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# MODELING THE VOLATILITY OF THE BET-FI INDEX

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## Abstract

In this paper we conducted an analysis of stock market risk in Romania, namely on the basis of BET-FI sectoral index (Bucharest Exchange Trading Investment Funds) volatility, developed by the Bucharest Stock Exchange (BSE). We tried to identify an econometric model to model the volatility of the BET-FI index. The analysis was performed using GARCH models, which are very useful tools applied in financial econometrics. In the case study we have identified the best model for analyzing the BET-FI index volatility for the period 03.01.2008 - 04.12.2013 (1332 daily values) and we noticed which are the periods with more pronounced volatility.

**Keywords:** stock market, stock index, volatility, profitability, capitalization, GARCH models.

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BET-FI is the first sectoral index of BSE (price index weighted by the market capitalization of companies included in the index basket, adjusted in accordance with the BSE principles) and expresses the tendency of prices of investment funds (SIFs) traded on BSE regulated market.

This index reflects the evolution of the entire financial investment companies listed on the BSE and other assimilated entities. Similar to other indices of BSE, the BET-FI index methodology reflects the evolution of stock prices traded on the main market section („Regular”).

BET-FI index basket consists of financial investment companies and other assimilated entities listed on the BSE regular market ( [http://www.bvb.ro/info/indices/Manual % 20BET-FI\\_RO.pdf](http://www.bvb.ro/info/indices/Manual%20BET-FI_RO.pdf) ).

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### BET-FI index composition

Table 1

BET-FI index composition on 30.04.2013

Symbol	Company name	Number of shares	Price	Free Float (FF) Factor	Factor of Representation (FR)	Price Correction Factor (CF)	(%)
<u>FP</u>	SC FONDUL PROPRIETATEA SA - BUCURESTI	13.778.392.208	0,6600	1,00	0,197000	1,000000	35,86
<u>SIF5</u>	SIF OLTENIA S.A.	580.165.714	1,3550	1,00	1,000000	1,000000	15,74
<u>SIF3</u>	SIF TRANSILVANIA S.A.	1.092.143.332	0,6520	1,00	1,000000	1,000000	14,25
<u>SIF4</u>	SIF MUNTENIA S.A.	807.036.515	0,7390	1,00	1,000000	1,000000	11,94
<u>SIF2</u>	SIF MOLDOVA S.A.	519.089.588	1,0690	1,00	1,000000	1,000000	11,11
<u>SIF1</u>	SIF BANAT CRISANA S.A.	548.849.268	1,0100	1,00	1,000000	1,000000	11,10

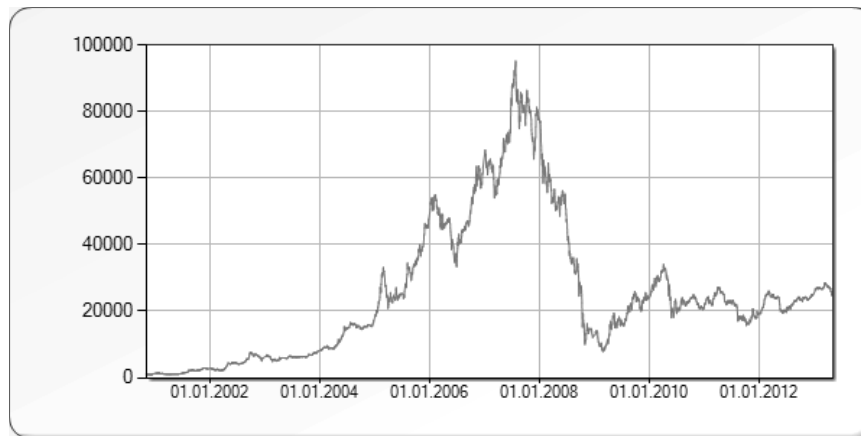
Capitalization index: 4.995.313.064,66 RON

Divider index: 201.807,6740

Source:

<http://www.bvb.ro/IndicesAndIndicators/indices.aspx?t=0&m=BSE&i=betfi&o=&d=5/1/2013>

### The evolution of the BET-FI index



Source:

<http://www.bvb.ro/IndicesAndIndicators/indices.aspx?t=4&p=BSE&i=BETFI&m=&d=5%2f1%2f2013>

Based on the risk-return correlation, we tried an analysis of the volatility of the BET-FI index - Bucharest Exchange Trading Investment Funds for the period 03.01.2008 - 04.12.2013 (1332 daily values).

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The analysis was performed using GARCH models (G – generalized, AR - autoregressive, C – Conditional, H - heteroskedasticity), which are very important instruments in financial applied econometrics. These models were first addressed in 1982 by Robert Engle – the ARCH model and Tim Bollerslev generalized them in 1986. Building an ARCH model one have to consider the following two equations: evolutionary yields equation (conditional average) and the volatility equation (the conditional variance).

### Using GARCH models in modeling financial time series

Successfully used in studies of volatility, the autoregressive conditional heteroskedastic model of volatility - GARCH includes in its equation both error terms (often called shock) and heteroskedasticity phenomenon. It is used in the series which are not normally distributed, but rather have thickened ends.

The first model used in 1982 was the ARCH model (Autoregressive Conditional Heteroskedasticity), introduced by Engle, which includes an equation for the average and one for dispersion, respectively:

$$y_t = \gamma x_t + \varepsilon_t$$
$$\sigma_t^2 = \omega + \alpha \varepsilon_{t-1}^2 + \beta \sigma_{t-1}^2$$

where:  $y_t$  – dependent variable in the current period;  $x_t$  – independent variable in the current period;  $\gamma$  - coefficient that shows the influence of the independent variable on the dependent variable;  $\varepsilon_t$  – the residual terms in the current period;  $\sigma_t^2$  - dispersion of the dependent variable in the current period;  $\omega$  - the constant of dispersion equation;  $\alpha$  - “ARCH” coefficient;  $\varepsilon_{t-1}$  – the residual terms from the previous period;  $\sigma_{t-1}^2$  - dispersion of the dependent variable in the previous period;  $\beta$  - “GARCH” coefficient.

This model is actually GARCH (1,1) model, where the first number symbolizes that residual terms act on the dispersion in the previous period (t-1) and the second number shows that the dispersion in the previous period influences current dispersion (t). For large series, the GARCH (1,1) model can be generalized to GARCH (p, q), and when q = 0, the GARCH model reduces to the ARCH model. ARCH model highlights information about the volatility of the earlier periods, measuring as the *lag* of the quadratic residues in the mean equation. A GARCH (1,1) model is equivalent to an ARCH (2) model while a GARCH (q, p) model is equivalent to an ARCH (q + p) model (Gujarati, 2003).

GARCH model includes error terms and heteroscedasticity in its equation having utility when the series does not have a normal distribution.

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Although financial series often have negative skewness and asymmetry this model remains a symmetrical model, ie, the residuals terms have the same sign.

Another approach to GARCH models is the possible existence of a leverage effect. GARCH (1,1) is a symmetrical model, which implies that the residual terms have the same sign. But reality often shows that the financial series have asymmetry. In this case can be used exponential GARCH or EGARCH model (introduced by Nelson in 1991):

$$\log(\sigma_t^2) = \omega + \log(\sigma_{t-1}^2) + \alpha \left| \frac{\varepsilon_{t-1}}{\sigma_{t-1}} \right| + \gamma \frac{\varepsilon_{t-1}}{\sigma_{t-1}}$$

Leverage effect can be seen by testing inequality  $g < 0$  and  $\gamma \neq 0$ , this model is similar to GARCH (1,1). However, through the presence of the *log* term, the model become a non-linear model, and the residual terms are reported to dispersion becoming *standardized residuals*.

Predictions about the risk of financial assets are often made. Modeling it has a special significance in the theory of financial markets. Given that residual returns have a big influence on yields, scientists have paid attention to *residual returns*.

These are part of the returns that were not captured by the independent variable of a particular model. Consider the market model:

$$r_{it} = \alpha_i + \beta_i r_{mt} + \varepsilon_{it}$$

where:  $r_{it}$  - return of individual title  $i$  in the time period  $t$ ;  $\alpha_i$  - constant term;  $\beta_i$  - relative market risk of an individual title;  $r_{mt}$  - return on market portfolio;  $\varepsilon_{it}$  - the error term.

The residual yields are represented of the  $\varepsilon_{it}$  term of the equation, that indicates which is the part of yield of an individual title not influenced by the return of market portfolio. Often these residual returns has an important percentage in the individual performance.

### **Analysis of the data series corresponding to the BET-FI index**

In practice, financial series do not follow a normal distribution. The same phenomenon was reported for the case study realized in this paper. We checked the following assumptions to determine the normality tests for data series of BET-FI index: Skewness, Kurtosis, Jarque-Bera, QQ Plot. In order to test the BET-FI index volatility we used daily closing data, taken from the daily market reports of the BSE website for specific **period 03.01.2008 - 12.04.2013**, comprising **1332 observations**.

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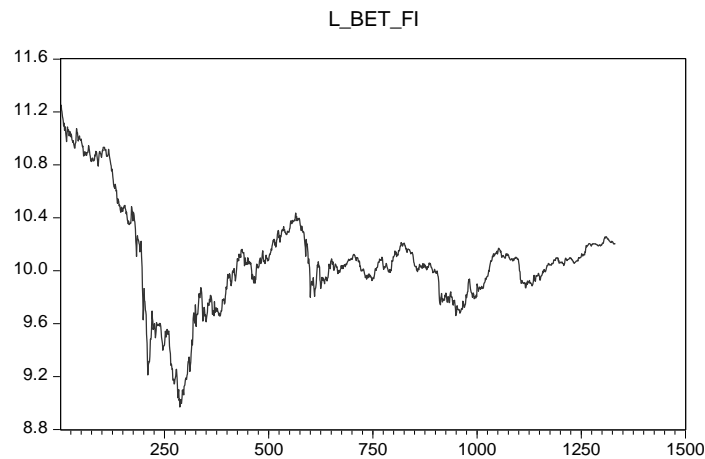
First we calculated the daily returns of the BET-FI index, based on primary data. Subsequently, the data were entered into Eviews to perform the related tests. Using the correlogram of square root of the return we tested the ARCH signature presence on the BET-FI index. Also, after observing the existence of the ARCH signature, we performed modeling of the conditional dispersion.

To this end, we compared the GARCH (1,1) model with EGARCH (1,1) to choose the most suitable model. After this step we tested the existence of residual terms, with the correlogram of standardized residuals square root terms and by applying ARCH\_LM.

The data series required application of mathematical operations, especially those of logarithm and the first difference, given that econometric analysis is performed generally with logarithmic series to facilitate interpretation of the coefficients obtained in regression. The first difference is used for stationarity analysis.

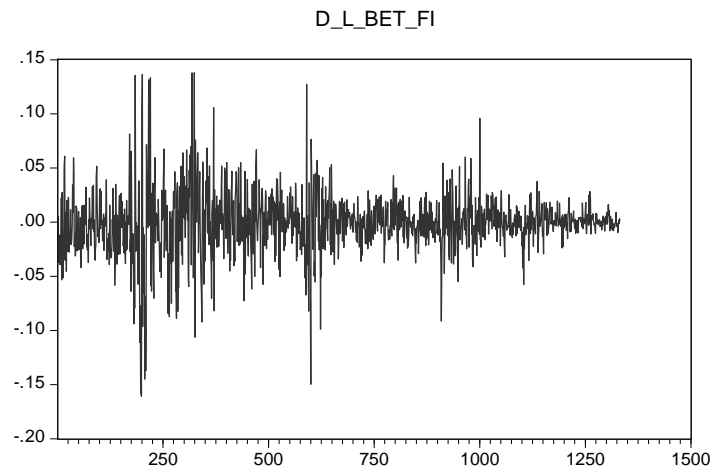
BET-FI series was transformed by logarithm (**L\_BET\_FI**) and the first difference operator was applied, the resulting series of first differences being called **D\_L\_BET\_FI**.

#### Evolution of the daily return of the BET-FI index



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### Evolution of the daily return of the BET-FI index



From the analysis of the two graphs it appears that L\_BET\_FI series is a non-stationary series, but D\_L\_BET\_FI series is stationary.

Next we examined the stationarity of series through **ADF test (Augmented Dickey-Fuller)**. The ADF test is a method for testing the stationarity which has as null hypothesis that the analyzed data series is not stationary (has a unit root). The null hypothesis is rejected if the test value is less than the critical value.

### Applying the ADF test on the L\_BET\_FI series

Table 2

Null Hypothesis: L\_BET\_FI has a unit root  
 Exogenous: Constant  
 Lag Length: 1 (Automatic - based on SIC, maxlag=22)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-3.062775	0.0297
Test critical values:		
1% level	-3.435056	
5% level	-2.863506	
10% level	-2.567866	

\*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation  
 Dependent Variable: D(L\_BET\_FI)  
 Method: Least Squares  
 Date: 04/22/13 Time: 08:33  
 Sample (adjusted): 3 1332  
 Included observations: 1330 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
L_BET_FI(-1)	-0.006198	0.002024	-3.062775	0.0022
D(L_BET_FI(-1))	0.128552	0.027126	4.739113	0.0000
C	0.061718	0.020390	3.026923	0.0025
R-squared	0.023625	Mean dependent var		-0.000787
Adjusted R-squared	0.022153	S.D. dependent var		0.028739
S.E. of regression	0.028419	Akaike info criterion		-4.281287
Sum squared resid	1.071713	Schwarz criterion		-4.269574
Log likelihood	2850.056	Hannan-Quinn criter.		-4.276898
F-statistic	16.05413	Durbin-Watson stat		2.005281
Prob(F-statistic)	0.000000			

The value of the statistics is -3.062775 and the associated probability p is 0.0297. The L\_BET\_FI series is non-stationary for a significance level of 1%, but stationary for 5% and 10%.

**Applying the ADF test on the D\_L\_BET\_FI series**

Table 3

Null Hypothesis: D\_L\_BET\_FI has a unit root  
 Exogenous: Constant  
 Lag Length: 0 (Automatic - based on SIC, maxlag=22)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-31.99858	0.0000
Test critical values:		
1% level	-3.435056	
5% level	-2.863506	
10% level	-2.567866	

\*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation  
 Dependent Variable: D(D\_L\_BET\_FI)  
 Method: Least Squares  
 Date: 04/22/13 Time: 08:40  
 Sample (adjusted): 3 1332  
 Included observations: 1330 after adjustments

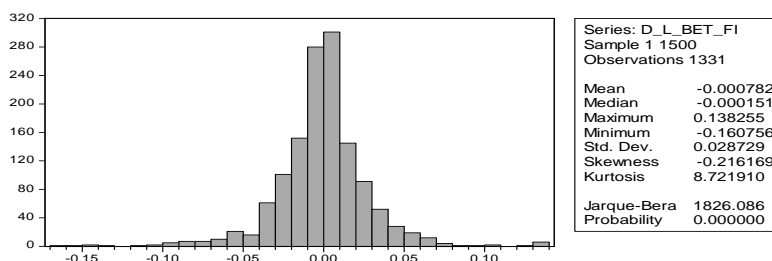
Variable	Coefficient	Std. Error	t-Statistic	Prob.
D_L_BET_FI(-1)	-0.870687	0.027210	-31.99858	0.0000
C	-0.000685	0.000782	-0.876420	0.3810
R-squared	0.435352	Mean dependent var		-3.58E-06
Adjusted R-squared	0.434927	S.D. dependent var		0.037924
S.E. of regression	0.028508	Akaike info criterion		-4.275747
Sum squared resid	1.079289	Schwarz criterion		-4.267938
Log likelihood	2845.372	Hannan-Quinn criter.		-4.272820
F-statistic	1023.909	Durbin-Watson stat		2.005111
Prob(F-statistic)	0.000000			

From the above table it appears that the series D\_L\_BET\_FI is stationary for all three levels of significance: 1%, 5%, 10%. The test value -31.99858 is less than the critical value for any given significance level. The null hypothesis (that the series is non-stationary) is rejected and the associated probability value  $p=0$  confirms this.



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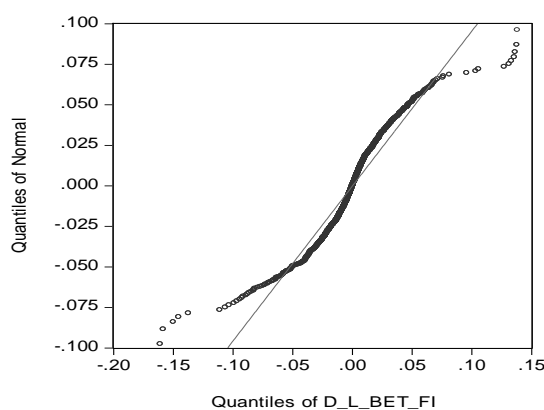
### The histogram of D\_L\_BET\_FI series distribution



By analyzing the graph it can be concluded that the average of daily distribution of D\_L\_BET\_FI series **-0.000782** shows negative average return of the index; right asymmetry of the distribution of returns (Skewness = -0.216169) shows that there are days in the period with high quotations; Kurtosis = 8.72 proves that the distribution is leptokurtic (level > 3); standard deviation - Std. dev = 0.028 indicates that in the period volatility was high but the series yields have not uniform evolution, periods with high volatility alternating with low volatility; Jarque-Berra test (1826.086,  $p = 0.00000$ ) leads to rejection of the hypothesis of normality of the series. Therefore, due to the fact that the test values are quite far from those of a normal distribution, *the series is not normally distributed*.

To test the normal distribution we also used **Quantiles-Quantiles-Plot** method of Eviews. Through this method we compared the BET-FI index value distribution with a normal distribution, to see if they coincide or not.

### QQ Plot



By analyzing the graph it appears that the BET-FI index *does not follow a normal distribution*.

Through the correlogram of daily returns radical we tested the presence of ARCH signature. For both series the number of lags used was 36. Analysing the correlogram we concluded that *there are ARCH effects*, because the probability for each lag has the value 0, thus rejecting the null hypothesis.

### Modeling volatility of the BET-FI series

First we tried to identify the equation that best describes the portfolio risk or portfolio volatility. In this context we estimated ARCH models in EViews.

Conditions to be fulfilled by the coefficients of a GARCH model are the following: the variance equation coefficients must be positive and the sum of coefficients of variance equation must be less than 1. Otherwise, we're talking about Integrated GARCH (IGARCH), where the volatility is explosive. We looked for a standard GARCH (1.1) model, noting the following: both terms have a significant influence on the dispersion.

### GARCH (1,1) Equation

Table 4

Dependent Variable: D\_L\_BET\_FI  
 Method: ML - ARCH (Marquardt) - Normal distribution  
 Date: 04/24/13 Time: 08:16  
 Sample (adjusted): 3 1332  
 Included observations: 1330 after adjustments  
 Convergence achieved after 17 iterations  
 Presample variance: backcast (parameter = 0.7)  
 GARCH = C(3) + C(4)\*RESID(-1)^2 + C(5)\*GARCH(-1)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
D_L_BET_FI(-1)	0.107783	0.026897	4.007227	0.0001
C	0.000591	0.000436	1.354744	0.1755
Variance Equation				
C	2.08E-06	8.72E-07	2.390324	0.0168
RESID(-1)^2	0.138337	0.012119	11.41483	0.0000
GARCH(-1)	0.869940	0.009728	89.42246	0.0000
R-squared	0.014233	Mean dependent var		-0.000787
Adjusted R-squared	0.013491	S.D. dependent var		0.028739
S.E. of regression	0.028544	Akaike info criterion		-4.849888
Sum squared resid	1.082022	Schwarz criterion		-4.830366
Log likelihood	3230.176	Hannan-Quinn criter.		-4.842572
Durbin-Watson stat	1.956790			

The above table shows that the changes caused by the volatility of previous periods are 0.869940. Durbin-Watson statistic is 1.956790. We applied standardized residuals correlogram, to ensure that there are higher correlation of the first order. Analyzing the correlogram of standardized residuals square root it resulted that the GARCH (1,1) equation is not the most appropriate, standardized residuals being strongly autocorrelated.

After trying to find an equation in GARCH (1,1), we have abandoned the classical or standard GARCH (1,1) model and **adopted asymmetric EGARCH (1,1) model**, taking advantage of the fact that there is a non-linear model. The volatility equation coefficients not having values imposed the EGARCH model is less restrictive, is very useful in cases of negative asymmetry.

#### The equation that models best the BET-FI index volatility - EGARCH (1,1) Model

Table 5

Dependent Variable: D\_L\_BET\_FI  
Method: ML - ARCH (Marquardt) - Normal distribution  
Date: 04/24/13 Time: 08:23  
Sample (adjusted): 3 1332  
Included observations: 1330 after adjustments  
Convergence achieved after 17 iterations  
Presample variance: backcast (parameter = 0.7)  
LOG(GARCH) = C(3) + C(4)\*ABS(RESID(-1)/@SQRT(GARCH(-1))) + C(5)\*RESID(-1)/@SQRT(GARCH(-1)) + C(6)\*LOG(GARCH(-1))

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	0.000131	0.000454	0.287753	0.7735
D_L_BET_FI(-1)	0.112281	0.025887	4.337376	0.0000
Variance Equation				
C(3)	-0.269472	0.032140	-8.384378	0.0000
C(4)	0.221278	0.021493	10.29525	0.0000
C(5)	-0.060852	0.012332	-4.934410	0.0000
C(6)	0.987498	0.003232	305.5454	0.0000
R-squared	0.015599	Mean dependent var		-0.000787
Adjusted R-squared	0.014858	S.D. dependent var		0.028739
S.E. of regression	0.028524	Akaike info criterion		-4.858037
Sum squared resid	1.080522	Schwarz criterion		-4.834610
Log likelihood	3236.594	Hannan-Quinn criter.		-4.849257
Durbin-Watson stat	1.968420			

It is noted that in the GARCH effects coefficients, ARCH and the EGARCH effect they are statistical significant which is indicated by probability less than 5%. Durbin-Watson test of 1.968420 and Log likelihood value of 3236.594 are also significant. However, we applied standardized residuals correlogram to make sure the lack of correlation. The coefficients C (4) and C (6) are statistically significant and the equation indicates that there is no leverage effect. The positive volatility coefficient from the average equation shows that when volatility increases, the quotes of BET-FI index decreases.

We performed the correlogram analysis of standardized residuals square root and applied a residual ARCH-LM test.

From the correlogram analysis it appears that the residuals terms are not autocorrelated. If the probability value is greater than 0.05, we accept the null hypothesis that **there is no residual ARCH effects**.

#### ARCH Test

Table 6

Heteroskedasticity Test: ARCH

F-statistic	2.018429	Prob. F	0.0896
Obs*R-squared	8.055044	Prob. Chi-Square	0.0896

The value of the probability should be in this case more than 5%, so that no residual effects exists on the dispersion of the series. It is noted that the value is 8.96%, which means that *there are no residual ARCH effect*.

In the last part of the analysis we tested whether there is heteroscedasticity phenomenon, applying the WHITE test. Because there is no residual heteroscedasticity effects (or GARCH effects) the probability of significance test for parameter  $WGT\_RESID^2(-1)$  must be more than 5%.

## WHITE Test

Table 7

Heteroskedasticity Test: White

F-statistic	2.614246	Prob. F(1,1328)	0.1061
Obs*R-squared	2.613039	Prob. Chi-Square(1)	0.1060
Scaled explained SS	5880997.	Prob. Chi-Square(1)	0.0000

Test Equation:

Dependent Variable: WGT\_RESID^2

Method: Least Squares

Date: 06/26/13 Time: 10:07

Sample: 3 1332

Included observations: 1330

Collinear test regressors dropped from specification

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.971838	0.050212	19.35478	0.0000
WGT_RESID^2 (-1)^2	33.26702	20.57504	1.616863	0.1061

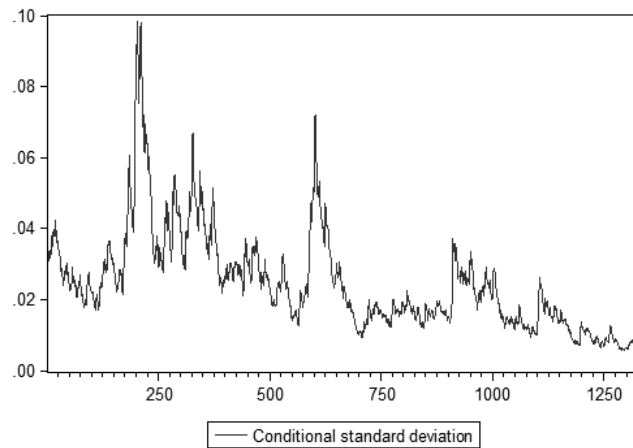
R-squared	0.001965	Mean dependent var	0.999314
Adjusted R-squared	0.001213	S.D. dependent var	1.724165
S.E. of regression	1.723119	Akaike info criterion	3.927652
Sum squared resid	3943.017	Schwarz criterion	3.935461
Log likelihood	-2609.888	Hannan-Quinn criter.	3.930578
F-statistic	2.614246	Durbin-Watson stat	1.923167
Prob(F-statistic)	0.106145		

The analysis of above table shows that the probability value for the coefficient  $WGT\_RESID^2 (-1)$  is 0.1061, that is greater than 0.05%, which leads to the idea that there is no residual GARCH effects. In conclusion, the EGARCH (1.1) model is best applied to model the volatility of the portfolio.

As noted in the previous analysis, the past information set has significantly influence on present yields. The dispersion of the portfolio is not constant throughout the series, but, as we have shown, there is an oscillating trend, with impact on volatility. These issues are relevant to econometricians, in terms of volatility behavior. But many investors are more interested in knowing and explaining the causes increasing risks in certain periods, if some cases were repeated in the market trend or there is a seasonal development of yields or not. Based on EGARCH (1.1) estimated volatility equation we generated historical series of conditional volatility.

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### BET-FI index volatility



The volatility, as is known, varies from one time to another, there are periods of high volatility, followed by the very low volatility. Explanation of the phenomenon on the BET-FI index consists in the shocks of the financial crisis which immediately raised the volatility level in terms of complicated economic situation.

### Conclusions

Volatility is a key variable in assessing the state of financial markets and adopting managerial decision specific of the actors in financial markets (investors, speculators, contractors, managers, regulators). In this context, ARCH and GARCH models have been applied in various analyzes of temporal distributions, their solutions are very important in financial economics with a special impact. In essence, the apparent change in the volatility of economic series of temporal data may be predictable, resulting in a nonlinear dependence. The EGARCH (Exponential GARCH - Nelson, 1991) is characterized by specifying the conditional variance in logarithmic form, without any constraint on estimates to avoid the negative alternative. We highlighted all these issues to justify why we analyzed the volatility of BET-FI sectoral index, using GARCH models in this paper. These models are very important in modeling risk and return of BET-FI index. The asymmetric EGARCH (1,1) proved to be the best in the analysis.

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