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IGARCH and variance change in the US long-run interest rate

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It is shown that a one-time variance change in the US long-run interest rate spuriously suggests that it can be described with an IGARCH(1,1) process. The variance change is detected using a simple statistical test, and it corresponds to a change in monetary policy.

I. INTRODUCTION

Many first differences of financial time series characteristics which can be most appropriately described by an autoregressive moving average (ARMA) model with generalized autoregressive conditional heteroskedasticity of order (1,1) [GARCH(1,1)] type errors. Denoting such a time series as y_t, this model is given by

$$\phi_p(B)y_t = \mu + \theta_q(B)\varepsilon_t$$
$$\varepsilon_t | I_{t-1} \sim (0, h_t)$$
$$h_t = \phi + \alpha\varepsilon^2_{t-1} + \beta h_{t-1}$$

(see Bollerslev, 1986). In the sequel it is assumed that the usual stationarity and regularity conditions for y_t apply, except if otherwise indicated. When $\alpha + \beta$ is equal to one, this process is called an IGARCH process of order (1,1). The model for h_t implies that highly volatile periods are succeeded by similarly volatile periods, and hence that the y_t series may show sequences of outlying observations. The IGARCH process assumes that such observations can have a persistent impact on the variance, although this persistence is usually not everlasting.

The IGARCH(1,1) process turns out to be an adequate statistical device to many financial time series. This has generated much research effort in the use of IGARCH processes for forecasting and economic theoretical analysis, and its effects on testing for cointegration, see Franses, Kofman and Moser (1992). It seems therefore of importance to check empirically whether the assumed IGARCH process does indeed yield a valid description. In particular, and parallel to the effect of a shift in mean on tests for unit roots, it may be worthwhile to investigate whether a one-time change in the variance of the process is causal to the detection of IGARCH errors. Such a variance change may spuriously give the impression that a shock has a permanent effect on the variance, see also Diebold (1986) and Lamoureux and Lastrapes (1990). In fact, it may occur that the assumption of IGARCH is based on only one observation.

This note presents an empirical study of the time series of the monthly US long-term interest rate for 1965:03–1988:04, of which the graph indicates that a one-time variance change could have occurred. The next section discusses some univariate models for the entire sample period and for two subperiods. For the entire sample it emerges that the first differences of the series can be modelled with an IGARCH(1,1) process, while allowing for one variance change yields two models without any ARCH patterns. A simple statistical test for such a variance change is proposed. The final section concludes with some remarks.

II. UNIVARIATE TIME SERIES MODELS

Consider the first differences of the US long-run interest rate series for the period 1965:04–1988:04 and denote this series as y_t. Knowledge of the process at hand (see, e.g. Mascaro and Meltzer, 1983 and Lastrapes, 1989), suggests that this variance change occurs around October 1979. In that month, the Federal Reserve Board announced that the money supply would not fluctuate with the business cycle any more, and hence that money supply would be fixed while interest rates would float. The variance change may not occur exactly in the same month, since the economic agents had to adjust to this change. Below, a simple statistical test will be used to indicate when this change in variance took place.

It may well be, however, that before and after this variance change, the process can be characterized by GARCH type processes. To analyse such time series aspects, one may start

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with estimating an AR(2) for the y_t series, or

$$y_t = 0.016 + 0.378\, y_{t-1} - 0.285\, y_{t-2} + \varepsilon_t \quad (1)$$
$$(0.017)\ (0.057)\qquad (0.057)$$

where the standard errors are given in parentheses. The F_{AR1}, F_{AR2} and F_{AR12} tests for residual autocorrelation of orders 1, 2 and 12 obtain values of 0.809, 0.462 and 1.235, respectively. The F_{ARCH1} test has a value of 10.897, and the kurtosis and skewness are estimated as 6.339 and 0.092. A $\chi^2(2)$ test for normality of the residuals yields 133.744. In summary, the mean equation seems to be well-specified, and the variance process may be appropriately modelled with an ARCH or GARCH process.

After a brief specification search, it emerges that an AR(2)-GARCH(1,1) model for y_t is most adequate. Its estimation results are

$$y_t = 0.020 + 0.296 y_{t-1} - 0.189 y_{t-2} + \varepsilon_t \quad (2)$$
$$(0.012)\ (0.062)\qquad (0.062)$$

$$\varepsilon_t | I_{t-1} \sim (0, h_t) \quad (3)$$

$$h_t = 0.002 + 0.198\varepsilon^2_{t-1} + 0.787 h_{t-1} \quad (4)$$
$$(0.001)\ (0.041)\qquad (0.036)$$

The Ljung–Box tests for normalized residuals and normalized residual-squares of order 12 have values of 9.964 and 14.128, respectively. The kurtosis is now estimated to be 4.158 and the skewness 0.284. Hence, the model in Equations 2, 3 and 4 seems to be a reasonably adequate representation of the data. The sum of α and β is 0.985. This implies that Equation 4 is likely to be an IGARCH(1,1) process.

From the unreported graph it can be observed that there seems to be a variance change around 1980. After that observation, the variance persists in being about twice as large as the variance in the first period. This variance change is caused by a change in monetary policy of the Federal Reserve Board. One could now apply modifications of the statistical test advocated in Tsay (1988) to detect the exact timing of the variance change. Here the following strategy is followed. An AR model of order 4 is fitted to the y_t^2 series. With the use of Chow-type tests it is decided when the parameters in this model change dramatically. It turns out that this is around 1980:02 and 1980:03. Fitting the same AR(4) model for the periods 1965:04–1980:01 and 1980:04–1988:04 indicates that now parameter constancy in these two subperiods cannot be rejected.

Univariate models for the two subperiods can now be fitted. For the first period, 1965:04–1980:01, this model is

$$y_t = 0.028 + 0.171 y_{t-1} + \varepsilon_t \quad (5)$$
$$(0.013)\ (0.076)$$

The relevant diagnostic test statistics F_{AR1}, F_{AR2}, and F_{AR12} yield values of 2.650, 1.775 and 1.259, respectively. The kurtosis is 4.551 and the skewness is 0.158. The $\chi^2(2)$ test statistic obtains a value of 18.366. Hence, there may be outlying observations. It is not likely, however, that such observations are generated by ARCH type processes since the F_{ARCH1} and F_{ARCH2} test statistics have values of 1.217 and 1.097. For the sample period 1980:04–1988:04, the estimated model is

$$y_t = -0.019 + 0.397 y_{t-1} - 0.307 y_{t-2} + \varepsilon_t \quad (6)$$
$$(0.038)\ (0.092)\qquad (0.087)$$

For this model it applies that F_{AR1}, F_{AR2}, F_{AR12} are 0.001, 0.302, 1.242, that the $\chi^2(2)$ test value is 1.137 since kurtosis is 3.498 and skewness is 0.023 and that the F_{ARCH1}, F_{ARCH2} test statistics have values of 0.609 and 0.284, respectively.

III. CONCLUSION

In this note it is illustrated with the US long-run interest series that an IGARCH(1,1) process can be spurious since it can be caused by one variance change. Not only is the integrated part of the IGARCH error process spurious, it can also be observed that subperiods do not show characteristics of ARCH type processes. Hence, the finding of the IGARCH process for the US long-run interest rate for 1965:04–1988:04 is caused by only one or two observations.

The finding in this note can have an impact on many issues. The first is that forecasting models for the US interest series may be most conveniently based on the last few years only. In that case one does not have to rely on complicated formulae for the forecast error variances. Further, it may be of interest to investigate whether related time series have a variance change in common with the interest rate. The statistical approach to detect the timing of the variance change in the present note may need some refinements. And, of course, an extension to more than one variance change should also be included in the list of topics for future research.

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