Applications of ARCH modelling in financial time series: the case of Germany

I. Exchange rate volatility modelling.

II. Time varying-premium in the term structure of interest rates.

Research Techniques Project

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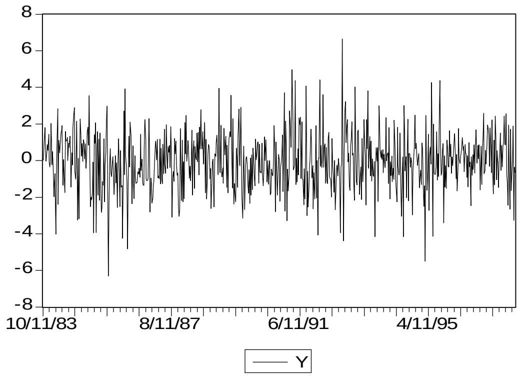
Introduction

ARCH and GARCH models in empirical finance have gained a wide use since their initial introduction by Engle (1982) to describe different phenomena. Mills (1999) and Bollerslev et al (1994) contain comprehensive surveys of these developments and of applications. This paper approaches two topics. In the first part we model the returns for the DEM/USD rate, more specifically its volatility, by using ARCH and GARCH models. In the second one, we apply the same tools to model a time-varying term premium in the yield curve that might explain failures of the expectation hypothesis.

PART 1 -Exchange rate volatility modelling

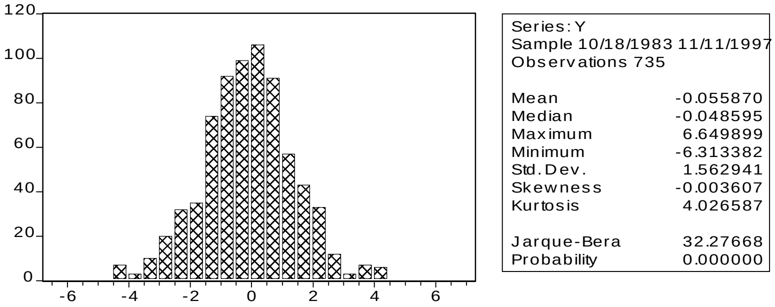
The data used in this part consists of weekly spot rates for the German mark over the period 11:10:1983-11:11:1997. The returns (first difference in logs) of the DEM exchange rate are plotted in Graph 1, resembling a white noise process, with the exception of a variable volatility (proxied by the variance), which will be investigated further.

Graph 1: DEM/USD returns



Further insights about the properties of the series can be gained by studying the histogram as plotted in Graph 2.

Graph 2: Histogram



```
Series:Y
Sample 10/18/1983 11/11/1997
Observations 735

Mean          -0.055870
Median        -0.048595
Maximum        6.649899
Minimum       -6.313382
Std.Dev.       1.562941
Skewness      -0.003607
Kurtosis       4.026587

Jarque-Bera    32.27668
Probability    0.000000
```

Examination of the histogram and descriptive statistics leads to the rejection of the normality of the series (which is often assumed in theoretical financial models). While the skewness is reasonably small, the excess kurtosis leads to the rejection of normality. This is indicated by the highly significant Jarque-Berra statistic. More specifically, the distribution is leptokurtic (it has fat tails), which usually generates a 'volatility smile' in the options on exchange rates (different implied volatilities for different exercise prices but same other characteristics). This finding is rather a common result (i.a Diebold and Nerlove (1989)). We also mention that the series is stationary, the ADF tests we performed rejecting the hypothesis of a unit root at 1% critical level (not reported, available at request), making subsequent statistical inference valid.

Correlogram of Y

```
Sample: 10/11/1983 11/11/1997
Included observations: 735
==========================================================================
Autocorrelation          Partial Correlation       AC      PAC     Q-Stat   Prob
==========================================================================
    .|*    |                .|*    |          1   0.070   0.070   3.6671   0.055
    .|.    |                .|.    |          2   0.023   0.018   4.0583   0.131
    .|.    |                .|.    |          3   0.026   0.023   4.5463   0.208
    .|.    |                .|.    |          4  -0.030  -0.034   5.2062   0.267
    .|.    |                .|.    |          5   0.027   0.031   5.7663   0.330
    .|.    |                .|.    |          6   0.008   0.004   5.8121   0.445
    .|.    |                .|.    |          7  -0.018  -0.018   6.0477   0.534
    .|.    |                .|.    |          8   0.030   0.030   6.7305   0.566
    .|.    |                .|.    |          9   0.026   0.024   7.2347   0.613
    .|.    |                .|.    |         10   0.024   0.020   7.6666   0.661
    .|.    |                .|.    |         11  -0.037  -0.045   8.7043   0.649
    .|.    |                .|.    |         12   0.023   0.030   9.0962   0.695
    .|.    |                .|.    |         13  -0.011  -0.014   9.1878   0.759
    .|.    |                .|.    |         14   0.034   0.036   10.034   0.760
    .|*    |                .|.    |         15   0.066   0.058   13.306   0.579
    .|.    |                .|.    |         16  -0.019  -0.025   13.570   0.631
    .|.    |                .|.    |         17   0.019   0.016   13.852   0.678
    .|.    |                .|.    |         18  -0.042  -0.048   15.166   0.651
    .|.    |                .|.    |         19  -0.003   0.009   15.172   0.712
    .|.    |                .|.    |         20  -0.008  -0.014   15.215   0.764
    .|.    |                .|.    |         21   0.005   0.014   15.237   0.811
    .|.    |                .|.    |         22  -0.005  -0.012   15.255   0.851
    .|.    |                .|.    |         23   0.028   0.028   15.832   0.862
    .|.    |                .|.    |         24  -0.040  -0.049   17.046   0.847
==========================================================================
```

In order to get some insights as to the dynamic data generating process for the Y series, we study the correlogram presented above. Based on this, we may conclude that only the first-order autocorrelation and partial autocorrelation functions are significant with values of 0.07 for both and a Q-statistic of 3.6671 (with an attached probability of 0.055). The other autocorrelations seem not to be significant.

1.1 ARCH and GARCH models

1.1.1 The mean equation

Based on the previous insights we try to estimate first some plausible models for the dynamics of the returns.

Generally, we estimate ARMA(p,q) models of the form:

$$y_t = c + \Phi(L) y_t + \theta(L)\varepsilon_t \qquad (1)$$

where $\mathbf{\Phi}$ and $\boldsymbol{\theta}$ are lag polynomials of the p and q order respectively, where $\mathbf{\Phi}$ does not have a free term.

As there appears to be informational content only for the first lag (judging by the correlograms), we tried to estimate AR(1), MA(1) and ARMA(1,1) models presenting the outputs in Appendix 2[1]. Judging by the AIC and the SBC the MA(1) model would seem the most appropriate. On the other hand, the AR(1) term proves to be significant in the ARMA (1,1) equation. We decided not to use the ARMA specification, however, due to the common factor that appears to be present. Testing (by a Wald test) the hypothesis that $\Phi_1=-\theta_1$ we obtained an F Statistic of 1.853856 (0.173755) leading to a non-rejection of the common factor. This would imply that the mean equation would comprise only a constant, which would be consistent with the non-predictability of returns (weak efficiency). However, as there seems to be informational content attached to the first lag (Φ_1 is marginally significant) we use an AR(1) model. This is far easier to manipulate and to use for forecasts and the improvement in the AIC and SBC are, however, marginal. In terms of the residual test, all the models perform similarly, so this cannot be a decision rule we rely upon. Moreover, we find support in Diebold and Nerlove (1989) who use an AR(3) even if they find a random walk to be the best description, arguing that this is a safeguard against specification error. This would account for any potential non-captured weakly serial correlation.

We present some of the residual tests for the chosen AR(1) (but not for the ARMA and MA models) model in Appendix 3. The Breusch-Godfrey test does not reject the null hypothesis of no serial correlation (conclusion supported by the plot of the correlogram) with a value of 0.451528 and an attached probability of 0.844079.

However, there is strong evidence of non-normality as indicated by the Jarque-Berra test (rejects normality at 0.00000 significance level) and the histogram plot.

An ARCH LM test indicates strong ARCH effects for the first three lags, consistent with the conclusion from the correlogram of the squared residuals. Thus the residuals are, although uncorrelatted, not independent. Finding and modelling ARCH effects help explaining contiguous periods of volatility and stability. Secondly, they are consistent with the unconditional leptokurtosis we found in the returns' distribution. Thirdly, they provide a parsimonious description of the evolving conditional variance. Fourthly, it would help forecasting the changing variance, i.e. to obtain time-varying confidence intervals for the point forecasts of the returns.

This leads us to the next step, i.e. using ARCH models to explain the changing variance.

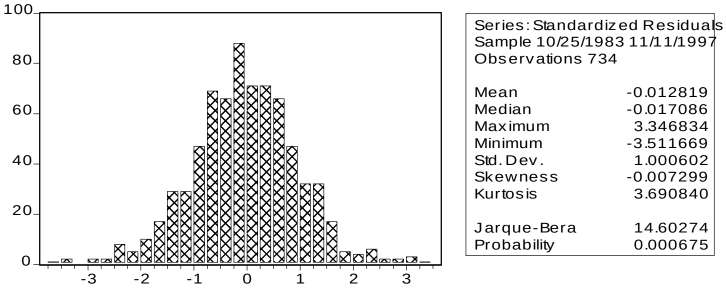
I.1.2 Modelling the conditional variance

Following Engle (1982), we estimate the model:

$$
\begin{aligned}
&y_t = c + \Phi_1 y_{t-1} + \varepsilon_t \\
&h_t = A(L)\varepsilon_t^2 \qquad\qquad\qquad (2) \\
&where \varepsilon_t / \Omega_{t-1} \sim N(0, h_t)
\end{aligned}
$$

A(L) is a lag polynomial of order m.

The first step is, as indicated by the ARCH test, the estimation of an ARCH(3,0)[2], i.e. m=3. As we can see from Appendix 4, the coefficients attached to all the ARCH terms (except the ARCH(1)) are statistically significant. There is however strong evidence of non-normality of residuals (excess Kurtosis) as indicated by the Jarque Berra test bellow.



```
Series: Standardized Residuals
Sample 10/25/1983 11/11/1997
Observations 734

Mean           -0.012819
Median         -0.017086
Maximum         3.346834
Minimum        -3.511669
Std. Dev.       1.000602
Skewness       -0.007299
Kurtosis        3.690840

Jarque-Bera    14.60274
Probability     0.000675
```

As we want to base our further tests on the standard errors of these residuals, we would have to use corrected standard errors in the subsequent estimations by using the Bollerslev-Wooldridge correction[3]. The estimation output with this correction is shown also in Appendix 4. We will use this correction in all the subsequent models.

We observe that using the corrected covariance matrix makes the a_2 and a_3 coefficients insignificant. Testing for non-captured ARCH effects by an LM test for four lags does not indicate the presence of any such effects (Appendix 4), not rejecting the null of all the coefficients of the squared residuals being jointly zero (F-stat=1.069770(0.3703)). However, we may observe the marginal significance of the fourth lag.

In light of this, we estimate an ARCH(4,0) and compare it with the previous one. As resulting from Appendix 5, the a_4 coefficient is significant. A Wald test for a_4=0 rejects the null hypothesis.

Wald Test:			
Equation: AR1			
Null Hypothesis:	C(7)=0		
F-statistic	3.768717	Probability	0.052606
Chi-square	3.768717	Probability	0.052220

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[1] I apologise for the rather huge number of Appendices but there was a trade-off between covering my statements with statistical output and providing a reasonably thin paper. I preffered to choose the first alternative

[2] All the GARCH estimation were carried in Eviews3.1 using the BHHH algorithm

[3] Alternatively, we could use the t distribution

As any ARCH model might have a more parsimonious GARCH representation (Bollerslev 1986, Boero 2000), the next step was to incorporate a GARCH term and test for its significance, as well as observing how the significance of the ARCH terms modifies. We thus estimated models that allow the conditional variance to be an ARMA process:

$$y_t = c + \Phi_1 y_{t-1} + \varepsilon_t$$

$$h_t = A(L)\varepsilon_t^2 + B(L)h_t \qquad (4)$$

$$where \varepsilon_t / \Omega_{t-1} \sim N(0, h_t)$$

where B(L) is a lag polynomial of order n.

The first GARCH model we estimate has m=4 and n=1 (i.e. there is a GARCH(4,1))[4] and we present the estimation output in Appendix 6. Observing that judging by the t-statistics the ARCH terms appear to be non-significant, we performed a Wald test for their joint significance (H_0: all a_i=0). The hypothesis is rejected at the 10% level but not at the 5% level.

Wald Test:			
Null Hypothesis:	a_i=0 for all i		
F-statistic	2.001979	Probability	0.092497
Chi-square	8.007914	Probability	0.091289

We thus try to adopt a general-to-specific approach in reducing the number of lags in the ARCH process. Testing for a_4 =0 is not rejected.

Wald Test:			
Null Hypothesis:	a_4=0		
F-statistic	0.058716	Probability	0.808605
Chi-square	0.058716	Probability	0.808536

We thus move to estimating GARCH(3,1) presenting the results in Appendix 6 together with a Wald test for a_3=0 which cannot be rejected even at 10% significance.

In light of this, we estimate a GARCH(2,1) (Appendix 7). The hypothesis a_2=0 is now rejected at a 0.0238 level.

Wald Test:			
Null Hypothesis:	a_2=0		
F-statistic	5.124232	Probability	0.023888
Chi-square	5.124232	Probability	0.023594

As the whole chain of tests led us to this last model, we would choose it as representing the dynamics of the series. Using the AIC and SBc as decision rules, we synthesize this information for all the estimated models in the next table

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[4] By a GARCH(m,n) process we mean a process with m ARCH terms. We use this notation to be consistent with the Eviews output, although iti is different from the usual one

Tests for AR(1) - GARCH(m,n) models, QML estimation, Bolerslev-Wooldridge Corrected Std Errors

	ARCH(3,0)	ARCH(4,0)	GARCH(4,1)	GARCH(3,1)	GARCH(2,1)
JB*	14.60274	12.10750	12.28501	12.16835	14.26392
ARCH(4)**	0.370396	0.987807	0.992430	0.997868	0.702314
AIC	3.724227	3.717924	3.716284	3.713582	3.714152
SBC	3.761817	3.761779	3.766404	3.757437	3.751742

*test values, ** significance levels

Not surprisingly, the conclusion from the AIC is different from the one based on SBC as the last one penalizes for the extra lags. However, since based on the Wald test we could reject the 3rd-order term in the ARCH we choose the GARCH(2,1) model to describe the dynamics as it is more parsimonious. We will thus use this model in the subsequent analysis.

Further analysis

In terms of forecasting, we again tried to compare the GARCH(2,1) and GARCH(3,1) models, presenting the results in Appendices 7A and 7B. The forecasts are made over the period 11:10:1995-11:11:1997 with the corresponding models[5]. Again, the GARCH(2,1) model performs better in terms of forecasting (static), judging by the RMSE of 1.194558 compared to 1.196235 for GARCH(2,1). For the dynamic method the values are 1.188447 as opposed to 1.189657 respectively.

We observe that the sum $a_1+a_2+b_1=0.892$ implying that the volatility shocks are persistent in the returns of the exchange rate, which comes as no surprise for the chosen high-frequency series. The IGARCH hypothesis has been tested and reported below:

Wald Test:			
Equation: AR1			
Null Hypothesis:	C(4)+C(5)+C(6)=1		
F-statistic	3.507739	Probability	0.061483
Chi-square	3.507739	Probability	0.061083

This fact makes also the forecast of the conditional variance converge to the steady state rather slowly (appendices 7ab). However, the process does not explode (sum of coefficients=1 rejected at 10%), which is consistent with the results rejection of a unit root. We also observe that $a_1<0$, but the conditional variance may still be well specified since it is of a rather small magnitude and is not significant statistically (the probability of the t-statistic is 0.6483).

For the chosen model we perform residual tests: there is no serial correlation as indicated by the correlogram and the Q-statistic.

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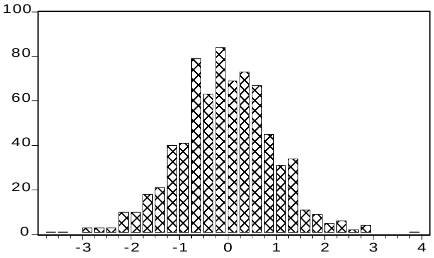
[5] We adopt this due to space constraints, although a rigorous procedure would imply performing the same algorithm for the subsample for estimation, insuring that the models give the best description

```
Q-statistic
probabilities adjusted
for 1 ARMA term(s)
==========================================================================
Autocorrelation        Partial Correlation          AC      PAC     Q-Stat   Prob
==========================================================================
      .|.    |           .|.    |            1   0.009   0.009   0.0562
      .|.    |           .|.    |            2   0.034   0.034   0.9021   0.342
      .|.    |           .|.    |            3   0.035   0.034   1.7915   0.408
      .|.    |           .|.    |            4  -0.027  -0.028   2.3126   0.510
      .|.    |           .|.    |            5   0.020   0.018   2.5980   0.627
      .|.    |           .|.    |            6   0.018   0.019   2.8422   0.724
      .|.    |           .|.    |            7  -0.010  -0.009   2.9117   0.820
      .|.    |           .|.    |            8   0.028   0.025   3.5034   0.835
      .|.    |           .|.    |            9   0.006   0.006   3.5320   0.897
      .|.    |           .|.    |           10   0.025   0.024   3.9831   0.913
      .|.    |           .|.    |           11  -0.034  -0.038   4.8227   0.903
      .|.    |           .|.    |           12   0.019   0.019   5.1010   0.926
      .|.    |           .|.    |           13  -0.009  -0.009   5.1619   0.952
      .|.    |           .|.    |           14   0.025   0.026   5.6147   0.959
      .|.    |           .|.    |           15   0.059   0.056   8.2415   0.876
      .|.    |           .|.    |           16  -0.031  -0.033   8.9773   0.879
      .|.    |           .|.    |           17   0.018   0.013   9.2090   0.905
      .|.    |           .|.    |           18  -0.032  -0.035   9.9716   0.905
      .|.    |           .|.    |           19   0.002   0.008   9.9733   0.933
      .|.    |           .|.    |           20  -0.004  -0.009   9.9836   0.953
      .|.    |           .|.    |           21   0.004   0.009   9.9959   0.968
      .|.    |           .|.    |           22   0.004   0.001   10.010   0.979
      .|.    |           .|.    |           23   0.041   0.040   11.292   0.970
      .|.    |           .|.    |           24  -0.041  -0.043   12.568   0.961
==========================================================================
```

The ARCH LM test indicates that there are no ARCH effects not captured by the model. (please see Appendix 7), the probability attached to the TR^2 being 0.8346 and thus not rejecting the 'no-further-ARCH' hypothesis.

However, we did not obtain normality, the Jarque Berra test strongly rejecting the normality hypothesis as shown below.

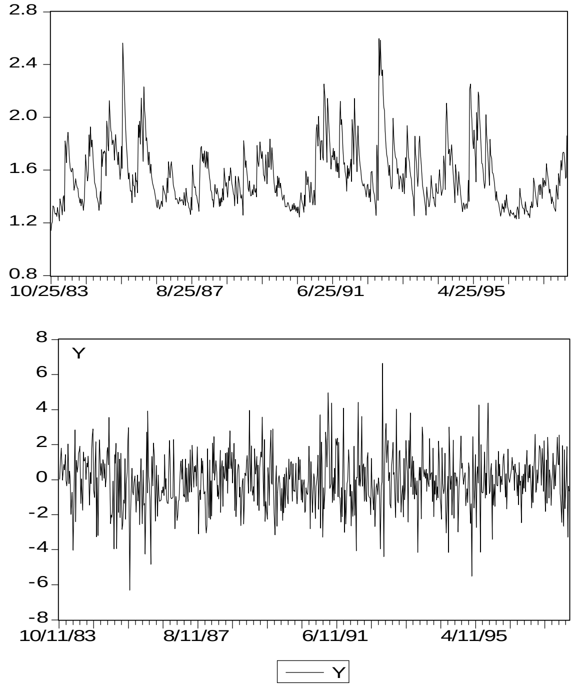


```
Series:Standardized Residuals
Sample 10/25/1983 11/11/1997
Observations 734

Mean         -0.020915
Median       -0.024659
Maximum       3.977519
Minimum      -3.543635
Std.Dev.      1.000026
Skewness      0.004140
Kurtosis      3.682881

Jarque-Bera   14.26392
Probability   0.000799
```

Even with non-normal residuals, the estimates are still consistent under QML estimation assumptions.

We can plot the graph of the one-step ahead conditional standard deviation

Conditional Standard Deviation vs Returns



Comparing it with the plot of the returns, we see that indeed increases in the conditional standard deviation are associated with clustering of large (in absolute value) observations in the original series. This is the usual volatility-clustering phenomenon observed in the behaviour of this series (i.a Diebold and Nerlove 1989) and other exchange rates.

Conclusions I

The univariate GARCH approach we tried up to now seems satisfactory in describing exchange rate movements. Notably, the forecasts of the variance improve and these are important in option pricing as traders actually 'trade volatility'. This is a rather common result in early ARCH modelling. However, for a better description of the dynamics a multivariate approach proves necessary. Covariances among exchange rates should be modelled as risk premia depend on them. They are likely to be non-zero and the conditional ones may vary over time (Diebold and Nerlove 1989). Moreover, latent variable considerations (presence of news) should lead to a multivariate specification.

PART TWO - The Expectations Hypothesis of the term structure and GARCH-M modelling

In this part we attempt to test the expectations hypothesis (EH, as opposed to the pure expectation hypothesis that says that expected excess return on long over short-term bonds is zero) for the term structure of interest rates for the case of Germany. By contrast, EH postulates that the expected excess returns are constant over time. While we do not attempt to give an account of the financial theory underlying it, a review of this can be found in Campbell et al (1997). Many attempts have been made to explain possible failures of the EH, a review of these being made in, e.g. Campbell et al. (1997). What we try in this part is to assess the explanatory power of ARCH and GARCH modelling for the potential failure of EH, i.e. to see whether the expected excess holding yield of a bond depends on its conditional variance. We follow the approach of, i.a. Engle et al (1987), Taylor (1992) or Engle and Ng(1993) to test for time-varying premia as a possible explanation.

The data used consists of weekly observations on bid Euro-interest rates for 1, 3 and 6 months maturity from the Bank of International Settlements, observed on Friday each week, 10 a.m. Swiss time.

The equations we estimate are approximations for weekly data of the theoretical versions of the EH for one and three month maturities as formulated in Boero (2000)

$$\frac{2}{3}(r_{t+4}^{1}-r_{t}^{1})+\frac{1}{3}(r_{t+9}^{1}-r_{t+4}^{1})=a+b(r_{t}^{3}-r_{t}^{1})+\varepsilon_{t+9} \qquad (5)$$

$$r_{t+4}^{3}-r_{t}^{3}=a+b\frac{1}{2}(r_{t}^{3}-r_{t}^{1})+\varepsilon_{t+4} \qquad (6)$$

II.1 Testing the EH with rational expectations.

Equations (5) and (6) can be estimated by OLS[6]. The outputs of these regressions are presented in Appendices 8 and 9.[7]. Investigation of the residuals (diagnostic tests reported in the appendices 8 and 9) of the equations reveals a few immediate problems. We expect the errors to be autocorrelated having the structure MA(i) where i is 9-1=8 and 4-1=1, respectively, due to overlapping expectational errors in the changes in the future short rates. Moreover, if there is a time-varying term premium, the errors are likely to display serial correlation, conditional heteroskedasticity and be correlated with the term spread (Tzavalis and Wickens 1997).

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[6] the variables were found to be I(0); the tests are not reported but are available at request

[7] Note that the names of the constructed variables are VDE and SPDE for eq. 5 and LRDE, respectively HSPDE for (6)

Inspecting the diagnostic tests we find confirmation of the expected results: there are strong serial correlation and ARCH effects as well as non-normality. Moreover, the correlograms of the residuals resemble the structure of MA(8) and MA(3) data generating processes, as expected.

In order to perform the subsequent analysis we will thus have to use a correction of covariance matrix, consistent with the presence of heteroskedasticity and serial correlation of unknown form, as the Newey-West correction provided by EViews. Estimation outputs using the corrected standard errors are presented in the final sections of Appendices 8 and 9. These are the representations we will use further.

In order to test for the Rational Expectations Hypothesis of the Term structure we perform Wald tests (which are valid using the robust standard errors) for testing the null hypothesis H0: $b=1$ in both equations, presenting the results in the table bellow:

Table: Tests of the REHTS

Wald Test:			
Equation 5			
Null Hypothesis:	C(2)=1		
F-statistic	7.988228	Probability	0.004893
Chi-square	7.988228	Probability	0.004708

Wald Test:			
Equation: 6			
Null Hypothesis:	C(2)=1		
F-statistic	1.421523	Probability	0.233701
Chi-square	1.421523	Probability	0.233153

For equation 5, the hypothesis is strongly rejected. For equation 6 the Wald test cannot reject the null. However, this does not mean that the EH is accepted. A careful look at the coefficient and its standard error leads us believe that there is such a great uncertainty attached to the estimated coefficient that the hypothesis b=0 is not rejected either (judging by its t-statistic). Thus, the conclusion is rather that the estimate is imprecise.

The rejections of the EH for Germany are in contrast with the findings of Hardouvelis (1994), who nevertheless used a different data set and differently constructed variables.

II.2 ARCH-M and GARCH-M models

Many attempts have been made to explain the failures of EH (either the varying premia or by modelling irrational expectations), involving a wide variety of methods, both uni- and multivariate.

Here we just follow one of them, i.e. using ARCH in mean and GARCH in mean processes to take into account a time varying term premium as pioneered by Engle et al(1987).

The argument for estimating such models runs as follows: variables with apparent explanatory power for the dynamics of the spread (useful in forecasting excess returns) may be correlated with the risk premia and thus would use their significance when a risk measure is included in the regression.

We would estimate models of the form:

$$\begin{aligned} y_t &= a + bx_t + f(h_t) + \varepsilon_t, \varepsilon_t / \Omega_t \sim N(0, h_t^2) \\ h_t &= A(L)h_t + B(L)\varepsilon_t^2 \end{aligned} \qquad (7)$$

where y and x are the corresponding spreads and f is either the variance or the standard deviation. For ARCH-M processes A(L) will be identically zero.

Looking at the ARCH test for equations 5 and 6 we try to model the documented ARCH effects. The 'algorithm' we followed is identical to the one in Part 1, but we decided not to present it in detail due to space constraints. For (5), we tried ARCH(1,0) but there were still non-captured ARCH effects. We moved to testing ARCH(2,0) and GARCH (1,1) and we have chosen the latter due to the AIC of -1.113283

as compared to -1.111797 for ARCH(2,0). For equation 6, following the same reasoning we also decided on a GARCH(2,1) model with an AIC of -0.297251 as compared to GARCH(1,1), having an AIC of -0.278928 and to -0.255415 for the ARCH(1,0). Estimation results are given in Appendix 10.

Diagnostic tests (Appendix 11) show that we have normality (for equation 5) and no further ARCH effects, but we still have the serial correlation, probably generated by the overlapping expectational errors. We mention that we use the Bollerslev-Wooldridge corrected standard errors.

However, the time-varying risk premium is swept into the error term and generates misspecification (ELR 1987 p. 400). We thus move to incorporate a measure of risk in the mean equation by estimating the described GARCH-M models. For both cases we included the standard deviation h_t in the mean equation. The statistical reason is that trying the variance this was not significant (for (6) it was but just at the 10% level)[8]. The economic reason is that changes in the variance are reflected less than proportionally in the mean. The estimation results are presented in Appendix 12 and summarised bellow.

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[8] we do not report the results for using the variance

Model (7) for:

Equation (5) with GARCH (1,1)

	Coefficient	Std. Error	z-Statistic	Prob.
SQR(GARCH)	-0.183494	0.072013	-2.548069	0.0108
C	0.005996	0.008530	0.702975	0.4821
SPDE	0.528680	0.026858	19.68459	0.0000
	Variance Equation			
C	0.002650	0.000560	4.735286	0.0000
ARCH(1)	0.822579	0.116609	7.054179	0.0000
GARCH(1)	0.219254	0.056620	3.872360	0.0001

Equation (6) with GARCH(2,1)

	Coefficient	Std. Error	z-Statistic	Prob.
SQR(GARCH)	-0.287861	0.083936	-3.429532	0.0006
C	0.042036	0.015671	2.682440	0.0073
HSPDE	0.534857	0.077924	6.863794	0.0000
	Variance Equation			
C	0.002408	0.000750	3.208853	0.0013
ARCH(1)	0.745117	0.109748	6.789330	0.0000
ARCH(2)	-0.535463	0.100888	-5.307508	0.0000
GARCH(1)	0.768512	0.060411	12.72140	0.0000

First of all, we observe that the sum of the estimated coefficients in the variance equation is greater than one in each situation, indicating that the unconditional variance of the yields is infinite and its distribution has fat tails. Shocks in its level thus have permanent effects, which is not an unusual result for yield curve modelling. Tests for the IGARCH hypothesis in both cases are reported below:

IGARCH test - equation 5

```
Wald Test:
Equation: EQ2A
=========================================================
Null Hypothesis:     C(5)+C(6)=1
=========================================================
F-statistic          0.225290     Probability    0.635243
Chi-square           0.225290     Probability    0.635038
=========================================================
```

IGARCH test - equation 6

```
Wald Test:
Equation: EQ3A
=========================================================
Null Hypothesis:     C(5)+C(6)+C(7)=1
=========================================================
F-statistic          0.682465     Probability    0.409125
Chi-square           0.682465     Probability    0.408739
=========================================================
```

For completion, we also estimated TARCH and EGARCH models for the same specification in order to take into account any asymmetric effects that are present[9]. While in all cases the asymmetric terms are statistically significant, they do not change the main conclusions (estimation outputs are presented in Appendix 13). Moreover, there is even a loss of statistical significance in (6) of the standard deviation in the mean equation if we are to choose the TARCH model as indicated by the AIC and SBC (Appendix 13).

Conclusions II

In contrast with the findings of ELR(1987), in our case introduction of a measure of risk does not do a good job in explaining the time varying term premium. The coefficient on the spread in (5) falls with 0.7 but its t-statistic actually rises. In equation (6) things are worse, the fall being of 0.05. However, the most important is the high statistical significance of the spread as opposed to the uncertainty in the OLS case. These results are hardly consistent with the 'dramatic' fall in ELR paper. However, the risk premium is statistically significant in explaining the time-varying term premium. Nevertheless, the unsuccess in explaining the EH failure does not exclude the possibility that another specification of the risk premium can do a better job (e.g. by taking into account only systematic risk by using a time-varying beta CAPM for the term structure as suggested by Taylor(1992)).

The failure of these simple models to explain why EH does not hold comes as no surprise. Even in this univariate case, any omitted variable has been swept into the disturbance and thus all the statistics are biased. In trying to explain failures of the EH it has been shown that multivariate models can do a better job as in Campbell and Shiller (1987) or Taylor (1992). Moreover, as the interest rates are also a policy variable, the relation between policy and the term spread needs to be modelled (Boero and Torricelli, 1998). Thus, a system estimation in which a policy rule is specified may prove necessary.

---

[9] Presence of such effects can be more plausible in analysing interest rates on corporate bonds. However, we present the results for completion

Appendix 2: different models for the mean equation

AR(1)

```
Dependent Variable: Y
Method: Least Squares

Sample(adjusted): 10/25/1983 11/11/1997
Included observations: 734 after adjusting endpoints
Convergence achieved after 3 iterations
==========================================================================
Variable              Coefficient  Std. Error   t-Statistic   Prob.
==========================================================================
C                     -0.056041    0.061995     -0.903958     0.3663
AR(1)                 0.070505     0.036873     1.912117      0.0563
==========================================================================
R-squared             0.004970       Mean dependent var       -0.055973
Adjusted R-squared    0.003611       S.D. dependent var       1.564004
S.E. of regression    1.561178       Akaike info criterion    3.731480
Sum squared resid     1784.087       Schwarz criterion        3.744010
Log likelihood        -1367.453      F-statistic              3.656190
Durbin-Watson stat    2.001929       Prob(F-statistic)        0.056251
==========================================================================
Inverted AR Roots          .07
===========================================================================
```

MA(1)

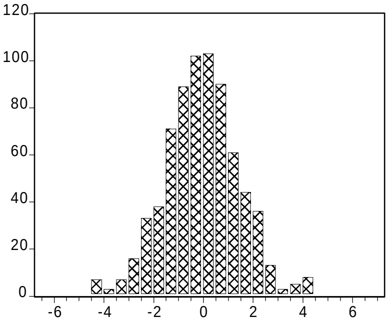
```
Dependent Variable: Y
Method: Least Squares

Sample(adjusted): 10/18/1983 11/11/1997
Included observations: 735 after adjusting endpoints
Convergence achieved after 4 iterations
Backcast: 10/11/1983
==========================================================================
Variable              Coefficient  Std. Error   t-Statistic   Prob.
==========================================================================
C                     -0.055922    0.061464     -0.909837     0.3632
MA(1)                 0.068095     0.036854     1.847711      0.0650
==========================================================================
R-squared             0.004791       Mean dependent var       -0.055870
Adjusted R-squared    0.003433       S.D. dependent var       1.562941
S.E. of regression    1.560256       Akaike info criterion    3.730294
Sum squared resid     1784.414       Schwarz criterion        3.742811
Log likelihood        -1368.883      F-statistic              3.528396
Durbin-Watson stat    1.997202       Prob(F-statistic)        0.060723
==========================================================================
Inverted MA Roots         -.07
===========================================================================
```

ARMA(1,1)

```
Dependent Variable: Y
Method: Least Squares

Sample(adjusted): 10/25/1983 11/11/1997
Included observations: 734 after adjusting endpoints
Convergence achieved after 15 iterations
Backcast: 10/18/1983
==========================================================================
Variable              Coefficient  Std. Error   t-Statistic   Prob.
==========================================================================
C                     -0.012954    0.017225     -0.752040     0.4523
AR(1)                 0.802950     0.177154     4.532506      0.0000
MA(1)                 -0.766333    0.191243     -4.007111     0.0001
==========================================================================
R-squared             0.006529       Mean dependent var       -0.055973
Adjusted R-squared    0.003811       S.D. dependent var       1.564004
S.E. of regression    1.561022       Akaike info criterion    3.732637
Sum squared resid     1781.292       Schwarz criterion        3.751432
Log likelihood        -1366.878      F-statistic              2.401922
Durbin-Watson stat    1.939587       Prob(F-statistic)        0.091258
==========================================================================
Inverted MA Roots          .77
===========================================================================
```

Appendix 3: tests for AR(1)

Histogram of residuals



```
Series: Residuals
Sample 10/25/1983 11/11/1997
Observations 734

Mean          -2.21E-17
Median        -0.007160
Maximum        6.711607
Minimum       -6.148869
Std. Dev.      1.560113
Skewness      -0.000997
Kurtosis       4.002072

Jarque-Bera    30.71035
Probability    0.000000
```

Correlogram of squared residuals

```
Sample: 10/25/1983 11/11/1997
Included observations: 734
  Q-statistic probabilities
   adjusted for 1 ARMA
          term(s)

   Autocorrelation       Partial Correlation        AC      PAC     Q-Stat    Prob

         .|.    |              .|.    |        1  -0.015  -0.015   0.1748
         .|*    |              .|*    |        2   0.068   0.068   3.6277   0.057
         .|*    |              .|*    |        3   0.079   0.082   8.2545   0.016
         .|.    |              .|.    |        4   0.058   0.057   10.754   0.013
         .|.    |              .|.    |        5   0.051   0.043   12.676   0.013
         .|.    |              .|.    |        6   0.019   0.007   12.941   0.024
         .|.    |              .|.    |        7  -0.004  -0.019   12.951   0.044
         .|.    |              .|.    |        8   0.052   0.040   14.990   0.036
         .|.    |              *|.    |        9  -0.057  -0.062   17.435   0.026
         .|.    |              .|.    |       10   0.024   0.014   17.871   0.037
         .|*    |              .|*    |       11   0.078   0.081   22.415   0.013
         .|.    |              .|.    |       12   0.023   0.030   22.811   0.019
```

LM test for serial correlation

```
Breusch-Godfrey Serial Correlation LM Test:

F-statistic           0.451528      Probability               0.844079
Obs*R-squared         2.728839      Probability               0.842029


Test Equation:
Dependent Variable: RESID
Method: Least Squares

Presample missing value lagged residuals set to zero.

Variable              Coefficient   Std. Error    t-Statistic    Prob.

C                     -0.001912     0.062184      -0.030751      0.9755
AR(1)                 14.61580      20.71762      0.705477       0.4807
RESID(-1)             -14.61586     20.71772      -0.705476      0.4807
RESID(-2)             -1.014079     1.461163      -0.694022      0.4879
RESID(-3)             -0.046562     0.109488      -0.425267      0.6708
RESID(-4)             -0.039859     0.037929      -1.050883      0.2937
RESID(-5)             0.028373      0.037250      0.761702       0.4465
RESID(-6)             0.007647      0.037264      0.205224       0.8375

R-squared             0.003718        Mean dependent var      -2.21E-17
Adjusted R-squared    -0.005888       S.D. dependent var      1.560113
S.E. of regression    1.564699        Akaike info criterion   3.744104
Sum squared resid     1777.454        Schwarz criterion       3.794224
```

```
Log likelihood          -1366.086     F-statistic              0.387024
Durbin-Watson stat      2.001730      Prob(F-statistic)        0.910188
```

ARCH Test:

```
F-statistic             2.707074      Probability              0.029360
Obs*R-squared           10.74253      Probability              0.029615

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares

Sample(adjusted): 11/22/1983 11/11/1997
Included observations: 730 after adjusting endpoints
Variable                Coefficient   Std. Error   t-Statistic   Prob.

C                       1.999293      0.232183     8.610857      0.0000
RESID^2(-1)             -0.024856     0.037083     -0.670287     0.5029
RESID^2(-2)             0.065177      0.036969     1.763008      0.0783
RESID^2(-3)             0.082937      0.037078     2.236820      0.0256
RESID^2(-4)             0.057166      0.037198     1.536823      0.1248

R-squared               0.014716      Mean dependent var       2.437385
Adjusted R-squared      0.009280      S.D. dependent var       4.223914
S.E. of regression      4.204270      Akaike info criterion    5.716904
Sum squared resid       12815.02      Schwarz criterion        5.748364
Log likelihood          -2081.670     F-statistic              2.707074
Durbin-Watson stat      2.004755      Prob(F-statistic)        0.029360
```

Appendix 4 ARCH and GARCH models - estimation results

ARCH (3,0)

```
Dependent Variable: Y
Method: ML - ARCH

Sample(adjusted): 10/25/1983 11/11/1997
Included observations: 734 after adjusting endpoints
Convergence achieved after 14 iterations
==========================================================================
                        Coefficient  Std. Error   z-Statistic   Prob.
==========================================================================
C                       -0.030130    0.060166     -0.500775     0.6165
AR(1)                   0.059383     0.036443     1.629498      0.1032
==========================================================================
                           Variance Equation
==========================================================================
C                       2.027690     0.153828     13.18152      0.0000
ARCH(1)                 -0.018993    0.025629     -0.741078     0.4586
ARCH(2)                 0.057829     0.032991     1.752870      0.0796
ARCH(3)                 0.131412     0.038958     3.373148      0.0007
==========================================================================
R-squared               0.004603       Mean dependent var       -0.055973
Adjusted R-squared      -0.002233      S.D. dependent var       1.564004
S.E. of regression      1.565750       Akaike info criterion    3.724227
Sum squared resid       1784.745       Schwarz criterion        3.761817
Log likelihood          -1360.791      F-statistic              0.673348
Durbin-Watson stat      1.978786       Prob(F-statistic)        0.643770
==========================================================================
Inverted AR Roots            .06
==========================================================================
```

ARCH(3,0,) with corrected standard errors

```
Dependent Variable: Y
Method: ML - ARCH

Sample(adjusted): 10/25/1983 11/11/1997
Included observations: 734 after adjusting endpoints
Convergence achieved after 14 iterations
Bollerslev-Wooldrige robust standard errors & covariance
==========================================================================
                        Coefficient  Std. Error   z-Statistic   Prob.
==========================================================================
C                       -0.030130    0.059346     -0.507697     0.6117
AR(1)                   0.059383     0.034433     1.724626      0.0846
==========================================================================
                           Variance Equation
==========================================================================
C                       2.027690     0.196954     10.29525      0.0000
ARCH(1)                 -0.018993    0.022351     -0.849773     0.3955
ARCH(2)                 0.057829     0.046158     1.252838      0.2103
ARCH(3)                 0.131412     0.060814     2.160892      0.0307
==========================================================================
R-squared               0.004603       Mean dependent var       -0.055973
Adjusted R-squared      -0.002233      S.D. dependent var       1.564004
S.E. of regression      1.565750       Akaike info criterion    3.724227
Sum squared resid       1784.745       Schwarz criterion        3.761817
Log likelihood          -1360.791      F-statistic              0.673348
Durbin-Watson stat      1.978786       Prob(F-statistic)        0.643770
==========================================================================
Inverted AR Roots            .06
==========================================================================

ARCH Test:
==========================================================================
F-statistic             1.069770       Probability              0.370396
Obs*R-squared           4.283311       Probability              0.369020
==========================================================================

Test Equation:
Dependent Variable: STD_RESID^2
Method: Least Squares

Sample(adjusted): 11/22/1983 11/11/1997
Included observations: 730 after adjusting endpoints
```

White Heteroskedasticity-Consistent Standard Errors & Covariance

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.937338	0.082663	11.33933	0.0000
STD_RESID^2(-1)	-0.003648	0.031911	-0.114316	0.9090
STD_RESID^2(-2)	-0.002302	0.040474	-0.056881	0.9547
STD_RESID^2(-3)	-0.005143	0.042772	-0.120237	0.9043
STD_RESID^2(-4)	0.076692	0.045436	1.687926	0.0919

R-squared	0.005868	Mean dependent var	1.002594
Adjusted R-squared	0.000383	S.D. dependent var	1.645197
S.E. of regression	1.644883	Akaike info criterion	3.840041
Sum squared resid	1961.588	Schwarz criterion	3.871500
Log likelihood	-1396.615	F-statistic	1.069770
Durbin-Watson stat	2.004306	Prob(F-statistic)	0.370396

Appendix 5
ARCH(4,0)

```
Dependent Variable: Y
Method: ML - ARCH

Sample(adjusted): 10/25/1983 11/11/1997
Included observations: 734 after adjusting endpoints
Convergence achieved after 14 iterations
Bollerslev-Wooldrige robust standard errors & covariance
=========================================================================
                         Coefficient   Std. Error   z-Statistic   Prob.
=========================================================================
C                        -0.017370     0.058566     -0.296592     0.7668
AR(1)                     0.070180     0.034785      2.017532     0.0436
=========================================================================
                              Variance Equation
=========================================================================
C                         1.766096     0.194403      9.084700     0.0000
ARCH(1)                  -0.021175     0.025352     -0.835213     0.4036
ARCH(2)                   0.061157     0.049106      1.245409     0.2130
ARCH(3)                   0.147761     0.061345      2.408677     0.0160
ARCH(4)                   0.097071     0.050003      1.941318     0.0522
=========================================================================
R-squared                 0.004441      Mean dependent var     -0.055973
Adjusted R-squared       -0.003776      S.D. dependent var      1.564004
S.E. of regression        1.566954      Akaike info criterion   3.717924
Sum squared resid         1785.036      Schwarz criterion       3.761779
Log likelihood           -1357.478      F-statistic             0.540453
Durbin-Watson stat        2.000203      Prob(F-statistic)       0.777606
=========================================================================
Inverted AR Roots            .07
=========================================================================
```

Appendix 6

GARCH (4,1)

```
Dependent Variable: Y
Method: ML - ARCH

Sample(adjusted): 10/25/1983 11/11/1997
Included observations: 734 after adjusting endpoints
Convergence achieved after 19 iterations
Bollerslev-Wooldrige robust standard errors & covariance
==========================================================================
                        Coefficient   Std. Error   z-Statistic   Prob.
==========================================================================
C                       -0.024296     0.057501     -0.422539     0.6726
AR(1)                    0.073170     0.035122      2.083275     0.0372
==========================================================================
                            Variance Equation
==========================================================================
C                        0.725906     0.330051      2.199378     0.0279
ARCH(1)                 -0.023305     0.027665     -0.842389     0.3996
ARCH(2)                  0.074520     0.051329      1.451794     0.1466
ARCH(3)                  0.117683     0.072115      1.631887     0.1027
ARCH(4)                  0.017066     0.070430      0.242315     0.8085
GARCH(1)                 0.523556     0.190585      2.747108     0.0060
==========================================================================
R-squared                0.004608       Mean dependent var      -0.055973
Adjusted R-squared      -0.004989       S.D. dependent var       1.564004
S.E. of regression       1.567901       Akaike info criterion    3.716284
Sum squared resid        1784.735       Schwarz criterion        3.766404
Log likelihood          -1355.876       F-statistic              0.480174
Durbin-Watson stat       2.006640       Prob(F-statistic)        0.849312
==========================================================================
Inverted AR Roots            .07
==========================================================================
```

GARCH(3,1)

```
Dependent Variable: Y
Method: ML - ARCH

Sample(adjusted): 10/25/1983 11/11/1997
Included observations: 734 after adjusting endpoints
Convergence achieved after 26 iterations
Bollerslev-Wooldrige robust standard errors & covariance
==========================================================================
                        Coefficient   Std. Error   z-Statistic   Prob.
==========================================================================
C                       -0.023574     0.057319     -0.411278     0.6809
AR(1)                    0.072331     0.035136      2.058603     0.0395
==========================================================================
                            Variance Equation
==========================================================================
C                        0.629986     0.279026      2.257807     0.0240
ARCH(1)                 -0.022974     0.027554     -0.833779     0.4044
ARCH(2)                  0.075566     0.051110      1.478490     0.1393
ARCH(3)                  0.114736     0.070143      1.635737     0.1019
GARCH(1)                 0.580713     0.156551      3.709420     0.0002
==========================================================================
R-squared                0.004595       Mean dependent var      -0.055973
Adjusted R-squared      -0.003620       S.D. dependent var       1.564004
S.E. of regression       1.566833       Akaike info criterion    3.713582
Sum squared resid        1784.759       Schwarz criterion        3.757437
Log likelihood          -1355.885       F-statistic              0.559360
Durbin-Watson stat       2.004898       Prob(F-statistic)        0.762804
==========================================================================
Inverted AR Roots            .07
==========================================================================

Wald Test:
Equation: AR1
=================================================================
Null Hypothesis:      C(6)=0
=================================================================
F-statistic           2.675637          Probability        0.102327
Chi-square            2.675637          Probability        0.101895
=================================================================
```

Appendix 7 GARCH(2,1)

Dependent Variable: Y
Method: ML - ARCH

Sample(adjusted): 10/25/1983 11/11/1997
Included observations: 734 after adjusting endpoints
Convergence achieved after 20 iterations
Bollerslev-Wooldrige robust standard errors & covariance

	Coefficient	Std. Error	z-Statistic	Prob.
C	-0.016055	0.057546	-0.279001	0.7802
AR(1)	0.067497	0.035574	1.897329	0.0578
		Variance Equation		
C	0.270859	0.144147	1.879048	0.0602
ARCH(1)	-0.014293	0.031340	-0.456074	0.6483
ARCH(2)	0.112061	0.049504	2.263677	0.0236
GARCH(1)	0.794662	0.084935	9.356087	0.0000

R-squared	0.004392	Mean dependent var	-0.055973
Adjusted R-squared	-0.002446	S.D. dependent var	1.564004
S.E. of regression	1.565916	Akaike info criterion	3.714152
Sum squared resid	1785.124	Schwarz criterion	3.751742
Log likelihood	-1357.094	F-statistic	0.642277
Durbin-Watson stat	1.994662	Prob(F-statistic)	0.667506
Inverted AR Roots	.07		

ARCH Test:

F-statistic	0.462372	Probability	0.836320
Obs*R-squared	2.790431	Probability	0.834653

Test Equation:
Dependent Variable: STD_RESID^2
Method: Least Squares

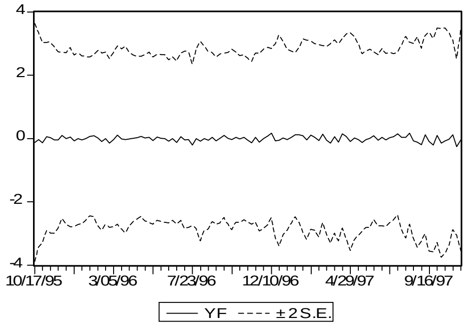
Sample(adjusted): 12/06/1983 11/11/1997
Included observations: 728 after adjusting endpoints
White Heteroskedasticity-Consistent Standard Errors & Covariance

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.013793	0.096752	10.47832	0.0000
STD_RESID^2(-1)	-0.004259	0.035387	-0.120366	0.9042
STD_RESID^2(-2)	-0.019039	0.035936	-0.529808	0.5964
STD_RESID^2(-3)	0.052185	0.064812	0.805185	0.4210
STD_RESID^2(-4)	-0.001052	0.030228	-0.034789	0.9723
STD_RESID^2(-5)	-0.020828	0.031164	-0.668334	0.5041
STD_RESID^2(-6)	-0.018512	0.034258	-0.540359	0.5891

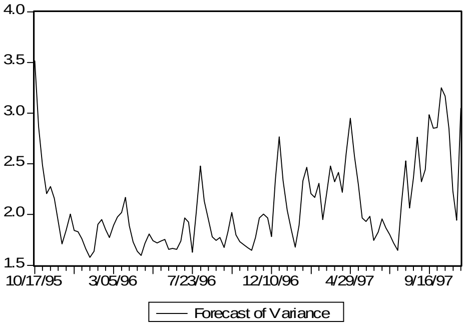
R-squared	0.003833	Mean dependent var	1.002101
Adjusted R-squared	-0.004457	S.D. dependent var	1.642468
S.E. of regression	1.646124	Akaike info criterion	3.844293
Sum squared resid	1953.712	Schwarz criterion	3.888431
Log likelihood	-1392.323	F-statistic	0.462372
Durbin-Watson stat	2.000571	Prob(F-statistic)	0.836320

Appendix 7A - Static Forecasts

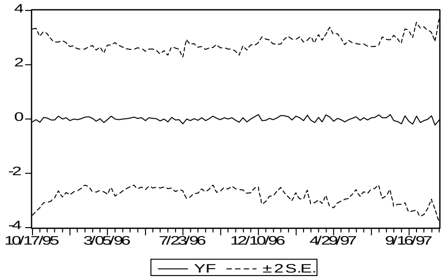
GARCH(3,1) - static



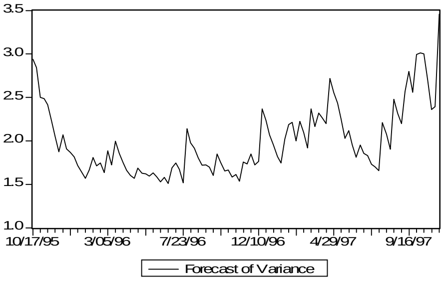
```
Forecast: YF
Actual: Y
Forecast sample: 10/17/1995 11
Included observations: 109

Root Mean Squared Error        1.196235
Mean Absolute Error            0.962281
Mean Abs. Percent Error        99.57621
Theil Inequality Coefficient   0.940267
     Bias Proportion           0.023437
     Variance Proportion       0.827319
     Covariance Proportion     0.149245
```



GARCH(2,1)-static

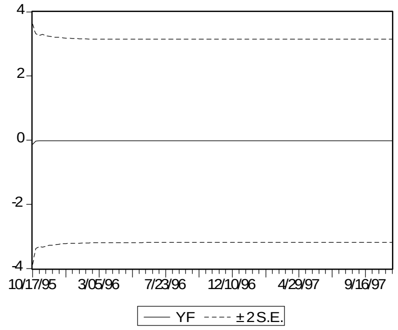


```
Forecast: YF
Actual: Y
Forecast sample: 10/17/1995 11
Included observations: 109

Root Mean Squared Error        1.194558
Mean Absolute Error            0.960632
Mean Abs. Percent Error        99.27896
Theil Inequality Coefficient   0.943539
     Bias Proportion           0.021964
     Variance Proportion       0.838375
     Covariance Proportion     0.139661
```

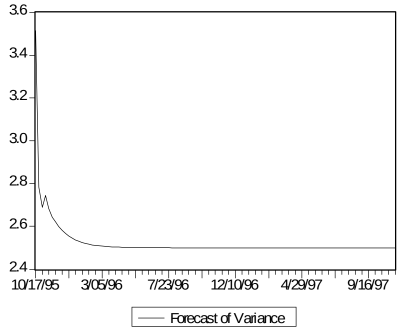


Appendix 7B Dynamic Forecasts

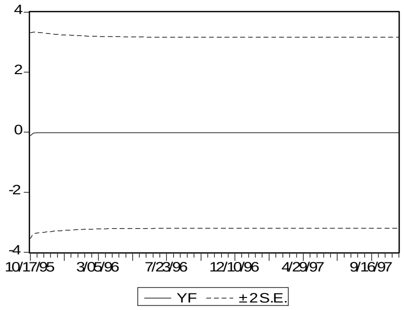
GARCH(3,1)-static



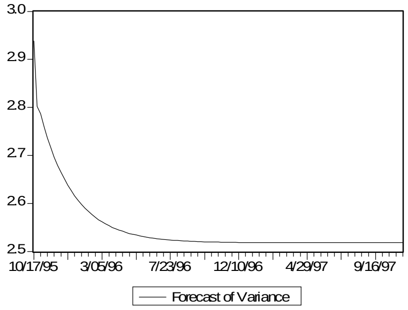
```
Forecast: YF
Actual: Y
Forecast sample: 10/17/1995 11
Included observations: 109

Root Mean Squared Error        1.189657
Mean Absolute Error            0.954024
Mean Abs. Percent Error        98.81488
Theil Inequality Coefficient   0.980970
     Bias Proportion           0.027659
     Variance Proportion       0.956681
     Covariance Proportion     0.015660
```



GARCH(2,1)



```
Forecast: YF
Actual: Y
Forecast sample: 10/17/1995 11
Included observations: 109

Root Mean Squared Error        1.188447
Mean Absolute Error            0.953056
Mean Abs. Percent Error        98.80839
Theil Inequality Coefficient   0.985773
     Bias Proportion           0.025630
     Variance Proportion       0.959644
     Covariance Proportion     0.014725
```



Appendix 8

Equation 5

```
Dependent Variable: VDE
Method: Least Squares

Sample(adjusted): 11/16/1985 9/09/1995
Included observations: 513 after adjusting endpoints
==========================================================================
Variable              Coefficient   Std. Error     t-Statistic     Prob.
==========================================================================
C                     -0.037569     0.009267       -4.054215       0.0001
SPDE                   0.602385     0.046152       13.05212        0.0000
==========================================================================
R-squared              0.250027       Mean dependent var           -0.005536
Adjusted R-squared     0.248559       S.D. dependent var            0.233478
S.E. of regression     0.202392       Akaike info criterion        -0.353329
Sum squared resid      20.93186       Schwarz criterion            -0.336798
Log likelihood         92.62894       F-statistic                   170.3578
Durbin-Watson stat     0.310656       Prob(F-statistic)             0.000000
==========================================================================
```

Correlogram and Q Statistics

```
Sample: 11/16/1985 9/09/1995
Included observations: 513
================================================================================
Autocorrelation          Partial Correlation        AC      PAC     Q-Stat   Prob
================================================================================
      .|*******|               .|*******|      1   0.845   0.845   368.06   0.000
      .|*****  |               .|.      |      2   0.705  -0.029   625.10   0.000
      .|****   |               *|.      |      3   0.548  -0.139   780.90   0.000
      .|***    |               *|.      |      4   0.378  -0.154   855.21   0.000
      .|**     |               .|**     |      5   0.321   0.283   908.65   0.000
      .|*      |              **|.      |      6   0.190  -0.306   927.51   0.000
      .|*      |               .|.      |      7   0.095  -0.018   932.19   0.000
      .|.      |               .|.      |      8   0.012  -0.049   932.26   0.000
      *|.      |               .|.      |      9  -0.077   0.042   935.38   0.000
      *|.      |               .|*      |     10  -0.063   0.123   937.45   0.000
      *|.      |               .|.      |     11  -0.067  -0.017   939.79   0.000
      .|.      |               .|.      |     12  -0.056  -0.042   941.47   0.000
================================================================================
```

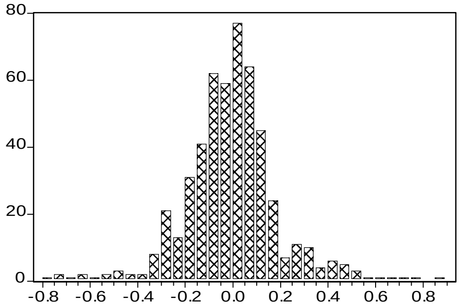
```
Breusch-Godfrey Serial Correlation LM Test:
==========================================================================
F-statistic            144.7192       Probability                   0.000000
Obs*R-squared          398.4967       Probability                   0.000000
==========================================================================

Test Equation:
Dependent Variable: RESID
Variable              Coefficient   Std. Error     t-Statistic     Prob.
==========================================================================
C                     -0.001257     0.004434       -0.283417       0.7770
SPDE                   0.023393     0.022447        1.042164       0.2978
RESID(-1)              0.965306     0.044686        21.60196       0.0000
RESID(-2)             -0.000840     0.062144       -0.013521       0.9892
RESID(-3)             -0.024455     0.061841       -0.395445       0.6927
RESID(-4)             -0.365769     0.061806       -5.917990       0.0000
RESID(-5)              0.494642     0.063752        7.758801       0.0000
RESID(-6)             -0.241420     0.067470       -3.578194       0.0004
RESID(-7)              0.045410     0.067522        0.672519       0.5016
RESID(-8)             -0.103292     0.063785       -1.619388       0.1060
RESID(-9)             -0.075664     0.061865       -1.223053       0.2219
RESID(-10)             0.136963     0.061906        2.212430       0.0274
RESID(-11)             0.022515     0.062219        0.361860       0.7176
RESID(-12)            -0.043608     0.044783       -0.973754       0.3307
==========================================================================
```

```
ARCH Test:
==========================================================================
F-statistic            63.91295       Probability                   0.000000
Obs*R-squared          306.1819       Probability                   0.000000
==========================================================================
```

Test Equation:
Dependent Variable: RESID^2

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.011823	0.003274	3.611249	0.0003
RESID^2(-1)	0.859547	0.045263	18.98993	0.0000
RESID^2(-2)	-0.033491	0.059674	-0.561235	0.5749
RESID^2(-3)	-0.146249	0.058822	-2.486318	0.0132
RESID^2(-4)	0.021093	0.058453	0.360852	0.7184
RESID^2(-5)	0.086703	0.058396	1.484731	0.1383
RESID^2(-6)	-0.036984	0.058289	-0.634490	0.5261
RESID^2(-7)	-0.118097	0.058278	-2.026426	0.0433
RESID^2(-8)	0.059136	0.058376	1.013009	0.3116
RESID^2(-9)	0.206505	0.058429	3.534275	0.0004
RESID^2(-10)	-0.224557	0.058797	-3.819202	0.0002
RESID^2(-11)	0.029097	0.059649	0.487809	0.6259
RESID^2(-12)	0.013301	0.045247	0.293964	0.7689

Normality



```
Series: Residuals
Sample 11/16/1985 9/09/1995
Observations 513

Mean          2.25E-17
Median        0.001426
Maximum       0.878616
Minimum      -0.798673
Std. Dev.     0.202194
Skewness      0.120643
Kurtosis      5.821932

Jarque-Bera   171.4600
Probability   0.000000
```

Equation 5 with corrected standard errors

Dependent Variable: VDE
Sample(adjusted): 11/16/1985 9/09/1995
Included observations: 513 after adjusting endpoints
Newey-West HAC Standard Errors & Covariance (lag truncation=5)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.037569	0.017799	-2.110720	0.0353
SPDE	0.602385	0.140682	4.281906	0.0000

R-squared	0.250027	Mean dependent var	-0.005536
Adjusted R-squared	0.248559	S.D. dependent var	0.233478
S.E. of regression	0.202392	Akaike info criterion	-0.353329
Sum squared resid	20.93186	Schwarz criterion	-0.336798
Log likelihood	92.62894	F-statistic	170.3578
Durbin-Watson stat	0.310656	Prob(F-statistic)	0.000000

Appendix 9

Equation 6

```
Dependent Variable: LRDE
Method: Least Squares

Sample(adjusted): 11/16/1985 10/14/1995
Included observations: 518 after adjusting endpoints
=========================================================================
Variable               Coefficient   Std. Error      t-Statistic    Prob.
=========================================================================
C                      -0.019900     0.013025        -1.527851      0.1272
HSPDE                  0.540194      0.130302        4.145717       0.0000
=========================================================================
R-squared              0.032234        Mean dependent var           -0.005676
Adjusted R-squared     0.030359        S.D. dependent var           0.290413
S.E. of regression     0.285971        Akaike info criterion        0.338001
Sum squared resid      42.19817        Schwarz criterion            0.354410
Log likelihood         -85.54220       F-statistic                  17.18697
Durbin-Watson stat     0.463649        Prob(F-statistic)            0.000040
=========================================================================
```

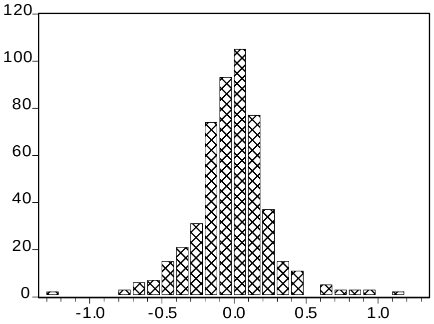
Correlogram

```
Sample: 11/16/1985 10/14/1995
Included observations: 518
===========================================================================
Autocorrelation       Partial Correlation        AC      PAC     Q-Stat  Prob
===========================================================================
   .|****** |            .|****** |        1   0.768   0.768   307.43  0.000
   .|****   |            *|.      |        2   0.532   -0.142  454.98  0.000
   .|**     |           **|.      |        3   0.274   -0.208  494.14  0.000
   .|.      |            *|.      |        4   0.022   -0.187  494.39  0.000
   .|.      |            .|***    |        5   -0.002  0.370   494.39  0.000
   .|.      |            *|.      |        6   -0.044  -0.158  495.40  0.000
   .|.      |            *|.      |        7   -0.045  -0.068  496.48  0.000
   .|.      |            .|.      |        8   -0.028  -0.037  496.90  0.000
   .|.      |            .|**     |        9   -0.013  0.226   496.99  0.000
   .|.      |            *|.      |        10  0.019   -0.095  497.17  0.000
   .|.      |            *|.      |        11  0.026   -0.064  497.54  0.000
   .|.      |            .|.      |        12  0.029   -0.008  497.98  0.000
===========================================================================
```

```
Breusch-Godfrey Serial Correlation LM Test:
=========================================================================
F-statistic            103.2125        Probability                  0.000000
Obs*R-squared          368.1782        Probability                  0.000000
=========================================================================

Test Equation:
Dependent Variable: RESID
Method: Least Squares

Presample missing value lagged residuals set to zero.
=========================================================================
Variable               Coefficient   Std. Error      t-Statistic    Prob.
=========================================================================
C                      -0.002635     0.007135        -0.369306      0.7121
HSPDE                  0.097259      0.078159        1.244377       0.2139
RESID(-1)              0.946663      0.044490        21.27798       0.0000
RESID(-2)              0.028210      0.061237        0.460669       0.6452
RESID(-3)              -0.089621     0.061258        -1.463023      0.1441
RESID(-4)              -0.631853     0.059955        -10.53879      0.0000
RESID(-5)              0.666396      0.065004        10.25162       0.0000
RESID(-6)              -0.086835     0.071371        -1.216669      0.2243
RESID(-7)              -0.084026     0.071394        -1.176933      0.2398
RESID(-8)              -0.258571     0.065157        -3.968450      0.0001
RESID(-9)              0.313342      0.059919        5.229380       0.0000
RESID(-10)             -0.032726     0.061386        -0.533124      0.5942
RESID(-11)             -0.058876     0.061402        -0.958868      0.3381
RESID(-12)             -0.013136     0.044830        -0.293011      0.7696
=========================================================================


=========================================================================
```

```
ARCH Test:
==========================================================================
F-statistic               76.38041      Probability               0.000000
Obs*R-squared             243.5844      Probability               0.000000
==========================================================================

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Date: 04/30/00   Time: 17:26
Sample(adjusted): 12/28/1985 10/14/1995
Included observations: 512 after adjusting endpoints
==========================================================================
Variable                  Coefficient  Std. Error   t-Statistic   Prob.
==========================================================================
C                         0.028428     0.007434     3.824152      0.0001
RESID^2(-1)               0.771410     0.044471     17.34647      0.0000
RESID^2(-2)               -0.167628    0.056161     -2.984800     0.0030
RESID^2(-3)               0.015757     0.056481     0.278972      0.7804
RESID^2(-4)               0.099482     0.056479     1.761405      0.0788
RESID^2(-5)               -0.028760    0.056159     -0.512119     0.6088
RESID^2(-6)               -0.036549    0.044469     -0.821895     0.4115
```

Normality



```
Series: Residuals
Sample 11/16/1985 10/14/1995
Observations 518

Mean          3.94E-17
Median        0.003694
Maximum       1.250993
Minimum      -1.293991
Std. Dev.     0.285694
Skewness      0.102411
Kurtosis      6.858273

Jarque-Bera   322.2008
Probability   0.000000
```

Equation 6 with corrected standard errors

```
Dependent Variable: LRDE
Method: Least Squares

Sample(adjusted): 11/16/1985 10/14/1995
Included observations: 518 after adjusting endpoints
Newey-West HAC Standard Errors & Covariance (lag truncation=5)
==========================================================================
Variable                  Coefficient  Std. Error   t-Statistic   Prob.
==========================================================================
C                         -0.019900    0.021632     -0.919957     0.3580
HSPDE                     0.540194     0.385654     1.400724      0.1619
==========================================================================
R-squared                 0.032234      Mean dependent var        -0.005676
Adjusted R-squared        0.030359      S.D. dependent var        0.290413
S.E. of regression        0.285971      Akaike info criterion     0.338001
Sum squared resid         42.19817      Schwarz criterion         0.354410
Log likelihood            -85.54220     F-statistic               17.18697
Durbin-Watson stat        0.463649      Prob(F-statistic)         0.000040
==========================================================================
```

Appendix 10

ARCH modelling for equation 5

```
Dependent Variable: VDE
Method: ML - ARCH

Sample(adjusted): 11/16/1985 9/09/1995
Included observations: 513 after adjusting endpoints
Convergence achieved after 16 iterations
================================================================
                      Coefficient   Std. Error   z-Statistic   Prob.
================================================================
C                     -0.015885     0.004560     -3.483816     0.0005
SPDE                   0.521266     0.024946     20.89558      0.0000
================================================================
                           Variance Equation
================================================================
C                      0.003780     0.000663      5.699912     0.0000
ARCH(1)                0.854450     0.115073      7.425259     0.0000
ARCH(2)                0.195038     0.057516      3.391026     0.0007
================================================================
R-squared              0.239947       Mean dependent var     -0.005536
Adjusted R-squared     0.233962       S.D. dependent var      0.233478
S.E. of regression     0.204348       Akaike info criterion  -1.111797
Sum squared resid      21.21319       Schwarz criterion      -1.070469
Log likelihood         290.1760       F-statistic             40.09358
Durbin-Watson stat     0.309033       Prob(F-statistic)       0.000000
```

```
Dependent Variable: VDE
Method: ML - ARCH

Sample(adjusted): 11/16/1985 9/09/1995
Included observations: 513 after adjusting endpoints
Convergence achieved after 16 iterations
================================================================
                      Coefficient   Std. Error   z-Statistic   Prob.
================================================================
C                     -0.015705     0.004511     -3.481696     0.0005
SPDE                   0.517079     0.025997     19.88996      0.0000
================================================================
                           Variance Equation
================================================================
C                      0.002809     0.000571      4.915303     0.0000
ARCH(1)                0.841089     0.108601      7.744757     0.0000
GARCH(1)               0.201328     0.047108      4.273779     0.0000
================================================================
R-squared              0.239494       Mean dependent var     -0.005536
Adjusted R-squared     0.233506       S.D. dependent var      0.233478
S.E. of regression     0.204409       Akaike info criterion  -1.113283
Sum squared resid      21.22583       Schwarz criterion      -1.071955
Log likelihood         290.5572       F-statistic             39.99410
Durbin-Watson stat     0.309060       Prob(F-statistic)       0.000000
================================================================
```

ARCH modelling for equation 6

ARCH(1,0)

```
Dependent Variable: LRDE
Method: ML - ARCH

Sample(adjusted): 11/16/1985 10/14/1995
Included observations: 518 after adjusting endpoints
Convergence achieved after 26 iterations
================================================================
                      Coefficient   Std. Error   z-Statistic   Prob.
================================================================
C                     -0.009704     0.009295     -1.043957     0.2965
HSPDE                  0.538849     0.082029      6.568981     0.0000
================================================================
                           Variance Equation
================================================================
C                      0.019779     0.001302      15.19362     0.0000
ARCH(1)                0.744679     0.114251      6.517906     0.0000
================================================================
R-squared              0.031008       Mean dependent var     -0.005676
Adjusted R-squared     0.025352       S.D. dependent var      0.290413
S.E. of regression     0.286708       Akaike info criterion  -0.255415
Sum squared resid      42.25166       Schwarz criterion      -0.222597
```

```
Log likelihood          70.15250        F-statistic                5.482650
Durbin-Watson stat      0.462995        Prob(F-statistic)          0.001029
===========================================================================
```

GARCH(1,1)

```
Dependent Variable: LRDE
Method: ML - ARCH

Sample(adjusted): 11/16/1985 10/14/1995
Included observations: 518 after adjusting endpoints
Convergence achieved after 25 iterations
===========================================================================
                        Coefficient   Std. Error   z-Statistic   Prob.
===========================================================================
C                       -0.016730     0.008147     -2.053475     0.0400
HSPDE                   0.494479      0.077264     6.399851      0.0000
===========================================================================
                              Variance Equation
===========================================================================
C                       0.009013      0.001455     6.195797      0.0000
ARCH(1)                 0.645768      0.094218     6.853990      0.0000
GARCH(1)                0.292287      0.032615     8.961623      0.0000
===========================================================================
R-squared               0.031958        Mean dependent var        -0.005676
Adjusted R-squared      0.024410        S.D. dependent var         0.290413
S.E. of regression      0.286847        Akaike info criterion     -0.278928
Sum squared resid       42.21024        Schwarz criterion         -0.237905
Log likelihood          77.24241        F-statistic                4.233871
Durbin-Watson stat      0.461290        Prob(F-statistic)          0.002216
===========================================================================
```

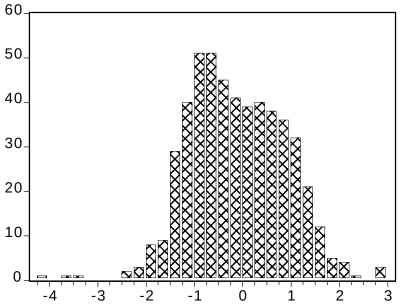
GARCh(2,1)

```
Dependent Variable: LRDE
Method: ML - ARCH

Sample(adjusted): 11/16/1985 10/14/1995
Included observations: 518 after adjusting endpoints
Convergence achieved after 31 iterations
===========================================================================
                        Coefficient   Std. Error   z-Statistic   Prob.
===========================================================================
C                       -0.014409     0.008137     -1.770661     0.0766
HSPDE                   0.539041      0.080909     6.662347      0.0000
===========================================================================
                              Variance Equation
===========================================================================
C                       0.004036      0.001923     2.098994      0.0358
ARCH(1)                 0.732548      0.113441     6.457506      0.0000
ARCH(2)                 -0.457894     0.145174     -3.154111     0.0016
GARCH(1)                0.683127      0.144011     4.743563      0.0000
===========================================================================
R-squared               0.031880        Mean dependent var        -0.005676
Adjusted R-squared      0.022426        S.D. dependent var         0.290413
S.E. of regression      0.287138        Akaike info criterion     -0.297251
Sum squared resid       42.21363        Schwarz criterion         -0.248023
Log likelihood          82.98792        F-statistic                3.372010
Durbin-Watson stat      0.463422        Prob(F-statistic)          0.005243
===========================================================================
```

Appendix 11: Diagnostic tests

Equation 5 with GARCH (1,1)

Normality



```
Series: Standardized Residuals
Sample 11/16/1985 9/09/1995
Observations 513

Mean          -0.085543
Median        -0.179317
Maximum        2.925953
Minimum       -4.035959
Std. Dev.      0.997196
Skewness      -0.003470
Kurtosis       3.223231

Jarque-Bera    1.066186
Probability    0.586787
```

Serial Correlation

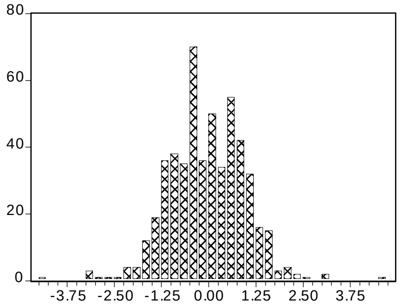
```
Sample: 11/16/1985 9/09/1995
Included observations: 513
=========================================================================
Autocorrelation        Partial Correlation        AC     PAC    Q-Stat  Prob
=========================================================================
      .|****  |             .|****  |       1   0.590  0.590   179.58  0.000
      .|***   |             .|*     |       2   0.447  0.152   282.87  0.000
      .|**    |             .|.     |       3   0.321  0.013   336.31  0.000
      .|*     |             *|.     |       4   0.147 -0.134   347.53  0.000
      .|**    |             .|**    |       5   0.244  0.258   378.54  0.000
      .|*     |             *|.     |       6   0.122 -0.130   386.31  0.000
      .|*     |             .|.     |       7   0.074 -0.035   389.15  0.000
      .|.     |             *|.     |       8   0.006 -0.104   389.17  0.000
      *|.     |             *|.     |       9  -0.135 -0.100   398.74  0.000
      .|.     |             .|*     |      10  -0.031  0.132   399.25  0.000
      .|.     |             .|.     |      11  -0.018  0.053   399.42  0.000
      .|.     |             .|.     |      12   0.011  0.006   399.48  0.000
=========================================================================
```

ARCH LM test

```
F-statistic          0.667733     Probability          0.572154
Obs*R-squared        2.011074     Probability          0.570111
==================================================================

Test Equation:
Dependent Variable: STD_RESID^2
Sample(adjusted): 12/07/1985 9/09/1995
Included observations: 510 after adjusting endpoints
Newey-West HAC Standard Errors & Covariance (lag truncation=5)
==================================================================
Variable             Coefficient  Std. Error   t-Statistic   Prob.
==================================================================
C                    1.013164     0.102998     9.836742      0.0000
STD_RESID^2(-1)      0.023764     0.031319     0.758772      0.4483
STD_RESID^2(-2)      0.020890     0.028878     0.723380      0.4698
STD_RESID^2(-3)      -0.054966    0.024762     -2.219781     0.0269
==================================================================
```

Equation 6 with GARCH(2,1)

Normality



Series: Standardized Residuals
Sample 11/16/1985 10/14/1995
Observations 518

Mean	-0.002025
Median	-0.013632
Maximum	4.603485
Minimum	-4.302942
Std. Dev.	1.000945
Skewness	-0.042139
Kurtosis	4.278197
Jarque-Bera	35.41590
Probability	0.000000

Serial Correlation

```
Sample: 11/16/1985 10/14/1995
Included observations: 518
Autocorrelation        Partial Correlation        AC      PAC      Q-Stat   Prob
     .|****   |            .|****   |       1   0.549    0.549    157.29   0.000
     .|***    |            .|*      |       2   0.392    0.129    237.60   0.000
     .|**     |            *|.      |       3   0.200   -0.086    258.43   0.000
     *|.      |           **|.      |       4  -0.066   -0.270    260.74   0.000
     .|.      |            .|**     |       5   0.017    0.214    260.90   0.000
     .|.      |            .|.      |       6  -0.011    0.035    260.96   0.000
     .|.      |            .|.      |       7   0.012   -0.010    261.04   0.000
     .|.      |            *|.      |       8   0.017   -0.102    261.19   0.000
     .|.      |            .|*      |       9   0.014    0.084    261.29   0.000
     .|.      |            .|.      |      10   0.001   -0.015    261.29   0.000
     .|.      |            .|.      |      11  -0.014   -0.015    261.40   0.000
     .|.      |            .|.      |      12  -0.026   -0.053    261.77   0.000
```

ARCH LM Test

F-statistic	0.806633	Probability	0.490562
Obs*R-squared	2.427345	Probability	0.488565

Test Equation:
Dependent Variable: STD_RESID^2
Method: Least Squares

Sample(adjusted): 12/07/1985 10/14/1995
Included observations: 515 after adjusting endpoints
Newey-West HAC Standard Errors & Covariance (lag truncation=5)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.965089	0.110658	8.721343	0.0000
STD_RESID^2(-1)	0.061561	0.036793	1.673165	0.0949
STD_RESID^2(-2)	0.004737	0.027252	0.173835	0.8621
STD_RESID^2(-3)	-0.030136	0.021693	-1.389196	0.1654

Appendix 12: GARCH-M models

Equation 5 - GARCH-M(1,1)

Dependent Variable: VDE
Method: ML - ARCH

Sample(adjusted): 11/16/1985 9/09/1995
Included observations: 513 after adjusting endpoints
Convergence achieved after 46 iterations

	Coefficient	Std. Error	z-Statistic	Prob.
SQR(GARCH)	-0.183494	0.072013	-2.548069	0.0108
C	0.005996	0.008530	0.702975	0.4821
SPDE	0.528680	0.026858	19.68459	0.0000
		Variance Equation		
C	0.002650	0.000560	4.735286	0.0000
ARCH(1)	0.822579	0.116609	7.054179	0.0000
GARCH(1)	0.219254	0.056620	3.872360	0.0001
R-squared	0.210791	Mean dependent var		-0.005536
Adjusted R-squared	0.203008	S.D. dependent var		0.233478
S.E. of regression	0.208436	Akaike info criterion		-1.120415
Sum squared resid	22.02694	Schwarz criterion		-1.070821
Log likelihood	293.3865	F-statistic		27.08303
Durbin-Watson stat	0.301035	Prob(F-statistic)		0.000000

Equation 6 - GARCH(2,1)

Dependent Variable: LRDE
Method: ML - ARCH

Sample(adjusted): 11/16/1985 10/14/1995
Included observations: 518 after adjusting endpoints
Convergence achieved after 41 iterations

	Coefficient	Std. Error	z-Statistic	Prob.
SQR(GARCH)	-0.287861	0.083936	-3.429532	0.0006
C	0.042036	0.015671	2.682440	0.0073
HSPDE	0.534857	0.077924	6.863794	0.0000
		Variance Equation		
C	0.002408	0.000750	3.208853	0.0013
ARCH(1)	0.745117	0.109748	6.789330	0.0000
ARCH(2)	-0.535463	0.100888	-5.307508	0.0000
GARCH(1)	0.768512	0.060411	12.72140	0.0000
R-squared	-0.029574	Mean dependent var		-0.005676
Adjusted R-squared	-0.041663	S.D. dependent var		0.290413
S.E. of regression	0.296401	Akaike info criterion		-0.312964
Sum squared resid	44.89325	Schwarz criterion		-0.255532
Log likelihood	88.05765	Durbin-Watson stat		0.448140

Appendix 13: Asymmetric GARCH Models

TARCH(1,1)- equation 5

Dependent Variable: VDE
Method: ML - ARCH

Sample(adjusted): 11/16/1985 9/09/1995
Included observations: 513 after adjusting endpoints
Convergence achieved after 98 iterations

	Coefficient	Std. Error	z-Statistic	Prob.
SQR(GARCH)	-0.361893	0.081294	-4.451648	0.0000
C	0.022711	0.008407	2.701404	0.0069
SPDE	0.536169	0.026655	20.11530	0.0000
	Variance Equation			
C	0.002601	0.000531	4.901595	0.0000
ARCH(1)	0.540528	0.094657	5.710389	0.0000
(RESID<0)*ARCH(1)	0.597623	0.219534	2.722236	0.0065
GARCH(1)	0.233454	0.051109	4.567762	0.0000

R-squared	0.202952	Mean dependent var	-0.005536
Adjusted R-squared	0.193501	S.D. dependent var	0.233478
S.E. of regression	0.209676	Akaike info criterion	-1.136851
Sum squared resid	22.24573	Schwarz criterion	-1.078992
Log likelihood	298.6023	F-statistic	21.47372
Durbin-Watson stat	0.310445	Prob(F-statistic)	0.000000

EGARCH(1,1)-equation 5

Dependent Variable: VDE
Method: ML - ARCH

Sample(adjusted): 11/16/1985 9/09/1995
Included observations: 513 after adjusting endpoints
Convergence achieved after 58 iterations

	Coefficient	Std. Error	z-Statistic	Prob.
SQR(GARCH)	-0.380394	0.087986	-4.323321	0.0000
C	0.022463	0.008146	2.757468	0.0058
SPDE	0.541346	0.024363	22.22030	0.0000
	Variance Equation			
C	-1.654720	0.245451	-6.741542	0.0000
|RES|/SQR[GARCH](1)	1.073453	0.134661	7.971499	0.0000
RES/SQR[GARCH](1)	-0.139625	0.066562	-2.097682	0.0359
EGARCH(1)	0.806380	0.043277	18.63313	0.0000

R-squared	0.222925	Mean dependent var	-0.005536
Adjusted R-squared	0.213711	S.D. dependent var	0.233478
S.E. of regression	0.207032	Akaike info criterion	-1.138876
Sum squared resid	21.68828	Schwarz criterion	-1.081016
Log likelihood	299.1217	F-statistic	24.19329
Durbin-Watson stat	0.323744	Prob(F-statistic)	0.000000

TARCH(2,1)- equation 6

Dependent Variable: LRDE
Method: ML - ARCH

Sample(adjusted): 11/16/1985 10/14/1995
Included observations: 518 after adjusting endpoints
Convergence achieved after 36 iterations

	Coefficient	Std. Error	z-Statistic	Prob.
SQR(GARCH)	-0.102610	0.099803	-1.028127	0.3039
C	0.010574	0.016429	0.643622	0.5198
HSPDE	0.545877	0.078911	6.917618	0.0000
	Variance Equation			
C	0.002274	0.000659	3.450332	0.0006
ARCH(1)	0.785764	0.121999	6.440755	0.0000

```
ARCH(2)                  -0.546531    0.099627     -5.485765    0.0000
(RESID<0)*ARCH(1)        -0.108757    0.044138     -2.464016    0.0137
GARCH(1)                  0.798179    0.052312     15.25802     0.0000
======================================================================
R-squared                 0.019768       Mean dependent var     -0.005676
Adjusted R-squared        0.006314       S.D. dependent var      0.290413
S.E. of regression        0.289495       Akaike info criterion  -0.345082
Sum squared resid         42.74177       Schwarz criterion      -0.279445
Log likelihood            97.37617       F-statistic             1.469263
Durbin-Watson stat        0.458750       Prob(F-statistic)       0.175789
```

EGARCH(2,1)

```
Dependent Variable: LRDE
Method: ML - ARCH

Sample(adjusted): 11/16/1985 10/14/1995
Included observations: 518 after adjusting endpoints
Convergence achieved after 74 iterations
======================================================================
                         Coefficient  Std. Error   z-Statistic  Prob.
======================================================================
SQR(GARCH)               -0.398103    0.091658     -4.343334    0.0000
C                         0.060420    0.014898      4.055432    0.0001
HSPDE                     0.414916    0.075729      5.478930    0.0000
======================================================================
                               Variance Equation
======================================================================
C                        -1.356985    0.175145     -7.747776    0.0000
|RES|/SQR[GARCH](1)       1.026911    0.102717      9.997514    0.0000
RES/SQR[GARCH](1)        -0.104128    0.078385     -1.328428    0.1840
|RES|/SQR[GARCH](2)      -0.067393    0.115088     -0.585580    0.5582
RES/SQR[GARCH](2)         0.147571    0.067806      2.176379    0.0295
EGARCH(1)                 0.816661    0.036794     22.19525     0.0000
======================================================================
R-squared                -0.085069       Mean dependent var     -0.005676
Adjusted R-squared       -0.102123       S.D. dependent var      0.290413
S.E. of regression        0.304882       Akaike info criterion  -0.323086
Sum squared resid         47.31303       Schwarz criterion      -0.249245
Log likelihood            92.67939       Durbin-Watson stat      0.437216
```

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