Applied Econometrics with R

Extension 1

Financial Econometrics

Financial Econometrics

Overview

Overview

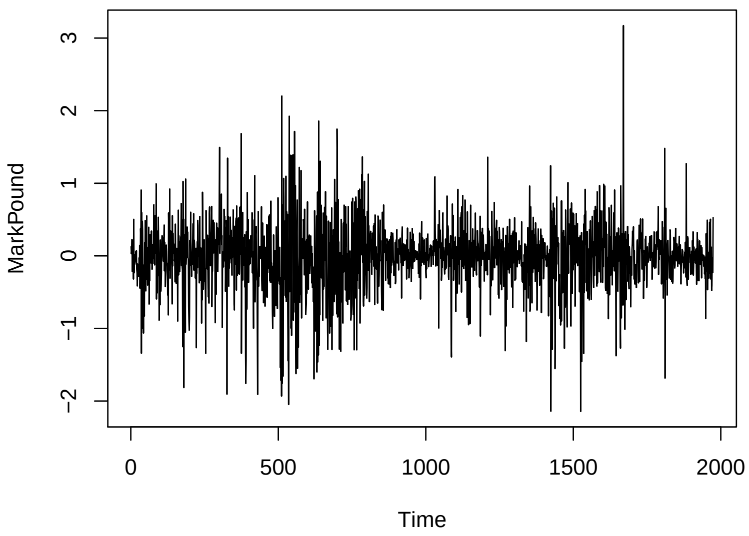
Further packages for time series analysis

- **dse** – Multivariate time series modeling with state-space and vector ARMA (VARMA) models.
- **FinTS** – R companion to Tsay (2005).
- **forecast** – Univariate time series forecasting, including exponential smoothing, state space, and ARIMA models.
- **fracdiff** – ML estimation of ARFIMA models and semiparametric estimation of the fractional differencing parameter.
- **longmemo** – Convenience functions for long-memory models.
- **mFilter** – Time series filters, including Baxter-King, Butterworth, and Hodrick-Prescott.
- **Rmetrics** – Some 20 packages for financial engineering and computational finance, including GARCH modeling in **fGarch**.
- **tsDyn** – Nonlinear time series models: STAR, ESTAR, LSTAR.
- **vars** – (Structural) vector autoregressive (VAR) models

Financial Econometrics

GARCH Modelling via tseries

GARCH models



GARCH models

tseries function `garch()` fits GARCH(p, q) with Gaussian innovations. Default is GARCH(1, 1):

$$\begin{aligned} y_t &= \sigma_t \nu_t, \quad \nu_t \sim \mathcal{N}(0,1) \text{ i.i.d.}, \\ \sigma_t^2 &= \omega + \alpha y_{t-1}^2 + \beta \sigma_{t-1}^2, \quad \omega > 0, \alpha > 0, \beta \geq 0. \end{aligned}$$

Example: DEM/GBP FX returns for 1984-01-03 through 1991-12-31

```
R> library("tseries")
R> mp <- garch(MarkPound, grad = "numerical", trace = FALSE)
R> summary(mp)

Call:
garch(x = MarkPound, grad = "numerical", trace = FALSE)

Model:
GARCH(1,1)

Residuals:
     Min       1Q   Median       3Q      Max
-6.79739 -0.53703 -0.00264  0.55233  5.24867
```


GARCH models

```
Coefficient(s):
    Estimate  Std. Error  t value Pr(>|t|)
a0    0.0109      0.0013     8.38   <2e-16
a1    0.1546      0.0139    11.14   <2e-16
b1    0.8044      0.0160    50.13   <2e-16

Diagnostic Tests:
        Jarque Bera Test

data:  Residuals
X-squared = 1100, df = 2, p-value <2e-16


        Box-Ljung test

data:  Squared.Residuals
X-squared = 2.5, df = 1, p-value = 0.1
```

Remarks:

- *Warning:* OPG standard errors assuming Gaussian innovations.
- More flexible GARCH modeling via `garchFit()` in **fGarch**.

Financial Econometrics

GARCH Modelling via Rmetrics

Rmetrics

Rmetrics

- Initiated and mainly developed by D. Würtz (ETH, Dept. of Theoretical Physics).
- Environment for financial engineering and computational finance.
- Currently comprises some 20 packages:
  fArma, **fAsianOptions**, **fAssets**, **fBasics**, **fBonds**, **fCalendar**, **fCopulae**, **fEcofin**, **fExoticOptions**, **fExtremes**, **fGarch**, **fImport**, **fMultivar**, **fNonlinear**, **fOptions**, **fPortfolio**, **fRegression**, **fSeries**, **fTrading**, **fUnitRoots**, **fUtilities**.
- Unified framework, initially designed for teaching purposes.
- Unified naming conventions via standardized wrappers.
  For example, `arima()` from **stats** appears as `armaFit()`.
- We consider GARCH modelling via `garchFit()` from **fGarch**.

GARCH modeling via `garchFit()`

Example: DEM/GBP FX returns for 1984-01-03 through 1991-12-31

```
R> library("fGarch")
R> mp_gf <- garchFit(~garch(1,1), data = MarkPound, trace = FALSE)
R> summary(mp_gf)
Title:
 GARCH Modelling

Call:
 garchFit(formula = ~garch(1, 1), data = MarkPound,
  trace = FALSE)

Mean and Variance Equation:
 data ~ garch(1, 1)
<environment: 0x564331d96378>
 [data = MarkPound]

Conditional Distribution:
 norm

Coefficient(s):
        mu       omega      alpha1       beta1
```


GARCH modeling via `garchFit()`

```
-0.0061903   0.0107614   0.1531341   0.8059737

Std. Errors:
 based on Hessian

Error Analysis:
        Estimate  Std. Error  t value Pr(>|t|)
mu     -0.006190    0.008462   -0.732 0.464447
omega   0.010761    0.002838    3.793 0.000149
alpha1  0.153134    0.026422    5.796  6.8e-09
beta1   0.805974    0.033381   24.144  < 2e-16

Log Likelihood:
 -1107    normalized:  -0.5606

Description:
 Thu Mar 16 09:50:07 2017 by user: zeileis


Standardised Residuals Tests:
                                Statistic p-Value
 Jarque-Bera Test   R    Chi^2  1060      0
```


GARCH modeling via `garchFit()`

```
 Shapiro-Wilk Test  R    W      0.9623    0
 Ljung-Box Test     R    Q(10)  10.12     0.4299
 Ljung-Box Test     R    Q(15)  17.04     0.3163
 Ljung-Box Test     R    Q(20)  19.3      0.5026
 Ljung-Box Test     R^2  Q(10)  9.063     0.5262
 Ljung-Box Test     R^2  Q(15)  16.08     0.3769
 Ljung-Box Test     R^2  Q(20)  17.51     0.6198
 LM Arch Test       R    TR^2   9.771     0.636

Information Criterion Statistics:
  AIC   BIC   SIC  HQIC
1.125 1.137 1.125 1.129
```

Remarks:

- Benchmark data set for GARCH$(1,1)$, see McCullough and Renfro (*J. Economic and Social Measurement* 1998). `garchFit()` hits the benchmark.
- Note that constant included by default (not possible with **tseries**).
- Standard errors are from the Hessian.

More on `garchFit()`

`garchFit()` **provides**

- ARMA models with GARCH-type innovations
- Various innovation distributions: Gaussian, *t*, GED, including skewed generalizations.
- Several algorithms for maximizing log-likelihood, default is `nlminb`.
- Two methods for initializing recursions.

ARMA models with GARCH components

Mean equation is ARMA

$$y_t = \mu + \sum_{t-i}^{m} \phi_i y_{t-i} + \sum_{t-j}^{n} \theta_j \varepsilon_{t-j} + \varepsilon_t$$

Variance equation for GARCH(p, q) is

$$\begin{aligned} \varepsilon_t &= \sigma_t \nu_t, \\ \nu_t &\sim \mathcal{D}_\vartheta(0,1) \text{ i.i.d.}, \\ \sigma_t^2 &= \omega + \sum_{i=1}^{p} \alpha_i \varepsilon_{t-i}^2 + \sum_{t-j}^{q} \beta_j \sigma_{t-j}^2. \end{aligned}$$

ARMA models with APARCH components

Mean equation is ARMA

$$y_t = \mu + \sum_{t-i}^{m} \phi_i y_{t-i} + \sum_{t-j}^{n} \theta_j \varepsilon_{t-j} + \varepsilon_t$$

Variance equation for APARCH(p, q) is

$$\begin{aligned} \varepsilon_t &= \sigma_t \nu_t, \\ \nu_t &\sim \mathcal{D}_\vartheta(0,1) \text{ i.i.d.}, \\ \sigma_t^\delta &= \omega + \sum_{i=1}^{p} \alpha_i (|\varepsilon_{t-i}| - \gamma_i \varepsilon_{t-i})^\delta + \sum_{t-j}^{q} \beta_j \sigma_{t-j}^\delta. \end{aligned}$$

where $\delta > 0$ and the leverage parameters $-1 < \gamma_i < 1$.
APARCH comprises various GARCH-type models, including ARCH, GARCH, Taylor/Schwert-GARCH, GJR-GARCH, TARCH, NARCH, log-ARCH, …

ARMA models with APARCH components

More complex example: Ding, Granger, Engle (*J. Emp. Fin.* 1993)
MA(1)-APARCH(1,1) model for S&P 500 returns (17055 observations)

```
R> sp_ap <- garchFit(~ arma(0,1) + aparch(1,1),
+  data = ts(100 * sp500dge), trace = FALSE)
```

Excerpt from `summary(sp_ap)`:

```
Std. Errors:
 based on Hessian

Error Analysis:
        Estimate  Std. Error  t value Pr(>|t|)
mu      0.020595    0.006342    3.247  0.00116
ma1     0.144709    0.008346   17.338  < 2e-16
omega   0.009991    0.001066    9.373  < 2e-16
alpha1  0.083792    0.004343   19.293  < 2e-16
gamma1  0.374182    0.028027   13.351  < 2e-16
```

Results broadly agree with original paper (p. 99, eq. (19)), where algorithm was BHHH. (Note: percentage returns!)

ARMA models with APARCH components

Further ARCH-type models:

Taylor-Schwert ARCH (compare Ding, Granger, Engle, eq. (16))

```
R> sp_tsarch <- garchFit(~ arma(0,1) + garch(1,1), delta = 1,
+  data = ts(100 * sp500dge), trace = FALSE)
```

Threshold ARCH (TARCH)

```
R> sp_tarch <- garchFit(~ arma(0,1) + garch(1,1), delta = 1,
+  leverage = TRUE, data = ts(100 * sp500dge), trace = FALSE)
```

GJR-GARCH

```
R> sp_tarch <- garchFit(~ arma(0,1) + garch(1,1), delta = 2,
+  leverage = TRUE, data = ts(100 * sp500dge), trace = FALSE)
```


ARMA models with APARCH components

Specifying innovation distributions:

`cond.dist` – specification of conditional distributions allowing for `"dnorm"`, `"dged"`, `"dstd"`, `"dsnorm"`, `"dsged"`, `"dsstd"`. Three of these (`"dsnorm"`, `"dsged"`, `"dsstd"`) are skewed. – Thus

GARCH(1,1) with Student-t (shape parameter estimated)

```
R> sp_garch_std <- garchFit(~ garch(1,1), cond.dist = "dstd",
+  data = ts(100 * sp500dge), trace = FALSE)
```

GARCH(1,1) with Student-t_3 (shape parameter fixed at 3)

```
R> sp_garch_std3 <- garchFit(~ garch(1,1),
+  cond.dist = "dstd", shape = 3, include.shape = FALSE,
+  data = ts(100 * sp500dge), trace = FALSE)
```

GARCH(1,1) with Laplace (a GED with shape fixed at 1)

```
R> sp_garch_ged <- garchFit(~ garch(1,1),
+  cond.dist = "dged", shape = 1, include.shape = FALSE,
+  data = ts(100 * sp500dge), trace = FALSE)
```


ARMA models with APARCH components

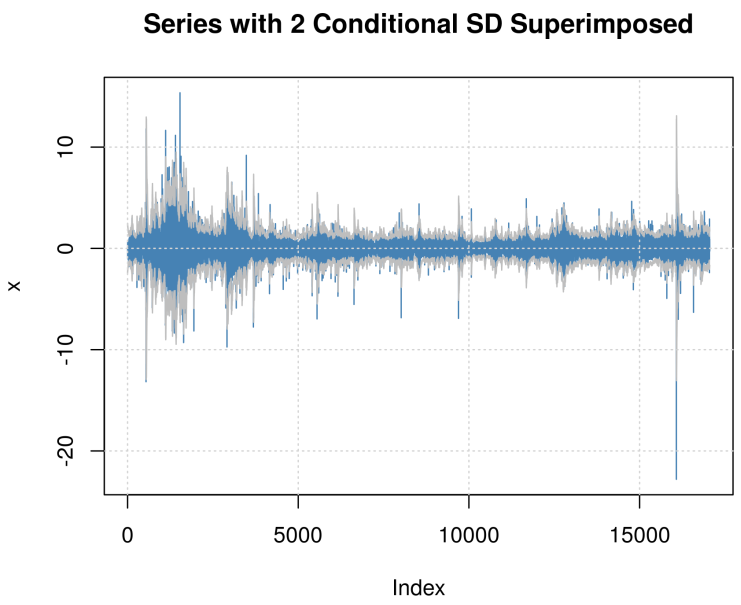
Further remarks:

- More details regarding fitting process, defaults, etc. upon setting `trace = TRUE`
- `plot()` method offers 12 types of plots: time series, conditional std. dev., ACF of obs. and squared obs., residuals, ACF of residuals and squared residuals,etc.

  Example: (ARMA-APARCH cont'd)
  Series with superimposed conditional std. dev. is

```
R> plot(sp_ap, which = 3)
```


ARMA models with APARCH components



Financial Econometrics

Extensions

Additional tools for financial engineering

- Portfolio management: **fPortfolio**, **portfolio** offer portfolio selection and optimization.
- Risk management:
  - Classical Value-at-Risk: **VaR.**
  - Extreme Value Theory models: **evd**, **evdbayes**, **evir**, **extRremes**, **ismec**, **POT**.
  - Multivariate modeling: **fCopulae**, **copula**, **fgac**
- High-frequency data: **realized**.

More complete overview in CRAN Task View Empirical Finance at

`http://CRAN.R-project.org/view=Finance`