

# **Empirical Evidence of Conditional Heteroskedasticity in Vietnam's Stock Returns Time Series**

**Vuong Quan Hoang**

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JEL Classifications: C12; C22

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**Empirical Evidence of Conditional Heteroskedasticity  
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(for its entire existence through August 21, 2002)**

Abstract:

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Author:

Vuong Quan Hoang

*Solvay Business School, Universite Libre de Bruxelles; and Mezfin Research (Vietnam)*

E-mail: qvuong@ulb.ac.be (alt. hoang@mezfin.com)

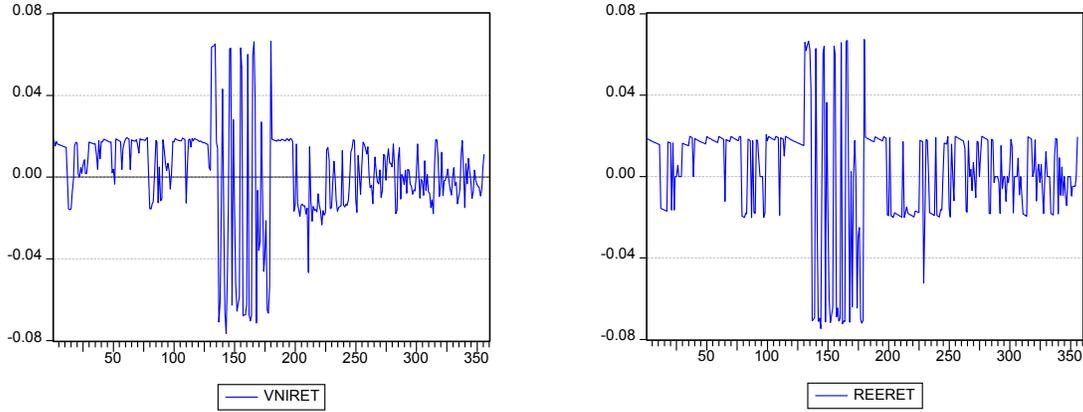
**The phenomenon of 'volatility clustering'**

Financial time series such as stock returns, usually exhibit the character of 'volatility clustering', especially with high-frequency data (daily). The phenomenon, for instance, characterizes the observed tendency, with which large change in stock return will likely be followed by subsequent large changes. As to Vietnam's 25-month-old stock market, the following graphs are to visualize the tendency of stock returns. Traditionally, daily returns are computed as follows:

$$r_t \simeq \ln(S_t / S_{t-1}) = \ln(S_t) - \ln(S_{t-1}) \quad (0.1)$$

where,  $S_t$  is stock price at time  $t$ . (Note: for market returns, stock price  $S$  is replaced by VN-Index.) Fig.1 presents the time series of stock returns for VNI and REE Corp. (one of the first two firms listed on Vietnam's stock market), showing similar patterns of movement over the entire period of 360 trading sessions from July 28, 2000 to August 22, 2002. Stock returns tend to 'cluster' in either upper limits or lower.

Figure 1. Stock returns



Next, a scatter plot in Fig.2 (see Appendix(1)) shows possibility of the serial correlation of daily stock returns. If this is confirmed, random walks are rejected. Intuitively, looking at these graphs gives us a ‘feel’ of daily returns trends. In suspicion of conditional volatility and non-linearity in return series, the following regression is considered:

$$\begin{aligned} (r_t)^2 &= \alpha + \rho(r_{t-1})^2 + u_t \\ t &= 3, 4, \dots, n \end{aligned} \quad (0.2)$$

The following table provides us with standard statistics, which confirm the well-known volatility clustering, based on the equation (1.2).

Table 1. Test statistics on volatility clustering

<i>Series</i>	$\hat{\alpha}$ ( <i>s.e.</i> )	$\hat{\rho}$ ( <i>s.e.</i> )	$R^2$ ( $\bar{R}^2$ )
VN-Index	0.00014926(*) (0.00004680)	0.73893656(*) (0.03582987)	0.54576246 (0.54447930)
REE Corp.	0.000183790(*) (0.00005429)	0.74717740(*) (0.03534808)	0.55794358 (0.55669484)
Samco	0.00017587(*) (0.00005251)	0.74868594(*) (0.03524149)	0.56042662 (0.55918489)
Hapaco	0.00160178 (0.00093448)	-0.00187756 (0.05337620)	0.00000035 (-0.00284547)
Transimex	0.00014844(*) (0.00005203)	0.80793797(*) (0.03233375)	0.65285501 (0.65180939)

(\*): significant at 1% level; t-Stat applicable for estimators  $\hat{\alpha}$  and  $\hat{\beta}$ .

The above statistics support the null of positive correlation between variances of the returns for four out of five time series, providing us a ground to further test GARCH effects.

### Model building and empirical results

ARCH models has been developed after the seminal work by Engle [4], which was later elaborated by Bollerslev’s Generalized ARCH (or GARCH) models [2][3]. Theoretically, ARCH is considered a special case of GARCH family. These models have since been widely

applied to deal with conditional heteroskedasticity and non-linearity in univariate financial time series.

The models:

GARCH concept, when speculative prices and rates of return are approximately uncorrelated, is described by Bollerslev [3] as follows:

$$y_t = E(y_t | \psi_{t-1}) + \varepsilon_t = y_{t|t-1} + \varepsilon_t \quad (2.1)$$

where  $t = 1, 2, \dots, T$ ;  $\psi_{t-1}$  denotes the  $\sigma$ -field generated by all the information up through time  $t - 1$  (for more details of Standardized  $t$ -distribution in relation to the model, see Appendix(2)). Let the mean level  $\mu = y_{t|t-1}$ , the initial equation becomes:

$$y_t = \mu + \varepsilon_t \quad (2.2)$$

A *GARCH*( $p, q$ ) effect is expressed in (2.3):

$$\begin{aligned} E(\varepsilon_t^2 | \psi_{t-1}) &= h_{t|t-1} \\ &= \omega + \sum_{i=1}^q \alpha_i \varepsilon_{t-i}^2 + \sum_{j=1}^p \beta_j h_{t-j|t-1-j} \end{aligned} \quad (2.3)$$

where  $\omega > 0, \alpha_i \geq 0, \beta_j \geq 0$ .

By far, the single most important GARCH model in analyzing financial time series, such as rates of stock return, is *GARCH*(1,1):

$$\begin{aligned} y_t &= \mu + \varepsilon_t \\ h_{t|t-1} &= \omega + \alpha \varepsilon_{t-1}^2 + \beta h_{t-1|t-2} \\ \varepsilon_t | \psi_{t-1} &\sim f_v(\varepsilon_t | \psi_{t-1}) \end{aligned} \quad (2.4)$$

It has been recommended by Bollerslev [3] to use Ljung-Box statistic for the standardized residuals ( $\hat{\varepsilon}_t \hat{h}_{t|t-1}^{-1/2}$ ) and squared residuals ( $\hat{\varepsilon}_t^2 \hat{h}_{t|t-1}^{-1}$ ) for checking further first or higher order serial dependence.

Model estimation and statistical findings:

The statistical findings are explored based on the following specific *AR*(1) process imposed by GARCH effects. This specific was proposed in Akgiray [1]:

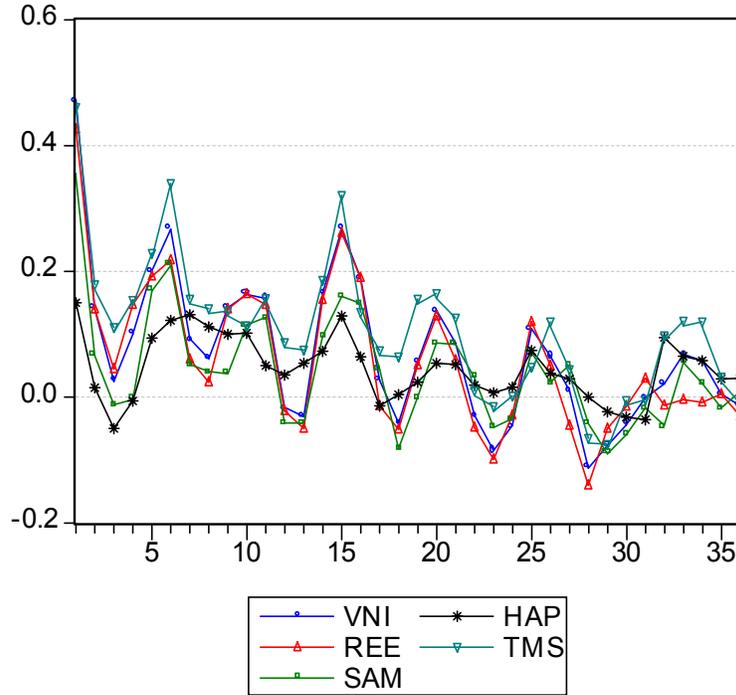
$$\begin{aligned} r_t | \psi_{t-1} &\sim f(\mu_t, v_t) \\ \mu_t &= \phi_0 + \phi_1 r_{t-1} \\ v_t &= \alpha_0 + \sum_{i=1}^q \alpha_i \varepsilon_{t-i}^2 + \sum_{j=1}^p \beta_j v_{t-j} \\ \varepsilon_t &= r_t - \phi_0 - \phi_1 r_{t-1} \end{aligned} \quad (2.5)$$

Estimating a *GARCH*( $p, q$ ) process is to identify the vector  $\theta \equiv (\phi_0, \phi_1, \alpha_0, \dots, \alpha_q, \beta_1, \dots, \beta_p)$ . In this job, values of  $p$  and  $q$  are prespecified; and a numerical maximization of its log-likelihood function needs be performed. The log-likelihood function is given by:

$$L(\theta|p,q) = \sum_{t=r}^T \log f(\mu_t, v_t) \quad (2.6)$$

where:  $r = \max(p, q)$ . Test for  $GARCH(p, q)$  are Lagrangean Multiplier (LM F-Stat.) under the null. Alternatively, if  $L(\theta_n)$  and  $L(\theta_a)$  are maximum values under null and alternative, then  $-2[L(\theta_n) - L(\theta_a)]$  is asymptotically  $\chi^2$  - distributed, with d.f. being the difference between the numbers of parameters under the null and the alternative.

We earlier on impose empirical tests on unit roots of the return series. The data supports null hypothesis of stationarity. See the autocorrelation function (ACF) below for confirmation of stationarity, and that strict white noise process for residuals is rejected. This means the dependence of returns on the past values, and we understand that the daily stock returns are not made up of independent variates.



The empirical results presented in Table 2 are obtained on examining  $GARCH(1,1)$  effects on daily stock returns time series (including VN-Index, considered a single composite stock weighted by number of outstanding shares volume). The series are computed using the above (1.1), then adjusted by annual dividends as follows:

$$r_t \simeq \ln(S_t + div_t / S_{t-1}) = \ln(S_t + div_t) - \ln(S_{t-1})$$

Table 2.  $GARCH(1,1)$  Model Estimation

Parameters	VN-Index	REE Corp.	Samco	Hapaco	Transimex
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$\phi_0$	0.002257(*) (3.505446)	0.002761(*) (3.33475)	0.002840(*) (3.358426)	0.000979 (0.460174)	0.004350(*) (4.9875471)
$\phi_1$	0.586895(*) (11.87782)	0.431821(*) (6.33798)	0.376666(*) (6.615925)	0.337356(*) (3.291754)	0.587331(*) (6.165655)
$\alpha_0$	0.0000092 (1.428794)	0.0000271 (1.638038)	0.0000267(*) (2.232323)	0.001266(***) (1.655678)	0.0000067(*) (1.155483)
$\alpha_1$	0.127740(**) (1.93566134)	0.207919(*) (4.238438)	0.313719(*) (3.647757)	0.064096 (0.531814)	0.218418(*) (2.355611)
$\beta_1$	0.830378(*) (19.19937)	0.716096(*) (13.33324)	0.624188(*) (7.882632)	0.230776 (1.007757)	0.788280(*) (10.89784)
$\alpha_1 + \beta_1$	0.95811840	0.92325652	0.93790723	0.29487225	1.00669568
$\sigma_\varepsilon^2 (\times 1000)$	0.01058171	0.03579292	0.03887622	1.35284878	0.00858515
$\sigma_r^2 (\times 1000)$	0.01614162	0.04408468	0.04530379	1.42895111	0.01310626
Log-likelihood	1031.76	941.97	947.12	646.57	945.60

Note: (\*)(\*\*)(\*\*\*): significant at 1%, 5%, 10%, respectively. Numbers in parentheses are  $t$ -Statistics. Unconditional variances of  $\varepsilon_t$ :  $\sigma_\varepsilon^2 = \alpha_0 / (1 - \alpha_1)$ . Unconditional variances of  $r_t$ :  $\sigma_r^2 = \sigma_\varepsilon^2 / (1 - \phi_1^2)$ .

Statistical findings confirm the GARCH(1,1) effect in stock return series, except for HAP stock. Most of the regression coefficients are significant at 1% level. We can also observe that all  $\alpha_1 + \beta_1$  are very close to unity (1.0), except HAP, which tells that the innovation shocks of the dynamic systems are quite permanent. Another exception is of TMS where  $\alpha_1 + \beta_1$  is greater than 1.0, in which case the time series exhibits the IGARCH process properties. The following Table 3 provides for test results on any possibility of GARCH effects on the residuals series. Our results reject the dependence of regression residuals series.

Table 3. ARCH LM tests on residuals series:

F-stat.	REE	SAM	HAP	TMS	VNI
Lag=1	0.373471	2.070303	0.0036	0.105725	0.036403
P-val	(0.541509)	(0.151073)	(0.952189)	(0.745269)	(0.848796)
Lag=2	0.190473	1.547304	0.001772	0.161078	0.072809
P-val	(0.826653)	(0.214261)	(0.99823)	(0.851292)	(0.929792)
Lag=3	0.280061	1.109728	0.002796	0.167938	0.050023
P-val	(0.839788)	(0.345117)	(0.999796)	(0.917969)	(0.98519)
Lag=4	0.267878	0.915233	0.003016	0.246068	0.041808
P-val	(0.898543)	(0.455105)	(0.999982)	(0.911942)	(0.996676)

### Remarks

In the paper, we examined the GARCH(1,1) effect in the daily stock returns series with Vietnam's market price index (VNI) and other four first listed stocks: REE, SAM, HAP and TMS, in this sequence. We found GARCH(1,1) effect present on four out of five series tested. Our estimation is supportive of the volatility clustering and conditional heteroskedasticity,

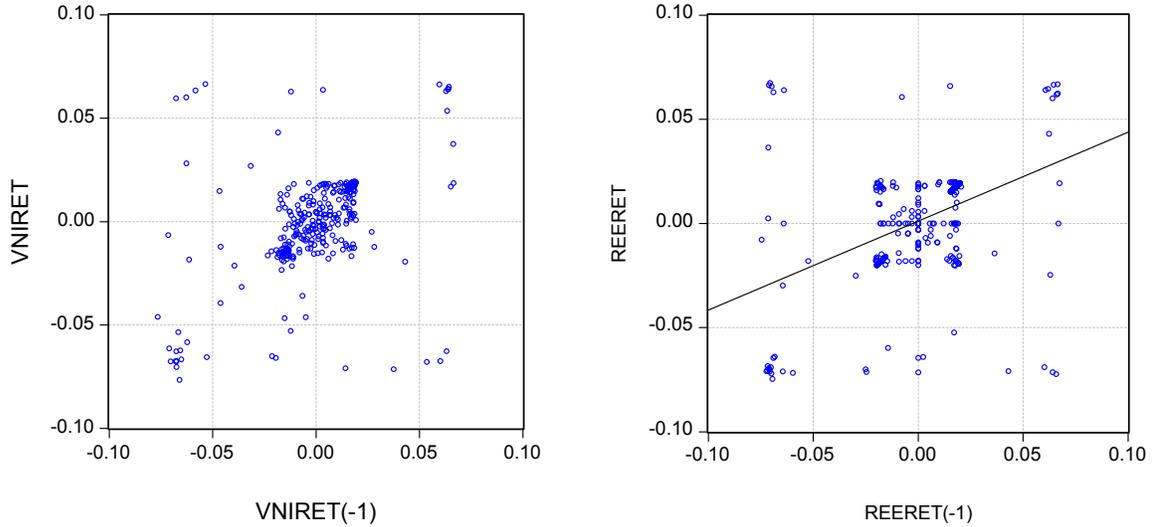
which have also been tested and supported by a rich literature in finance around the world. The results are twofold. On the one hand, we confirm the theoretical phenomenon that usually leads to market trend. On the other hand, the result might imply that existing trading technicalities and rules could have profound impact on market moves, which will require further research on informational content of stock price fluctuation.

**Acknowledgement:**

We would like to thank Prof. André Farber and Ariane Szafarz, University of Brussels, for comments and suggestions about the market disequilibria and likely positive serial correlation of Vietnam’s emerging stock market. Specifically, Prof. Farber in his lecturing visit, and his conference therewith, to Vietnam’s National Economics University suggested that the situation of highly likely serial correlation phenomenon of Vietnam’s stock market in its infancy would be worth considering. This paper has evolved since we took this point seriously.

**Appendix**

(1) Figure 2. Scatter plot of daily return against first-order lagged values



(2) Standardized *t*-distribution:

The conditional distribution of series  $y_t$  be standardized t-distribution, with  $\mu = y_{t|t-1}$ ;  $\text{var}(y_t) = h_{t|t-1}$ ; degree of freedom  $\nu$ . The random term  $\varepsilon_t$  in (1.3)(1.4) is described as follows:

$$\varepsilon_t | \psi_{t-1} \sim f_\nu(\varepsilon_t | \psi_{t-1}) = \Gamma\left(\frac{\nu + 1}{2}\right) \Gamma\left(\frac{\nu}{2}\right)^{-1} \left((\nu - 2)h_{t|t-1}\right)^{-1/2} \times \left(1 + \varepsilon_t^2 h_{t|t-1}^{-1} (\nu - 2)^{-1}\right)^{-(\nu+1)/2} \tag{4.1}$$

where:  $\nu > 2$ ;  $f_\nu(\varepsilon_t | \psi_{t-1})$ : the conditional density function for  $\varepsilon_t$  given the information set  $\psi_{t-1}$ .

The Gamma function  $\Gamma(n) = \int_0^\infty t^{n-1} e^{-t} dt$  has the properties:  $\Gamma(n+1) = n\Gamma(n)$ . When  $n$  is nonnegative integer:  $\Gamma(n+1) = n!$ .

*Vuong Quan Hoang, Solway Business School & Mezzfin Research  
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