Zagreb International Review of Economics & Business, Vol. 14, No. 2, pp. 1-14, 2011

ISSN 1331-5609; UDC: 33+65

The Impact of Euro on Athens Stock Market Index

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Abstract: This paper examines whether the introduction of Euro in the Greek market has changed the attitude of the Athens Stock Index due time. The estimation results indicate that after the introduction of Euro, the ASE index had more asymmetric effect, while there was a decrease in the existing persistence. In addition, it was depicted that the sign of innovations is significant in the after-Euro period, showing that only the large negative shocks can cause more volatility in contrast to the pre-Euro period, and thus the risk of the ASE index's stocks was more increased in the after-Euro period.

Keywords: Athens Stock Market, Impact of Euro, EGARCH, IGARCH, Asymmetries.

JEL Classification: C58, G15.

Introduction

Afterwards 1992, a landmark in the history of the EMU[1] via the signature of the Treaty of Maastricht, Greece had not only to adapt fast to the changing European economic environment but also to complete the required structural changes in order to achieve as quickly as possible the convergence criteria[2] that existed in the treaty and to complete its goal to become a member of the Euro zone. In this period of massive changes in the Athens Exchange Stock Market, and more specifically in the General Athens stock index (ASE index)[3], a very interesting behaviour was observed which was intensified as the moment of the introduction of Euro in the

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Greek economy was approaching and was extended even more throughout the period of the Athens Stock Market crisis in 1999. Thus, this crucial period for the Athens Stock Market (1993-2010) has to be examined in order to specify the role that the common currency played in the returns and the volatility of the Athens stocks, and also to evaluate the size of the changes that occurred because of the introduction of the common currency in the Greek economy, since no-one until now have compared the volatility together with the persistence and the possible asymmetries during the periods before and after the introduction of Euro (1993-2001 and 2002-2010).

The thorough analysis of the ASE index during the periods before and after the introduction of Euro (1993-2001 and 2002-2010) will certainly show us a more explicit picture of the Athens Stock Market and allow us to focus more on the impact of the introduction of Euro. Thus in our research, we will use the EGARCH and the IGARCH model in order to depict any possible asymmetries, the volatility and the persistence that could be depicted in the ASE index, before and afterwards the introduction of Euro. Moreover, four diagnostic tests will be used on the asymmetries in order to focus more on their sign and size, showing a more explicit picture upon the asymmetries and the Athens Stock Market in general. Furthermore, we will use different mean equations in each model in order to see the differences among different AR(p) and where the results fit better. Using all the models and tests referred above, we will be able to justify whether important changes in the returns and the other properties of the stocks happened or not because of the introduction of Euro in the Greek economy.

Literature Review

Many researchers have used the GARCH(p,q) model (Bollerslev, 1986) in the last 20 years in order to show the volatility of several stock market indexes (see for example Pederzoli, 2006; Bollerslev and Mikkelsen, 1996; Hung-Chun and Jui-Cheng, 2010). The GARCH model is the natural generalisation of the ARCH (Autoregressive Conditional Heteroskedastic) model which had been introduced by Engle (1982) to allow past conditional variances in the current conditional variance equation. Moreover, GARCH models can successfully capture several characteristics of the stock return series, such as thick tails and volatility clustering, helping researchers focusing on the volatility of indexes, stocks, options, futures or other assets. However, GARCH model has some serious drawbacks (Nelson, 1991). Mainly, it can not depict the possible asymmetry that may exist in financial return series, while also imposes parameter restrictions that may restrict the dynamics of the conditional variance. Finally, it can not interpret whether shocks to conditional variance persist or not, because the usual norms measuring persistence often do not agree.

For these reasons there were created alternative models, which were based in the GARCH approach, in order to depict in a more clear way the volatility, the asymmetries and the persistence. Two of these different GARCH models were the IGARCH model (Engle and Bollerslev, 1986a) and the EGARCH model (Nelson, 1991), which can clearly depict the persistence and the asymmetries respectively. More specifically for the IGARCH(1,1) model, Lumsdaine (1996) proved that the quasi-maximum likelihood estimators of all the parameters in IGARCH(1,1) model were consistent and jointly asymptotically normal, while the presence of a unit-root in the conditional variance did not affect the distribution of the estimators, as they remained normally distributed. In addition, looking closely the EGARCH(1,1) model, due to the structure of this model, it can capture the asymmetries and thus it has already been used in a large number studies examining the asymmetries in stock markets (e.g. Ferreira et. al., 2007; Alberg et. al., 2008; Ederington and Guan, 2010). The utility of these models can clearly be shown as both have been used in a large number of studies (Phich and Hengshan, 2010; Balaban et.al., 2006; Morana, 2002; Franses et.al., 1992; Choudhry, 1995), but they have never been used for a research on the main index (ASE) of the Athens Stock Market comparing the pre-Euro period with the after-Euro period.

However, studies have already been conducted examining other periods and indices of the Athens Stock Market. Some of them have examined the FTSE20 index[4] focusing only in this index while others examined the Athens Stock market in periods well before the introduction of Euro (Panas, 1990; Alexakis and Petrakis, 1991; Alexakis and Xanthakis, 1995; Siriopoulos, 1996; Barkoulas and Travlos, 1998; Apergis and Eleptheriou, 2001; Panagiotidis, 2005). In addition there were studies focusing in the Efficient Market Hypothesis of the Athens Stock Market after the introduction of Euro in the Greek Economy (see for example Panagiotidis, 2010) or focusing on the day of the week effect (Kenourgios and Samitas, 2008).

Data and methodology

In our research we used daily stock index closing prices of the ASE index over a period of around seventeen years, from the beginning of January 1993 until the end of December 2010. The logarithmic stocks' returns were computed as follows in order to extinct the trend:

$$R_t = \ln(Y_t) / \ln(Y_{t-1}) = \ln(Y_t)\text{-}\ln(Y_{t-1}) \tag{1}$$

where, R_t is the logarithmic return in day *t*, Y_t is the price in day *t* and Y_{t-1} is the price of the previous day.

Looking to examine closely the asymmetric effects that might have occurred during this period, we decided to use the EGARCH model which has the capability to allow good and bad news to have different impact on volatility and moreover allows big shocks to have a greater impact on volatility than GARCH model (Engle and Ng, 1993). In addition, there are no constraints for the parameters to be positive, as in the GARCH model. This happens because the equation of the conditional variance for the EGARCH(1,1) model takes the following form:

$$\text{Log}\,\sigma^2_t = c + \beta * \log \sigma^2_{t-1} + \alpha * (|\varepsilon_{t-1}/\sigma_{t-1}|) + \gamma * (\varepsilon_{t-1}/\sigma_{t-1}) \quad (2)$$

where, σ^2_t is the variance, σ^2_{t-1} is the variance in the time t - 1, *c* depicts the constant, β, α and γ show the coefficients and ε_{t-1} is the residuals in the time t - 1. To have an asymmetric effect in our time series there must be applied $\gamma < 0$. Furthermore the bigger the coefficient *a* is, the stronger persistence we have, something that may lead us to the conclusion of the small amount of market efficiency. Moreover, we have used four diagnostics tests introduced by Engle and Ng (1993) in order firstly to focus on the impact of the negative and positive innovations, and secondly to justify whether the squared standardised residuals are indeed independent and identically distributed. These tests are the Sign-Bias Test, the Negative-Size-Bias Test, the Positive-Size-Bias Test and the Joint Test. The equations of the Sign-Bias Test (3), the Negative-Size-Bias Test (4), the Positive-Size-Bias Test (5) and the Joint Test (6) have the following forms respectively

$$z_t^2 = a + bS_t^- + e_t \quad (3)$$

$$z_t^2 = a + bS_t^- E_{t-1} + e_t \quad (4)$$

$$z_t^2 = a + b(1 - S_t^-)E_{t-1} + e_t \quad (5)$$

$$z_t^2 = a + b_1 S_t^- + b_2 S_t^- E_{t-1} + b_3(1 - S_t^-)E_{t-1} + e_t \quad (6)$$

where, z_t^2 is the squared normalised residuals from an AR (p) filter using constant variance, S_t^- is a dummy variable taking a value of 1 if E_{t-1} is negative and zero otherwise. The Sign-Bias Test focuses on the different impact that positive and negative innovations have on volatility. The Negative-Size-Bias Test examines the impacts that large and small negative innovations have on volatility, while on the contrary the Positive-Size-Bias Test examines the impacts of large and small positive innovations on volatility. Finally, the Joint Test is the F-statistic form of the three tests above.

Moreover, looking to examine the existing persistence in the Athens Stock Exchange Market on the ASE index, we decided to use the IGARCH model as in markets with strong persistence of outer shocks, like the Athens Stock Market, the persistence is near to one if we try to measure it using the GARCH model. Thus, the equation that we will use for the variance is an IGARCH(1,1) model and has the following form:

$$\sigma^2_t = c + \alpha * \varepsilon^2_{t-1} + (1-\alpha) * \sigma^2_{t-1} \quad (7)$$

where c is the constant, a and $1 - a$ are coefficients, ε^2_{t-1} is the squared residuals in day $t - 1$, σ^2_t is the variance and σ^2_{t-1} is the variance in the time $t - 1$. In addition, for the constant c must be applied $c > 0$ because if $c = 0$ then the σ^2_t will fall to zero, but if $c > 0$ then the σ^2_t is strictly stationary (Geweke, 1986; Nelson, 1990a).

Furthermore, we have to point out that the equation of the mean, in both used models, is AR(p) and has the following form:

$$R_t = \omega + \phi_1 * R_{t-1} + \ldots + \phi_p * R_{t-p} + \varepsilon_t \quad (8)$$

with $\varepsilon_t \sim N(0, \sigma^2_t)$,

where, R_t is the return in day t, ω is the constant, ϕ_1 to ϕ_p is the coefficients, ε_t represents the residuals. In our study, we will examine EGARCH and IGARCH models with AR(1) to AR(5), looking at the differences between these two kinds of models.

Finally, in order to be sure for the explanatory power of our models, we used the ARCH test that has been proposed by Engle (1982), which can detect any ARCH disturbances and thus confirm the existence of heteroskedasticity in our financial residual series.

Analysis of empirical results

Table 1 reports the results of the estimation using the AR(p)-EGARCH(1,1) model, in the two different periods pre-Euro (1993-2001) and after-Euro (2002-2010). Examining the results of the first period, we have to underline the non significance of the gamma coefficient for the first four mean equations. More specifically, looking at the results of the AR(1)-EGARCH(1,1), AR(2)-EGARCH(1,1), AR(3)-EGARCH(1,1), AR(4)-EGARCH(1,1) models, we point out the fact that the gamma coefficient is not statistically significant for the 5% significance level showing that γ is equal to zero. However, for five lags in the mean equation we notice that the gamma coefficient is statistically significant for 5% significance level and that it is equal to -0.0345, something that clearly indicates the existence of an asymmetric effect in the Athens Stock Market in the period 1993-2001. This result shows that the negative shocks that appeared in the Athens Stock Market during this period, affected more the volatility and thus the risk (as we know greater volatility means greater risk for an investment), than any positive shocks that happened in the returns of the ASE index.

In table 2, we can see that the result from the estimation of AR(5)-EGARCH(1,1) is the best among the others, as the maximum log-likelihood function from this estimation is greater by all the others. Thus, we can conclude that there is indeed an asymmetric effect in the pre-Euro period.

In order to verify the results above, we did the Likelihood-ratio test (LR) using the AR(5)-EGARCH(1,1) model as a benchmark. The equation for the LR test is

$$LR = 2 * \ln(likelihood_b - likelihood_a) \tag{9}$$

with $df = df_b - df_a$

where, $likelihood_b$ is the likelihood of the benchmark model, $likelihood_a$ is the likelihood of the alternative model, df_b is the degrees of freedom of the benchmark model and df_a is the degrees of freedom of the alternative model. Table 3 shows the likelihood-ratio test results, comparing them with the critical values of X^2 distribution.

Examining the results of table 3, we have to focus on the fact that the closer the number of parameters of the mean equation comes to the number of parameters of the benchmark model (AR(5)-EGARCH(1,1)), the more difficult it is for the LR measure to be statistically significant for a smaller significance level (e.g. at 1%). This clearly indicates that adding more parameters in the mean equation makes our model fit even better to our financial return series.

Comparing the pre-Euro period with the after-Euro period in table 1, we immediately notice that in this period the gamma coefficient is statistically significant in all mean equations. Moreover, its values are between the range of -0.0798 to -0.0857, depicting the existence of asymmetric effects and clearly showing that in the period after the introduction of Euro the asymmetric effects are much stronger in the ASE index since the values of the gamma are much bigger than the value of -0.0345 of the gamma coefficient in the pre-Euro period. This means that any negative shocks that happened on the ASE index during the after-Euro period affected the volatility of the index more, raising even more the risk of the stocks of the ASE index.

In addition, comparing the two periods we should point out that in the after-Euro period the persistence in the market was clearly decreased since *a* coefficient was around 0.19 and statistically significant (for 5% significance level) for AR(1) to AR(5), in contrast with the pre-Euro period when *a* coefficient was around 0.369 and statistically significant. This clearly indicates that the structures of the Athens

Stock Market have changed after the introduction of Euro thus probably increasing the market's efficiency as well, as the persistence was decreased[5]. Furthermore, we notice that in both periods β coefficient is around 0.94 and 0.97 respectively, depicting that the volatility of the previous day always had a great impact in the volatility of the next day and showing that the estimate of β is in all cases consistent and asymptotically normal, since $\sigma < 1$ in all cases and it is also statistically significant for 5% significance level.

Table 4 shows the results from our four diagnostic tests for the pre-Euro and after-Euro period focusing on the existing asymmetry in both periods. As we can notice looking at the pre-Euro period, the negative size-bias, the positive size-bias and the joint tests are the highly significant ones, for 1% significance level. These results highly suggest that innovations' sign is not very important and that large negative or positive innovations cause more volatility than the small ones, rising more the existing risk for the investors. However, negative large innovations cause volatility which is more than double compared to the one caused by the large positive innovations, a fact that is in agreement with the estimation of AR(5)-EGARCH(1,1) that clearly indicated the existence of asymmetric effect in the pre-Euro period. Focusing in the after-Euro period we notice that the sign bias, the negative size-bias and the joint test are highly significant for 1% significance level. The fact that the sign bias test is significant is totally consistent with the fact that positive size-bias test is not significant and thus the sign of innovations does matter on the volatility. Moreover, these results are strongly consistent with the estimation of the AR(5)-EGARCH(1,1) model depicting the existence of an asymmetric effect in the after-Euro period and justifying the results of this model.

Looking at table 5, we can see the results of AR(p)-IGARCH(1,1) estimation for the two different periods we studied. More specifically, comparing the period pre-Euro and after-Euro, we should underline the fact that β coefficient is around 0.788 for the different mean equations we used for the period 1993-2001, in contrast to the period 2002-2010 that β coefficient is around 0.883. This lead us to the conclusion that the existed volatility of the previous day affected more the volatility of the next day in the period after the introduction of Euro, showing that there is an increase in volatility in the after-Euro period and thus a rise on the risk of the stocks of the ASE index. This result of IGARCH agrees totally with the previous results we had from the analysis using the EGARCH model, since β coefficient was bigger in the period after-Euro in both used models. In addition, looking at c coefficient in the AR(p)-IGARCH(1,1) model we can see that $c > 0$ and statistically significant, for 5% significance level, in both periods, thus the β^2_t is strictly stationary.

In order to be sure about the explanatory capability of our models, we used the ARCH test for ARCH disturbances that has been proposed by Engle (1982). As we can see from the table 6 for the pre-Euro and from the table 7 for the after-Euro period, the best AR(P)-EGARCH(1,1) model is the AR(5)-EGARCH(1,1) as it has the greatest log-likelihood compared to the others in both periods. Looking at the AR(P)-IGARCH(1,1) models for both periods, we have to point out that they have the same log-likelihood value with the AR(P)-EGARCH(1,1) models, thus the AR(5)-IGARCH(1,1) is the best model among the other IGARCH(1,1) models for both periods too.

In table 8, we can see the result from the estimation of the likelihood ratio test comparing the AR(5)-EGARCH(1,1) and the AR(5)-IGARCH(1,1) model of the pre-Euro period with the AR(5)-EGARCH(1,1) and the AR(5)-IGARCH(1,1) model of the after-Euro period respectively. In this test, we used the AR(5)-EGARCH(1,1) model and the AR(5)-IGARCH(1,1) model as benchmarks in order to estimate the test. As we can see in table 8, the estimation of the likelihood-ratio test is statistically significant for 1% significance level, something that clearly indicates that AR(5)-IGARCH(1,1) and AR(5)-EGARCH(1,1) models, of the after-Euro period, outperform comparing to the AR(5)-IGARCH(1,1) and AR(5)-EGARCH(1,1) models of the pre-Euro period. Having chosen these four models (AR(5)-EGARCH(1,1) and AR(5)-IGARCH(1,1) for the pre-Euro period, AR(5)-EGARCH(1,1) and AR(5)-IGARCH(1,1) for the after-Euro period), we used the ARCH test in order to find the existence or not of ARCH disturbances. Looking at table 9 , we should underline the fact that *Sign.Level* < 005 in both periods for both models, confirming our assumption for ARCH disturbances. Thus, our models are well-established as we had a heteroskedastic financial residual series.

Conclusion

In order to study and evaluate the possible structural changes that happened in the main Athens index (ASE) of the Athens Stock Exchange Market, by the introduction of Euro, we decided to use two heteroskedastic models since we had a changeable variance, something that was justified by the results of ARCH test we used, which depicted clearly that we had an heteroskedastic financial residual series. Moreover, in order to study closely the possible asymmetries and the persistence that may have changed by the introduction of Euro, we decided that the AR(p)-EGARCH(1,1) and the AR(p)-IGARCH(1,1) model can appropriate depict them. Looking at the results from an overall perspective, we should point out that the persistence in the after-Euro period was decreased significantly, showing that the introduction of Euro had indeed changed the time that outer shocks lasted in the Athens Stock Market significantly, affecting this way the market's efficiency. In addition, after the introduction of Euro there is a significant change in the volatility of the ASE index, showing that the risk for the investors has also increased. More specifically, examining the asymmetries and the possible differences between the two periods, we have come to the conclusion that a big asymmetric effect existed in the period 2002-2010 in contrast to the period 1993-2001 in which the asymmetric effect was much smaller. The existence of asymmetries suggests the asymmetric increase of volatility of the ASE index, and thus the risk of the stocks, only when there was bad news. In addition, with the intent to analyze the existing asymmetries in a great depth, we used four diagnostic tests. In these tests the results are totally consistent with the estimation of the AR(P)-EGARCH(1,1) for both periods, since they found the existing asymmetry too, justifying the estimation's results. Furthermore, they showed that in the pre-Euro period the sign of innovations is not very important and that large negative or positive innovations cause more volatility than the small ones, while in the contrary in the after-Euro period, innovations' sign does matter since large negative innovations create more volatility, but this is something that does not appeal to the large positive innovations. This clearly suggests the increase of risk, in the after-Euro period, for the investments based on the stocks of the ASE index, especially when there was bad news on the market as the diagnostic test indicated.

NOTES

[1] Economic and Monetary Union.

[2] Also known as "The Maastricht criteria".

[3] It includes the 60 largest companies (blue chips) with the biggest capitalisation (big cap).

[4] FTSE20 includes the 20 largest companies with the greatest capitalization.

[5] The persistence is well-known as one of the factors that increase or not a market's efficiency, but it is not the only factor.

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APPENDIX

Table 1. Estimation results of AR(p)-EGARCH(1,1)

Pre-Euro Period

	AR(1)-EGARCH(1,1)			**AR(2)-EGARCH(1,1)**		
Parameters	Coefficient	T-Stat	Significance	Coefficient	T-Stat	Significance
c	-0.2949	-76.1271	0.0000	-0.2952	-7.4130	0.0000
β	0.9484	163.8466	0.0000	0.9487	65.2434	0.0000
α	0.3685	66.4231	0.0000	0.3695	7.9405	0.0000
γ	-0.0383	-1.5852	0.1129	-0.0347	-1.9248	0.0543
	AR(3)-EGARCH(1,1)			**AR(4)-EGARCH(1,1)**		
Parameters	Coefficient	T-Stat	Significance	Coefficient	T-Stat	Significance
c	-0.2950	-7.1659	0.0000	-0.2951	-6.0851	0.0000
β	0.9488	61.6994	0.0000	0.9488	52.1682	0.0000
α	0.3693	7.5836	0.0000	0.3694	6.4042	0.0000
γ	-0.0348	-1.7749	0.0759	-0.0346	-1.7110	0.0871
	AR(5)-EGARCH(1,1)					
Parameters	Coefficient	T-Stat	Significance			
c	-0.2952	-6.8017	0.0000			
β	0.9488	80.6444	0.0000			
α	0.3694	7.0694	0.0000			
γ	-0.0345	-2.1357	0.0327			

After-Euro Period

	AR(1)-EGARCH(1,1)			**AR(2)-EGARCH(1,1)**		
Parameters	Coefficient	T-Stat	Significance	Coefficient	T-Stat	Significance
c	-0.1582	-9.0107	0.0000	-0.1581	-8.2111	0.0000
β	0.9794	167.7600	0.0000	0.9794	156.9959	0.0000
α	0.1926	8.9585	0.0000	0.1925	8.0625	0.0000
γ	-0.0798	-5.1628	0.0000	-0.0799	-4.9969	0.0000
	AR(3)-EGARCH(1,1)			**AR(4)-EGARCH(1,1)**		
Parameters	Coefficient	T-Stat	Significance	Coefficient	T-Stat	Significance
c	-0.1577	-9.4390	0.0000	-0.1552	-9.0144	0.0000
β	0.9794	263.4359	0.0000	0.9798	179.0885	0.0000
α	0.1918	9.4600	0.0000	0.1894	8.8919	0.0000
γ	-0.0816	-7.0114	0.0000	-0.0857	-5.0203	0.0000
	AR(5)-EGARCH(1,1)					
Parameters	Coefficient	T-Stat	Significance			
c	-0.1553	-9.0253	0.0000			
β	0.9798	163.8751	0.0000			
α	0.1895	9.3179	0.0000			
γ	-0.0855	-5.2863	0.0000			

Table 2. Log-Likelihood Results

	AR(1)-EGARCH(1,1)	AR(2)-EGARCH(1,1)	AR(3)-EGARCH(1,1)	AR(4)-EGARCH(1,1)	AR(5)-EGARCH(1,1)
Log-Likelihood	-3163.4097	-3161.0718	-3159.7924	-3157.8356	-3156.3375

Table 3. Likelihood-ratio test results

	AR(5)-EGARCH(1,1) with AR(1)-EGARCH(1,1)	AR(5)-EGARCH(1,1) with AR(2)-EGARCH(1,1)	AR(5)-EGARCH(1,1) with AR(3)-EGARCH(1,1)	AR(5)-EGARCH(1,1) with AR(4)-EGARCH(1,1)
Likelihood-ratio test	14.1443*	9.4685**	6.9097**	2.9961***

Note: (*) denotes significance at the (1%) level, (**) at the (5%) significance level and (***) at the (10%) significance level.

Table 4. Diagnostic tests on asymmetry

Pre-Euro Period

Market Index	Sign bias(t-test)	Negative size bias (t-test)	Positive size bias test (t-test)	Joint test (F-test)
ASE Index	0.0440	-0.7622*	0.3315*	57.9446*

After-Euro Period

ASE Index	0.3686*	-0.8078*	0.1345	36.2956*

Sign bias test: $$z_t^2 = a + bS_t^- + e_t \quad \text{(i)}$$

Negative size bias test: $$z_t^2 = a + bS_t^- E_{t-1} + e_t \quad \text{(ii)}$$

Positive size bias test: $$z_t^2 = a + b\left(1 - S_t^-\right)E_{t-1} + e_t \quad \text{(iii)}$$

Joint test: $$z_t^2 = a + b_1 S_t^- + b_2 S_t^- E_{t-1} + b_3\left(1 - S_t^-\right)E_{t-1} + e_t \quad \text{(iv)}$$

Notes: (*) denotes significance at the (1%) level. z_t is the normalised residual from an AR (p) filter using constant variance. S^-_t is unity if E_{t-1} is negative and zero otherwise. The t-statistics for the sign bias, negative size bias and positive size bias tests are those of coefficient b in regression (i), (ii) and (iii), respectively. The F-statistic is based on regression (iv).

Table 5. Estimation results of AR(P)-IGARCH(1,1)

Pre-Euro Period

	AR(1)-IGARCH(1,1)			**AR(2)-IGARCH(1,1)**		
Parameters	Coefficient	T-Stat	Significance	Coefficient	T-Stat	Significance
c	0.0238	2.9332	0.0034	0.0241	2.9957	0.0027
β	0.7894	20.4223	0.0000	0.7877	20.4751	0.0000
α	0.2106	5.4495	0.0000	0.2123	5.5183	0.0000
	AR(3)-IGARCH(1,1)			**AR(4)-IGARCH(1,1)**		
Parameters	Coefficient	T-Stat	Significance	Coefficient	T-Stat	Significance
c	0.0240	3.0963	0.0020	0.0241	2.8639	0.0042
β	0.7883	21.3590	0.0000	0.7875	20.7738	0.0000
α	0.2117	5.7366	0.0000	0.2125	5.6060	0.0000
	AR(5)-IGARCH(1,1)					
Parameters	Coefficient	T-Stat	Significance			
c	0.0242	3.2717	0.0011			
β	0.7868	21.6950	0.0000			
α	0.2132	5.8792	0.0000			

After-Euro Period

	AR(1)-IGARCH(1,1)			**AR(2)-IGARCH(1,1)**		
Parameters	Coefficient	T-Stat	Significance	Coefficient	T-Stat	Significance
c	0.0084	2.9703	0.0030	0.0084	2.9988	0.0027
β	0.8841	49.4427	0.0000	0.8838	48.8378	0.0000
α	0.1159	6.4805	0.0000	0.1162	6.4238	0.0000
	AR(3)-IGARCH(1,1)			**AR(4)-IGARCH(1,1)**		
Parameters	Coefficient	T-Stat	Significance	Coefficient	T-Stat	Significance
c	0.0085	3.0371	0.0024	0.0085	2.9666	0.0030
β	0.8836	48.9679	0.0000	0.8833	47.6941	0.0000
α	0.1164	6.4484	0.0000	0.1167	6.3033	0.0000
	AR(5)-IGARCH(1,1)					
Parameters	Coefficient	T-Stat	Significance			
c	0.0086	2.9303	0.0034			
β	0.8826	47.4333	0.0000			
α	0.1174	6.3073	0.0000			

where 1-$\alpha = \beta$ in parameters

Table 6. Log-Likelihood Results for the pre-Euro period

					Pre-Euro period
	AR(1)-EGARCH(1,1)	AR(2)-EGARCH(1,1)	AR(3)-EGARCH(1,1)	AR(4)-EGARCH(1,1)	AR(5)-EGARCH(1,1)
Log-Likelihood	-3163.4097	-3161.0718	-3159.7924	-3157.8356	-3156.3375
	AR(1)-IGARCH(1,1)	AR(2)-IGARCH(1,1)	AR(3)-IGARCH(1,1)	AR(4)-IGARCH(1,1)	AR(5)-IGARCH(1,1)
Log-Likelihood	-3163.4097	-3161.0718	-3159.7924	-3157.8356	-3156.3375

Table 7. Log-Likelihood Results for the after-Euro period

					After-Euro period
	AR(1)-EGARCH(1,1)	AR(2)-EGARCH(1,1)	AR(3)-EGARCH(1,1)	AR(4)-EGARCH(1,1)	AR(5)-EGARCH(1,1)
Log-Likelihood	-2936.2476	-2932.8478	-2931.7977	-2928.2738	-2927.2493
	AR(1)-IGARCH(1,1)	AR(2)-IGARCH(1,1)	AR(3)-IGARCH(1,1)	AR(4)-IGARCH(1,1)	AR(5)-IGARCH(1,1)
Log-Likelihood	-2936.2476	-2932.8478	-2931.7977	-2928.2738	-2927.2493

Table 8. Likelihood-ratio test result

Likelihood-ratio test	458,1765*

Note: (*) denotes significance at the (1%) level. The result is the same for the AR(5)-EGARCH(1,1) and the AR(5)-IGARCH(1,1) model, since they have the same likelihoods.

Table 9. ARCH Test

Period Pre-Euro		
	Test Statistic	Significance Level
AR(5)-EGARCH(1,1)	135.0018*	0.0000
AR(5)-IGARCH(1,1)	134.7384*	0.0000
Period After-Euro		
	Test Statistic	Significance Level
AR(5)-EGARCH(1,1)	75.4479*	0.0000
AR(5)-IGARCH(1,1)	76.8803*	0.0000

Note: (*) denotes significance at the (1%) level