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Stock price behavior of the Greek oil sector: The case of Hellenic petroleum S.A. Greece

Eleni Zafeiriou^{1*}, Nikolaos Sariannidis², Garyfallos Arabatzis³ and Spyridon Sofios^{4*}

¹Department of Rural Development, Democritus University of Thrace, Komotini, Rodopi, Greece.

²Department of Financial Applications, Technological Institute of Western Macedonia, Kozani, Florina, Greece.

³Management of the Environment and Natural Resources Department of Forestry, Democritus University of Thrace, Komotini, Rodopi, Greece.

⁴Management of the Environment and Natural Resources Department of Forestry, Democritus University of Thrace, Komotini, Rodopi, Greece.

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The present study investigated the underlying process of the stock price returns time series of the oil sector taking as an example the case of Hellenic Petroleum SA, Greece. The data used are daily for over a 13 – year period. Nonlinearities were detected with different univariate tests that surveyed the independence and nonlinear deterministic structure of the time series studied. The data employed for these tests are the closing prices of Hellenic Petroleum SA, Greece. All the tests confirmed the existence of nonlinearities in the time series studied. Furthermore, a Layapunov test was employed to detect the chaotic behaviour of the stock prices under review. As it is well known, the macroeconomic environment plays an important role in the formation of the stock prices. Thus, the Johansen cointegration technique was employed to survey the inflation as an explanatory variable of the stock prices behaviour. Confirming that the two variables are not cointegrated, the noisy Mackey – Glass model was estimated, which is an equation with errors that follow an F- GARCH (p, q) process. This model was used in order to become able to interpret the volatility clustering as an endogenous phenomenon.

Key words: Stock prices, oil sector, Mackey – Glass – F – GARCH, nonlinearities, chaotic behaviour.

INTRODUCTION

General

Energy has been, within the last centuries, an important source of economic growth for a country. The exploitation and the use of energy resources is determined by a number of factors like technology, production cost, the international economic and political relationships between producers and consumers or even the market structure under review. Furthermore, the international energy market is strongly affected by the conditions dominating in the oil market (Vlachou, 2001).

The international demand for oil has been concentrated to developing and less price demanding countries

(Dargay and Gately, 2010). For instance, within the last decades the oil demand in China is characterized by a sharp increase. To be more specific, within three decades (1978 to 2008) an increase that exceeded four times the initial demand, has turned China into the second oil consumer of the international market. In addition, the oil demand is expected to increase further in the future, while transportation and industry are expected to dominate in oil consumption (Leung, 2010). An important problem for the developed countries is related lately with the extremely high prices in the international oil market (Cologni and Manera, 2008). That is why for instance within the Euro countries, the oil price is considered as an indicator of the price volatility in the energy sector (Oberndorfer, 2009).

In China, it has been confirmed that an increase in the oil prices is a constraint for the investments and

*Corresponding author. E-mail: spyrossofios@gmail.com.

Figure 1. The three different types of the stock price volatility.

production leading to an increase of inflation and interest rates (Tang et al., 2010). Especially, in oil producing countries like Iran, the oil price volatility affects significantly the inflation rate (Farzanegan and Markwardt, 2010). Energy consumption and economic development are significantly related in Turkey and China, according to findings of different studies (Lise and Van Mantfort, 2007; Yuan et al., 2007; 2008).

The existence of a long term relationship between energy consumption and economic development was confirmed for Greece according to Hondroyannis et al. (2002). The study involved data with reference time period 1960 to 1996. In addition, according to Papapetrou (2001), the oil price volatility affects the economic activity and employment. The relationship between the stock prices, macroeconomic factors and oil prices has been a subject of study mainly in the developed countries like USA, UK, Japan, and Canada (Filis, 2010). In general, an increase in the oil prices affects not only the stock market in general but also the stock prices' performance (Chen, 2010).

The oil prices in Greece interpret adequately the stock prices volatility (Papapetrou, 2001); while empirical findings have confirmed that the oil prices affect in a negative way the stock market and the consumer price index (Filis, 2010). The volatility of the stock prices has been a subject of extended study in the past. The stock market, in general, is a dynamic system. This fact hassles the predictability of the stock price value in the long term, while it allows only the short-term predictions. The most empirical works based on sophisticated statistical procedures (correlation dimension method for instance) have shown that stock returns are characterized by complexity. For this result may account

for the significant role of noise and uncertainty in the function of most financial markets (Kyrtsov, 2006).

Trading process plays an important role in the stock volatility. This is known as "price driven volatility". This volatility contradicts the event price volatility (that is consistent with the efficient market hypothesis) and the error driven volatility that is related to the reactions of the economic agents to the inflow of the information (Haugen, 1999).

The stock volatility is given by the following equation (Figure 1)

$$\text{Stock price volatility} = \text{Price driven volatility} + \text{Event price volatility} + \text{Error driven volatility} \quad (1)$$

The information used by the economic agents involves the macroeconomic environment, the conditions in the oil market (volatility of oil prices, oil crisis and other), and the government policy applied on the companies studied (floor prices, taxes and other measures).

The oil sector in Greece

The performance of an economic system is strongly affected by energy availability while the oil determines the function of the international energy market. The energy needs of Greece increase with a rate determined by GDP as well as by the sectoral reforms of the economic system (Vlachou, 2001). Oil and oil products provide almost 2/3 of the total energy at disposal. The significance of the oil market and oil products is related to the fact that all the oil products are inputs in every sector of economic activity in Greece. The contribution of the oil

Table 1. The main financial data for Hellenic Petroleum in the year 2009.

Group's brief financial data 2009	
Turnover	6,757
EBITDA	390
Net profit	175
Capital employed	3,927
Net borrowing	1,419

Source: www.elpe.gr.

sector' turnover to the GDP of Greece is more than 4%, measured in current prices, within the last few years (Manolas, 2007). The significance of the oil market and its products is related to its use as inputs in every production activity. In particular, the oil sector is strongly affected by the international economic and political factors:

1. The total balance of payments given that the oil sector products dominate on the balance of the energy sector.
2. The normal function of industry, of transports, of the army, as well as the efficient supply of all Greek regions especially for mountainous and insular regions.
3. The price formation given that the cost of wares and services depends on the volatility of oil prices.
4. The immediate economic burden of the households, since they use oil as a means of heating or transporting.
5. The national defense which in cases of crisis must be amble in stock of fossil fuels.

After the deregulation of the energy market and the implementation of the European Union's regime, the oil sector has started to be affected more and more by the European energy policies that constitute the framework of the position of Greece in the international energy market.

The appearance of new firms in the energy market, the mergers and acquisitions of the existing firms, and the expanded investment on the production of renewable resources are few of the features that describe adequately the new type of competition arising. The Greek oil market is structured as follows: four refineries and almost 50 firms involved in the oil products trading as well as a great number of retailers and gas stations that serve as providers of oil products to the final consumers. The same price and the same quantity is recorded for the last few years in the domestic market indicating that there is no evident competition among the refinery firms (Manolas, 2007).

The firm

Hellenic Petroleum S.A, Greece (ELPE), is one of the greatest Greek energy sector corporations, with solid foundations. The firm under preview is profitable and is a

leader in Greece, and is a dominant firm in the Southeast Europe. The main economic activities of ELPE are the following:

1. Refining of crude oil and fuel supply.
2. Retailing of oil products, including sales abroad.
3. Production and trading of petrochemicals and chemicals.
4. Oil and gas exploration and production.
5. Production and trading of power generation through Elpedison, the 50/50 joint venture with Italy's Edison.
6. Participation in the natural gas market, through the 35% stake in DEPA S.A.
7. Provision of consulting and engineering services to hydrocarbon related project.
8. Production and trading of any other form of energy.
9. Participation in the transportation of crude oil and products (pipe-lines, sea transportation).

Hellenic Petroleum was founded in the year 1998, and is considered as one of the leading energy groups in South East Europe. In the year 2009, the net earnings of the Group reached €150 millions, on total revenues of €6.8bn. The most important shareholders of are the Greek State (35.5%) and Paneuropean Oil and Industrial Holdings S.A. (39%), with the remaining 25.5% free float split between institutional (16.7%) and private (8.8%) investors. Refining is the group's core business, accounting for over 70% of total assets and profitability. Hellenic Petroleum owns three of the four refineries in Greece, with a 72% share of the Greek wholesale oil products market. The main financial data for Hellenic Petroleum in the year 2009 are presented in Table 1. Regarding the financial features of the firm under preview the following data have to be underlined. The parent company, Hellenic Petroleum S.A., Greece (ELPE), controls the management while it is the sole or the majority shareholder in the subsidiaries and associated companies. Each company of the group has its own board of directors and management structure; however, investment plans, financial management and annual budgets are all controlled centrally by the parent company. Subsidiaries and associated companies submit their financial results to the parent company.

The economic activities of the corporation take place in 11 countries while its shares are primarily listed on the Athens Exchange (ATHEX: ELPE). Figure 2 describes the evolution of ELPE stock price compared to that of the General Index in Athens Stock Exchange. The comparison of the two indices refers to the last three years. In general, the two indices have a similar behaviour. At the end of 2008 though, the situation changed utterly. In particular, the general price index is much lower than the ELPE stock price, giving the impression that different factors determine the value of the stock prices of the Hellenic Petroleum S.A. compared to those affecting the General Index of Athens Stock Exchange. The present study is organized as follows: In the first part of the study

Figure 2. The volatility of the ELPE and ASE closing price indices.

the literature review of the subject studied is presented; while in the second part, the methodology and the data employed are described. Finally, the results of the methodology applied are given as well as the conclusions derived by the present study.

LITERATURE REVIEW

The existence of nonlinearities in the formation of economic series is a usual phenomenon. A stock market is characterized by great complexity in its function, resulting in high level dynamical noise. This fact implies that linear models cannot be used for describing the formation of stock prices. In addition advanced tests have to be used in order to survey the interactions within the agents as well as changes in economic systems (Kyrtsou, 2005). The dynamic element of the stock market makes it unpredictable in the long term while only the short term predictions are feasible. The stock prices of Hellenic Petroleum S.A. reflect a number of macroeconomic and microeconomic factors such as the inflation in Greece, the profitability of the firm, dividend policy of the firm and other financial data. In our study, the oil prices may well account for the volatility of ELPE stock prices.

Within the last decade, the existence of nonlinearities has been a subject of extended study. In particular, numerous of tests have been introduced aiming at the detection or evaluation of heteroskedasticity, chaos, short and long memory, cyclicity and other features frequently met in financial time series. All those aforementioned

features have been studied by Agnon et al. (1999), as well as by Kyrtsou (2003). The existence of those phenomena can be attributed to risk as well as to heterogeneity in the expectations and behaviour of economic agents. This finding is empirical and opposes the assumption in finance as well as in macroeconomics of rational expectations. The heterogeneity of traders' expectations may also account for the chaotic and nonlinear behaviour of asset prices (Frydman and Phelps, 1983; Kyrtsou and Terraza, 2003).

In order to survey the existence of a chaotic behaviour, the correlation dimension is usually employed. In most cases, the result is a high value of correlation dimension implying that the chaotic behaviour is not confirmed. Uncertainty, as well as noise may account for this result (Kyrtsou and Terraza, 2003).

The non – validity of the low – dimensional chaos becomes evident by two facts:

1. High estimated and unstable correlation dimensions.
2. Limited evidence of out – of – sample predictability.

According to Scheinkman and LeBaron (1989), "the data are not incompatible with a theory where some of the variation in weekly returns could come from nonlinearities as opposed to randomness and are not compatible with a theory that predicts that returns are generated by independently identically distributed (IID) random variables".

The aforementioned sentence describes either a noisy chaotic model or a non–linear stochastic time series model.

Figure 3. The volatility of ELPE closing price. Source: Athens Stock Exchange (ASE).

Figure 4. The returns series (c_1) of ELPE stock. Source: Athens Stock Exchange (ASE).

The most important features for the distributions of returns are the following:

1. Volatility clustering
2. High peaks around the mean
3. Leptokurtosis

Given the complexity of the behaviour of the stock markets, it is believed that robustness becomes more intense in the data with a non-linear chaotic model with dynamic noise than the common stochastic approach.

This model is going to have zero autocorrelations but the variance of the stochastic component is going to be conditional. This is characterized as heteroskedasticity. We assume then that the errors of the model follow a GARCH (p, q) process. The present paper is going to examine the nonlinearity in the generating process of the stock returns as well as the chaotic behaviour of one of the greatest firms in the oil sector of Greece. A few univariate tests will be employed while at the same time, a model will be used in order to describe the formation of the stock prices. To be more specific, a model that has mean dynamic chaotic with a variance that follows a GARCH process was employed. The main disadvantage of this model is that it is suitable only for short term and not for long run forecasts.

METHODOLOGY AND DATA

The study of the behavior of the stock prices in the Greek oil sector was based on the closing prices of the stock of the firm Hellenic Petroleum (ELPE) one of the greatest firms in the Greek oil market. Daily data were used, while the time period studied extends from 30.6.1998 to 17.09.2009. The data was derived from the Athens Stock Exchange (ASE). In addition, in the study of the macroeconomic environment (inflation) and the oil prices (in Greece), we used monthly data for the time period 30-06-1998 to 12-04-2008. The software employed for this study was R project, and Eviews. The main objective of this study is to survey the nonlinear behavior of the stock prices in the case of the Greek oil sector. The main objective of this study is to detect dependencies in the financial series with the application of univariate tests related to the nonlinear deterministic structures.

Figure 3 depicts the volatility of the closing price of ELPE. Initially, we calculated the returns of the ELPE stock price, and its volatility is depicted in Figure 4. In every test employed, we

Table 2. Results of ADF test.

Variable	ADF statistic
C ₁	-2.811679
ΔC ₁	-50.61646

Notes: The critical values for this test since only constant and no trend is included are -3.43, -2.86 and -2.567 for 1, 5 and 10%, respectively.

Table 3. BDS statistics at dimensions (M) 2 to 6.

m	ε
2	111.4598
3	222.9197
4	334.3795
5	445.8394
6	427.54145

used a modified form of the stock prices, the returns.

Methodology

The test applied for the survey of nonlinearities and chaotic behaviour in the formation of the ELPE returns is the BDS test (Brock et al., 1996), an evolution of correlation dimension test (Kyrtsou and Serletis, 2006). The test aforementioned is very demanding regarding the size of the sample, since enormous amount of data is needed in case of high dimensional chaos.

BDS test, tests the null hypothesis of whiteness (independently and identically distributed observations) against an unspecified alternative through a nonparametric technique. To be more specific, the BDS statistic is given by the following equation;

$$BDS = \frac{C(T, m, \varepsilon) - \hat{\sigma}(T, m, \varepsilon)}{\hat{\sigma}(T, m, \varepsilon)} \quad (2)$$

Where;

m; embedding dimension

C(T, m, ε): the correlation integral

$\hat{\sigma}(T, m, \varepsilon)$: an estimate of the asymptotic standard deviation

The statistic BDS under the null hypothesis is asymptotically normal (Brock et al., 1996). This test was applied on our data, while the time series studied was investigated with the ADF test in order to examine the stationarity of the series and was found stationary in first differences and not in levels (Table 2). The BDS test was then applied and the results of this test are given in Table 3 for dimensions 2 to 6.

The next step involves the survey of autocorrelations in the time series studied. This survey is based on the Q test for 36 lags of the time series studied.

The next univariate tests employed for the survey of nonlinearities are the McLeod – Li (1983) and Engle (1982) tests.

The first test may be conducted with the application of the Box – Ljung Q statistic of the squared residuals. An ARMA process is preceded aiming at the filtering of our data. The initial (raw) data may be examined with the use of the k autocorrelation coefficients

for $\{x_t\}$ and $\{x_t^2\}$. The Q statistic was used aiming at the examination of the existence of serial correlation.

According to this method, a time series consists an i.i.d. process (under the null hypothesis) if for a fixed L the following equation:

$$\frac{1}{L} \sum_{j=1}^L x_j^2 \quad (3)$$

is asymptotically a multivariate unit normal.

As a consequence, for a high value of L, the Box – Ljung statistic $Q-x^2(L)$. Q is given by the following equation:

$$Q = L \sum_{j=1}^L \frac{x_j^2}{T} \quad (4)$$

The null hypothesis is that of a linear generating mechanism for the data. The other test (Engle, 1984) examines the non – linearity through a Lagrange multiplier test in the second moments. This test preconditions the regression of the squared residuals.

$$e_t^2 = \alpha + \sum_{j=1}^p \alpha_j e_{t-j}^2 + v_t \quad (5)$$

The non-existence of ARCH – type effects means the coefficients are non-significant, thus the regression will have a limited explanatory power while the coefficient of determination is very low. According to the null hypothesis given that the sample size is T, there are no ARCH – type effects and the statistic used for this test

is the $T \times R^2 \sim \chi_p^2$. If $T \times R^2$ is large enough then we reject the null hypothesis under which there are no ARCH – type errors.

Regarding the chaotic behaviour of the time series studied, we employed the Lyapunov exponent as defined by Kantz (1994). The calculation of the particular exponent is based on the following formula:

$$L = \lim_{\tau \rightarrow \infty} \frac{1}{\tau} \ln \left(\frac{\text{dist}(x_t, x_{t+\tau})}{\text{dist}(x_t, x_{t+\tau})} \right) \quad (6)$$

where; dist $(x_t, x_{t+\tau})$ defines the distance between a reference trajectory x_t and a neighbour $x_{t+\tau}$ after the relative time τ . The maximal Lyapunov exponent is the slope of the curve $S(\tau)$ in the scaling region.

In order to examine other potential determinants of the value of the ELPE returns we used the inflation rate of Greece as a representative of the macroeconomic environment in Greece.

The cointegration analysis is based on Johansen's multivariate cointegration methodology (1988, 1992). Regarding the estimation of the cointegration vectors, the treatment of the Johansen's maximum likelihood approach was used. According to Johansen and Juselius (1990), any p – dimensional vector autoregression can be written in the following "error correction" representation.

$$\Delta X_t = \sum_{i=1}^k \Gamma_i \Delta X_{t-i} + \Pi X_{t-k} + \mu + \varepsilon_t \quad (7)$$

where;

X_t : p – dimensional vector of I(1) processes,

μ : a constant

ε_t : a p – dimensional vector with zero mean (Δ is the variance – covariance matrix).

The Π matrix has a rank that is limited in the interval $(0, r)$ and can be decomposed into components as follows:

$$\Pi = \alpha\beta' \quad (8)$$

where;

α, β : $p \times r$ matrices

r : distinct cointegrating vectors.

The procedure of Johansen provides the maximum likelihood estimates of α, β , while Π and the two likelihood ratio test statistics determine the rank of the cointegration space. The trace and the maximum eigenvalue statistics are used to determine the rank of Π and to reach a conclusion on the number of cointegrating equations, r , in our VAR system. Given that the time series studied are $I(1)$, according to the results of the ADF (1979) test, we can use Johansen technique to examine whether there is a combination (linear relation) of the variables that is stationary. In this case, the variables studied are cointegrated and hence, there is a long – run relationship between them.

As already mentioned, the cointegration technique can be applied since the time series are non-stationary in levels and stationary in first differences. The Johansen cointegration technique (1988), involves testing the null hypothesis that there is no cointegration against the alternative that there is cointegration. In order to apply the Johansen technique, it is necessary to calculate the number of lags of the endogenous variables of the model since an autoregressive coefficient is used in modeling of each variable. The determination of the number of lags depended on the likelihood test statistic that was introduced by Sims (1980).

This test is given by the following formula:

$$LR = -2 \ln \frac{l_0}{l_1} \quad (9)$$

Where l_i is the likelihood given by the VAR test with the use of $p_{0,1}$ lags. According to the results taken by EViews 5.0 the number of lags was found equal to 3.

The LR trace statistic and the maximum eigenvalue LR test were employed for the determination of the number of the relations connecting the variables under preview (rank of r). In particular, this statistic tests the null hypothesis of r cointegrating relations against k cointegrating relations ($r = 0, 1, 2, \dots, k-1$).

The LR trace statistic is calculated with the formula:

$$LR = -2 \ln \frac{l_0}{l_1} = -2 \ln \frac{\sum_{i=1}^k \lambda_i^2}{\sum_{i=1}^k \lambda_i} \quad (10)$$

The critical values are taken from Osterwald – Lenum (1992), which differ slightly from those reported in Johansen and Juselius (1990).

The final step employed in the methodology applied involves the estimation of Mackey GARCH (p, q) model. In order to model the observed dynamics in financial markets we use an equation that includes two parts. The first part is deterministic (intrinsic deterministic dynamics) and the other one is the stochastic part (the random noise). The model might have the following form:

$$X_t = f(X_{t-1}, \dots, X_{t-p}) + \varepsilon_t \quad (11)$$

Where;

$\varepsilon_t \sim iid$: Observable non – linear function

f : a deterministic non- linear function

In order to detect the complexity of the financial time series, we use a version of the Mackey – Glass equation (Mackey and Glass, 1977). This model is a noisy Mackey – Glass equation whose errors follow a GARCH (p, q) process. That is why it is called a MG – GARCH (p, q) model. The particular model provides us with an econometric tool to study volatility – clustering phenomena. Its main characteristic is that volatility – clustering is interpreted as an endogenous phenomenon. The existence of volatility clustering stems from the interactions between fundamentalists and noisy traders (Kyrtou, 2003). The behavior of the noisy traders cannot be explained and thus it is given exogenously. This is the stochastic part of the Mackey – Glass equation. The deterministic part of the MG – GARCH (p, q) model represent the determinant stock prices given that the market is dominated by fundamentalists. As fundamentalists are considered, the traders who have rational expectations are based on the information from the macroeconomic environment, regarding the future price and dividends of an asset. This fact is not valid in reality though and that is why this equation cannot represent all the traders. The model is given by the following equations:

$$R_t = \frac{R_t}{1 + R_t} + \varepsilon_t \quad (12)$$

$$h_t = \omega + \alpha_1 \varepsilon_t^2 + \beta_1 h_{t-1} \quad (13)$$

Where;

t, j : denote the delays

c : constant

R_t : the returns

h_t : the GARCH variance

$$\frac{R_t}{1 + R_t} - \delta R_t$$

The part filters the dynamics that positive feedback trading causes, consisting the discretized version of the

model under preview, whereas the part $b R_t (1 - R_t)$ models structures that may be attributed to negative feedback in the market. The positive feedback describes the investors that buy when the price rises and sell when the price falls. The negative feedback describes the opposite investors' behavior.

The main advantage of this model is that two nonlinear trading strategies may capture more complicated dynamics. To be more specific, this model consists of a more realistic approach given that the assumption of the existence of more than one type of investor as the driving force of endogenous perturbations is more realistic.

RESULTS AND DISCUSSION

The application of the BDS test has given the results presented in Table 3. According to the results presented in Table 3, the BDS test rejects the null hypothesis of independent and identically distributed observations. According to Kyrtou (2006), this result can confirm neither nonlinearity nor chaotic behavior. This test may be used only in order to produce indirect evidence regarding the nonlinear dependence either chaotic or stochastic which is a necessary but not a sufficient condition for chaos (Barnett et al., 1997).

Table 4. Significance level for McLeod Li and Engle test.

Series	McLeod – Li (L = 24)	Engle (p = 4)
Δc	0.000	0.000

Table 5. Lyapunov exponent method results, using the Kantz's algorithm (1994).

m = 2	-0.002112
m = 3	0.000011
m = 4	0.000642
m = 5	-0.001007
m = 6	0.003942
m = 7	0.001444
m = 8	0.001081
m = 9	-0.000151
m = 10	-0.002139

Table 6. Results of ADF test.

Variable	ADF statistic
c_1	-1.547890
Δc_1	-9.744220
$\ln 1$	-0.523185
$\Delta \ln 1_{\ln}$	-3.464595

Notes: The critical values for this test since only constant and no trend is included are -3.43, -2.86 and -2.567 for 1, 5 and 10%, respectively.

The next tests employed in order to detect the existence of nonlinearities are McLeod Li and Engle test, the results are given in Table 4.

According to the results given in Table 4 regarding the McLeod – Li test, we reject the null hypothesis under which there is a linear generating mechanism for the data, while according with the results of the Engle test the null hypothesis that there are no ARCH – type errors was rejected.

The last test employed in order to survey the chaotic behavior of our data series is the Lyapunov test, results are given in Table 5. According to the aforementioned result the exponent is slightly negative. This result implies that the returns tend to converge to a slightly negative value. This result is compatible to that of Kyrtsov (2003), for the case of aluminium, nickel and tin.

Furthermore, Kyrtsov and Terraza (2001b, 2002), argue that noisy chaotic processes can have Lyapunov exponents that are very close to zero (positive when the noise is small and negative when the noise is large). Thus, the results obtained from the Lyapunov exponent methods must be interpreted with caution.

The implementation of the Johansen cointegration

technique confirmed the existence of two cointegrating equations and consequently the two variables studied are not cointegrated. The Johansen cointegration technique was applied on the first differences of the raw data given that the time series are $I(1)$. The results of the ADF test are presented in Table 6.

The results of Johansen cointegration technique are given in the next Table 7. According to the results given above both null hypothesis are rejected for 5% level of significance and consequently both tests confirm the existence of no cointegration between the variables studied.

The co-existence of noise and chaotic behaviour was modelled in the present study with the estimation of CMG–GARCH (1, 1) model. The results of the estimation are given in Table 8.

The first part of the mean equation $\alpha \frac{R_t}{1+R_t} - \beta R_{t-1}$ provides the dynamics that positive feedback trading causes while it consists of the discretized version of the model under preview, whereas the last term of the mean equation $\beta R_{t-1}(1-R_{t-1})$ describes structures related to the negative feedback in the market. The positive feedback involves the investors that buy when the price rises and sell when the price falls. The negative feedback describes the opposite investors' behavior (Kyrtsov, 2006).

The structure of the model can describe adequately two different types of investors and thus, can be considered as a more realistic approach. That is because more than one type of investors functions as a driving force of endogenous perturbations (Brock et al., 1996; Kyrtsov, 2005; Kyrtsov, 2006).

As it can be concluded from the results, the non linear components of the model are statistically significant for 5% level of significance. This result confirms the existence of nonlinearities in the returns of the Greek Petroleum. The nonlinearity in the mean of the time series studied can be explained by a chaotic noisy structure.

The results given in Table 8 were taken for $\tau = 2$, $j = 2$ and $c = 12$. The detection of the two lags in the GMG equation gives us a signal regarding the presence of a complex underlying deterministic structure in the series of the closing prices of ELPE. The significance of all the coefficients indicates that there is an important element of nonlinearity in the returns series.

In Figure 5, the fitted, actual and the residuals of the MGM – GARCH equation are presented graphically. The histogram and the important statistics of the residuals are presented in Figure 6. As it can be concluded, the residuals are normal and no problems of skewness or kurtosis were detected.

Another important issue regarding the application of the CMG – GARCH model is the fact that the residuals suffer by autocorrelation. The results of autocorrelation and partial autocorrelation are given in Table 9.

Table 7. Results of the Johansen cointegration techniques.

Lags	Rank under null hypothesis	Trace statistic	Max. eigenvalue
(1)	$r = 0$	47.695*	33.133*
	$r \leq 1$	14.562*	14.562*

Table 8. CMG – Garch (1, 1) estimation results.

Coefficient	Estimate	t - statistic
α	0.234	2.581012
δ	-2.004130	-2.220397
b	0.223043	2.574801
α_0	1.20E-05	4.149943
α_1	0.099344	7.233383
β_1	0.879721	61.55021

Table 9. The autocorrelations and PAC of the MCG-GARCH (1, 1) residuals.

S/N	AC	PAC	Q-Stat	Prob
1	0.022	0.022	1.3773	0.241
2	0.012	0.011	1.7918	0.408
3	0.005	0.005	1.8792	0.598
4	0.009	0.008	2.0982	0.718
5	0.011	0.010	2.4439	0.785
6	0.001	0.001	2.4491	0.874
7	0.014	0.014	3.0527	0.880
8	-0.016	-0.017	3.8096	0.874
9	-0.011	-0.011	4.1902	0.898
10	0.012	0.012	4.5811	0.917
11	-0.009	-0.009	4.8214	0.940
12	-0.021	-0.021	6.1549	0.908
13	0.041	0.042	11.030	0.608
14	0.043	0.042	16.517	0.283
15	0.015	0.012	17.140	0.311
16	0.025	0.024	18.993	0.269
17	-0.003	-0.006	19.018	0.328
18	-0.047	-0.049	25.530	0.111
19	0.016	0.017	26.260	0.123
20	-0.004	-0.006	26.303	0.156
21	0.003	0.003	26.339	0.194
22	0.000	0.004	26.339	0.237
23	-0.015	-0.015	27.015	0.255
24	0.014	0.015	27.567	0.279
25	-0.002	0.002	27.585	0.327
26	-0.001	-0.004	27.589	0.379
27	-0.004	-0.007	27.645	0.429
28	-0.023	-0.024	29.262	0.399
29	-0.016	-0.021	30.062	0.411
30	-0.029	-0.031	32.625	0.339
31	-0.010	-0.005	32.916	0.373
32	-0.003	0.001	32.936	0.421
33	-0.016	-0.013	33.692	0.434

Table 9. Contd.

34	-0.020	-0.017	34.920	0.424
35	0.016	0.017	35.713	0.435
36	-0.029	-0.030	38.236	0.368

Table 10. ARCH – LM test on CMG – GARCH (1, 1) residuals.

Heteroskedasticity test: ARCH	
F-statistic	6.532823 (0.0106)
T*R ² (statistic)	6.522694 (0.0107)

According to the results of the table no autocorrelation is detected for 12, 24, or 36 lags. What must also be mentioned is the limitation of heteroskedasticity despite the fact that it still exists as we may conclude by a conduct of a GARCH test on the CMG – GARCH (1, 1) model (Table 10).

It is evident that the residuals still suffer from heteroskedasticity but they are not autocorrelated.

Conclusions

The energy dependence of Greece on oil is evident and confirmed by different studies. This dependence is significant given that its cost is highly related to the economic development, to the inflation rate, to the employment while it affects strongly the sense of security in the provision of energy resources in case of crisis. The oil market presents significant particularities given that the prices are related not only with supply – demand factors but also to a number of geopolitical factors.

The present study surveys the nonlinearities and the behaviour of stock prices in the Greek oil sector. In particular, we study the returns of ELPE. ELPE is the leading firm in the Greek oil market and that is why it was chosen as a representative of the Greek oil market. The BDS test has confirmed that the time series of returns lacks independence but this is not an evidence for non-linear behavior of the time series studied. Thus, more tests were employed. The other tests applied (Engle and McLeod and Li) confirmed that the behavior of the time series is non-linear, a result that is consistent with other studies that examined the nonlinearity of different financial time series (Campbell et al., 1997).

The application of the Johansen cointegration technique confirmed that the inflation rate is not cointegrated with ELPE returns. Consequently, other factors may account for the volatility of the return of the particular firm either financial or macroeconomic. For instance the conditions in the international oil market may well interpret the behavior of the stock prices studied. This is not an objective of the present study though.

Finally, the GMG – GARCH model was estimated in order to survey the fit of this model to our data. The estimation of this model confirmed the existence of the non-linear behavior of the financial time series studied, since both nonlinear terms are found to be statistically significant. Furthermore, this model may describe more efficient the complexity of the behavior of the stock return, which in return reflects a number of factors that affect this value. The fact that the macroeconomic variables cannot account for the volatility of the stock prices leads us to an inquiry of potential environmental policies that may affect the value of share of an oil firm. To be more specific, as it is known, the effects of the release of carbon dioxide and other greenhouse gases as emissions from energy systems are crucial for the earth's climate system. Thus, oil companies will have to deal with at least a major issue in the next decade, namely the prospect of policies to contrast global warming. This issue is likely to affect companies' sales, operating costs, asset values and others. This result though remains to be surveyed in the future through another study.

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