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VOLATILITY PERSISTENCE
A GRACH APPLICATION TO JAMAICAN STOCK RETURNS

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Abstract: This paper uses alternative univariate formulations of the GARCH process to examine the stock returns on the Jamaica Stock Exchange. The results show that the observed stock price returns are autocorrelated and negatively related to changes in the treasury bill rate, and the volatility of the returns can be predicted by a GARCH specification. Further, a measure of volatility persistence is dependent on the model specification.

Keywords: GARCH process; volatility persistence

Introduction

Stock markets in developing countries are typically characterised as fragmented and thin. They generally have high transactions costs (especially high minimum commissions) which tend to deter small investors and leave the market under the operation of a small number of large, dominant operators who can affect market prices substantially. A low volume of transactions relative to gross domestic product and a relatively small number of market participants are characteristics of a thin market. Bourne (1988) argues that these markets tend "to exhibit stock price volatility, stock price manipulation and market inefficiency in that some investors have a systematic tendency to gain from stock price movements".

Research on developed country stock markets have suggested that rates of return are approximately uncorrelated over time, but characterised by tranquil and volatile periods Bollerslev (1986)) . Research on developing country equity markets have focussed on efficiency issues. This paper estimates the observed time varying volatility of equity returns using a GARCH model framework.

The results show that the GARCH technique (Engle (1982), Bollerslev (1986)), which recognises that both conditional means and variances may be time dependent, is capable of predicting stock return volatility on the Jamaica Stock Exchange. In addition, it is shown that an observed unit root in the variance of returns is likely to be a reflection of model misspecification. A GARCH model's ability to predict volatility is shown to have strategic utility for portfolio management in both developed and emerging equity markets.

Section 1 provides a brief institutional perspective and the model structure is described in section 2. The empirical results are discussed in section 3, with conclusions and directions for further research following in Section 4.

Institutional Overview

The Jamaica Stock Exchange began trading on February 2, 1969. The securities traded include common shares, preference shares and corporte bonds. Trading is undertaken by broker-members. There are twelve brokerage houses qualified to conduct business through the Exchange. The number of listed companies have grown from 34 in 1969 to 50 at the end of 1993.

The common stock index is a weighted index of shares listed on the Exchange based on closing prices and firm capitalisation. From a base of 100 in June 1969, the index rose to an all time high of 32,421.71 at the end of January 1993. The all time low of 35.84 was recorded in February 1978. The phenomenal growth rate in 1991 placed the Jamaica Stock Exchange among the top ten equity markets in 1992. The market has since recorded strong trading growth, a sharp decline in the index and a fall in market capitalisation.

During the first two decades of stock market operations, the Jamaican economy experienced long periods of both declining and growing investment climates as the administrations' ideological stance shifted from predominantly socialist to predominantly private enterprise regimes. There was a prolonged decline in output growth, general economic uncertainty, high inflation, financial sector regulation and a series of economic stabilisation programs with the International Monetary Fund (See Bank of Jamaica (1985) and Sharpley (1984)). As a result, the market experienced periods of both large and small price changes.

At the end of 1993, the Jamaica Stock Exchange, which started operations in 1969, had a listing of 50 companies with a market capitalisation of J$41.9 billion. Total trading volume in 1993 was 567.45 million (value J$8.35 billion) compared with 395.61 million (value J$4.69 billion) in 1992. The stock index had plunged from a 1992 year end high of 25,745 to 13,100, a 49 percent fall compared to the over two hundred percent increases in both 1991 and 1992, and market capitalisation declined 45.6 percent.

Model Specification

Let y be the rate of return of the market portfolio from time t-1 to t for an information set of past realizations up to t-1. The rate of return,DLR, is modelled as a linear function of a vector of explanatory variables, X, its own standard deviation, $h^{1/2}$, and a disturbance term u. The disturbance term is assumed to follow a moving average process, and the innovation follows a normal or t - distribution with variance specified as an augmented GARCH process.

$$DLR_t|\Phi_{t-1} \sim (V_t, h_t)$$
$$_t = \theta_0 + \sum_{j=1}^{p} \theta_j DLR_{t-j} + \beta' X + \delta h_t^{\frac{1}{2}} + u_t$$
$$u_t = \varepsilon_t - \sum_{j=1}^{q} \gamma_j \varepsilon_{t-j} \qquad (1)$$
$$\varepsilon_t|\Phi_{t-1} \sim N(0,h_t) \quad or \; \sim t.d(0,h_t,\upsilon)$$
$$h_t = f(\varepsilon_{t-j}, h_{t-j}) + \xi' Z$$

Z is a vector of additional variables explaining the variance of the innovation process. Different formulations of f(.) exist. Subset restrictions on the parameters of the general structure define special cases and ensure finite variance and stationarity.

The GARCH model hypothesises that the conditional variance can be modelled as a function the unexpected returns prior to time t. Bollerslev(1986) defines the GARCH(p,q) process as

$$h_t = \alpha_0 + \sum_{i=1}^{q} \alpha_i \varepsilon_{t-i}^2 + \sum_{i=1}^{p} \beta_i h_{t-i} \qquad (2)$$

where $\alpha_1, \cdots, \alpha_q, \beta_1, \cdots, \beta_p$, and α_0 are constant parameters. The model is well defined if if the coefficients of its infinite autoregressive representation are all non-negative, and the roots of the moving average polynomial of squared innovations lie outside the unit circle. In the GARCH(1,1) model, the effect of a shock on volatility declines geometrically over time.

Nelson (1990) argues that returns may exhibit asymmetrical conditional variance behaviour in that positive shocks generate an unequal impact on volatility than negative shocks. He proposed an exponential GARCH or EGARCH(p,q) model to capture that asymmetry.

$$\log(h_t) = \alpha_0 + \sum_{j=1}^{i} \beta_j \log(h_{t-j}) + \sum \omega_j \left(\gamma \frac{\varepsilon_{t-j}}{\sqrt{h_{t-j}}} + \alpha \left[\frac{|\varepsilon_{t-j}|}{\sqrt{h_{t-j}}} - E\left\{ \frac{|\varepsilon_{t-j}|}{\sqrt{h_{t-j}}} \right\} \right] \right) \quad (3)$$

where $\omega_j, \beta_j, \gamma$, and α are constant parameters. The terms $\varepsilon_{t-1}/\sqrt{h_{t-1}}$ in the equation ensure asymmetry through their coefficients. If negative, the variance increases (decreases) when the error innovation is negative (positive). Stationarity requires the roots of the autoregressive polynomial to lie outside the unit circle. Since information flow affects portfolio selection different models of predictability of market volatility will have different implications for asset pricing or strategic decisions.

In addition to the asymmetric behaviour, the assumption of conditional normality may be untenable. Bollerslev(1987) suggests the use of the t-distribution to account for the fat tails normally observed in observed equity returns. The model equations, grouped in Table 1, include three univariate conditional normal models and one univariate t-distribution model.

Table 1: Alternative GARCH Models

GARCH(1,1)

$$h_t = \alpha_0 + \alpha\varepsilon_{t-1}^2 + \beta h_{t-1}$$

EGARCH(1,1)

$$\log(h_t) = \alpha_0 + \beta \cdot \log(h_{t-1}) + \gamma \cdot \frac{\varepsilon_{t-1}}{\sqrt{h_{t-1}}} + \alpha\left[\frac{|\varepsilon_{t-1}|}{\sqrt{h_{t-1}}} - \sqrt{2/\pi}\right]$$

VGARCH(1,1)

$$h_t = \omega + \beta h_{t-1} + \alpha\left(\varepsilon_{t-1}/\sqrt{h_{t-1}} + \gamma\right)^2$$

The above models are augmented in the mean through the inclusion of the nominal treasury bill rate which captures the interdependence between financial assets. Other effects could include traded volume and dummy variables for regime shifts. The absolute value of lagged changes in the treasury bill rate indicates that volatility is influenced by both positive and negative changes in the treasury bill rate. The moving average process is expected to reflect the seasonal effects of announcements on dividends and earnings reports. The models are estimated by maximisation of the log likelihood function. For the sample period the likelihood function is given by

$$L(\phi) = \sum_{t=1}^{T} L_t(\phi), \qquad \text{where}$$

$$L_t(\phi) = -0.5 \log h_t - 0.5\varepsilon_t^2 h_t^{-1}, \quad \text{for the Normal,}$$

$$L_t(\phi) = \ln\Gamma\big(0.5(\nu+1)\big) - \ln\Gamma(0.5\nu) - 0.5\ln(\nu-2) - 0.5\ln h_t$$
$$- 0.5(\nu+1)\cdot\ln\big(1 + u_t^2/(h_t(\nu-2))\big) \quad \text{for the t-distribution} \qquad (4)$$

Empirical Results

The data are monthly closing indices for the Jamaica stock market index spanning the period 1969:07 to 1994:5. The analysis is conducted on the entire sample, but could in principle be split to accommodate the pre- and post- 1979 periods of declining and rising trends, respectively, in the index.

The graph of log of the composite monthly stock price index for the period 1969:07 to 1994:05 suggested non-stationarity, possibly with a drift factor. The distinct cut off in the partial correlation function, the smooth and slowly declining autocorrelation function (value of 0.91 at lag 10) and the value of 0.992 for the first sample partial auto-correlation suggested first order non- stationarity. The augmented Dickey-Fuller Test of a unit root is not rejected, indicating that the logarithm of the stock price index was a martingale difference process.

The partial autocorrelation function of the log change of the price index indicated at most a second order autoregression. The residuals from the second order autoregression revealed no evidence of serial correlation, but the absolute and squared residuals had significant partial autoregressions. Non-normality, mainly due to leptokurtosis, was also indicated. The linear dependence in the monthly returns indicates that the reaction of share prices to new information is not immediate, and the peakedness in the distribution suggests changing variances, possibly due to the low level of trading activity, and uncertainty about future government policy and economic fundamentals and the current and expected corporate decisions. The above statistics confirm that a model of stock price returns must explain the observed autocorrelation in the returns and the dependence in the squared returns.

The estimates for the specified models for the period 1970:1 to 1994:05 are shown in Table 2. The parameters are well determined and significant at the 5 per cent level. The lagged conditional variance term is significant and positive in every model. The magnitudes indicate stable variance functions. The Ljung-Box test for serial correlation in the standardised residuals and their squares do not indicate any violations. The VGARCH has the highest log likelihood. The positive gamma coefficient in the EGARCH is small and insignificant indicating that shocks have a symmetrical effect on the volatility, but suggests positive return shocks generate more volatility than negative return shocks.

The standard models indicate GARCH models that are integrated in the variance with trend, thus indicating that shocks to the system persist for a long time. Assuming that the near integratedness is indicative of misspecification in the model structure, the paper explores the predictive content of implicit monthly effective treasury bill rates on the monthly stock returns. The results show that the lagged monthly treasury bill rate is negatively related to the mean of the stock return; also, the absolute value of the most recent change in the treasury bill rate has a positive effect on the variance of stock returns. In addition to the one month variance effect and three month mean effect, the moving average parameter suggests a further quarterly dynamic link, possibly due to the impact of quarterly announcements on dividends and earnings. In each case, the extended model cannot be rejected against the more restricted basic model. Further, the persistence factors are reduced so that the autoregressive parameterisations are stable.

The mean lag in the conditional variance ranges from 1.3 to 3 months, the GARCH specification having the longest lag and the exponential model the shortest. In every case there is a significant reduction in the fourth moment but the standardised residuals show some remaining leptokurtosis.

Conclusion

This paper provides supporting evidence that stock returns on the Jamaica Stock Exchange are autocorrelated and exhibit time varying volatility. The linear dependence of the returns indicates imperfect utilisation of information flows. A first order GARCH process fits the data adequately. It is shown that the predictive content of the models can be improved by the incorporation of relevant explanatory variables. Further research is clearly needed to explore the relationships among the stock returns, trading volume and other monetary and price aggregates. In the emerging market context, the results possibly point to the need for a stable macroeconomic environment to generate stable growth of equity markets.

Table 2: Estimates of Alternative Volatility Models

GARCH(1,1)

$$DLR_t = \underset{(2.34)}{0.64} + \underset{(10.95)}{0.62}\, DLR_{t-1} - \underset{(2.74)}{0.15}\, DTB_{t-3}$$
$$h_t = \underset{(2.07)}{2.56} + \underset{(4.38)}{0.34}\, h_{t-1} + \underset{(6.43)}{0.57}\, \varepsilon_{t-1}^2 + \underset{(2.09)}{1.14}\left|DTB_{t-1}\right|$$
$$\varepsilon_t = u_t - \underset{(4.60)}{0.43}\, u_{t-4} \qquad L = -615.28$$

$$DLR_t = \underset{(1.85)}{0.44} + \underset{(10.74)}{0.54}\, DLR_{t-1}$$
$$h_t = \underset{(3.02)}{3.91} + \underset{(6.67)}{0.40}\, h_{t-1} + \underset{(7.56)}{0.75}\, \varepsilon_{t-1}^2 \qquad L = -627.84$$

VGARCH(1,1)

$$DLR_t = \underset{(2.56)}{0.80} + \underset{(10.39)}{0.56}\, DLR_{t-1} - \underset{(2.24)}{0.14}\, DTB_{t-3}$$

$$h_t = \underset{(0.15)}{0.30} + \underset{(6.87)}{0.55}\, h_{t-1} + \underset{(5.80)}{0.13}\left(\varepsilon_{t-1}\Big/\sqrt{h_{t-1}} + \underset{(1.42)}{1.44}\right)^2 + \underset{(1.89)}{0.82}\left|DTB_{t-1}\right|$$
$$\varepsilon_t = u_t - \underset{(2.15)}{0.21}\, u_{t-4} \qquad L = -614.27$$

$$DLR_t = \underset{(2.71)}{0.77} + \underset{(10.37)}{0.55}\, DLR_{t-1}$$

$$h_t = \underset{(0.44)}{0.93} + \underset{(7.95)}{0.56}\, h_{t-1} + \underset{(6.69)}{0.17}\left(\varepsilon_{t-1}\Big/\sqrt{h_{t-1}} + \underset{(2.40)}{2.06}\right)^2, \qquad L = -624.09$$

EGARCH(1,1)

$$DLR_t = \underset{(2.51)}{0.74} + \underset{(9.61)}{0.59}\, DLR_{t-1} - \underset{(2.46)}{0.14}\, DTB_{t-3}$$
$$\log(h_t) = \underset{(0.44)}{0.08} + \underset{(12.87)}{0.75}\log(h_{t-1}) + \underset{(0.89)}{0.004}\frac{\varepsilon_{t-1}}{\sqrt{h_{t-1}}} + \underset{(11.34)}{0.09}\left[\frac{\left|\varepsilon_{t-1}\right|}{\sqrt{h_{t-1}}} - \sqrt{2/\pi}\right] + \underset{(2.05)}{0.03}\left|DTB_{t-1}\right|$$
$$\varepsilon_t = u_t - \underset{(4.93)}{0.42}\, u_{t-4} \qquad L = -613.73$$

$$DLR_t = \underset{(2.30)}{0.60} + \underset{(10.03)}{0.55}\, DLR_{t-1}$$
$$\log(h_t) = \underset{(0.29)}{0.06} + \underset{(11.83)}{0.76}\log(h_{t-1}) + \underset{(1.22)}{0.001}\frac{\varepsilon_{t-1}}{\sqrt{h_{t-1}}} + \underset{(12.80)}{0.10}\left[\frac{\left|\varepsilon_{t-1}\right|}{\sqrt{h_{t-1}}} - \sqrt{2/\pi}\right], \qquad L = -625.29$$

TGARCH(1.1)

$$DLR_t = \underset{(2.03)}{0.48} + \underset{(10.64)}{0.57}\, DLR_{t-1} - \underset{(2.73)}{0.16}\, DTB_{t-3}$$

$$h_t = \underset{(1.53)}{4.27} + \underset{(2.57)}{0.35}\, h_{t-1} + \underset{(2.82)}{0.44}\, \varepsilon_{t-1}^2 + \underset{(1.55)}{1.71} \left| DTB_{t-1} \right|$$

$$\varepsilon_t = u_t - \underset{(3.10)}{0.52}\, u_{t-4}, \qquad \upsilon = \underset{(3.08)}{3.75} \qquad L = -704.67$$

$$DLR_t = \underset{(1.53)}{0.37} + \underset{(10.50)}{0.55}\, DLR_{t-1}$$

$$h_t = \underset{(1.89)}{5.49} + \underset{(4.94)}{0.53}\, h_{t-1} + \underset{(2.74)}{0.49}\, \varepsilon_{t-1}^2, \quad \upsilon = \underset{(3.40)}{3.48} \qquad L = -715.23$$