Università Commerciale
Luigi Bocconi

Lab 6: A GARCH Analysis of the Euro/USD Exchange Rate

(Reminder: this is optional)

Prof. Massimo Guidolin

20192– Financial Econometrics

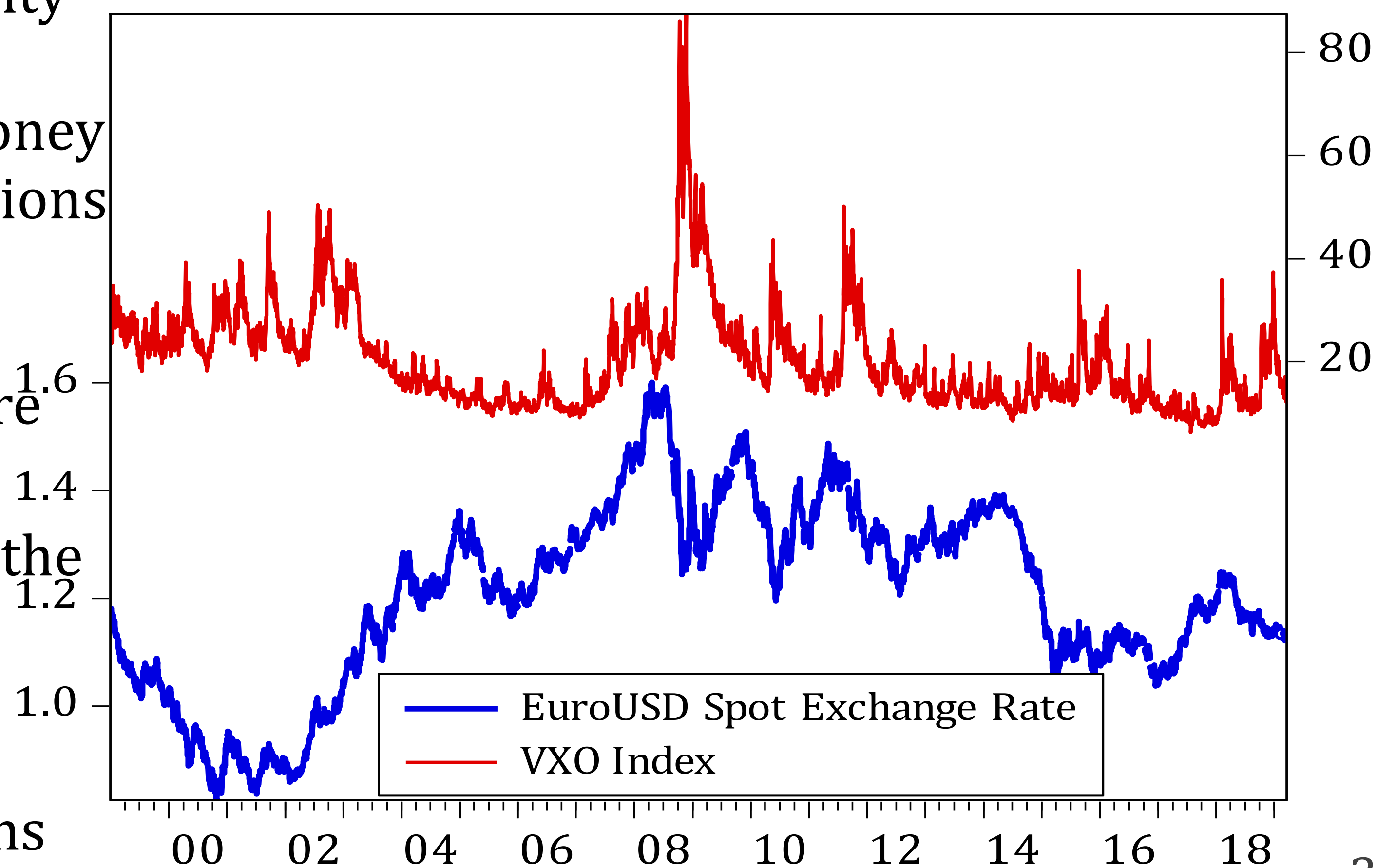
Winter/Spring 2019

The Goal

- Understand the difference between unconditional and conditional distribution of the log changes in the EuroUSD spot exchange rate
- Show that while the unconditional density is highly non-normal, the conditional density has an approximate bell-shape
- Test whether relatively simple GARCH models can capture such dynamics over time, i.e., whether mixing over time simple conditional density driven by wisely selected $\mu_{t+1|t}$ and $\sigma^2_{t+1|t}$ may deliver a realistic unconditional density
  - The log-changes of the EuroUSD exchange rate are similar to continuously compounded retuns
  - Yet these are more similar to long-short strategy returns in which you short USD and go long in euro riskless deposits
- The empirical strategy has far-reaching implications:
  - Can we use Black-Scholes formula to price options written on EuroUSD exchange rate (futures)?
  - Is mean-variance appropriate to multi-currency returns?
  - Can VaR and ES be computed assuming a Gaussian distribution?

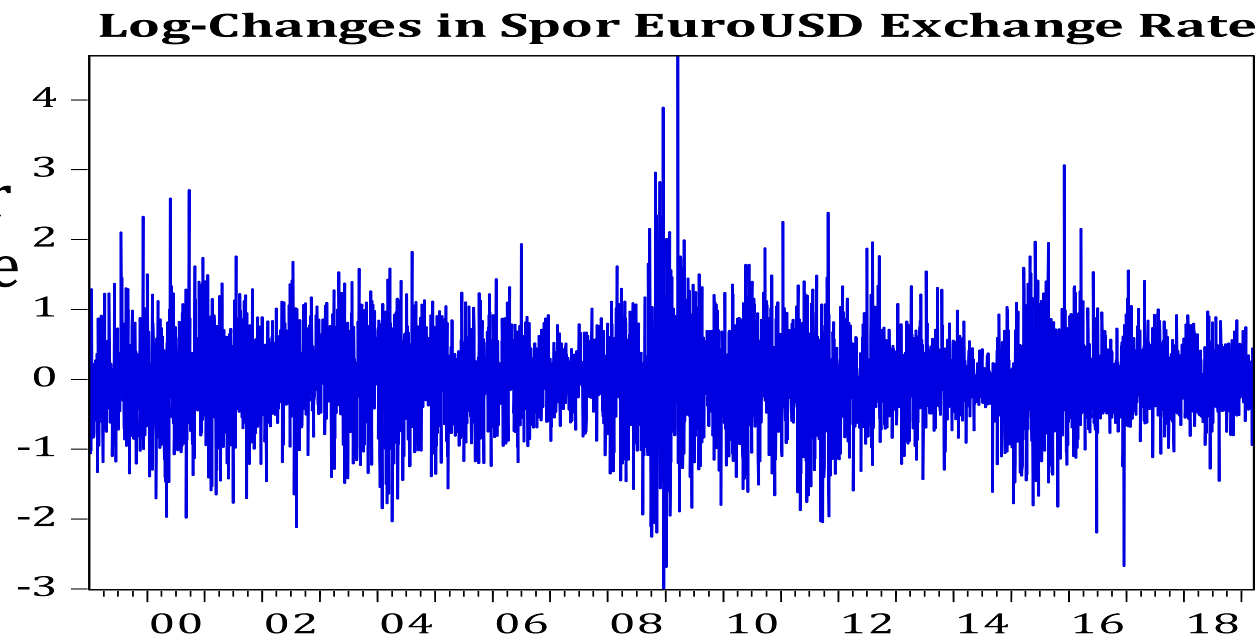
Step 0/Inspecting the Data

- We use daily data covering a Jan. 4, 1999 – March 15, 2019 sample, for a total of 5,270 observations
  - The data are collected from the Federal Reserve Bulleting through https://fred.stlouisfed.org/ (good web site to recall for your thesis)
  - Data supplemented by the series of VXO log-changes
  - VXO is a volatility index inferred from at-the-money short-term options written on the S&P 100, often used to measure risk aversion
  - Different from the traditional VIX that is instead derived from S&P 500 options

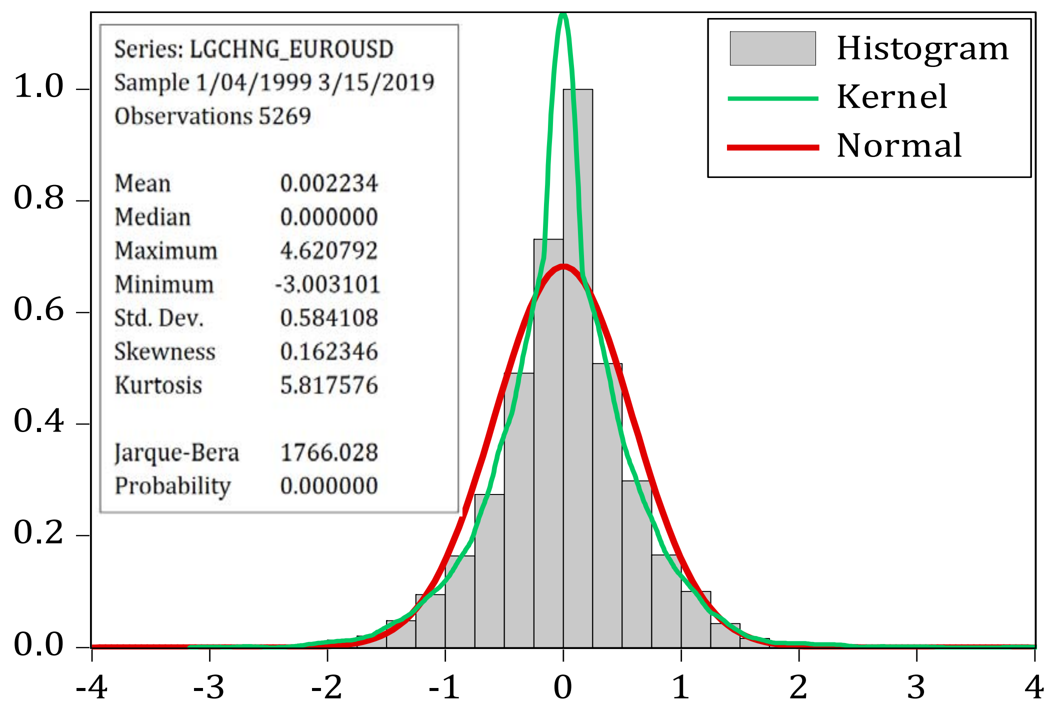


Step 1/The Unconditional Distribution

- As it is typical, a plot of the log-changes in the spot exchange rate offer few clues apart from the occurrence of volatility clustering:

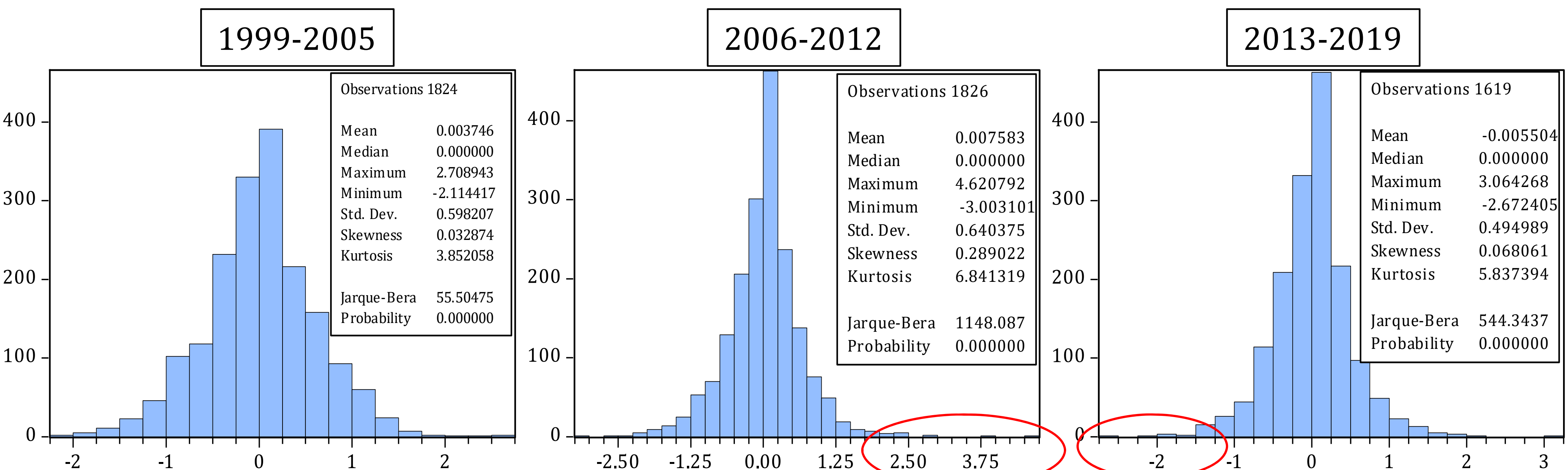


- Also as a result of clustering, the unconditional density of the data appears leptokurtic and highly non-normal
  - Here the kernel density represents a local smoother of the histogram
  - Comparing the green continuous density with the red Gaussian $\Rightarrow$ leptokurticity



Step 2/The Conditional Distribution

- However, we suspect that such leptokurtic neture of the log-changes in the spot exchange rate may derive from unstable conditional densities
- Even though the ones below are **not** conditional densities $f_{t+1|t} \equiv Prob(\Delta lnE_{t+1}|\Delta lnE_{t}, \Delta lnE_{t-1}, \ldots, \Delta lnE_{1})$, instability of histograms as one considers sub-samples is typically a sign of time-varying $f_{t+1|t}$
- Indeed, if we split the data in 3 sub-samples $\Rightarrow$ considerable variation
  - The mean switches sign as the USD depreciates during the GFC
  - The kurtosis ranges from 3.9 to 6.8; skewness btw. 0.03 and 0.29
  - Volatility is much higher in central period, when leptokurticity is massive



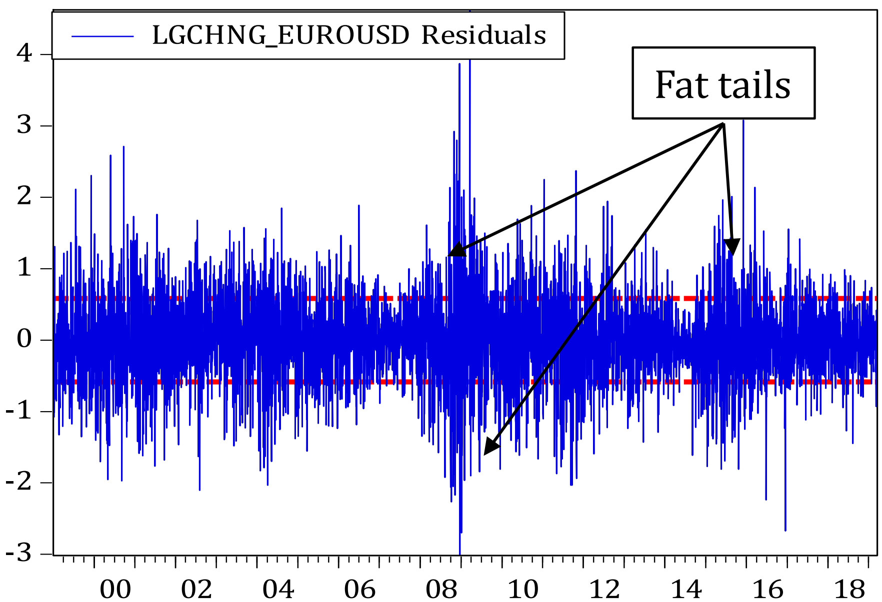
Step 3/Selecting a Model for the Conditional Mean

- Because $\mu_{t+1|t}$ determines the location of the conditional density and, moreover, it enters the definition of $\sigma_{t+1|t}$, the first natural step consists of specifying a good model for the mean
  - We do that for the residual of a regression in which the Euro is taken as a risk-off (low yield) asset vs. the USD so that large increases in the VXO forecast large depreciation of the USD vis-à-vis the USD

Dependent Variable: LGCHNG_EUROUSD
Method: Least Squares
Sample: 1/01/2013 3/15/2019
Included observations: 1619

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.005422	0.012294	-0.441019	0.6593
LGCHANG_VXO(-1)	0.002436	0.001388	1.754342	0.0796

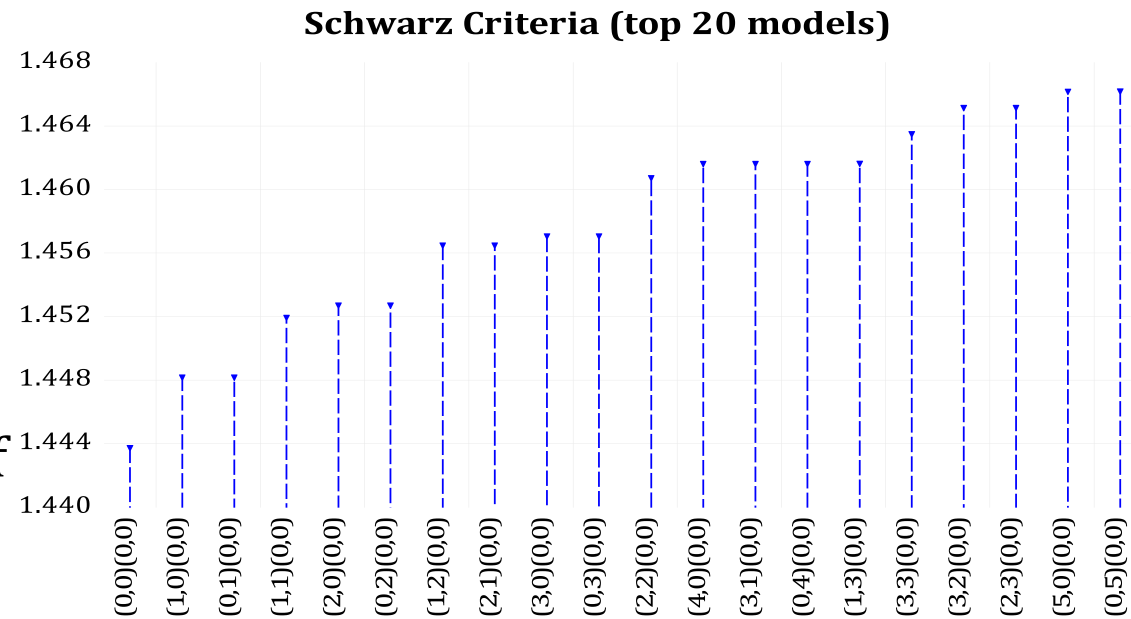
R-squared	0.001900	Mean dependent var	-0.005504
Adjusted R-squared	0.001282	S.D. dependent var	0.494989
F-statistic	3.077715	Durbin-Watson stat	2.028428
Prob(F-statistic)	0.079561		



  - Recall that VXO is often interpreted as a risk-aversion indicator
  - From now on we devote our efforts on a Box-Jenkins' analysis of the regression residuals
  - We use the automatic procedure offered by EViews

Step 3/Selecting a Model for the Conditional Mean

- As in Lab 2, select the best model using the BIC, setting pmax = qmax = 10
- We end up selecting a ARMAX(0,0) = white noise in which the VXO appears an exogeneous regression
- This matches the fact that the SACF and PACF reveal no ARMA structure in the residuals ⇒ forex market is efficient, as expected
- Yet there is strong evidence of rich structure in the squared residuals ⇒ GARCH



Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.051	0.051	13.964	0.000
		2	0.136	0.134	111.36	0.000
		3	0.056	0.044	127.89	0.000
		4	0.106	0.086	187.09	0.000
		5	0.069	0.050	212.33	0.000
		6	0.124	0.096	293.43	0.000
		7	0.074	0.047	322.64	0.000
		8	0.056	0.015	339.24	0.000
		9	0.083	0.051	375.18	0.000
		10	0.100	0.066	428.16	0.000
		11	0.058	0.018	445.77	0.000
		12	0.067	0.023	469.45	0.000

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.006	0.006	0.1729	0.678
		2	-0.007	-0.007	0.4389	0.803
		3	-0.006	-0.006	0.6321	0.889
		4	0.024	0.024	3.5572	0.469
		5	-0.004	-0.004	3.6431	0.602
		6	0.002	0.002	3.6595	0.723
		7	0.015	0.016	4.8963	0.673
		8	0.021	0.020	7.2735	0.507
		9	-0.001	-0.001	7.2838	0.608
		10	-0.021	-0.020	9.5644	0.480
		11	-0.007	-0.007	9.7880	0.550
		12	0.008	0.007	10.096	0.608

Step 4/Selecting a Model for Conditional Variance

- Conditional variance model are selected with the usual criteria
- Unfortunately Eviews does not that automatically for us
- We set up a by-hand search based on the max Log-likelihood and ICs

Model description	Log-Lik	AIC	BIC	H-Q	LM ARCH test
Homoskedastic regression (20191)	-4641.55	1.7626	1.7651	1.7635	0.000
Gaussian ARCH(1)	-4624.31	1.7568	1.7618	1.7586	0.000
Gaussian ARCH(9)	-4442.17	1.6907	1.7057	1.6959	0.026
Gaussian GARCH(1,1)	-4310.66	1.6381	1.6444	1.6403	0.024
Gaussian GARCH(1,1) with var. target	-4310.66	1.6378	1.6427	1.6395	0.024
Gaussian RiskMetrics(1)	-4319.29	1.6407	1.6444	1.6420	**0.051**
Gaussian GARCH(1,1) with var. target	-4310.66	1.6378	1.6427	1.6395	0.024
t-Student GARCH(1,1) with var. target	-4210.06	1.6000	1.6062	1.6021	0.022
t-Student GARCH(1,2) with var. target	-4205.77	1.5987	1.6062	1.6013	**0.078**
t-Student GARCH(2,1) with var. target	-4209.27	1.6000	1.6075	1.6026	0.036
t-Student GARCH(2,2) with var. target	-4205.76	1.5991	1.6078	1.6021	**0.081**
Gaussian EGARCH(1,1)	-4313.90	1.6394	1.6456	1.6415	0.021
t-Student EGARCH(1,1)	-4211.67	1.6009	1.6084	1.6036	0.021
t-Student Threshold GARCH(1,1) w/v.t.	-4208.36	1.6001	1.6088	1.6031	0.025
t-Student GARCHX(1,2) with var. target	-4201.39	1.5974	1.6061	1.6005	**0.091**

Step 5/ML Estimation of the Joint Model

- We end up selecting a rather complex GARCH(1,2) model with
  - t-student shocks
  - Variance targeting restriction imposed
  - One exogeneous regressor in the variance equation, the log-change in VXO

$$\Delta lnE_{t+1} = \mu + \sigma_{t+1|t} z_{t+1} \qquad z_{t+1}\ IID\ t(d)$$

Type equation here.

$$\sigma^2_{t+1|t} = (1-\alpha-\beta_1-\beta_2)\left(T^{-1}\sum_{t=1}^{T}\varepsilon_t^2\right) + \alpha\underbrace{(\sigma_{t|t-1}z_t)^2}_{\varepsilon_t^2} + \beta_1\sigma^2_{t|t-1} + $$
$$+\beta_2\sigma^2_{t-1|t-2} + \gamma\Delta lnVXO_{t+1}$$

Method: ML ARCH - Student's t distribution (BFGS / Marquardt steps)
Sample (adjusted): 1/05/1999 3/15/2019
Included observations: 5269 after adjustments
Estimation settings: tol= 0.00010, derivs=numeric (linear)
Initial Values: C(1)=0.00221, C(2)=-0.00178, C(3)=0.34094, C(4)=0.53333, C(5)=0.04444, C(6)=0.00000, C(7)=20.0000
Failure to improve likelihood (singular hessian) after 63 iterations
Coefficient covariance computed using outer product of gradients
Presample variance: backcast (parameter = 0.7)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	0.004432	0.006560	0.675618	0.4993
LGCHANG_VXO(-1)	-0.001293	0.000871	-1.484164	0.1378

Variance Equation

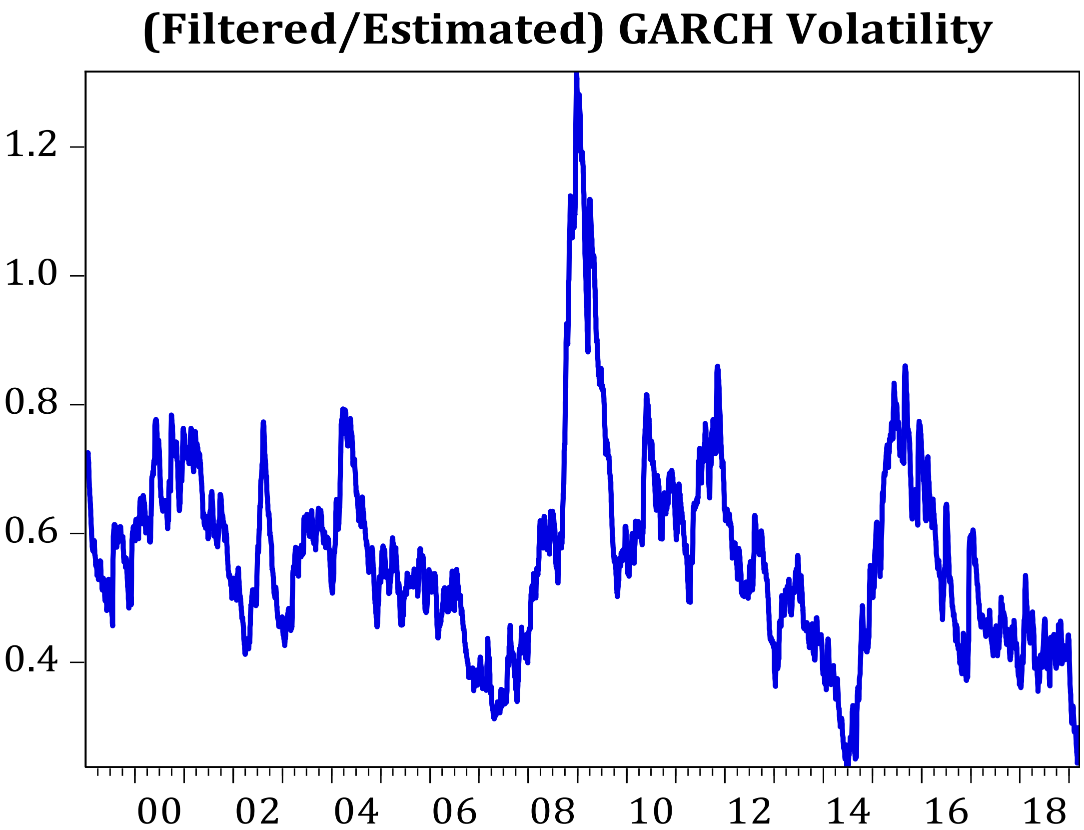
C	0.000259	--	--	--
RESID(-1)^2	0.009958	0.004725	2.107453	0.0351
GARCH(-1)	1.622752	0.179976	9.016516	0.0000
GARCH(-2)	-0.633470	0.175107	-3.617612	0.0003
LGCHANG_VXO(-1)	0.000429	0.000230	1.862281	0.0626
T-DIST. DOF	6.406486	0.457573	14.00102	0.0000

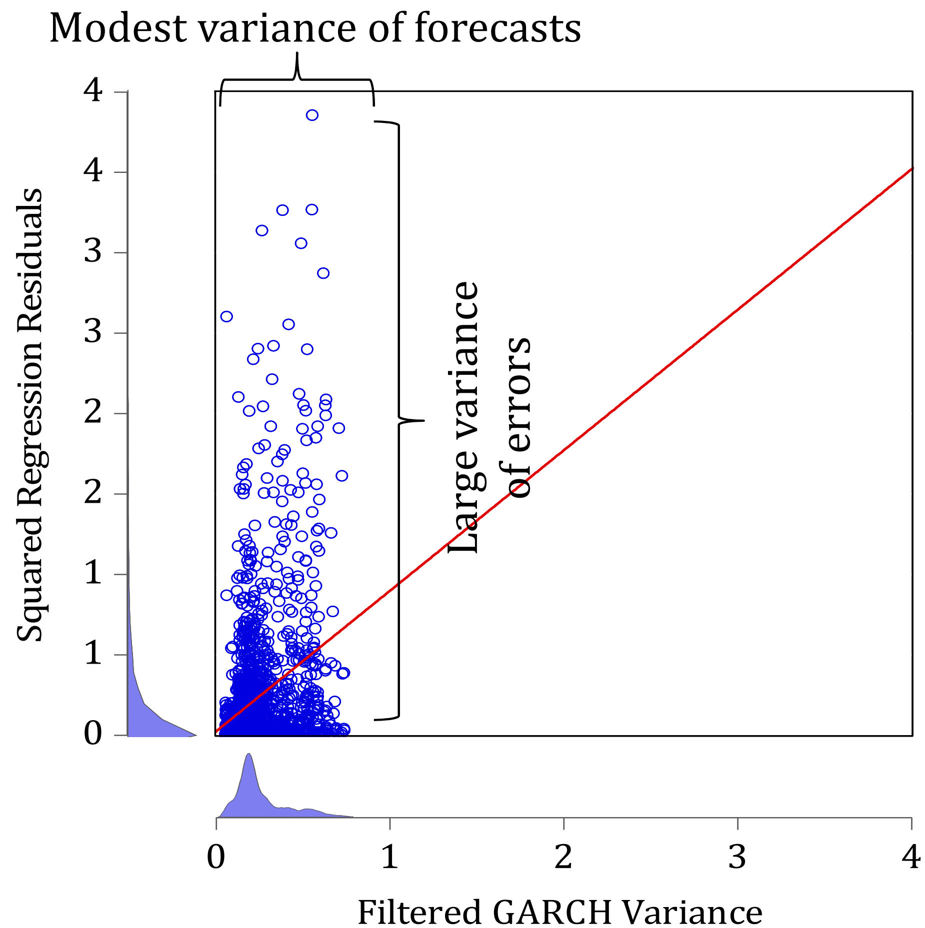
~~R-squared~~	~~0.000462~~	Mean dependent var	0.002234
~~Adjusted R-squared~~	~~0.000272~~	S.D. dependent var	0.584108
S.E. of regression	0.584028	Akaike info criterion	1.597414
Sum squared resid	1796.517	Schwarz criterion	1.606142
Log likelihood	-4201.387	Hannan-Quinn criter.	1.600465

Also the conditional mean estimates are influenced by CH under MLE (earlier estimate was 0.0025)

Step 5/ML Estimation of the Joint Model

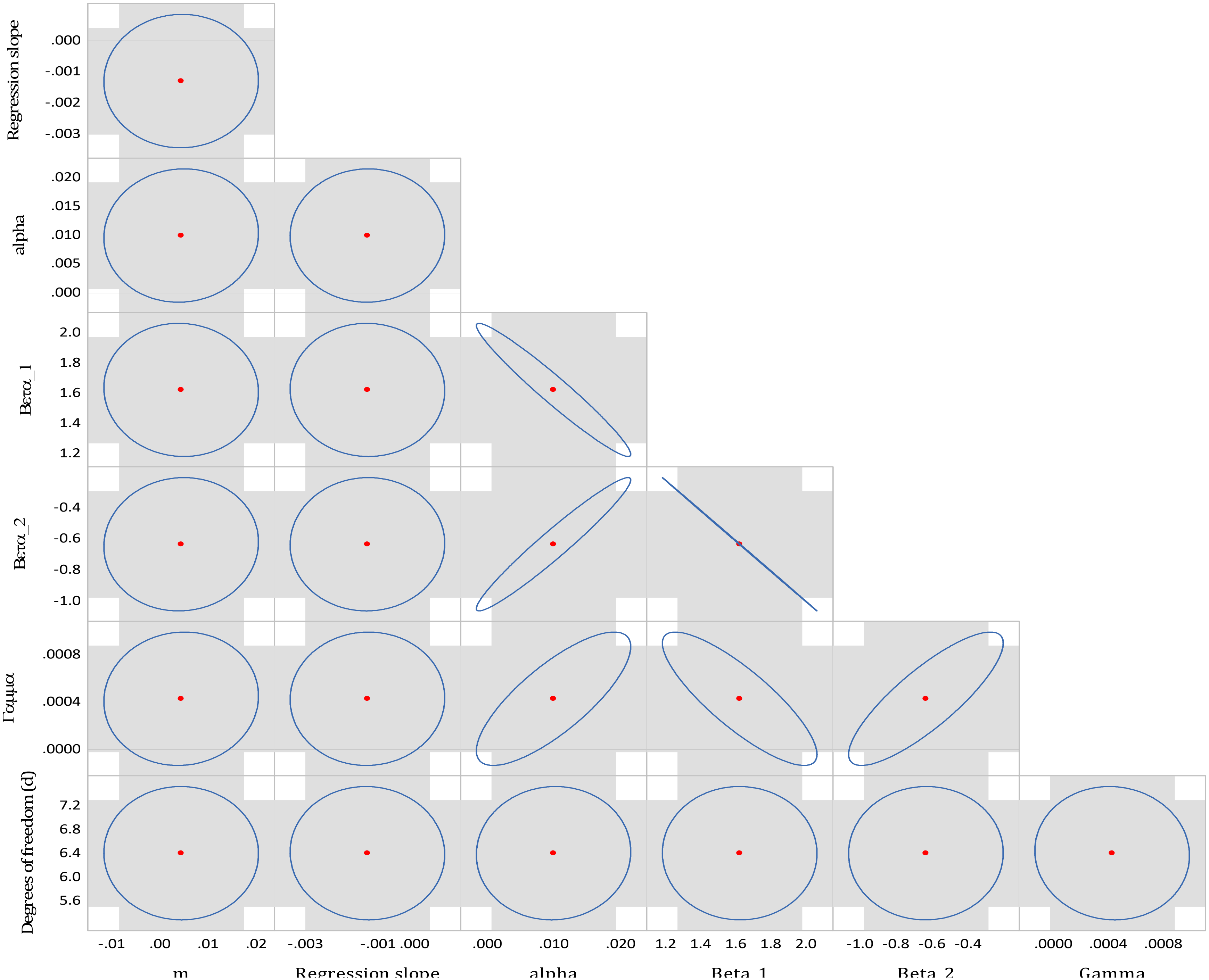
- We plot the implied, filtered daily standard deviation, which seems to oscillate around an average long-run variace of about 0.6% a day





- In the next slide we show confidence intervals (the shaded gray areas, the marginal intervals) and joint confidence ellipses for all the cofficients

Step 5/ML Estimation of the Joint Model



Step 6/Diagnostic Checks

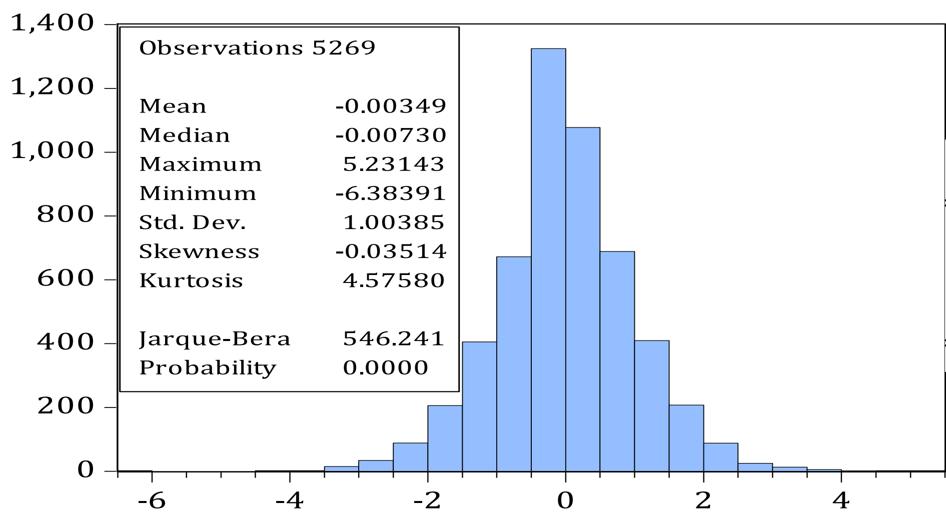
- We now ask whether the model is viable both in an economic and in a statistical sense
- Statistically, the news are excellent

Standardized residuals

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob*
		1	0.007	0.007	0.2247	0.635
		2	0.009	0.009	0.6349	0.728
		3	0.001	0.001	0.6440	0.886
		4	0.014	0.014	1.6738	0.795
		5	0.003	0.003	1.7124	0.887
		6	0.001	0.000	1.7141	0.944
		7	0.006	0.006	1.9254	0.964
		8	0.013	0.012	2.7534	0.949
		9	0.002	0.002	2.7808	0.972
		10	-0.013	-0.013	3.6408	0.962
		11	0.001	0.001	3.6476	0.979
		12	0.002	0.002	3.6643	0.989

Standardized squared residuals

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob*
		1	-0.004	-0.004	0.0931	0.760
		2	-0.022	-0.023	2.7612	0.251
		3	-0.020	-0.021	4.9357	0.177
		4	-0.001	-0.002	4.9415	0.293
		5	0.026	0.025	8.6074	0.126
		6	0.021	0.021	10.962	0.090
		7	-0.026	-0.025	14.544	0.042
		8	-0.015	-0.013	15.696	0.047
		9	-0.009	-0.009	16.089	0.065
		10	0.016	0.014	17.516	0.064
		11	-0.005	-0.007	17.653	0.090
		12	-0.010	-0.009	18.168	0.111



Heteroskedasticity Test: ARCH

F-statistic	1.633325	Prob. F(10,5248)	0.0908
Obs*R-squared	16.31670	Prob. Chi-Square(10)	0.0909

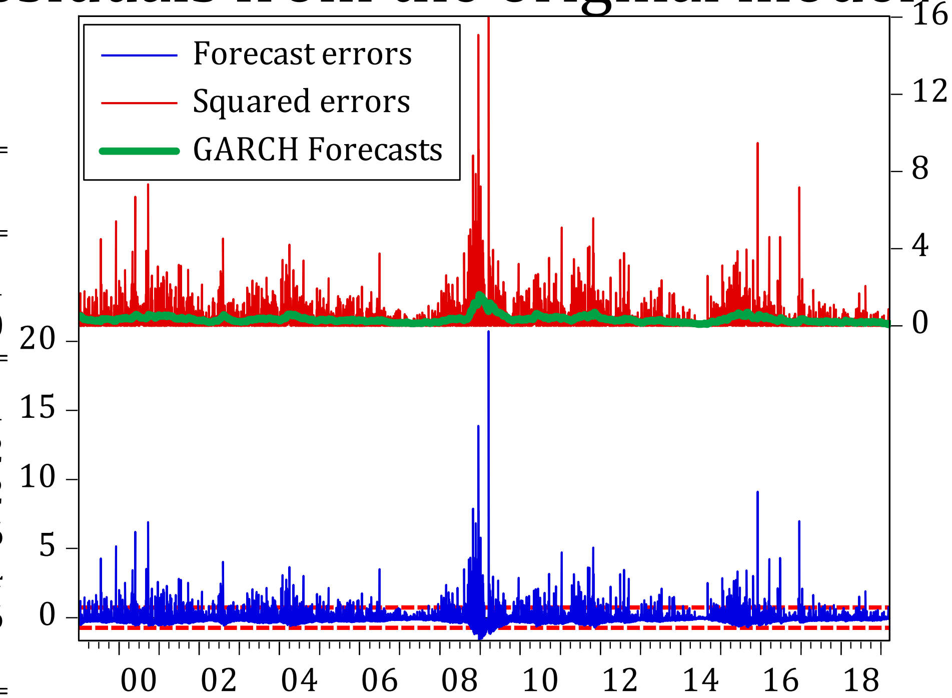
Step 6/Diagnostic Checks

- We perform a regression test to check whether, in economic terms, GARCH variance forecasts represent an unbiased and efficient prediction of the squared regression residuals from the original model:

Method: Least Squares
Sample (adjusted): 1/05/1999 3/15/2019
Included observations: 5269 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.025939	0.019258	1.346951	0.1781
GARCH_VAR	0.918064	0.048003	19.12523	0.0000

R-squared	$\boxed{0.064937}$	Mean dependent var	0.341021
Adjusted R-squared	0.064759	S.D. dependent var	0.748532
S.E. of regression	0.723889	Akaike info criterion	2.192022
Sum squared resid	2759.988	Schwarz criterion	2.194516
Log likelihood	-5772.882	Hannan-Quinn criter.	2.192894
F-statistic	365.7744	Durbin-Watson stat	2.049066
Prob(F-statistic)	0.000000		



Wald Test:
Equation: Untitled

Test Statistic	Value	df	Probability
F-statistic	1.480653	(2, 5267)	0.2276
Chi-square	2.961307	2	0.2275

Null Hypothesis Summary:

Normalized Restriction (= 0)	Value	Std. Err.
C(1)	0.025939	0.019258
-1 + C(2)	-0.081936	0.048003

- The test is ambiguous, the null hypothesis of intercept = 0 and slope = 1 cannot be rejected but the R-square is disappointing

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Lab 6: Debriefing

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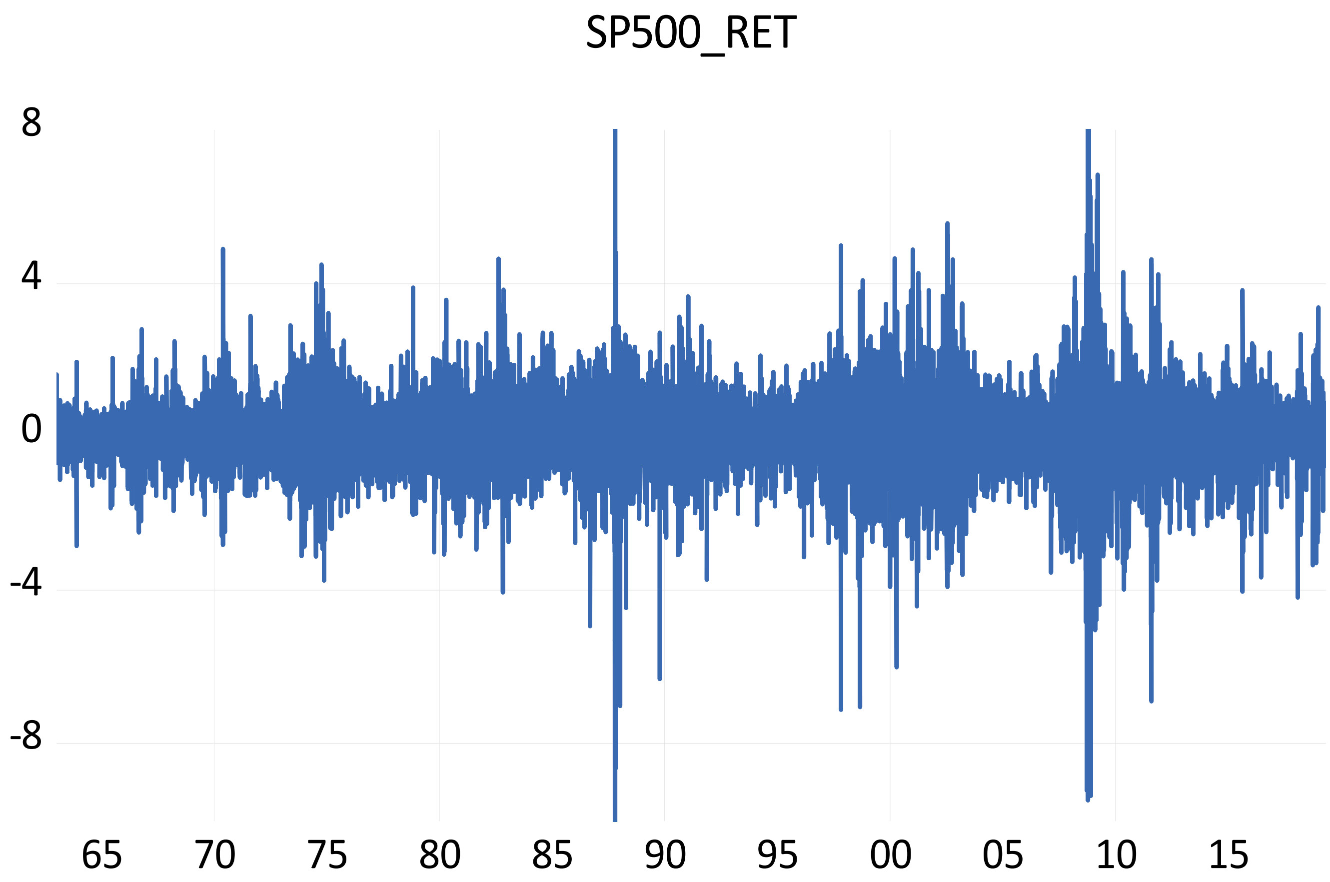
20192– Financial Econometrics

Winter/Spring 2019

Inspecting the Data

- We use daily data for the S&P500 between Jan. 2, 1963 – May 1, 2019, for a total of 14,696 observations
- The plot of S&P 500 returns highlights the presence of volatility clustering
  - Unusual high volatility persisted for many years after the last financial crisis and around the turn of the millenium

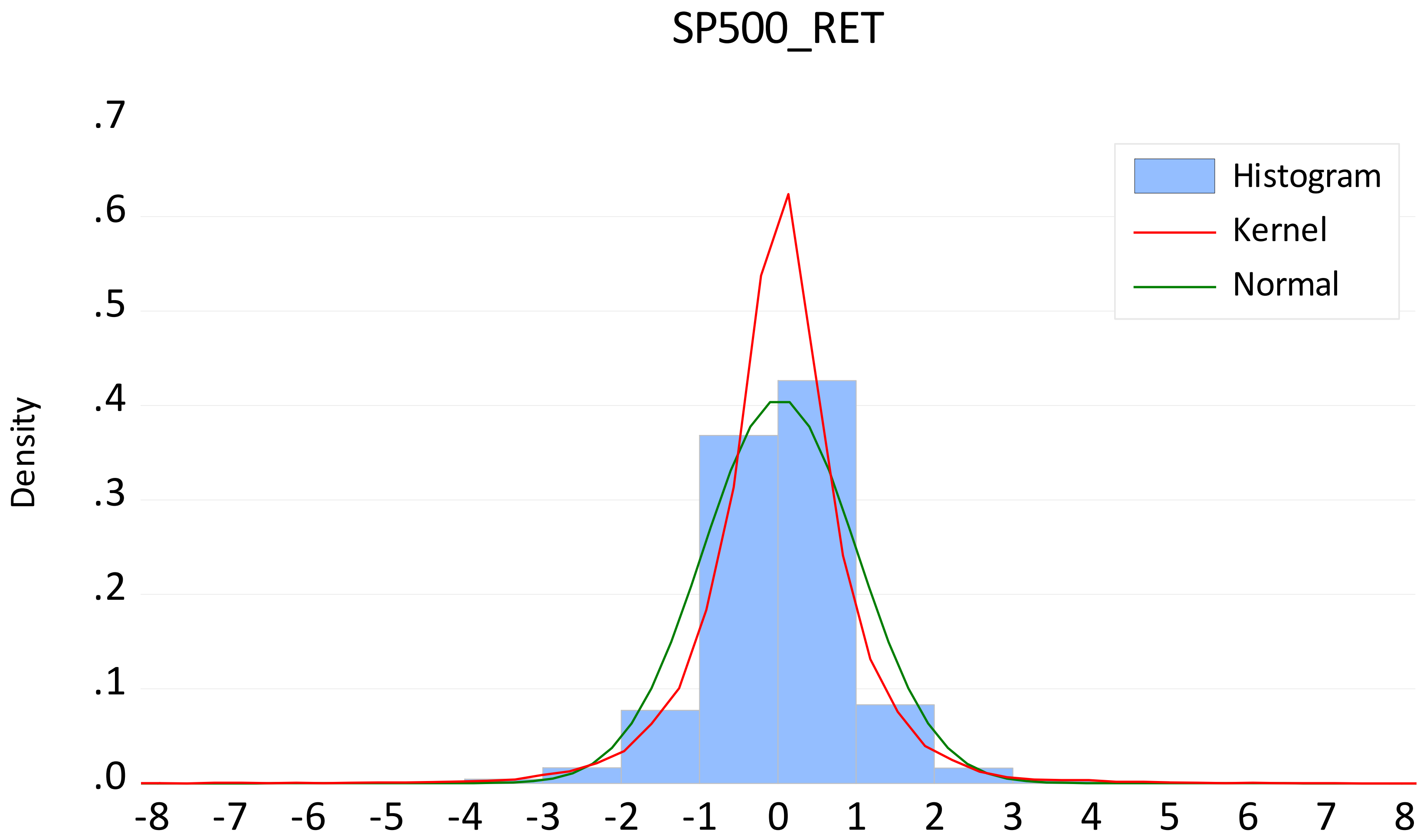


Date: 05/08/19 Time: 11:22
Sample: 1/02/1963 5/01/2019

	SP500_RET
Mean	0.025955
Median	0.039650
Maximum	10.95720
Minimum	-22.89970
Std. Dev.	0.980762
Skewness	-1.061108
Kurtosis	32.06906
Jarque-Bera	520185.9
Probability	0.000000
Sum	381.4344
Sum Sq. Dev.	14135.04
Observations	14696

The Unconditional Distribution

- As a result of volatility clustering, the unconditional density of the data appears leptokurtic and highly non-normal
  - Although it is not immediately visible from the histogram itself, you can zoom in the picture to check that the kernel estimator lies above the Gaussian density in extreme regions



Selecting a Model for the Conditional Mean

- Because $\mu_{t+1|t}$ determines the location of the conditional density and, moreover, it enters the definition of $\sigma_{t+1|t}$, the first natural step consists of specifying a good model for the mean
- We turn to the automatic selection tool provided by EViews which selects ARMA(0,2) = MA(2) as the best model according to BIC with pmax = qmax = 4

Automatic ARIMA Forecasting
Selected dependent variable: SP500_RET
Date: 05/08/19 Time: 17:30
Sample: 1/02/1963 5/01/2019
Included observations: 14696
Forecast length: 0

Number of estimated ARMA models: 25
Number of non-converged estimations: 0
Selected ARMA model: (0,2)(0,0)
SIC value: 2.7994396885

Dependent Variable: SP500_RET
Method: ARMA Maximum Likelihood (OPG - BHHH)
Date: 05/08/19 Time: 17:27
Sample: 1/02/1963 5/01/2019
Included observations: 14696
Convergence achieved after 54 iterations
Coefficient covariance computed using outer product of gradients

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.025951	0.008465	3.065627	0.0022
MA(1)	0.030621	0.003643	8.406585	0.0000
MA(2)	-0.034787	0.003209	-10.84121	0.0000
SIGMASQ	0.959782	0.003024	317.4063	0.0000

R-squared	0.002128	Mean dependent var	0.025955
Adjusted R-squared	0.001924	S.D. dependent var	0.980762
S.E. of regression	0.979818	Akaike info criterion	2.797372
Sum squared resid	14104.95	Schwarz criterion	2.799440
Log likelihood	-20551.09	Hannan-Quinn criter.	2.798059
F-statistic	10.44452	Durbin-Watson stat	1.999609
Prob(F-statistic)	0.000001		

Inverted MA Roots	.17	-.20

Selecting a Model for the Conditional Mean

- Using ARMA(0,2) leaves significant structure in the level of residuals while the SACF of squared residuals confirms the presence of volatility clusters

Date: 05/08/19 Time: 17:38
Sample: 1/02/1963 5/01/2019
Included observations: 14696
Q-statistic probabilities adjusted for 2 ARMA terms

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.000	0.000	0.0004	
		2	0.000	0.000	0.0022	
		3	-0.005	-0.005	0.3357	0.562
		4	-0.014	-0.014	3.1997	0.202
		5	-0.007	-0.007	3.8616	0.277
		6	-0.013	-0.013	6.1823	0.186
		7	-0.026	-0.026	16.369	0.006
		8	0.019	0.019	21.833	0.001
		9	-0.023	-0.024	29.854	0.000
		10	0.016	0.015	33.524	0.000
		11	0.000	-0.000	33.526	0.000
		12	0.001	0.001	33.558	0.000
		13	0.008	0.007	34.520	0.000
		14	0.004	0.004	34.776	0.001
		15	-0.010	-0.009	36.275	0.001
		16	0.018	0.017	41.241	0.000
		17	0.016	0.018	44.863	0.000
		18	-0.030	-0.031	58.001	0.000
		19	-0.000	0.001	58.002	0.000
		20	0.004	0.004	58.193	0.000
		21	-0.008	-0.008	59.201	0.000
		22	-0.012	-0.012	61.245	0.000
		23	0.005	0.006	61.574	0.000
		24	-0.015	-0.016	64.675	0.000

Date: 05/08/19 Time: 17:39
Sample: 1/02/1963 5/01/2019
Included observations: 14696

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.155	0.155	351.54	0.000
		2	0.191	0.172	890.50	0.000
		3	0.115	0.068	1085.4	0.000
		4	0.090	0.037	1204.3	0.000
		5	0.193	0.156	1751.6	0.000
		6	0.102	0.038	1903.3	0.000
		7	0.095	0.018	2036.3	0.000
		8	0.109	0.054	2212.5	0.000
		9	0.101	0.048	2363.7	0.000
		10	0.082	0.005	2462.2	0.000
		11	0.102	0.044	2616.2	0.000
		12	0.084	0.030	2721.2	0.000
		13	0.079	0.013	2812.9	0.000
		14	0.051	-0.013	2851.6	0.000
		15	0.071	0.025	2925.1	0.000
		16	0.072	0.021	3002.2	0.000
		17	0.077	0.023	3089.4	0.000
		18	0.078	0.026	3179.9	0.000
		19	0.070	0.022	3251.7	0.000
		20	0.067	0.011	3316.9	0.000
		21	0.073	0.021	3394.7	0.000
		22	0.058	0.006	3444.4	0.000
		23	0.056	0.003	3490.1	0.000
		24	0.069	0.021	3559.6	0.000

Selecting a Model for Conditional Variance

- In the attempt to properly capture the dynamics of S&P500 returns, we turn to the analysis of the conditional variance
- Because Eviews does not provide an automated selection tool to identify a proper model, we consider a t-Student EGARCH(1,1) and evaluate its adequacy
- All estimates in the equation for the conditional variance are highly significant with 0 p-values
- Yet the coefficient associated to the second MA component becomes non-significant—such a difference possible as conditional mean and variance interact in estimation

Dependent Variable: SP500_RET
Method: ML ARCH - Student's t distribution (BFGS / Marquardt steps)
Date: 05/08/19 Time: 17:45
Sample: 1/02/1963 5/01/2019
Included observations: 14696
Convergence achieved after 48 iterations
Coefficient covariance computed using outer product of gradients
MA Backcast: 12/31/1962 1/01/1963
Presample variance: backcast (parameter = 0.7)
LOG(GARCH) = C(4) + C(5)*ABS(RESID(-1)/@SQRT(GARCH(-1))) + C(6)
*RESID(-1)/@SQRT(GARCH(-1)) + C(7)*LOG(GARCH(-1))

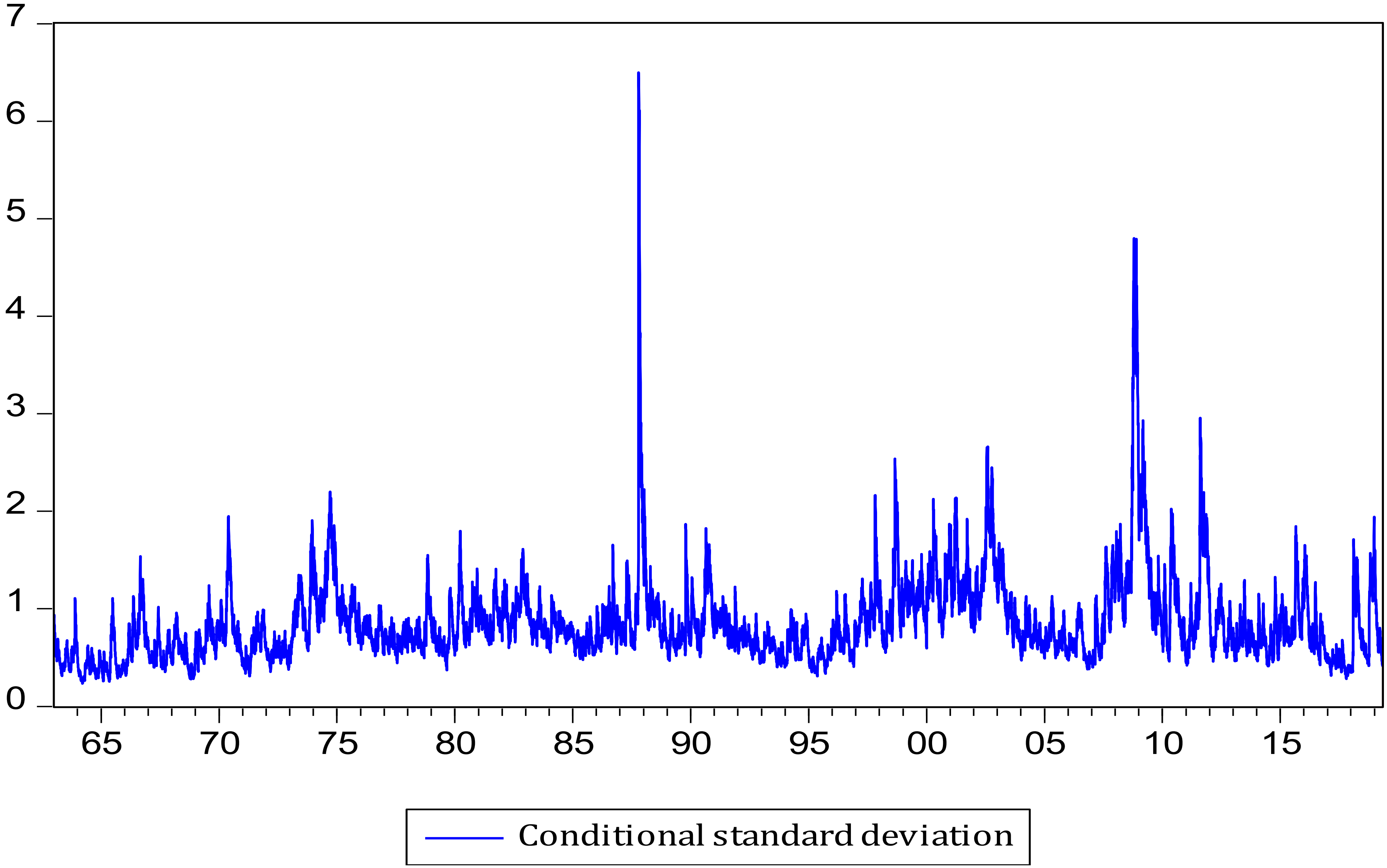
Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	0.034001	0.005628	6.041643	0.0000
MA(1)	0.083097	0.008260	10.06059	0.0000
MA(2)	-0.003142	0.008219	-0.382327	0.7022
Variance Equation				
C(4)	-0.111328	0.005819	-19.13343	0.0000
C(5)	0.137702	0.007470	18.43476	0.0000
C(6)	-0.087019	0.005154	-16.88248	0.0000
C(7)	0.987643	0.001295	762.6085	0.0000
T-DIST. DOF	6.958842	0.346908	20.05961	0.0000

R-squared	-0.001376	Mean dependent var	0.025955
Adjusted R-squared	-0.001512	S.D. dependent var	0.980762
S.E. of regression	0.981503	Akaike info criterion	2.310958
Sum squared resid	14154.48	Schwarz criterion	2.315093
Log likelihood	-16972.92	Hannan-Quinn criter.	2.312331
Durbin-Watson stat	2.101172		

Inverted MA Roots	.03	-.11

Plotting the estimated conditional volatility

- The plot of the estimated conditional volatility reveals expected peaks and clusters following, for instance, the recent financial crisis in 2008-2009 and so-called «Black Monday» in 1987



Diagnostic Checks

- Moreover, after the joint model is considered, there is no significant structure left in either the residuals or in the squared residuals
- Thus, the model seems to be viable in statistical terms

Date: 05/08/19 Time: 18:11
Sample: 1/02/1963 5/01/2019
Included observations: 14696
Q-statistic probabilities adjusted for 2 ARMA terms

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob*
		1	0.006	0.006	0.4976	
		2	0.002	0.002	0.5404	
		3	-0.003	-0.003	0.6484	0.421
		4	-0.003	-0.003	0.7916	0.673
		5	-0.001	-0.001	0.8120	0.847
		6	-0.015	-0.015	4.1729	0.383
		7	-0.007	-0.006	4.8062	0.440
		8	0.006	0.006	5.2551	0.512
		9	-0.017	-0.017	9.6004	0.212
		10	0.020	0.020	15.629	0.048
		11	-0.009	-0.009	16.720	0.053
		12	0.009	0.009	17.915	0.056
		13	0.006	0.006	18.453	0.072
		14	-0.002	-0.002	18.498	0.101
		15	-0.001	-0.001	18.504	0.139
		16	-0.011	-0.011	20.439	0.117
		17	0.010	0.011	21.993	0.108
		18	-0.015	-0.016	25.470	0.062
		19	-0.007	-0.006	26.219	0.071
		20	0.009	0.008	27.329	0.073
		21	-0.009	-0.008	28.473	0.075
		22	-0.008	-0.009	29.481	0.079
		23	-0.009	-0.009	30.777	0.077
		24	-0.003	-0.003	30.921	0.098

*Probabilities may not be valid for this equation specification.

Date: 05/08/19 Time: 18:11
Sample: 1/02/1963 5/01/2019
Included observations: 14696

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob*
		1	0.021	0.021	6.6219	0.010
		2	0.008	0.007	7.4976	0.024
		3	0.005	0.004	7.8214	0.050
		4	0.004	0.004	8.0401	0.090
		5	0.010	0.010	9.5673	0.088
		6	-0.007	-0.007	10.253	0.114
		7	-0.006	-0.006	10.741	0.150
		8	-0.003	-0.003	10.898	0.208
		9	0.013	0.013	13.394	0.146
		10	0.012	0.011	15.426	0.117
		11	-0.006	-0.007	15.964	0.142
		12	-0.000	-0.000	15.965	0.193
		13	-0.004	-0.004	16.164	0.240
		14	0.002	0.002	16.236	0.299
		15	-0.006	-0.006	16.734	0.335
		16	-0.005	-0.005	17.134	0.377
		17	0.001	0.002	17.152	0.444
		18	-0.005	-0.005	17.535	0.487
		19	0.003	0.003	17.715	0.542
		20	-0.005	-0.005	18.031	0.585
		21	-0.013	-0.013	20.648	0.481
		22	-0.011	-0.010	22.295	0.442
		23	-0.006	-0.006	22.883	0.468
		24	-0.001	-0.000	22.895	0.526

*Probabilities may not be valid for this equation specification.

Diagnostic Checks

- We perform a regression test to check whether, in economic terms, GARCH variance forecasts represent an unbiased and efficient prediction of the squared regression residuals from the original model

Dependent Variable: RESID_SQ
Method: Least Squares
Date: 05/08/19 Time: 18:24
Sample: 1/02/1963 5/01/2019
Included observations: 14696

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.029632	0.047863	-0.619116	0.5358
GARCH_VAR	1.061368	0.026151	40.58584	0.0000

R-squared	0.100801	Mean dependent var	0.963152
Adjusted R-squared	0.100740	S.D. dependent var	5.259163
S.E. of regression	4.987229	Akaike info criterion	6.051774
Sum squared resid	365475.9	Schwarz criterion	6.052808
Log likelihood	-44466.44	Hannan-Quinn criter.	6.052118
F-statistic	1647.210	Durbin-Watson stat	1.945024
Prob(F-statistic)	0.000000		

- Notice that we cannot reject the null hypothesis of the intercept being equal to zero
- Nonetheless, the slope appears to be significantly different from 1, with t-statistic equal to 2.3467
- However, an F-test leads to ambiguous results