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A Time Series Model for the Romanian Stock Market

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Abstract:

The purpose of this study is to investigate the performance of the Romanian stock market using daily data for the period 1997-2007. During this period the European Union finalized many of its operational issues and EMU was put into effect. Additionally globalization brought increased attention to stock markets throughout the world, while the free trade and the technological financial innovations have changed the world stock market considerably.

To test the impact in the Romanian stock market from these developments a number of different time series models are proposed in an attempt to clarify whether or not the Romanian stock market has been adjusted accordingly and to forecast the series. The proposed model is an ARIMA (p,d,q) process fitting the data very well.

The results indicate that the Romanian stock market went through a significant structural change during the study period.

Keywords: Time series methodology, forecasting stock markets, stationarity tests.
JEL Classification: C22, C50, C53.

1. Introduction

According to *Ripley* (1973) stock market prices represent the economic conditions in each country. Therefore the Romanian stock market should react accordingly due to the fact what the EU had decided the last enlargement which included Romania. Stock markets will be more integrated as a result of more similar conditions across the countries within Europe. Additionally, during recent years there has been a positive progress towards financial integration in the EU with the implementation of a single market legislation affecting the Romanian stock market too. The data used in this study consist of the daily stock index closing price of Romania. The sample period starts in September 20, 1997 and ends in November 14, 2007, totaling 2,507 observations. Data was provided by the Romanian stock exchange.

A detailed literature review is given in *Thalassinos* (2006). As it is mentioned in this work *Erb, Harvey, and Viskanta (1994)* have found some evidence that cross-equity correlations in the G-7 countries are affected by the business cycle 5. The same relationship has been noticed by *Ragunathan, Faff and Brooks (1999)* in the

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specific case between US and Australian markets. *Bracker, Docking, and Koch (1999)* found a statistically significant relationship between bilateral import dependence and the degree of stock market integration. *Dumas, Harvey, and Ruiz (2000)* take the opposite view and calculate the theoretical degree of return correlations both under integration and segmentation after controlling for the degree of commonality of country outputs. They find that the assumption of market integration leads to a better explanation of the level of observed correlations than the assumption of market segmentation.

King and Whadhawani (1990), *King, Sentana and Whadhawani (1994), Karolyi and Stulz (1996)*, and *Bekaert and Harvey (2000)* investigate time-varying linkages between international stock markets and find that correlations increase when global factors dominate domestic ones. In addition, several authors have documented that correlations are much higher when markets go simultaneously down, further reducing the insurance effect from international diversification (*Longin and Solnik 2001)*).

2. Stationarity

As it is pointed out in *Thalassinos* (2006), it is interesting to examine the hypothesis of a stationary series for the available stock market index. In this way, it is necessary to empirically examine the weak form efficient market hypothesis for the series. It is known that various tests are being applied in order to test the latter hypothesis, with the unit root tests. Specifically, the unit root test of Dickey-Fuller (*Dickey and Fuller (1979, 1981)* is the most widely used unit root test.

Let us consider the following AR (1) process:

$$y_t = \mu + \rho y_{t-1} + \varepsilon_t \tag{1}$$

where μ (constant) and ρ are parameters and variable ε_t is assumed to be white noise. Series y_t is a stationary time series if $-1<\rho<1$. If $\rho=1$, the series is a non-stationary series. The Dickey-Fuller (DF) unit root test, tests then the null hypothesis:

$$H_0 : \rho = 1$$
$$vs \tag{2}$$
$$H_1 : \rho < 1$$

However, the above described simple DF test is valid only if the series is an AR (1) process. If the series is correlated at higher order lags the assumption of white noise is violated. In order to correct this restriction, the augmented Dickey-Fuller (ADF) test makes a parametric correction for higher order correlation by assuming that the series follows an AR (p) process, adjusting accordingly the test methodology as presented below in section 3.1.

Having concluded that the Romanian stock market daily price index is not a stationary series a new series of first differences defined as $\mathrm{Re}\,turn_t = 100 * [\ln(Index_t) - \ln(Index_{t-1})]$ may be used which is the main aim of another research in progress in an attempt to investigate the degree of integration of the Romanian daily stock price index compared to 14 other European daily stock market price indexes.

3. The Empirical Evidence

We employed daily data from the Romanian stock market price index for the period 1997-2007 totaling 2507 observations in an attempt to evaluate the performance of the series during the sample period with respect to structural changes and the forecasting ability of the model.

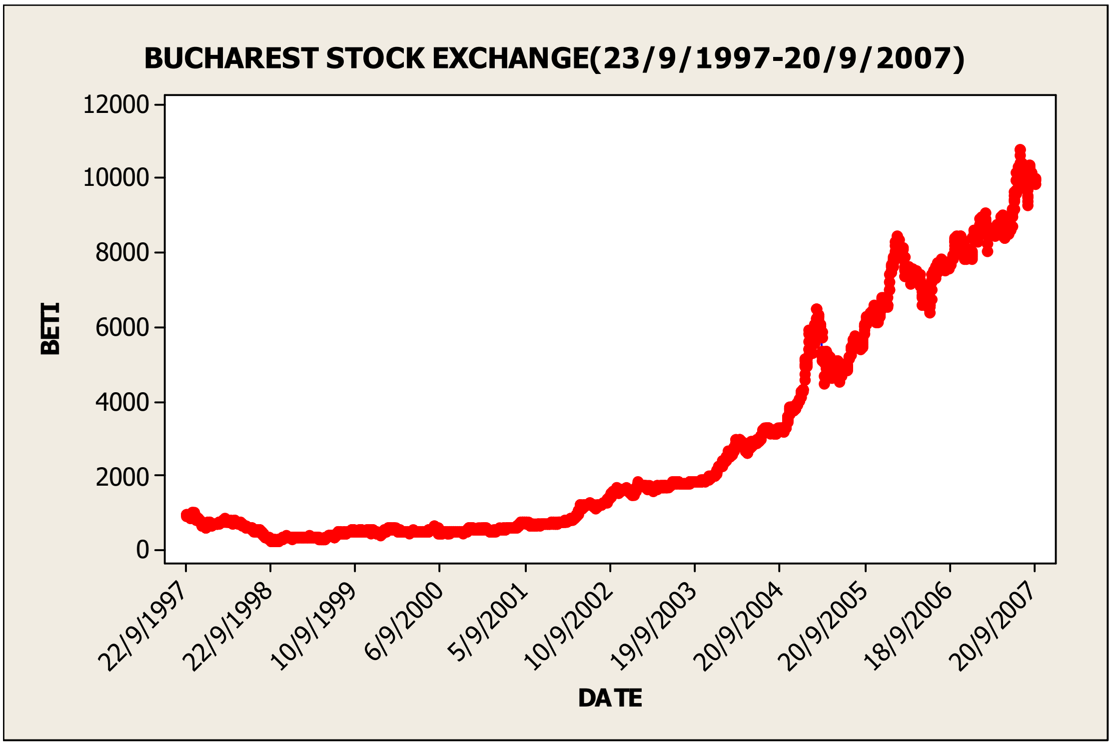


Diagram 1: Bucharest Stock Exchange 23.09.1997-20.09.2007

Diagram 1 shows the pattern of the Romanian stock market price index during the period under study. Simple regression models have been used in a first attempt for modeling the original series. However due to stationarity and unit root problems time series methodology were used leading to the selection of an ARIMA (1,1,0) model that explains the series quite well as it will be presented below.

3.1 Model Identification

Several regression models have been used for the modeling of the series in question leading to a simple form of a regression model that fits the data well with the lowest AIC and SCH coefficients, the Lagrange multipliers LM(1) and LM(2) smaller than their corresponding values and the highest R-SQ. The proposed model is a simple regression model with a constant, a trend variable and the dependent variable in one period lag. The estimated model is:

$$BETI = -66{,}31192 - 0{,}14296TIME + 0{,}962081BETI(-1) \quad (3)$$
$$(3{,}730) \qquad (6{,}346) \qquad (4{,}765)$$

R-SQ = 0,9835 LM (1) = 744,8986 greater than X-SQ = 574,0281
LM (2) = 552,5632 smaller than X-SQ = 766,3872 (4)

AIC statistic = 14,71809, SCH statistic = 14,7251

However, there is a significant problem in the residuals of this model because the Lagrange Multiplier LM (1) is greater than the corresponding X-SQ statistic indicating first order autocorrelation in the residuals. Every time we have a notion that autocorrelation is being founded in the residuals, a higher order lag is introduced in the model.

The next step is to examine the series for stationarity as it is described above using the ADF test. The MINITAB econometric software package performs the widely used tests, the Dickey-Fuller (DF) and the augmented Dickey-Fuller (ADF) pretty well. The null hypothesis of a unit root, i.e. non-stationarity of the series, is rejected against the one-sided alternative if the ADF test statistic is less than its critical values.

Using the original data of the series in question ADF statistics for six different processes are estimated as presented in Table 1 with the corresponding critical values for 1%, 5% and 10% significance levels. ADF statistic with a first order lag is greater than the 1%, 5% and 10% critical values, indicating that there is no reason to reject the null hypothesis of the unit root, while ADF statistics in all other processes are less than the corresponding critical values for 1%, 5% and 10% significance levels.

It is known that the model with the lowest AIC and SCH coefficients is the best, with the condition that LM (1) and LM (2) are idle (LM (1) <X-SQ and LM (2) <X-SQ) as presented in Table 2.

Table 1: ADF Coefficients

		CRITICAL VALUES		
LAG	ADF	1%	5%	10%
1ST	4,073584	3,9672	3,4142	3,1289
2ND	2,927128	3,9672	3,4142	3,1289
3RD	2,374151	3,9672	3,4142	3,1289
4TH	2,033309	3,9672	3,4142	3,1289
5TH	1,777211	3,9672	3,4142	3,1289
6TH	*1,6156*	3,9672	3,4142	3,1289

Source: Romanian Stock Exchange Daily Data 23.09.1997-14.11.2007

Table 2: AIC, SCH, ADF Coefficients

LAG	**1ST**	**2ND**	**3RD**	**4TH**	**5TH**	**6TH**
AIC	14,4571	14,3524	14,3102	14,2873	14,2701	*14,2632*
SCH	14,4665	14,3641	14,3243	14,3037	14,2888	*14,2820*
LM(1)	277,3413	110,0740	60,5390	46,1629	23,6911	*8,2705*
X-SQ	249,9782	105,6528	59,2627	45,4647	23,5518	*8,2762*
LM(2)	199,8194	86,6383	53,9101	35,1414	16,0155	*6,6431*
X-SQ	345,0472	162,4176	103,6580	68,5912	31,7494	*13,2740*
ADF	**4,073584**	**-2,927128**	**-2,37415**	**-2,033309**	**-1,777211**	***-1,6156***

Source: Romanian Stock Exchange Daily Data 23.09.1997-14.11.2007

Table 2 show that the model with the sixth lag difference inserted is the best, because it has the lowest AIC and SCH coefficients and there is no signal of autocorrelation in the residuals because LM (1) and LM (2) Lagrange Multipliers are lower than the corresponding X-SQ values, indeed LM (1) = 8,2705 less than X-SQ = 8,2762 and LM (2) = 6,6431 less than X-SQ = 13,2740 even thought it has a unit root problem. Any attempt to improve the model by eliminating autocorrelation with a valid unit root condition was unsuccessful.

3.2 ARIMA Methodology

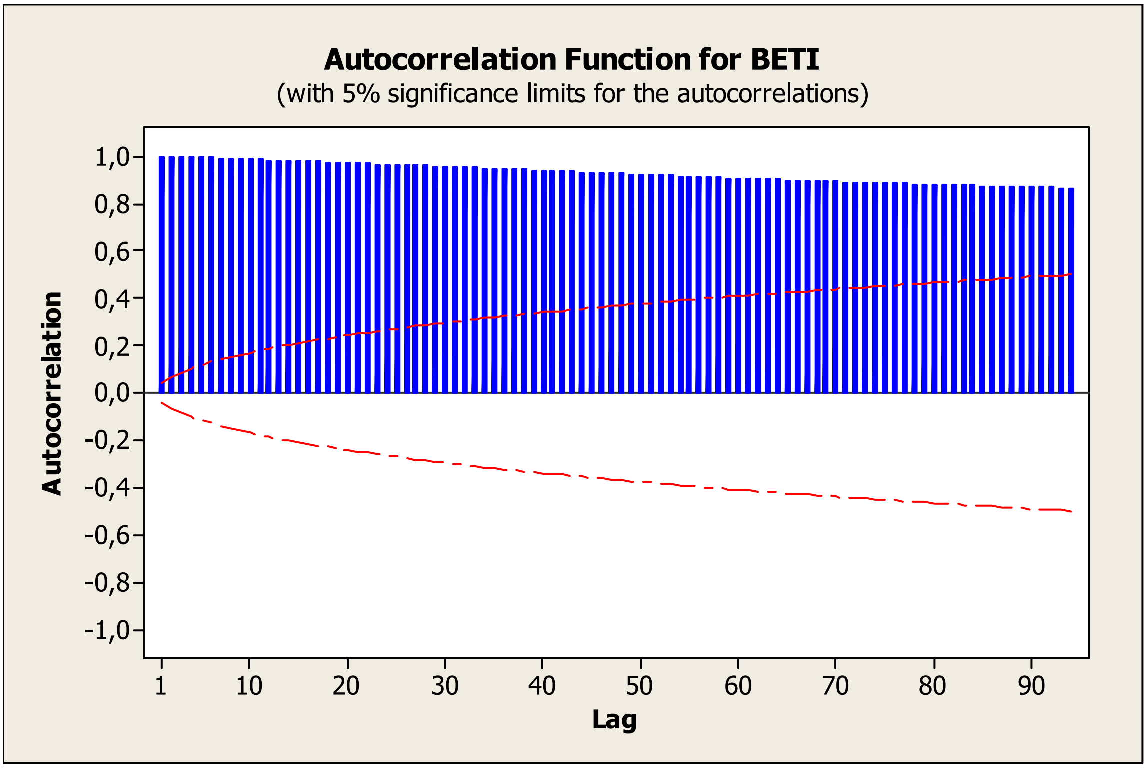
As it has mentioned above ARIMA methodology has been selected for the modeling of the Romanian stock market price index as an alternative to simple regression models because of stationarity and unit root limitations in the series. Autocorrelation and partial autocorrelation coefficients have been estimated and are presented in Diagram 3. All autocorrelation coefficients are statistically significant while the partial autocorrelation function shows one significant spike in period one leading to an AR process in the series.

Autocorrelation Function for 20 Lags: BETI

Lag	ACF	T	LBQ
1	0,998556	49,83	2485,80
2	0,997031	28,75	4965,02
3	0,995568	22,26	7437,96
4	0,994076	18,80	9904,49
5	0,992617	16,56	12364,77
6	0,991160	14,97	14818,82
7	0,989687	13,76	17266,57
8	0,988190	12,80	19707,90
9	0,986662	12,02	22142,66
10	0,985099	11,36	24570,70
11	0,983557	10,79	26992,12
12	0,981996	10,31	29406,83
13	0,980404	9,88	31814,69
14	0,978800	9,49	34215,65
15	0,977143	9,15	36609,46
16	0,975446	8,84	38995,92
17	0,973745	8,56	41375,02
18	0,972063	8,31	43746,88
19	0,970481	8,07	46111,97
20	0,968952	7,86	48470,57
21	0,967348	7,66	50822,33
22	0,965862	7,47	53167,81
23	0,964447	7,30	55507,37
24	0,963014	7,14	57840,93
25	0,961659	6,99	60168,88
26	0,960272	6,84	62491,05
27	0,958754	6,71	64806,84
28	0,957152	6,58	67115,82
29	0,955506	6,46	69417,81
30	0,953853	6,34	71712,77
31	0,952179	6,23	74000,61
32	0,950492	6,12	76281,28
33	0,948857	6,02	78555,04
34	0,947257	5,93	80822,05
35	0,945632	5,83	83082,22
36	0,944029	5,75	85335,64

Partial Autocorrelation Function for 25 Lags: BETI

Lag	PACF	T
1	0,998556	49,83
2	-0,028619	-1,43
3	0,021688	1,08
4	-0,012256	-0,61
5	0,011758	0,59
6	-0,001132	-0,06
7	-0,005797	-0,29
8	-0,008953	-0,45
9	-0,010955	-0,55
10	-0,012768	-0,64
11	0,006834	0,34
12	-0,008360	-0,42
13	-0,010460	-0,52
14	-0,005394	-0,27
15	-0,018671	-0,93
16	-0,013776	-0,69
17	-0,002249	-0,11
18	0,006026	0,30
19	0,033059	1,65
20	0,016199	0,81
21	-0,025897	-1,29
22	0,042326	2,11
23	0,021664	1,08
24	-0,004656	-0,23
25	0,026207	1,31
26	-0,013894	-0,69
27	-0,044157	-2,20
28	-0,029514	-1,47
29	-0,016022	-0,80
30	-0,003363	-0,17
31	-0,012162	-0,61
32	-0,006263	-0,31
33	0,015923	0,79
34	0,008378	0,42
35	-0,007365	-0,37
36	0,008461	0,42



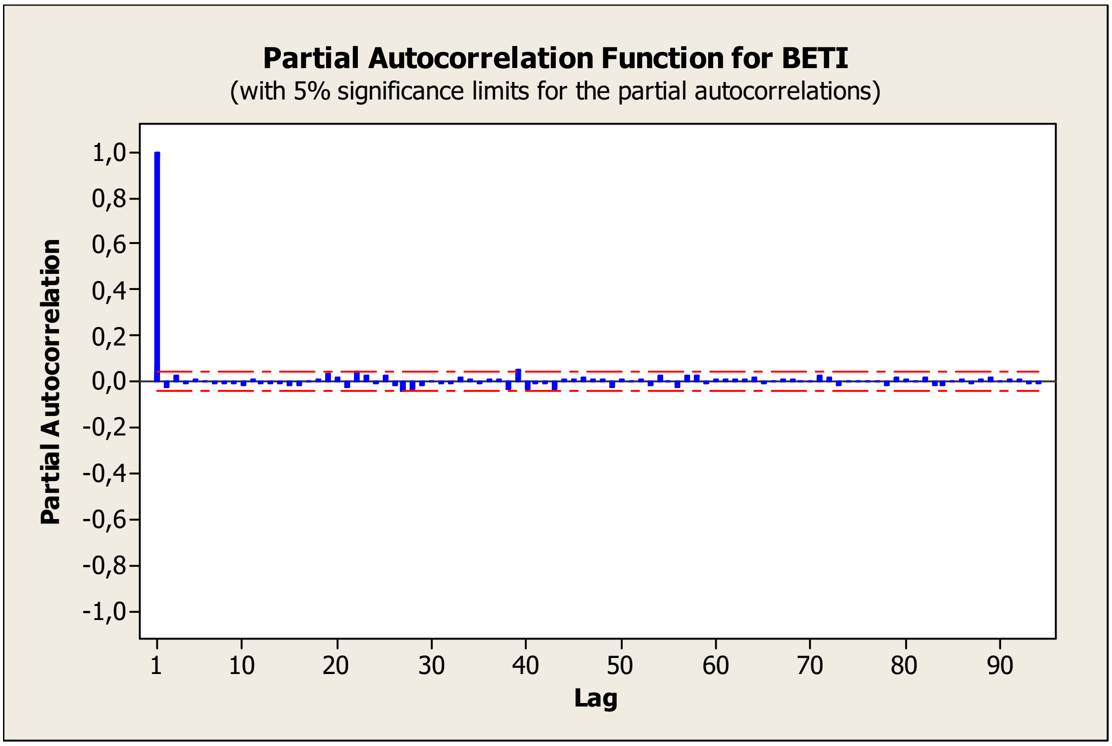
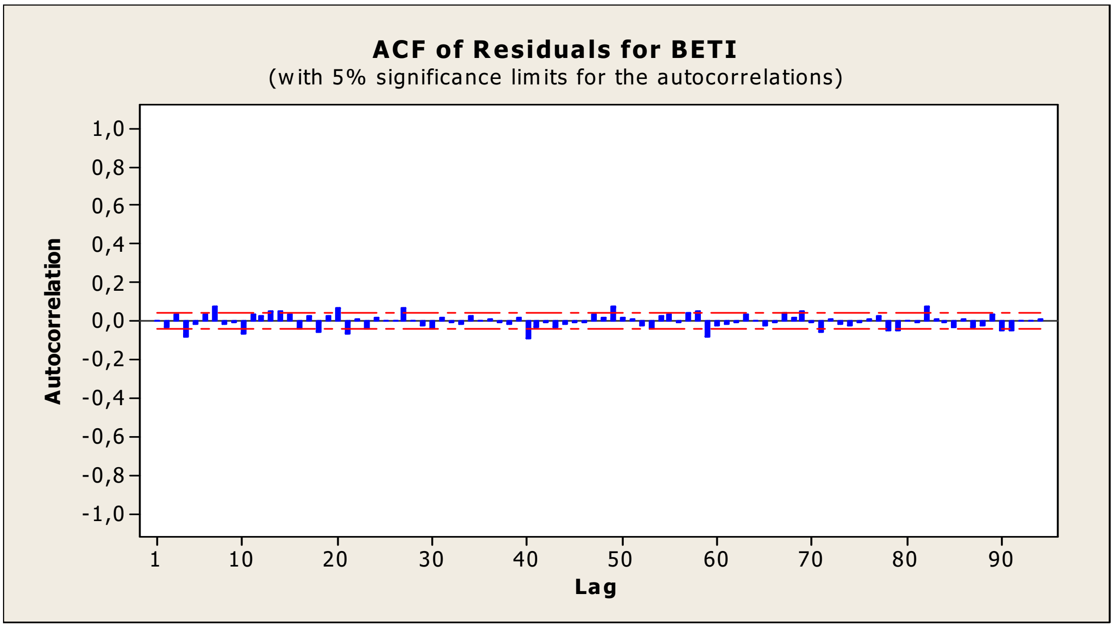


Diagram 3: Autocorrelation and Partial Autocorrelation Functions

The above functions lead to an AR (1) process which after one time lag to an ARIMA (1,1,0) process. The autocorrelation and partial autocorrelation functions of the residuals of this process are shown below in Diagram 4.



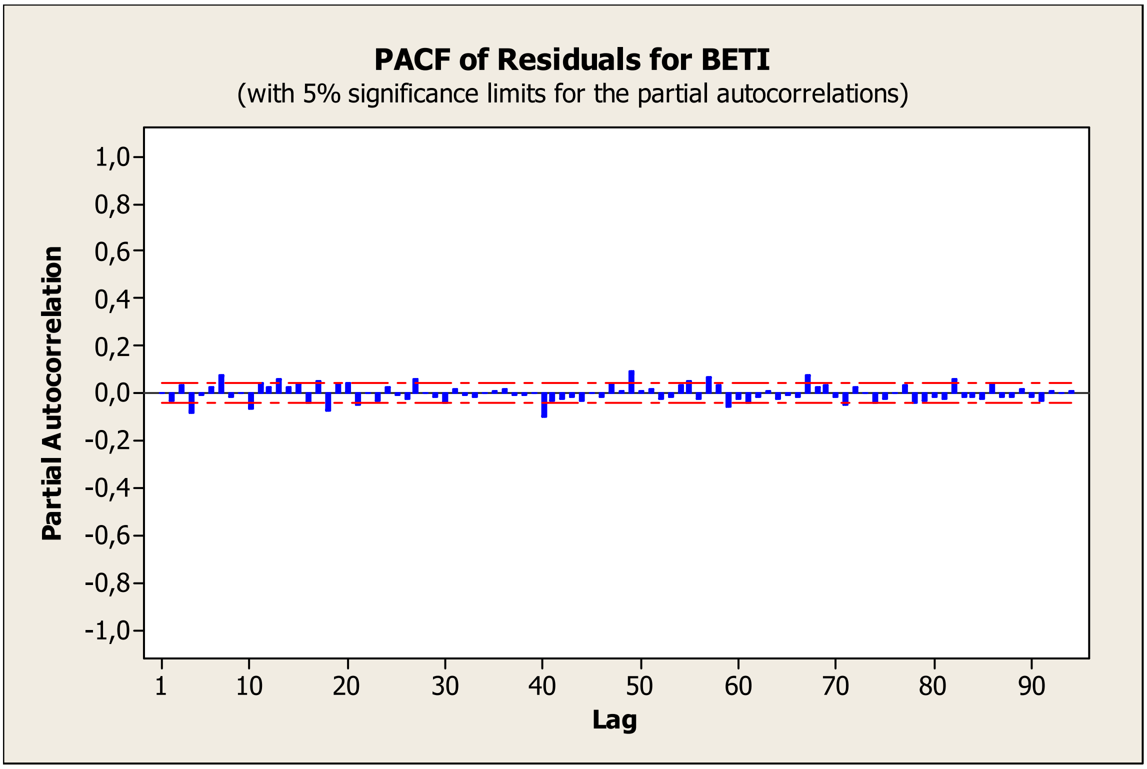


Diagram 4: Autocorrelation and Partial Autocorrelation Functions

The estimation of the selected model is shown below in Table 7.

Table 7: ARIMA (1,1,0) Model Estimation

Final Estimates of Parameters

Type	Coef	SE Coef	T	P
AR 1	0,1303	0,0198	6,57	0,000
Constant	3,188	1,211	2,63	0,009

Differencing: 1 regular difference
Number of observations: Original series 2507, after differencing 2506
Residuals: SS = 9209210 (backforecasts excluded)
MS = 3678 DF = 2504

Modified Box-Pierce (Ljung-Box) Chi-Square statistic

Lag	12	24	36	48
Chi-Square	52,2	110,2	133,0	156,1
DF	10	22	34	46
P-Value	0,000	0,000	0,000	0,000

Source: Romanian Stock Exchange Daily Data 23.09.1997-09.11.2007

For security reasons, the histogram of the residuals must reveal that they are equally distributed between the mean. That is relevantly obvious in Diagram 5.

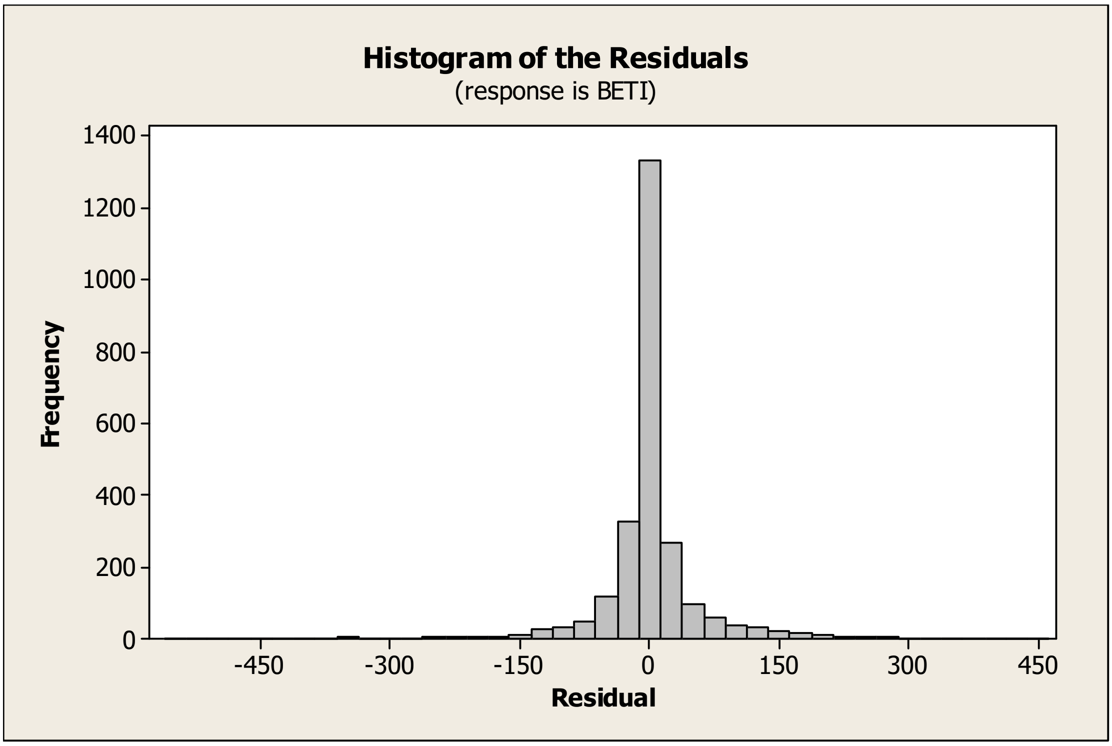


Diagram 5: ARIMA (1,1,0) Model, Histogram of the Residuals

At the same time the residuals are normally distributed as it is shown in Diagram 6 below.

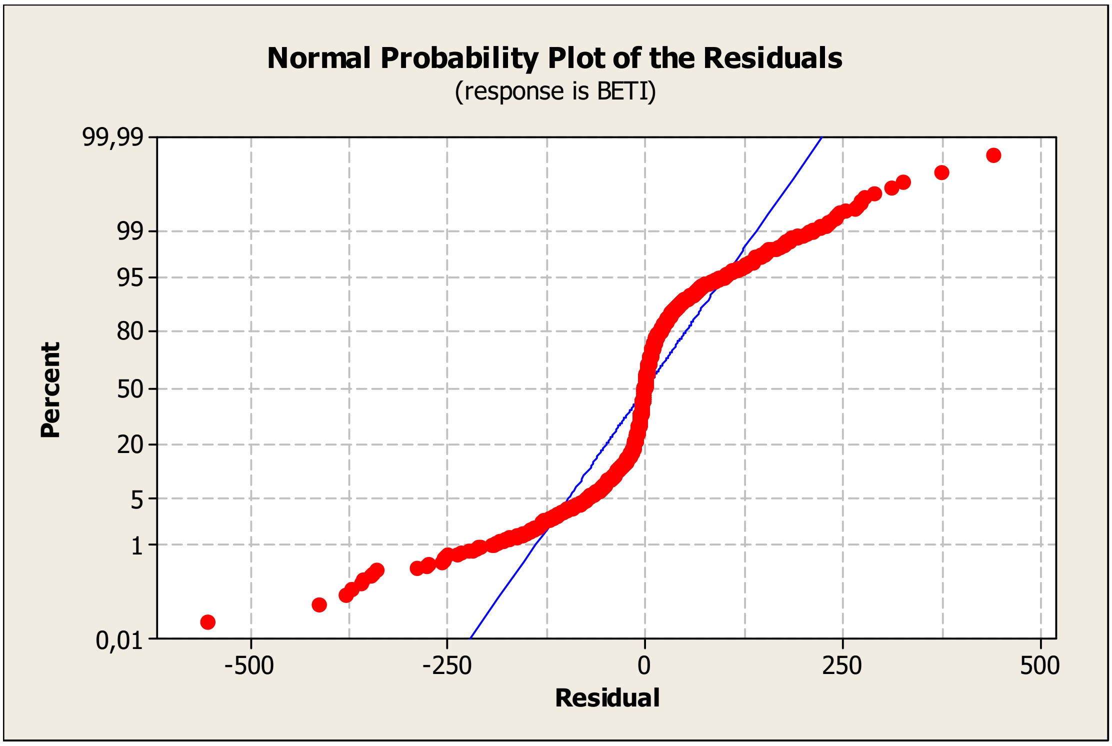


Diagram 6: ARIMA (1,1,0) Model, Normal Probability Plot of the Residuals

The proposed model ARIMA (1,1,0) fits well to the data and it can be used to forecast the Romanian stock market price index as it is shown in Diagram 7.

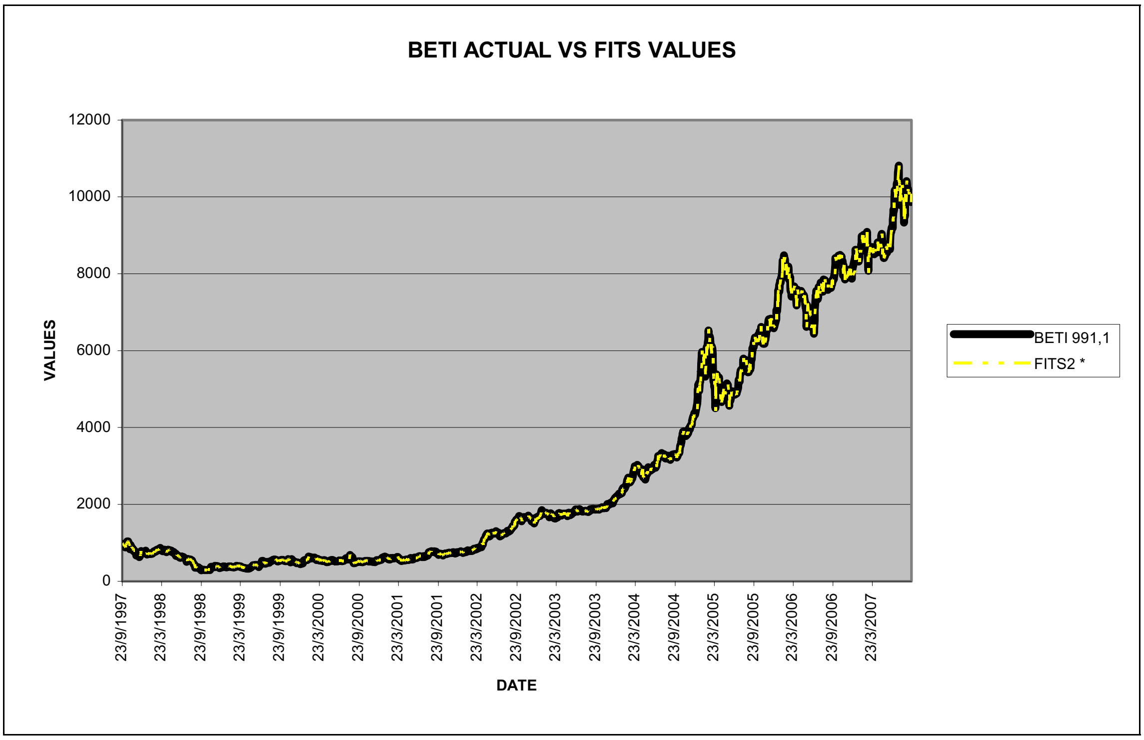


Diagram 7: ARIMA (1,1,0) Model, Actual vs Fits Values

The pattern in Diagram 7 shows that the model fits the data well. Diagram 8 shows the forecasted period within the 5% significance level for the Romanian stock market price index while in Table 8 a 17 days index forecast with the percentage deviation and the upper and lower acceptable limits are presented.

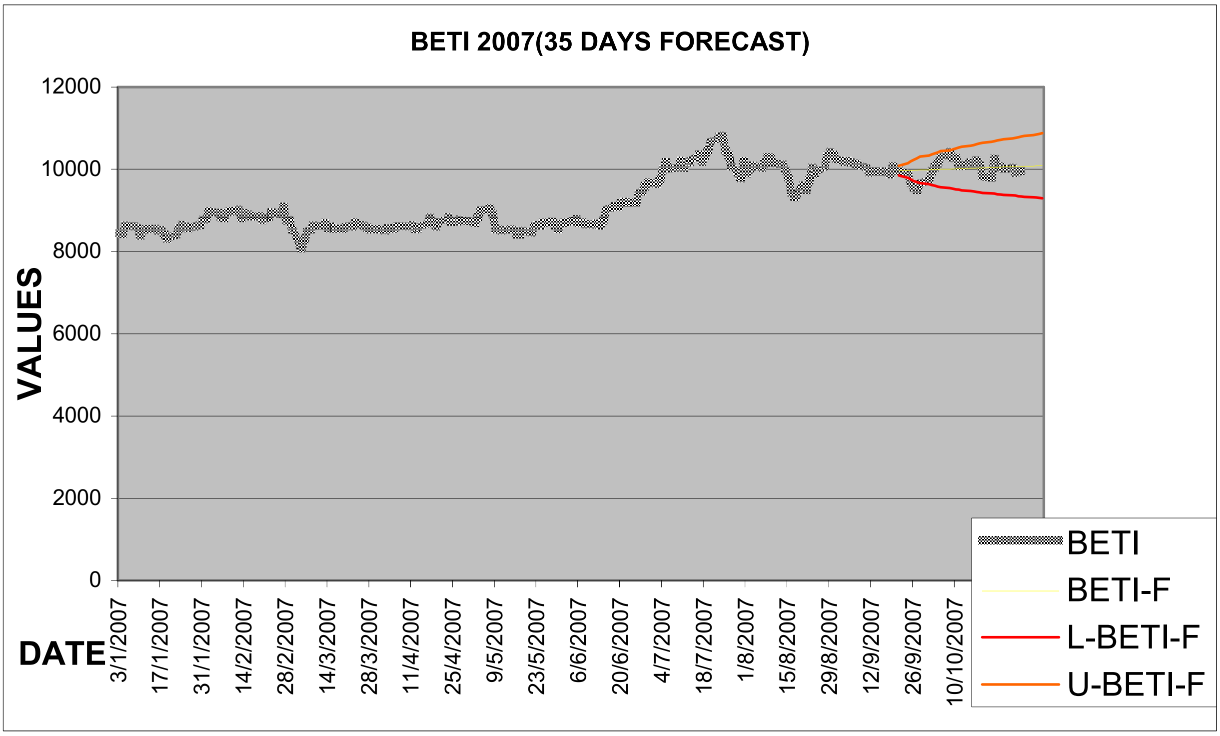


Diagram 8: ARIMA (1,1,0) Model Forecasts

Table 8. Romanian Stock Market Forecasts (09.11.07 to 03.12.07)

DATE	BETI ACT	BETI-F	U-BETI-F	L-BETI-F	DIFFERENCE BETIACT-BETIF	PERCENT DECLINE BETIACT-BETIF
16/10/2007	10125,46	10182,1	10063,2	10301	-56,64	-0,56%
17/10/2007	10206,23	10187,2	10007,8	10366,6	19,03	0,19%
18/10/2007	10115,98	10191,1	9965,7	10416,4	-75,12	-0,74%
19/10/2007	9840,8	10194,8	9931,2	10458,3	-354	-3,60%
22/10/2007	9784,45	10198,4	9901,5	10495,3	-413,95	-4,23%
23/10/2007	10246,16	10202,1	9875,2	10529	44,06	0,43%
24/10/2007	10099,79	10205,8	9851,5	10560,1	-106,01	-1,05%
25/10/2007	10055,77	10209,4	9829,7	10589,2	-153,63	-1,53%
26/10/2007	10002,34	10213,1	9809,5	10616,7	-210,76	-2,11%
29/10/2007	10027,56	10216,8	9790,6	10642,9	-189,24	-1,89%
30/10/2007	9914,7	10220,4	9772,9	10667,9	-305,7	-3,08%
31/10/2007	9950,13	10224,1	9756,2	10692	-273,97	-2,75%
1/11/2007	9962,99	10227,8	9740,3	10715,3	-264,81	-2,66%
2/11/2007	9921,68	10231,4	9725,1	10737,7	-309,72	-3,12%
5/11/2007	9743,97	9999,7	9487,4	10512,0	-255,73	-2,62%
6/11/2007	9518,88	9883,3	9473,8	10532,7	-364,42	-3,82%
7/11/2007	9552,41	9766,8	9460,8	10552,9	-214,39	-2,24%
8/11/2007	9447,36	9610,4	9448,3	10572,6	-163,04	-1,72%
9/11/2007	N/A	9590,94	9030,51	10136,52	N/A	N/A
12/11/2007	N/A	9586,93	9019,38	10154,47	N/A	N/A
13/11/2007	N/A	9590,39	9008,63	10172,15	N/A	N/A
14/11/2007	N/A	9593,75	8998,16	10189,44	N/A	N/A
15/11/2007	N/A	9597,21	8988,06	10206,46	N/A	N/A
16/11/2007	N/A	9600,67	8978,15	10223,10	N/A	N/A
19/11/2007	N/A	9604,04	8968,61	10239,56	N/A	N/A
20/11/2007	N/A	9607,50	8959,36	10255,64	N/A	N/A
21/11/2007	N/A	9610,96	8950,29	10271,63	N/A	N/A
22/11/2007	N/A	9614,32	8941,50	10287,24	N/A	N/A
23/11/2007	N/A	9617,78	8932,80	10302,77	N/A	N/A
26/11/2007	N/A	9621,24	8924,48	10318,01	N/A	N/A
27/11/2007	N/A	9624,61	8916,25	10333,06	N/A	N/A
28/11/2007	N/A	9628,07	8908,21	10347,93	N/A	N/A
29/11/2007	N/A	9631,53	8900,45	10362,61	N/A	N/A
30/11/2007	N/A	9634,89	8892,79	10377,10	N/A	N/A
3/12/2007	N/A	9638,35	8885,21	10391,50	N/A	N/A

Source: Romanian Stock Exchange Daily Data 23.09.1997-08.11.2007

As it is shown in Table 8 the model explains the series relatively well. The biggest deviation in forecasts is -413,95 points or -4,23% . The model seems to overestimate the series except in two days (17/10/2007 and 23/10/2007). The forecasts in these two days are lower than the actual prices. Actual prices, deviations and percentage deviation after 9/11/2007 are in red since they are added day after day as they are published in the Romanian stock exchange.

4. Structural Change

A recursive residual analysis is contacted in order to detect structural change in the data sets. The one-step-ahead forecast error vector for observation i, v_i is defined as:

$$v_i = y_i - x'_i ß_{i-1} \quad (5)$$

By dividing equation (5) by d_i, where d_i is defined as:

$$d_i = (1 + x'_i(X'_{i-1}X_{i-1})^{-1}x_i)^{.5} \quad (6)$$

the standardized one-step-ahead prediction error is given as:

$$w_i = v_i / d_i. \quad (7)$$

In order for the parameters to be stable we expect w_i to be independent, normally distributed with mean zero and constant variance and it is also expected that E $(ß_i - ß_{i-1}) = 0$. The most suitable tests for the recursive residuals are the CUSUM, CUSUMSQ tests.

The CUSUM test is a summary measure for parameter stability. This test is particularly useful in detecting systematic departures of beta coefficients using the ratio in equation (8):

$$\Gamma_i = \Sigma (w_j / \sigma) \quad (8)$$

If this ratio stays within the bounds there is no statistically significant systematic departure of beta coefficients. The CUSUMSQ test is useful in detecting haphazard departures of beta coefficients. The test is conducted by plotting the following equation

$$\Gamma^*_i = \sum_{j=K+1}^{i} (w_j^2) / \sum_{j=K+1}^{T} (w_j^2) \quad i \in \{K+1,\ldots,T\} \quad (9)$$

If this ratio follows the diagonal, beta coefficients are constant. However, if the plot lies above the diagonal, the regression tracks poorly in the early sub-sample versus the total sample; a plot below the diagonal suggests that the regression is tracking better in the early sub-sample than in the complete sample (*Thalassinos* 2006).

Examining the residuals after the CUSUM and CUSUMSQ tests we realized that there was a structural change in the series after the second half of the year 2001 as it is shown in Diagram 2. A reasonable explanation is that after the second half of the year 2001 the Romanian stock market started to act in a bullish way overwhelming its highest peaks ever, as it is stated in Wikipedia (2003): *"The exchange turned to a bull market in 2001, strong growth in capitalisation, trading volume and stock prices lasting up to the present. In the next years, stock prices soared, registering record increases. In 2002, BET index increased by 117.5%".*

This increase has been largely prompted by growing confidence in the Romanian government and the Romanian economy since the initial talks for the future enlargement of the EU, which includes Romania, came to an end, but it is also due to the growing investor awareness for the country. Romania would be among the countries joining EU in 2007 depending on certain conditions that the Romanian economy has to pursuit.

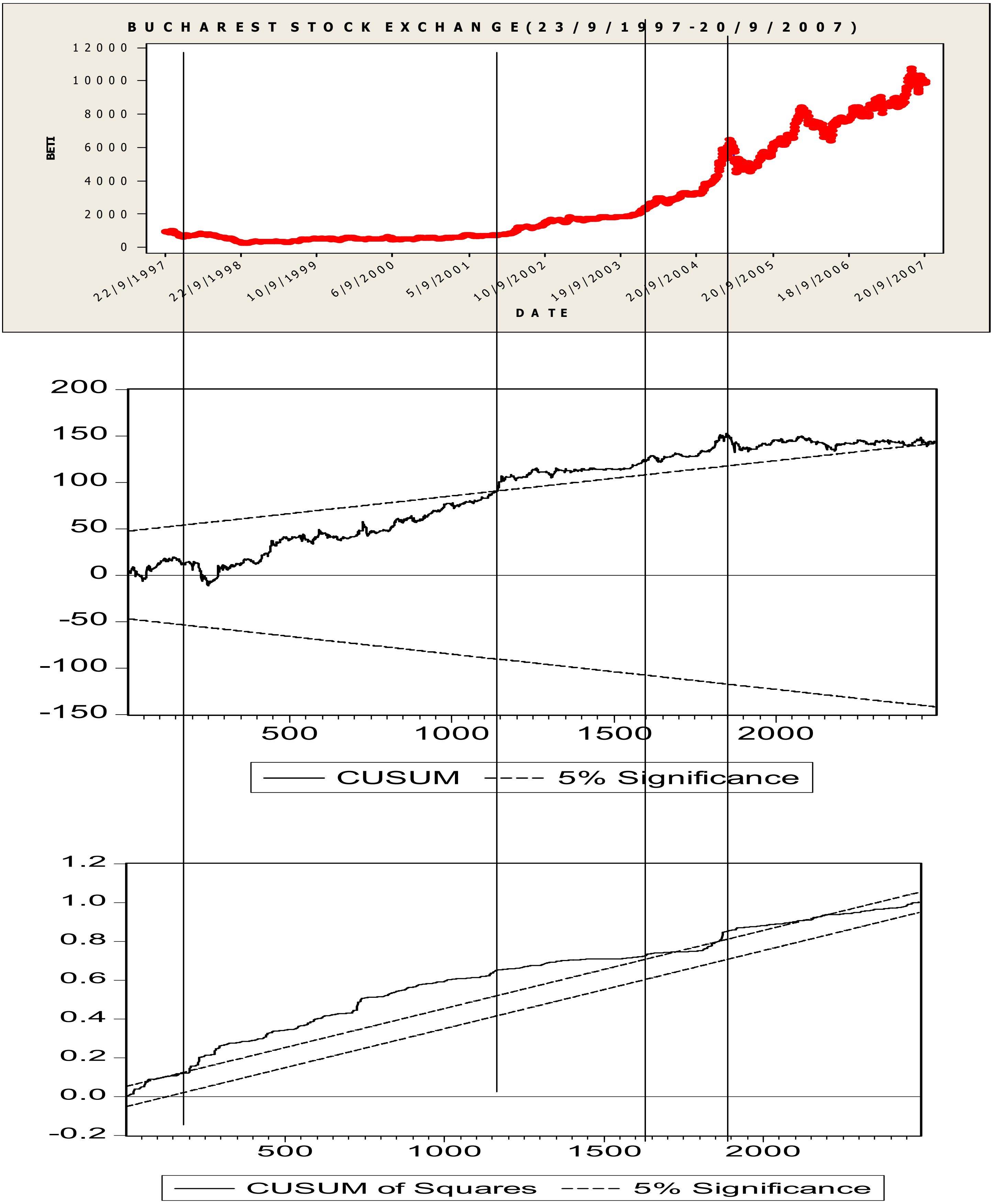


Diagram 2: CUSUM and CUSUMSQ for the Bucharest Stock Exchange

4. Conclusions

The Romanian stock market considered in this research went through a structural change over the sample period. This structural change did not occur simultaneously with similar structural changes in other European countries based on findings from other research studies (*Thalassinos* 2006) because of the different level of readiness, degree of integration as well as the saturation rate in each European stock market. The introduction of the new currency clearly added to the pressures from the technological change and globalization for the creation of stronger links among the exchanges of Europe and did not cause any unique or distinguishable effect.

A time series model, an ARIMA (1,1,0) seems to fit well to the series of data making acceptable forecasts in the short run. The simulation process show a high degree of forecasting ability of the model used while the 30 day future forecast came out relatively well. It is clear that the Romanian stock market price index is adjusting relatively fast to the European stock market price indexes.

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