light commercial vehicles, motorcycles, etc.) engined vehicles (PARKG) are obtained from the database of the Association of Motor Vehicle Importers–Representatives (AMVIR).

In the empirical analysis, we test for the existence of a long-run relationship among the variables of the two models (Eqs. (1) and (2)) applying cointegration techniques (Johansen procedure). In order to capture the short-run dynamics (elasticities), we use estimates of the two-vector error-correction models (gasoline and diesel demand) and employ impulse response functions and variance decomposition analysis.

In the first stage of our empirical analysis, we have to check for the presence of unit roots. 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, we have applied a series of diagnostic tests both in levels and first differences of these variables (Augmented Dickey–Fuller, Phillips–Perron and KPSS tests).

The results of the above tests are presented in Table 1. Applying the relevant tests, we observe that the null-hypothesis of a unit root cannot be rejected at 5% critical value for all the relevant variables. In other words, all the series are non-stationary. From the results of Phillips–Perron test, we observe that the levels of the series RPDIESEL and PARKD appear to be stationary at $\alpha = 0.05$ level of significance. However, the combined results of Dickey–Fuller and KPSS tests show little support for the stationary hypothesis. By taking first differences of the non-stationary variables, the hypothesis of stationarity cannot be rejected at $\alpha = 0.05$ level of significance. For D(PARKG), however, the unit root hypothesis cannot be rejected implying that the variable PARKG is I(2). This implies that there can be no long-run and short-run effects from the per

[3] The above mentioned results are available from the author upon request.

[4] The data on road energy demand comes from “Energy Balances in OECD Countries”.

Table 1
Tests for unit roots

Variables	Augmented Dickey–Fuller						Phillips–Perron		KPSS				Order of integration
	Lags	τ_t	Φ_3	τ_μ	Φ_2	τ	τ_t	τ_μ	$l=1$		$l=4$		
									n_μ	n_τ	n_μ	n_τ	
Levels													
GDP	1	−2.43	6.00	0.40	1.25	1.31	−1.40	0.80	1.15**	0.27**	0.54*	0.15*	I(1)
GASOL	1	−1.08	2.51	−2.14	4.85	1.83	−0.62	−1.10	1.34**	0.27**	0.60*	0.14*	I(1)
DIESEL	1	−0.57	2.04	−2.06	4.74	−2.70	−0.39	−2.16	1.26**	0.27**	0.58*	0.16*	I(1)
RPGASOL	1	−2.05	2.56	−1.81	2.65	−0.72	−1.88	−1.31	1.08**	0.22**	0.53*	0.14*	I(1)
RPDIESEL	2	−2.93	4.31	−1.72	1.58	−0.75	−4.17*	−3.50*	0.77**	0.05	0.53*	0.06	I(1)
PARKG	1	−1.93	4.00	−2.21	3.33	1.55	−1.46	−3.61*	1.35**	0.25**	0.63*	0.15*	I(2)
PARKD	2	−2.04	6.52	−2.46	4.19	−1.62	−4.34*	−3.75**	1.37**	0.20*	0.63*	0.16*	I(1)
First differences													
D(GDP)	1	−4.08*	–	–	–	–	−3.90*	−3.32*	0.36	0.04	0.31	0.07	I(0)
D(GASOL)	1	−3.63*	–	–	–	–	−2.92	−2.42	0.31	0.17*	0.20	0.12	I(0)
D(DIESEL)	1	−4.71**	–	–	–	–	−5.88**	−3.96**	0.37	0.05	0.36	0.09	I(0)
D(RPGASOL)	1	−4.25*	–	–	–	–	−5.53**	−4.68**	0.09	0.05	0.13	0.08	I(0)
D(RPDIESEL)	2	−4.19*	–	–	–	–	−7.32**	−8.45**	0.09	0.05	0.14	0.08	I(0)
D(PARKG)	1	−3.18	5.70	−2.13	1.36	−1.22	−2.63	−1.67	0.56*	0.08	0.43	0.08	I(1)
D(PARKD)	2	−3.64*	–	–	–	–	−12.7**	−6.13**	0.33	0.06	0.40	0.10	I(0)

The relevant tests are derived from the OLS estimation of the following autoregression for the variable involved:

$$\Delta Y_t = \delta + \beta Y_{t-1} + \gamma t + \sum \alpha_i {*} \Delta Y_{t-1} + u_t. \quad (1a)$$

τ_μ is the t-statistic for testing the significance of β when a time trend is not included in Eq. (1a) and τ_t is the t-statistic for testing the significance of β when a time trend is included in Eq. (1a). The calculated statistics are those reported in Dickey and Fuller (1981). The critical values at 5% and 1% for $N=50$ are given in Dickey and Fuller (1981). The lag length structure of α_i of the dependent variable y_t is determined using a recursive procedure in the light of a Lagrange multiplier LM autocorrelation test for orders up to 4 which is asymptotically distributed as chi-squared distribution and the value of t-statistic of the coefficient associated with the last lag in the estimated autoregression. The critical values for the Phillips–Perron unit root tests are obtained from Dickey and Fuller (1981). n_μ and n_τ are the KPSS statistics for testing the null hypothesis that the series are I(0) when the residuals are computed from a regression equation with only an intercept and intercept and time trend, respectively. The critical values are given in Kwiatkowski et al. (1992).

* Indicates significance at the 1% level.

** Indicates significance at the 5% level.

capita fleet of petrol-engined vehicles (PARKG) on gasoline demand and thus this variable should be omitted from the model.[5]

4. Empirical application

In order to assess road consumption by source of energy (gasoline and diesel), we followed the error-correction mechanism by estimating two VARs for gasoline and diesel demand, respectively. The reason for using cointegration techniques is that nonstationary time series result to spurious regressions and hence do not allow statistical interpretation of the estimations. In order to overcome this problem, we apply the Johansen (1992) technique. This method allows us to examine whether there is a long-run co-movement of the variables.

[5] According to Φ_2-statistic, all the examined variables do not include deterministic terms (trend and intercept).

Table 2
Johansen's maximum likelihood method test for cointegration relationship

Null hypothesis, H_o	Alternative hypothesis, H_1	Eigenvalue	Critical values	
			95%	99%
Gasoline demand: VAR = 2, variables: GASOL, GDP, RPGASOL, RPDIESEL				
Maximum eigenvalues				
$r=0$	$r=1$	47.14[a]	31.46	36.65
$r\leq 1$	$r=2$	23.47	25.54	30.34
Trace statistic				
$r=0$	$r\geq 1$	100.82[a]	62.99	70.05
$r\leq 1$	$r\geq 2$	40.25	42.44	48.45
Diesel demand: VAR = 2, variables: DIESEL, GDP, RPGASOL, RPDIESEL, PARKD				
Maximum eigenvalues				
$r=0$	$r=1$	38.11[a]	30.04	35.17
$r\leq 1$	$r=2$	23.4	23.80	28.82
Trace statistic				
$r=0$	$r\geq 1$	79.88[a]	59.46	66.52
$r\leq 1$	$r\geq 2$	41.76[b]	39.89	45.58

r: denotes the number of cointegrating equations.
[a] Denotes significance at $\alpha=0.01$.
[b] Denotes significance at $\alpha=0.05$.

The first step is to choose the lag value of the multivariate system of equations. By setting the lag length equal to 2, we ensure that the residuals of the two VAR models are white noise (Gaussian errors).[6] Log-likelihood ratio tests are then used for testing the deletion of two dummy variables from the two VAR models.

The first dummy variable (D1988) accounts for the introduction of unleaded gasoline in the market staring in 1988, while the second dummy (D1991) accounts for the implementation of the "withdrawal" measure that came into force at 1991. All the relevant tests cannot reject the null hypothesis of the deletion of the two dummy variables from the corresponding VAR models. Finally, the estimation procedure for the one of the two VAR models (gasoline) assumes no intercept but deterministic trend, while the second VAR model that estimates diesel demand is characterized by the absence of deterministic terms (drift and trend).

Table 2 presents the maximum-likelihood eigenvalue statistics.[7] It becomes clear from the table that the null hypothesis is rejected at 1% level (see Osterwald-Lenum, 1992 for critical values). The estimated likelihood ratio tests and eigenvalues indicate that there is one cointegration vector for each model (gasoline and diesel).

Having specified the number of cointegrating relations for each VAR, we investigate whether all variables enter statistically significant in the cointegrating vectors. Table 3 reports the likelihood ratio tests as analytically described in Johansen and Juselius (1990). The results suggest that all the variables except for real price of gasoline (RPGASOL) in the diesel model enter statistically significant into the cointegrating vectors.

[6] To determine the lag length of the VARs, an extensive diagnosing testing of the OLS residuals is employed for various lag lengths. Each equation of the VAR systems passes a series of diagnostic tests including serial correlation based on the autocorrelation functions of the residuals as well as the reported Lagrange multiplier (LM test).

[7] The null hypothesis is that there is no cointegration relationship, so $r=0$.

Table 3
LR test of restrictions that each variable does not enter in the cointegrating vector

Variables	Gasoline	Diesel
GASOL	9.97[a]	–
DIESEL	–	6.19[a]
GDP	5.59[b]	5.35[a]
RPGASOL	13.19[a]	1.88
RPDIESEL	4.36[b]	7.04[a]

LR tests are distributed as χ^2 distribution with degrees of freedom the number of cointegrating vectors.
[a] Denotes rejection of the null hypothesis at $\alpha = 0.01$.
[b] Denotes rejection of the null hypothesis at $\alpha = 0.05$.

The resulting normalized parameter estimates of our gasoline model from the cointegration analysis are as follows:

$$\text{GASOL} = \underset{(0.09)}{0.79\text{GDP}} - \underset{(0.03)}{0.38\text{RPGASOL}} + \underset{(0.02)}{0.10\text{RPDIESEL}} + \underset{(0.04)}{0.03\text{TREND}} + U \tag{3}$$

where the numbers in parentheses denote standard errors. From Eq. (3), it is evident that all the coefficients – except for time trend – are statistically significant and have the anticipated signs. More specifically, the income effect (GDP) on gasoline demand is positive and quite substantial in magnitude, with the relevant long-run elasticity bellow unity (0.79).

This means that a 1% increase of per capita GDP will lead to an increase of gasoline demand by 0.79%. Furthermore, an increase in real price level of gasoline leads to a decrease in the level of gasoline consumption. The estimated elasticity is equal to -0.38. The relevant low magnitude of own price elasticity goes along with expectations in a country where transport is totally dependent on petroleum to operate (Alves and Bueno, 2003). In addition, low price sensitivity means that taxing gasoline can be a good source of revenues in the long-run, given the imperfect substitutability with respect to diesel. Cross-price elasticity (RPDIESEL) is equal to 0.10 implying – as it was stated above – imperfect substitutability between the two fuels. The small value of cross-price elasticity is explained by the relatively high costs associated with changing from automobile engines from gasoline–fuel to diesel–fuel. By the improvement of the diesel-engined technology vehicles (catalysts, electrostatic filters for diesel) and the progressive compliance with Kyoto targets, the substitution between gasoline and diesel would be applicable (RAE, 2003).

The estimation period for this study covers the somewhat volatile time of the introduction of unleaded gasoline (1988) and the implementation of the “withdrawal” measure in 1991. Hence, it is crucial to check the cointegration relationship (long-run) for the existence of structural breaks. For this purpose, we apply in the empirical analysis econometric techniques to capture possible changes in the gasoline demand, such as recursive OLS (i.e. CUSUM tests, recursive residuals, one step forecast test and recursive coefficients). The results indicate the absence of structural break in the long-run gasoline demand equation (Fig. 1). This means that the long-run gasoline demand in Greece remained unchanged during the estimation period.[8]

To sum up, the estimated cointegrating vector of gasoline demand is affected by changes in real per capita income and real price level of gasoline and diesel, respectively, while the magnitude of long-run gasoline demand elasticities does not deviate substantially from other empirical studies (Ramanathan, 1999; Ramanathan and Geetha, 1998; Bentzen, 1994; Eltony

[8] We reach the same conclusion if we estimate relevant tests such as Chow (breakpoint or forecast) test or Ramsey test. For the sake of simplicity, we selected to present only the recursive OLS tests.

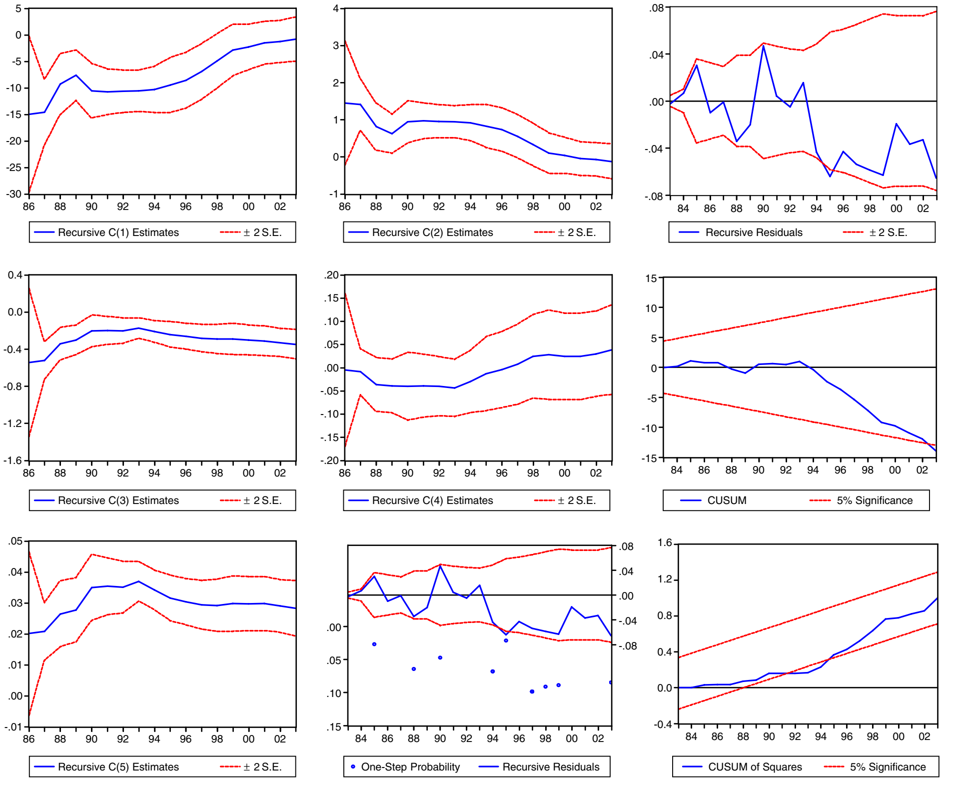

Fig. 1. Recursive estimates for the long-run gasoline demand. The graphs in the left and middle columns (except the bottom in the middle column) present recursive coefficients. The bottom graph in the middle column presents one-step-forecast test. The top graph in the right column presents recursive residuals, while the center graph presents CUSUM test. The bottom graph in the right column presents CUSUM of squares test. Source: Author's calculations.

and Al-Mutairi, 1995). Moreover, no sign of structural shift was found in the long-run gasoline demand equation reflecting the low level of efficiency in the road energy sector in Greece.

Having specified the gasoline demand model we apply the VAR methodology to diesel model. The resulting normalized parameter estimates of our model are as follows:

$$\text{DIESEL} = \underset{(0.14)}{1.18\text{GDP}} - \underset{(0.37)}{0.71\text{RPGASOL}} - \underset{(0.32)}{0.44\text{RPDIESEL}} + \underset{(0.34)}{1.78\text{PARKD}} + U \qquad (4)$$

where the numbers in parentheses stand for the resulting standard errors. From the above normalized equation, several main points can be drawn. First, an upward shock in real per capita income increases the level of diesel consumption. The estimated long-run elasticity of income is above unity (1.18). This means that a 1% increase of per capita GDP will increase diesel demand by 1.18% (elastic demand). Second, the own price and the cross-price elasticities are negative (inelastic demand) and less than unity (-0.44 and -0.71, respectively). However, cross-price elasticity is not statistically significant (see also Table 3). The absence of close substitutes such as petrol, natural gas, LPG, and hydrogen that could have significant impact on the environment (i.e. combating CO_2 emissions) may support the argument that the scope of energy switching in road sector is still limited. Finally, as it is expected from the theory the per capita vehicle fleet (PARKD) has a positive impact to the level of diesel demand with the relevant elasticity equals to 1.78.

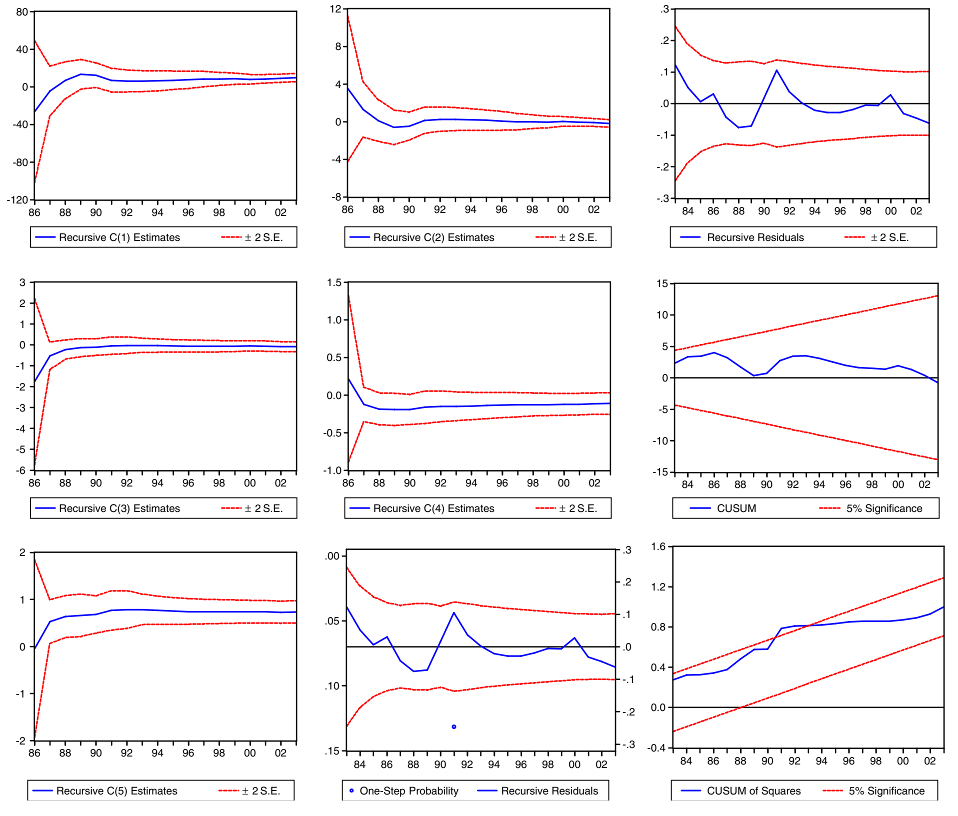

Fig. 2. Recursive estimates for the long-run diesel demand. The graphs in the left and middle columns (except the bottom in the middle column) present recursive coefficients. The bottom graph in the middle column presents one-step-forecast test. The top graph in the right column presents recursive residuals, while the center graph presents CUSUM test. The bottom graph in the right column presents CUSUM of squares test. Source: Author's calculations.

The existence of structural stability in the long-run diesel demand equation can be found by using relevant tests that employ recursive OLS methodology. From their results, we conclude that in the long-run, there is no sign of structural break in the diesel demand equation (Fig. 2).[9]

The above results are close to those reported for other countries, such as Fouquet et al. (1997) who report a 1.95 estimated income elasticity for United Kingdom and Wohlgemuth (1997) who report a 1.10 and 1.00 estimated income elasticities for Brazil and South Africa, respectively. However, the reported price elasticities for countries Brazil, South Africa, Mexico and Middle East seem to be much lower than our estimates.

5. Short-run dynamics

Having specified long-run elasticities from the Johansen procedure, we opt to estimate vector error-correction models in order to obtain short-run responses (elasticities). Table 4 shows the results from the estimation of the two VECMs for road demand. Each coefficient of the variables denotes the short-run elasticity. All the coefficients of the variables of the gasoline demand

[9] The same result holds if we apply the Chow or Ramsey tests in the long-run diesel demand equation. The statistical results are available from the author upon request.

Table 4
Results of vector error-correction models (VECM)

Variables	Δ(GASOL) (1)	Δ(DIESEL) (2)
Δ(GDP)	0.36[a]	0.42[a]
	(2.15)	(2.28)
Δ(RPGASOL)	−0.10[b]	−0.54
	(−2.14)	(−0.77)
Δ(RPDIESEL)	−0.002	−0.07[c]
	(−0.16)	(−1.75)
Δ(PARKD)	–	1.10[b]
		(2.02)
Δ(GASOL(−1))	−0.34[b]	–
	(−1.86)	
Δ(DIESEL(−1))	–	0.62[b]
		(2.19)
$(ECT)_{t-1}$	−0.24[b]	−0.38[a]
	(−1.86)	(−3.08)
Diagnostics		
R^2	0.58	0.54
Adjusted R^2	0.47	0.46
Durbin–Watson	1.93	1.98
LM test	0.58	0.35
	[0.54]	[0.61]
LM (5)	0.63	0.51
	[0.79]	[0.77]
White test	0.48	0.31
	[0.88]	[0.74]
J. Bera	0.80	0.96
	[0.65]	[0.47]
ARCH test	0.47	0.56
	[0.41]	[0.45]
LMARCH (5)	0.26	0.41
	[0.89]	[0.66]
Forecast-test	0.51	0.46
	[0.82]	[0.88]
Chow-test	0.83	0.79
	[0.56]	[0.58]

Source: Author's calculations.
The numbers in parentheses and in the square brackets are t and p values, respectively. LM (5) and LMARCH (5) are Lagrange multiplier tests for fifth order autocorrelation and fifth order autoregressive conditional heteroskedasticity (ARCH), respectively. Forecast and Chow tests are tests for testing the structural stability of gasoline and diesel demand function, respectively.

[a] Denotes significance at $\alpha=0.01$.
[b] Denotes significance at $\alpha=0.05$.
[c] Denotes significance at $\alpha=0.10$.

(column 1) are in alignment with the theory and are statistically significant, except for the price of diesel which is not statistically significant and has the opposite sign, implying that, in the short-run, petrol does not have close substitutes. Short-run income elasticity is bellow unity and is estimated to be 0.36, implying that a 1% increase of per capita GDP will increase gasoline demand at a much slower rate (0.36%). The short-run elasticity with respect to own price is estimated to be less than unity (−0.10).

The low level response of gasoline demand to its own price fluctuations reveals the difficulty of consumers to substitute petrol with other energy products (diesel, natural gas, hydrogen, fuel cells, etc.). Finally, growth in gasoline consumption a year before the current consumption (DGASOL($-$1)) has a statistical significant negative effect (-0.34) that cannot be easily interpreted.

As expected, short-run elasticities are lower than their longer-run counterparts satisfying Lechatelier principle. The error correction term $(\mathrm{ECT})_{t-1}$ is strongly significant with an adjustment coefficient of -0.24, implying that, in the case we are off the long-run demand curve, gasoline consumption adjusts towards its long-run level with about 24% of this adjustment taking place within the first year.[10]

The dynamic demand function for gasoline appears to be well behaved to the diagnostic tests including the serial correlation (LM test), the autoregressive conditional heteroskedasticity test (ARCH test) and the white for heteroskedasticity test. In addition, the estimated regression is tested whether it is stable throughout the sample, using Chow breakpoint and Forecast tests. All tests do not reject the null hypothesis of no split in the data. In other words, the estimated statistics support the structural stability of the estimated regression (gasoline demand) for the examined period used in the empirical analysis.

The results of income and price elasticity are comparable to those of Nicol (2003), Alves and Bueno (2003), Ramanathan (1999) and Eltony and Al-Mutairi (1995) who report similar income and price elasticities. Some of the differences in the income and price elasticities may be attributed to the different sources, estimation periods and methodology employed in the various studies (see Bentzen, 1994; Alves and Bueno, 2003).

The estimation of diesel 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 (-0.07 and 0.42, respectively). This result is similar with the findings by Fouquet et al. (1997) who estimated own price elasticity of diesel for United Kingdom ranging from -0.07 to -0.09, while income elasticity ranges from 0.37 to 0.45. Cross-price elasticity does not alter diesel demand since it is not found a statistical significant relationship. The per capita vehicle fleet affects positively diesel demand since the relevant elasticity is statistical significant and less than unity (0.62). Finally, the error-correction term is equal to -0.38 suggesting that the speed of adjustment is equal to 38%. In other words, an increase in the demand of diesel of 1% in $t-1$ above what would be predicted by the cointegrating equation would lead to a negative change in demand in the following year (0.38%) (Alves and Bueno, 2003).

Generally speaking, the above dynamic equation fits to the data quite well, with high R^2 (54%). The statistical tests reject the presence of autocorrelation of first or higher order and heteroskedasticity. Moreover, the primary short-run diesel demand function is tested whether it is stable throughout the sample applying structural stability tests (Chow breakpoint and forecast tests). Their results indicate no structural break in the diesel demand function in Greece.

Although the above analysis shows that there are short-run relationships between the variables of each model (gasoline and diesel model), it does not reveal the direction of their causal relationship. Our main interest is to examine the dynamic interactions between gasoline and diesel demand. An alternative way to obtain the information regarding the relationships among the variables of the two relevant models is through the estimation of the impulse response functions (IRFs) and variance decomposition (VDC). It has to be mentioned that both the VECM models

[10] This outcome is very similar to the one obtained by Ramanathan (1999), who estimated the error correction term at the level of -0.28.

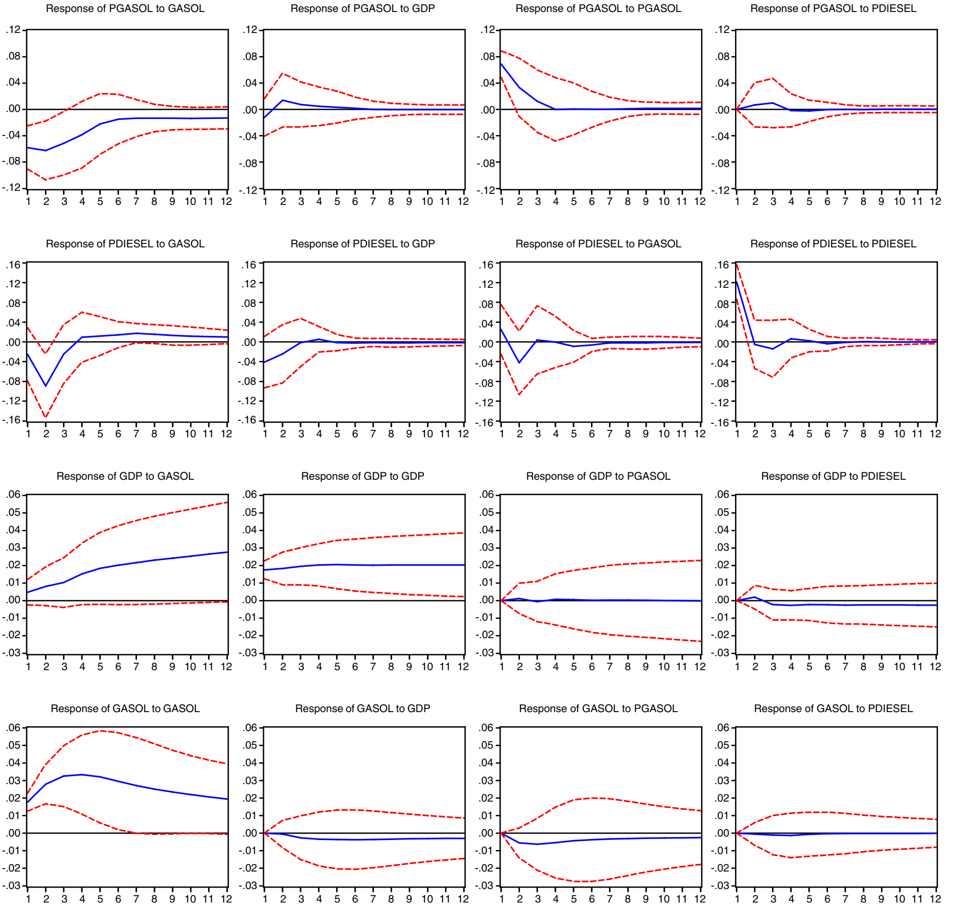

Fig. 3. Impulse response functions for gasoline VAR. Source: Author's calculations.

and the statistical inference (*F*- and *t*-tests) may be interpreted as within-sample causality tests. They can indicate only the exogeneity or endogeneity of the dependent variables within the sample period. In other words, they do not provide an indication of the dynamic properties of the system, nor do they allow us to gauge the degree of exogeneity amongst the variables beyond the sample period (Masih and Masih, 1996). By using IRFs and VDC analysis, which may be turned as out-of-sample causality tests, we would be able to capture these relativities.[11]

The IRFs derived from the unrestricted VAR (3) for gasoline demand are presented in Fig. 3. This diagram reports the response of each variable of the VAR to its own innovation and to the innovations of other variables. The cointegration analysis indicates that there is a positive relationship between gasoline demand and income (GDP); the IRF does not seem to confirm this relationship. From the first row of the diagram, it becomes clear that the effect of one standard deviation shock of GDP on gasoline demand is negative and significant for a period of 4 years. Subsequently, the confidence bounds become very wide, making the response of gasoline

[11] However, the issue of causality is beyond the scope of this paper.

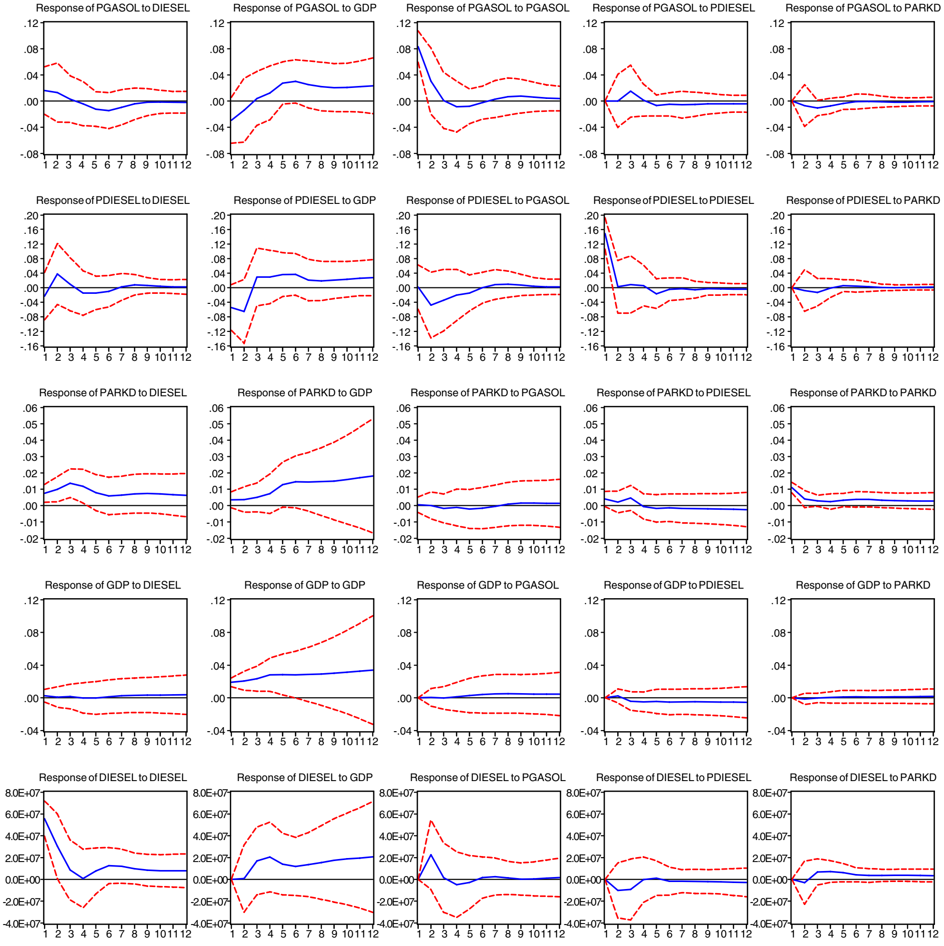

Fig. 4. Impulse response functions for diesel VAR. Source: Author's calculations.

demand to income fluctuations insignificant. The response of gasoline consumption to real price of gasoline (PGASOL) is also found to be negative as it is expected from the theory. Approximately the response of gasoline demand to one standard deviation shock of its own price is less than 0.01% per annum, implying that a 1% increase in real price of petrol's innovation causes a small decrease (<0.01%) in gasoline consumption. The peak response of gasoline demand to innovations of its own price occurs 2 years after the initial shock, stabilizing thereafter. On the other hand, the response of gasoline demand to real price of diesel's innovation is estimated equal to zero for the whole period. Effectively this outcome enhances the argument that the scope of energy switching in road sector is still limited.

Fig. 3 also shows that the response of per capita income (GDP) to its own innovations is positive stabilizing after the 4-year period. The response of GDP to a one standard deviation shock of price of gasoline is effectively zero for the whole period, while the response of income to innovation of price of diesel turns negative after the second year. It is evident that the response of GDP to innovation of gasoline consumption (GASOL) is positive in the first 2 years (short-run) and then the confidence bounds become very wide, making the response insignificant. The same result holds for the response of gasoline consumption to its own innovations. Finally, the responses of price of gasoline and diesel to one standard deviation shock of output (GDP) are approaching zero after the first 4 years of the initial shock.

These results come in agreement with the ones reported by the VDC estimations and provide further evidence favouring the importance of real price gasoline fluctuations in explaining the variation of gasoline demand.[12]

The impulse responses function derived from the unrestricted VAR of the diesel model are presented in Fig. 4. It is evident from the last row of the diagram that the effect of one standard deviation shock of GDP on diesel demand is positive and significant for almost a period of 6 years.

Subsequently, the confidence bounds become very wide, making the response of diesel demand to GDP fluctuations insignificant. The peak response of diesel demand to per capita GDP innovations occurs 4 years after the initial shock, stabilizing thereafter. It is crucial to mention that the positive relationship between income and diesel demand has also been detected in the cointegration analysis.

In addition, the response of diesel demand to its own price innovations is in alignment with the theory and negative. On the other hand, response of diesel demand to real price of petrol's innovation turns to be slightly negative after the 3-year period, stabilizing at the value of zero thereafter.

This means that the interaction between gasoline price and diesel consumption is not so straightforward due to the non-substitutability of diesel with gasoline. Another interesting outcome is that the response of diesel demand to a one standard deviation shock of per capita vehicle fleet (PARKD) turns to be positive after the first 2 years (short-run period) and more statistically significant implying that it is realised in the long-run. In addition, the response of PARKD to an income shock (GDP) is positive as expected from the theory since economic development will trigger disposable income and lead to an increase in the number of diesel-engined vehicles. However, after the first 3 years (short-run), the confidence bounds become very wide, eliminating the positive response of PARKD to fluctuations of output.

The same outcome holds if we examine the response of GDP to its own innovations. Finally, Fig. 4 also shows that the response of PARKD to a price shock of diesel (PDIESEL) is positive in the short-run, while after the first 4 years becomes negative as expected from the theory.

To sum up, these results seem to be in line with the ones reported by the VDC analysis providing evidence in favour of the importance income fluctuations in explaining the variation of diesel demand.

6. Concluding remarks

In this paper, we have attempted to investigate the main determinants of the road energy demand in Greece. For this purpose, we estimated the income and price elasticities of gasoline and diesel demand in Greece during the period 1978–2003 using annual time series. Cointegration techniques were applied to estimate road demand and to examine the issue of income and price sensitivity of both the short and long-run road demand for gasoline and diesel, respectively. In order to capture short-run dynamics of road demand in Greece, we utilized the

[12] Due to space limitations, the tables of the VDC analysis for gasoline and diesel demand, respectively, can be provided by the author upon request.

vector error-correction methodology and estimate the impulse response functions as well as the variance decomposition of the variables entered the two models.

The empirical analysis has revealed some very useful structural characteristics of the Greek road demand. Firstly, in the long-run, gasoline energy demand is price and income inelastic, while diesel demand appears to be price inelastic and income elastic. However, according to some recent studies for Greece, it is estimated that the magnitude of the income elasticities in the Greek road sector will decline gradually for the next 10 years approaching zero in the long-run. Secondly, in the long-run, the cross-price elasticities of the two sources of energy (gasoline and diesel) imply a statistically significant substitutability (although imperfect one) relationship of gasoline with diesel, while in the short-run this relationship does not exist. The small value of cross-price elasticities of gasoline demand reflects the relatively high costs for the driver associated with changing from one source of energy to another (gasoline with diesel). Additionally, diesel demand seems to be affected by changes in the vehicle stock both in the short-run and the long-run periods. None of the two dummy variables that capture the introduction of unleaded gasoline (D1988) and the implementation of "withdrawal" measure (D1991) had a significant impact on road energy demand. This implies that there was not found a structural change in road demand, something that is probably due to the low efficiency of the road sector as a result of the low degree of substitutability between the sources of energy. The above conclusion can also be drawn using the results of the recursive OLS techniques and Chow tests that both provide evidence for a structural stability in the pattern of road energy demand in Greece.

According to the results of the impulse responses functions and variance decomposition analysis there is an increase over the years of the importance of petrol price fluctuations to explain variation in gasoline consumption, confirming the long-run relationship found to hold among them by the Johansen cointegration analysis. In addition, the variation of real price of gasoline and diesel, respectively, are largely explained by their own innovations denoting the exogeneity of the variables.

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 road 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 fact that the Greek GDP has been growing over the last 5 years above the European Union average and that this trend is expected to continue in the next few years, the (road) energy demand will be rising unless the government implements serious measures for energy conservation. Two of the most effective measures that could be used in order to overcome the problem of energy profusion are the development of road infrastructure combined with the "promotion" of public transportation (e.g. gas-consumed buses, expansion of the subway lines, etc.). It has to be mentioned that income elasticities tend to be smaller in high-income developed countries than in less developed ones like Greece. This means that the road energy sector in Greece tends to be more sensitive to income fluctuations than it is in other more industrially advanced countries (e.g. Scandinavian countries, Germany, United Kingdom, etc.) that have a different level of growth and road infrastructure.

The small magnitude of own price gasoline elasticity combined with the imperfect substitutability with diesel even in the long-run, reveals that government could increase the level of taxation (VAT, excise taxes) in order to raise significant revenues. This has very useful implications since Greece has to be fully complied with the European Directive (2003/96/EC) according the minimum level of energy taxation from 2010 onwards. On the other hand, the empirical findings suggest that changes in pricing policy (i.e. increase excise taxes) cannot be an effective instrument for achieving road energy conservation because both in the long and the short-run, changes in pricing policy of gasoline and diesel will not alter the level of their consumption.

Finally, 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 vehicles and to give incentives for the use of environment friendly sources of energy (hydrogen, bio-fuels, fuel cells, solar energy, etc.). However, we must mention that achieving the Kyoto commitments means more than just taxing gasoline and diesel or give subsidies. Others sectors contributing to an increase in greenhouse gas emissions like industry, households or agriculture needs to be included in any environmental policy aimed at reaching the Kyoto targets.

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References

Alves, D., Bueno, R., 2003. Short-run, long-run and cross elasticities of gasoline demand in Brazil. Energy Economics 25, 191–199.

Baltagi, B., Griffin, M., 1983. Gasoline demand in the OECD – an application of pooling and testing procedures. European Economic Review 22, 117–137.

Bauer, M., Mar, E., Elizalde, A., 2003. Transport and energy demand in Mexico: the personal income shock. Energy Policy 31, 1475–1480.

Belhaj, M., 2002. Vehicle and fuel demand in Morocco. Energy Policy 30, 1163–1171.

Bentzen, J., 1994. An empirical analysis of gasoline demand in Denmark using cointegration techniques. Energy Economics 16, 139–143.

Bikos, P., 2004. The market for oil products in Greece. Special Sectoral Themes 9. Foundation for Economic and Industrial Research (in Greek).

Christodoulakis, N.M, Kalyvitis, S.C., Lalas, D.P., Pesmajoglou, S., 2000. Forecasting energy consumption and energy related CO_2 emissions in Greece: an evaluation of the consequences of the Community Support Framework II and natural gas penetration. Energy Economics 22, 395–422.

Christopoulos, D., 2000. The demand for energy in Greek manufacturing. Energy Economics 22, 569–586.

Dahl, C., 1986. Gasoline demand survey. The Energy Journal 7 (1), 67–82.

Dahl, C., Sterner, T., 1991. Analyzing gasoline demand elasticities: a survey. Energy Economics 13 (3), 203–210.

Dickey, D.A., Fuller, W.A., 1981. The likelihood ratio statistics for autoregressive time series with a unit root. Econometrica 49, 1057–1072.

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.

Dunkerley, J., Hoch, I., 1987. Energy for transport in developing countries. Energy Journal 8 (3), 57–72.

Eltony, M., Al-Mutairi, N., 1995. Demand for gasoline in Kuwait: an empirical analysis using cointegration techniques. Energy Economics 17, 249–253.

Fouquet, R., Pearson, R., Hawdon, D., Robinson, C., Stevens, P., 1997. The future of UK final user energy demand. Energy Policy 25 (2), 231–240.

Garbacz, C., 1989. Gasoline, diesel and motor-fuel demand in Taiwan. Energy Journal 10 (2), 153–163.

Hondroyiannis, G., 2004. Estimating residential demand for electricity in Greece. Energy Economics 26, 319–334.

Hondroyiannis, G., Lolos, S., Papapetrou, E., 2002. Energy consumption and economic growth: assessing the evidence from Greece. Energy Economics 24, 319–336.
Johansen, S., 1992. Cointegration in partial systems and the efficiency of single-equation analysis. Journal of Econometrics 52, 389–402.
Johansen, S., Juselius, K., 1990. Maximum likelihood estimation and inference on cointegration with applications to the demand for money. Oxford Bulletin of Economics and Statistics 52, 169–210.
Kwiatkowski, D., Phillips, P.C.B., Schmidt, P., Shin, Y., 1992. Testing the null hypothesis of stationarity against the alternative of a unit root. Journal of Econometrics 54, 159–178.
Masih, M.M.A., Masih, R., 1996. Energy consumption, real income and temporal causality: results from a multi-country study based on cointegration and error-correction modelling techniques. Energy Economics 18, 165–183.
McRae, R., 1994. Gasoline demand in developing Asian countries. Energy Journal 15 (1), 143–155.
Ministry for the Environment, Physical Planning and Pubic Works and National Observatory of Athens, 2004. National inventory for greenhouse and other gases for the years 1990–2002.
Nicol, C.J., 2003. Elasticities of demand for gasoline in Canada and the United States. Energy Economics 25, 201–214.
Osterwald-Lenum, M., 1992. A note with quantiles of the asymptotic distribution of the maximum likelihood cointegration rank test statistics. Oxford Bulletin of Economics and Statistics 54, 461–472.
Ramanathan, R., 1999. Short and long-run elasticities of gasoline demand in India: an empirical analysis using cointegration techniques. Energy Economics 21, 321–330.
Ramanathan, R., Geetha, S., 1998. Gasoline consumption in India: an econometric analysis. Proceedings of the First Asia Pacific Conference on Transportation and the Environment. National University of Singapore, Singapore, pp. 312–319.
Rapanos, V.T., Polemis, M.L., 2005. Energy demand and environmental taxes: the case of Greece. Energy Policy 33, 1781–1788.
Rapanos, V.T, Polemis, M.L., in press. The structure of residential energy demand in Greece. Energy Policy.
Regulatory Authority for Energy, 2003. Long-term Energy Planning of the Greek Energy System. Draft Proposal for Debate January 2003.
Samimi, R., 1995. Road transport energy demand in Australia. Energy Economics 17 (4), 329–339.
Sharma, D.P., Chandramohanan Nair, P.S., Balasubramanian, R., 2002. Demand for commercial energy in the state of Kerala, India: an econometric analysis with medium-range projections. Energy Policy 30, 781–791.
Wohlgemuth, N., 1997. World transport energy demand modelling: methodology and elasticities. Energy Policy 25, 1109–1119.