Non linearities and chaos in stock price behavior of Greek oil sector; The case of Hellenic Petroleum S.A.

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Abstract

The behaviour of different financial or economic time series is captured mainly by nonlinear models. The present study investigates the underlying process of the stock price returns time series of the oil sector taking as an example the case of Hellenic Petroleum SA. The data used are daily for over a 13 – year period. Nonlinearities are detected with different univariate tests that survey 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. All the tests confirm the existence of nonlinearities in the time series studied. Furthermore, we employ a Layapunov test to detect the chaotic behaviour of the stock prices. Finally, we estimate the noisy Mackey – Glass model, which is an equation with errors that follow an F- GARCH (p, q) process. This model is structured in order to enable us to interpret the volatility clustering as an endogenous phenomenon.

Keywords: Stock prices; Oil Sector; Mackey – Glass – F -GARCH; Nonlinearities; Chaotic Behavior.

Introduction

The volatility of the stock prices has been a subject of extended study in the past. The stock market in general, is a dynamical system. This fact hassles the predictability for 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 the significant role of noise and uncertainty in the function of most financial markets.

Trading process plays the greatest role in the stock volatility. This is known as 'price driven volatility'. This volatility is the contradiction to 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).

Thus the stock volatility is given by the following equation (Fig. 4);

Stock price volatility = Price driven volatility + Event price volatility + Error driven volatility (4)

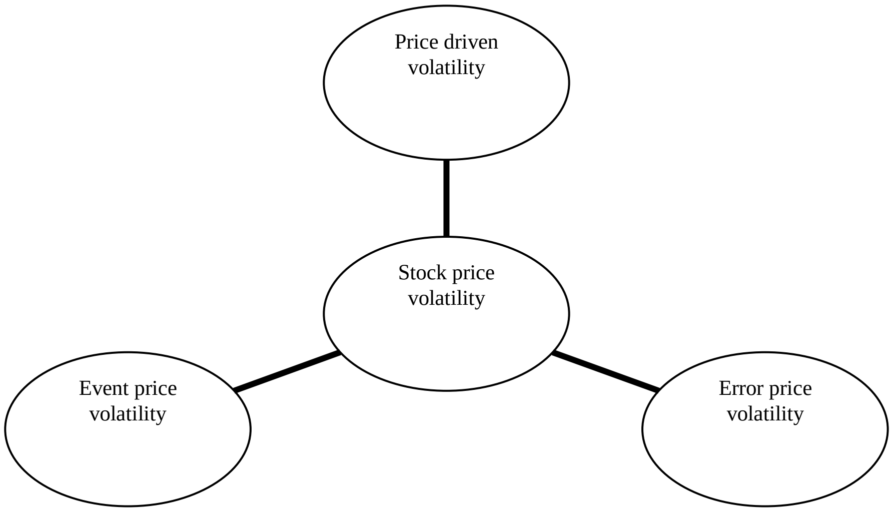


Figure 4. The three different types of the stock price volatility

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), as well as the government policy applied on the companies studied (floor prices, taxes and other measures).

The firm

Hellenic Petroleum S.A. (ELPE), is the greatest Greek energy sector dynamic Group, with solid foundations. The firm is characterized by continuous profitability while it holds a leading position in Greece as well as in the greater area of Southeast Europe. The main activities of ELPE are the following;

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

Hellenic Petroleum was established in 1998 and is considered as one of the leading energy groups in South East Europe. In the year 2009, the Group adjusted net earnings amounted to €150m, 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 given in the following table 1;

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

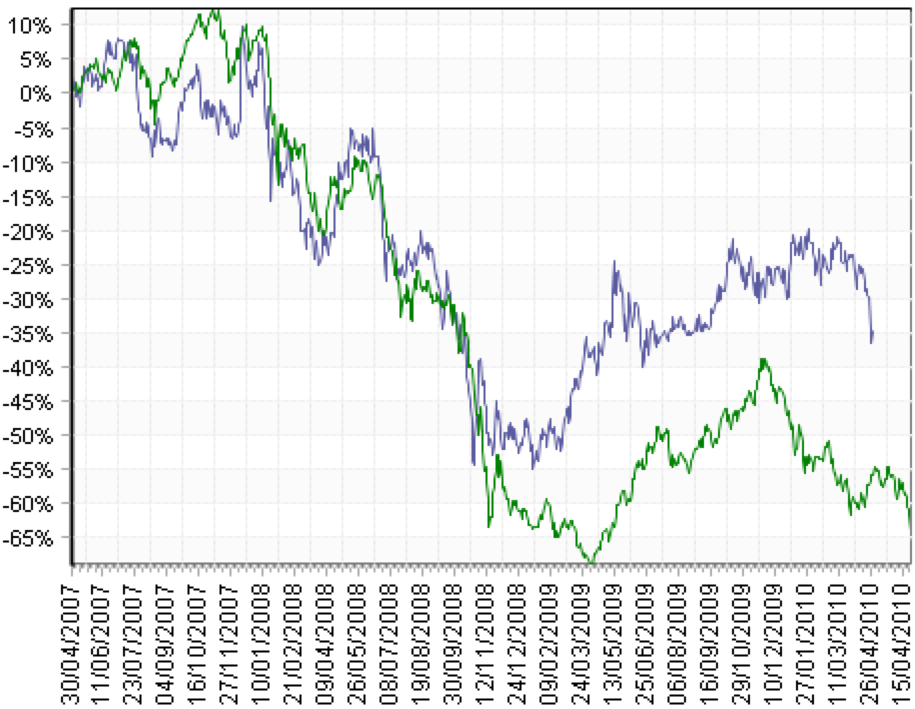
Group's Brief Financial Data 2009	
Turnover	6,757
EBITDA	390
Net profit	175
Capital employed	3,927
Net borrowing	1,419

Source; www.ELPE.gr

Regarding the financial features of the firm under preview the following have to be underlined;

The parent company, Hellenic Petroleum S.A. (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 results to the parent company.

The company is activated in 11 countries while its shares are primarily listed on the Athens Exchange (ATHEX: ELPE). In the following figure is depicted the evolution of ELPE stock price to be compared to that of the General Index in Athens Stock Exchange.



The figure refers to the last three years. In general, the two indices have a similar behaviour, at the end of the year 2008 though, the situation changes 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. related to the General Index of Athens Stock Exchange.

The present study is organizes as follows;

In the first part of the study 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 and the conclusions derived.

Literature Review

The existence of nonlinearities in the formation of economic series is a usual phenomenon. In particular, the stock market is characterized by great complexity in its function, having as a result 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 we must also take into account the oil prices in Greece, since they play an important role in the financial status of the firm under preview.

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

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

- High estimated and unstable correlation dimensions.

- 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”. This sentence describes either a noisy chaotic model or a non – linear stochastic time series model.

- Volatility clustering
- High peaks around the mean
- Leptokyrtosis

are the most important features for the distributions of returns.

Given the complexity of the behavior 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 heteroscedasticity. 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 we are going to use a model in order to describe the formation of the stock prices. To be more specific we will employ a model that its mean is dynamic chaotic with a variance that follows a GARCH process. The main disadvantage of this model is that it is suitable only for short term and not for long run forecasts.

Data

The study the of behavior of the stock prices in the Greek oil sector will be 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 time period studied extends from 30.6.1998 to 17.09.2009. The data were 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 30.6.1998-12.4.2008. The softwares employed for this study are 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.

The next figure depicts the volatility of the closing price of ELPE;

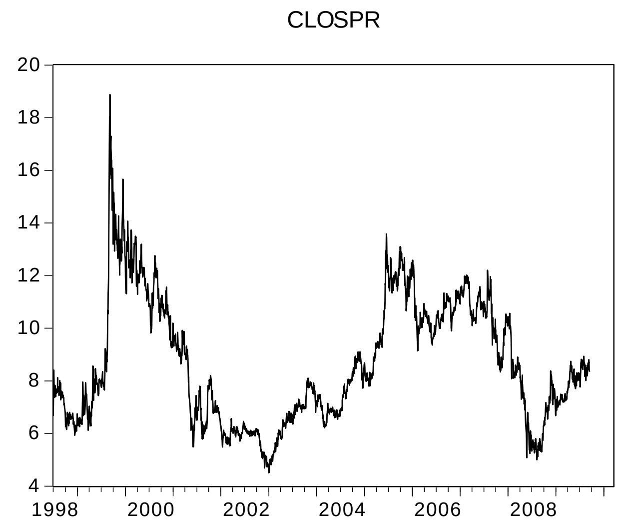


Figure 1; The volatility of ELPE closing price
Source: Athens Stock Exchange (ASE)

Initially we calculated the returns of the ELPE stock price, and its volatility is depicted in the next figure 2.

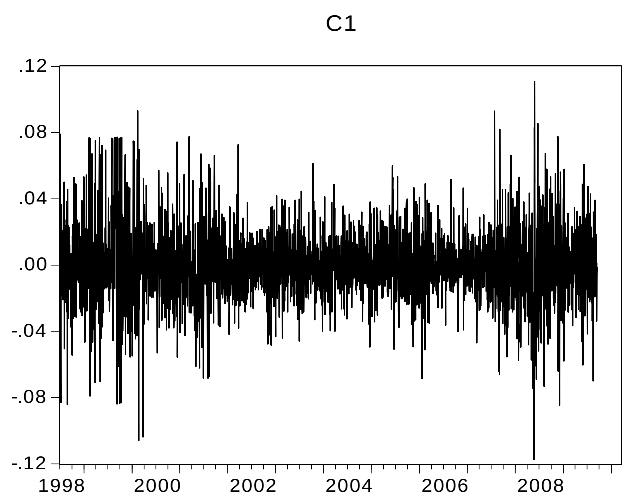


Figure 2; The returns series (c_1) of ELPE stock
Source: Athens Stock Exchange (ASE)

In every test employed we used a modified form of the stock price, the returns.

Methodology

The test applied for the survey of nonlinearities and chatic 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 mentioned above 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;

$$W(T,m,\varepsilon) = \sqrt{\mathrm{T}}\,\frac{C(T,m,\varepsilon) - C(T,1,\varepsilon)}{\hat{\sigma}(\mathrm{T},m,\varepsilon)} \quad (1)$$

Where;

m; embedding dimension

C(T, m, ε): the correlation integral

$\hat{\sigma}(\mathrm{T},m,\varepsilon)$: 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 1; 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.

The BDS test was then applied and the results of this test are given in the next Table VI for dimensions 2 – 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 $\{x_t\}$ and $\{x_t^2\}$. The Q statistic is 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;

$$T^{\frac{1}{2}}\rho^2(k) = [\rho^2(1),...,\rho^2(L)] \quad (2)$$

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;

$$Q = T(T+2)\sum_{j=1}^{L}\frac{\rho^{2\{[\kappa]\}^2}}{T-j} \quad (3)$$

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;

$$\hat{\varepsilon}_t^2 = a_0 + \sum_{j=1}^{\rho}\alpha_j\varepsilon_{t-j}^2 + u_t \quad (4)$$

The non – existence of ARCH – type effects means the coefficients are non – significant and 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 $TxR^2 \sim x_p^2$. If TxR^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;

$$k_t \approx \lambda + \left(\frac{\sigma_{\iota,T}}{dist(x_t, x_i, \tau)}\right) - \left(\frac{\sigma_{\iota,\tau-1}}{dist(x_t, x_i, \tau)}\right) \quad (5)$$

where;

$dist(x_t,x_i;\tau)$ defines the distance between a reference trajectory xt and a neighbour x_i after the relative time τ. The maximal Lyapunov exponent is the slope of the curve S(τ) 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.

$$\Delta X_t = \sum_{i=1}^{k} \Gamma_i \Delta X_{t-i} + \Pi X_{t-k} + \mu + \varepsilon_t \qquad (2)$$

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;

$$\Pi = \alpha\beta' \qquad (3)$$

where;

α, β: p x 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 it was already mentioned above, 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;

$$LR = -2(l_o - l_1) \quad (4)$$

Where l_i is the likelihood given by the VAR test with the use of $p_{o,1}$ lags. According to the results taken be E - views 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 test the null hypothesis of r cointegrating relations against k cointegrating relations (r=0, 1, 2,…, k-1).

The LR trace statistic is calculated with the formula;

$$LR(r/k) = -T\sum_{i=r+1}^{k}\ln(1-l_i) \quad (5)$$

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 me 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;

$$X_t = f(X_{t-1},...) + \varepsilon_t \qquad (6)$$

Where;

X_t*: observable non – linear function*

f: a deterministic non- linear function

$\varepsilon_t \sim iid$

In order to detect the complexity of the financial time series we are going to 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 (Kyrtsou, 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;

$$R_t = \alpha \frac{R_{t-\tau}}{1+R^c_{t-\tau}} - \delta R_{t-1} + bR_{t-j}(1-R_{t-j}) + \varepsilon_t \quad (7)$$

$$h_t = \alpha_0 + \alpha_1 \varepsilon^2_{t-1} + \beta_1 h_{t-1} \quad (8)$$

Where;

t, j: denote the delays

c: constant

R_t: the returns

h_t : the GARCH variance

The part $a \frac{R_{t-\tau}}{1+R^c_{t-\tau}} - \delta R_{t-1}$ filters the dynamics that positive feedback trading causes, consisting the discretized version of the model under preview, whereas the part $bR_{t-j}(1-R_{t-j})$ 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 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

The application of the BDS test has given the results presented in table 2.

Table 2; BDS Statistics at Dimensions (M) 2 – 6

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

According to the results presented in the aforementioned table the BDS test rejects the null hypothesis of independent and identically distributed observations. According to Kyrtsou (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).

The next tests employed in order to detect the existence of nonlinearities are Mc Leod Li and Engle test, the results of which are given in table 3.

Table 3; Significance Level for Mcleod Li and Engle Test

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

According to the results given above 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 we reject the null hypothesis that there are no ARCH – type errors.

The last test employed in order to survey the chaotic behavior of our data series is the Lyapunov test, whose results are given in table 4.

Table 4; 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

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 Kyrtsou, (2003), for the case of aluminium, nickel and tin.

Furthermore, Kyrtsou and Terraza (2001b, 2002b), 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 given in tables 5;

Table 5; Results of Adf Test

Variable	ADF statistic
c_1	-1.547890
Δc_1	-9.744220
*In*1	-0.523185
Δ*In*1 In	-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.

Regarding the results of the Johansen cointegration technique, they are given in the next table 6;

Table 6; 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*

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 the following table 7.

Table 7; 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

The first part of the mean equation $a\frac{R_{t-\tau}}{1+R^{c}_{t-\tau}} - \delta R_{t-1}$ filters the dynamics that positive feedback trading causes while it consists the discretized version of the model under preview, whereas the last term of the mean equation $bR_{t-j}(1-R_{t-j})$ models structures related to the 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 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; Kyrtsou, 2005; Kyrtsou, 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 the previous Table were taken for τ = 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 the next figure are presented graphically the fitted, actual and the residuals of the MGM – GARCH equation.

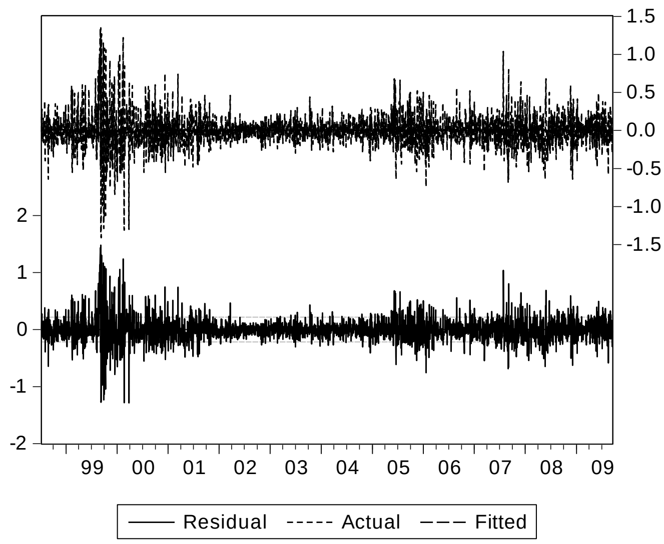


Figure 2; The actual, fitted and residuals graph

The histogram and the important statistics of the residuals are presented in the following figure 3;

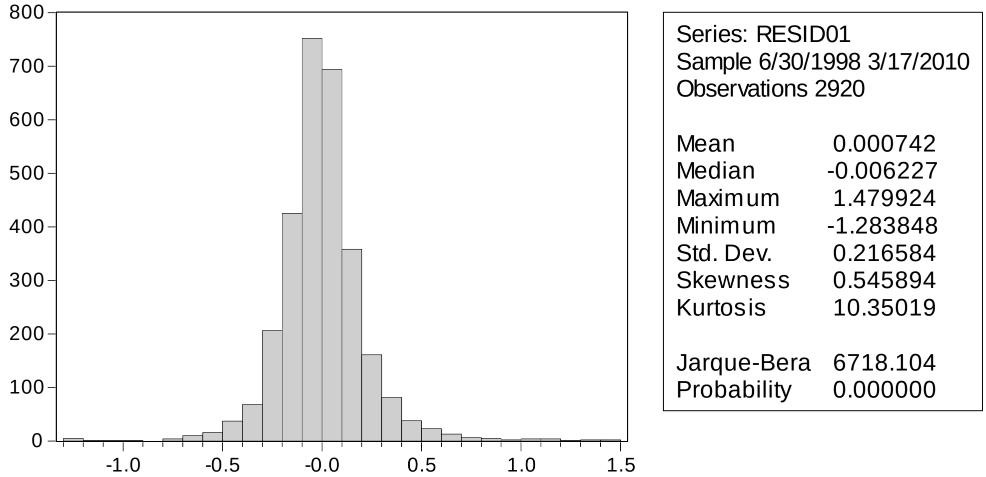


Figure 3; Histogram and stats of the MGM – GARCH model

As it can be concluded the residuals are normal and no problems of skewness or kyrtosis 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 the following table 8;

Table 8; The autocorrelations and PAC of the MCG-GARCH (1,1) residuals

	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
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

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 heteroscedasticty 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 9; 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)

It can be concluded that the residuals continue to be heteroscedastic but not autocorrelated.

Conclusions

The present study surveys the nonlinearities and the behaviour of stock prices in the Greek oil sector stock prices. In particular, we study the returns of ELPE. The BDS test has shown that the time series of returns lacks independence but this is not evidence for non - linear behavior of the time series studied. Thus, more tests were applied. The other tests applied (Engle and McLeod and Li) confirmed that the behavior of the time series is nonlinear, a result that is consistent with other studies that examined the nonlinearity of other financial time series (Campell 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 like the conditions in the international oil market. 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 nonlinear 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.

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