

Ch 8 – ARCH, GARCH Model

2014/ ZA Q1

Define the lag operator L as the application $Lx_t = x_{t-1}$ for any series $\{x_t\}_t$. The component GARCH model can then be rewritten:

$$\begin{aligned}\sigma_{t+1}^2 &= \nu_{t+1} + \alpha_\sigma(R_t^2 - L\nu_{t+1}) + \beta_\sigma(\sigma_t^2 - L\nu_{t+1}) \\ &= \alpha_\sigma R_t^2 + \beta_\sigma \sigma_t^2 + (1 - (\alpha_\sigma + \beta_\sigma)L)\nu_{t+1}\end{aligned}$$

$$\begin{aligned}\nu_{t+1} &= \sigma^2 + \alpha_\nu(R_t^2 - \sigma_t^2) + \beta_\nu(\nu_t - \sigma^2) \\ &= \sigma^2 + \alpha_\nu R_t^2 - \alpha_\nu \sigma_t^2 + \beta_\nu L\nu_{t+1} - \beta_\nu \sigma^2.\end{aligned}$$

The long-run variance factor ν_{t+1} can be written as:

$$\nu_{t+1} = \frac{1}{1 - \beta_\nu L} ((1 - \beta_\nu)\sigma^2 + \alpha_\nu R_t^2 - \alpha_\nu \sigma_t^2).$$

Replacing into the equation for σ_{t+1}^2 one obtains:

$$\sigma_{t+1}^2 = \alpha_\sigma R_t^2 + \beta_\sigma \sigma_t^2 + \frac{(1 - (\alpha_\sigma + \beta_\sigma)L)L}{1 - \beta_\nu L} [(1 - \beta_\nu)\sigma^2 + \alpha_\nu R_t^2 - \alpha_\nu \sigma_t^2].$$

Multiplying both sides by $1 - \beta_\nu L$ and simplifying we get:

$$\begin{aligned}\sigma_{t+1}^2 &= \beta_\nu L\sigma_{t+1}^2 + (1 - \beta_\nu L)(\alpha_\sigma R_t^2 + \beta_\sigma \sigma_t^2) \\ &\quad + (1 - (\alpha_\sigma + \beta_\sigma)L)((1 - \beta_\nu)\sigma^2 + \alpha_\nu R_t^2 - \alpha_\nu \sigma_t^2) \\ &= \beta_\nu \sigma_t^2 + \alpha_\sigma R_t^2 + \beta_\sigma \sigma_t^2 - \beta_\nu \alpha_\sigma R_{t-1}^2 - \beta_\nu \beta_\sigma \sigma_{t-1}^2 \\ &\quad + (1 - (\alpha_\sigma + \beta_\sigma))(1 - \beta_\nu)\sigma^2 + \alpha_\sigma R_t^2 \\ &\quad - (\alpha_\sigma + \beta_\sigma)\alpha_\nu R_{t-1}^2 - \alpha_\nu \sigma_t^2 + (\alpha_\sigma + \beta_\sigma)\alpha_\nu \sigma_{t-1}^2 \\ &= (1 - (\alpha_\sigma + \beta_\sigma))(1 - \beta_\nu)\sigma^2 + (-\alpha_\nu + \beta_\nu + \beta_\sigma)\sigma_t^2 \\ &\quad + ((\alpha_\sigma + \beta_\sigma)\alpha_\nu - \beta_\nu \beta_\sigma)\sigma_{t-1}^2 \\ &\quad + (\alpha_\sigma + \alpha_\nu)R_t^2 + (-(\alpha_\sigma + \beta_\sigma)\alpha_\nu - \beta_\nu \alpha_\sigma)R_{t-1}^2.\end{aligned}$$

So the component GARCH model can be identified as a GARCH(2,2) model:

$$\sigma_{t+1}^2 = \omega + \alpha_1 R_t^2 + \alpha_2 R_{t-1}^2 + \beta_1 \sigma_t^2 + \beta_2 \sigma_{t-1}^2$$

where:

$$\begin{aligned}\omega &= (1 - (\alpha_\sigma + \beta_\sigma))(1 - \beta_\nu)\sigma^2 \\ \alpha_1 &= \alpha_\sigma + \alpha_\nu \\ \alpha_2 &= -(\alpha_\sigma + \beta_\sigma)\alpha_\nu - \beta_\nu \alpha_\sigma \\ \beta_1 &= -\alpha_\nu + \beta_\nu + \beta_\sigma \\ \beta_2 &= (\alpha_\sigma + \beta_\sigma)\alpha_\nu - \beta_\nu \beta_\sigma.\end{aligned}$$

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