FACULTATEA de FINANTE, ASIGURARI, BANCI si BURSE de VALORI

DOFIN

DOCTORAL SCHOOL OF FINANCE AND BANKING - European Centre of Excellence

TESTING THE EFFICIENT MARKET HYPOTHESIS ON THE ROMANIAN STOCK MARKET

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THE EFFICIENT MARKET HYPOTHESIS

- THE EFFICIENT MARKETS HYPOTHESIS (EMH) STATES THAT CURRENT STOCK PRICES FULLY REFLECT THE AVAILABLE INFORMATION ON THE VALUE OF THE FIRM, AND THERE IS NO WAY TO EARN EXCESS PROFITS (MORE THAN THE MARKET OVERALL) BY USING THIS INFORMATION.

- THE CURRENT PRICES REFLECTED THIS INFORMATION BECAUSE ALL INVESTORS HAD EQUAL ACCESS TO IT, AND, BEING RATIONAL, THEY WOULD, IN THEIR COLLECTIVE WISDOM, VALUE THE SECURITY ACCORDINGLY. THUS INVESTORS COULD NOT PROFIT FROM THE MARKET BECAUSE THE MARKET EFFICIENTLY VALUED SECURITIES AT A PRICE THAT REFLECTED ALL KNOWN INFORMATION.

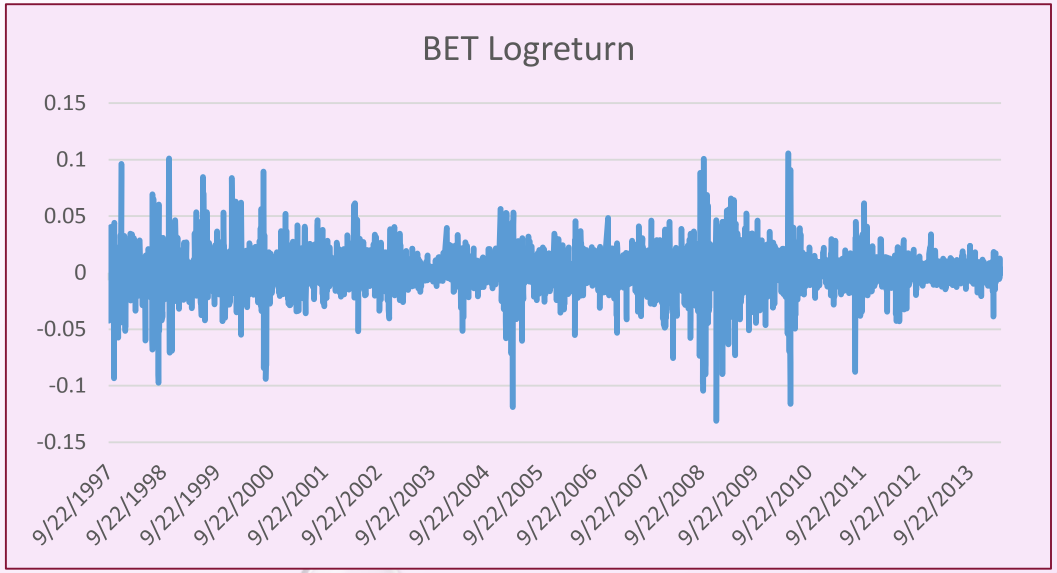
- THIS PAPER FOCUSES ON THE WEAK-FORM VERSION OF THE EMH, WHICH ASSERTS THAT SECURITY PRICES FULLY REFLECT ALL INFORMATION CONTAINED IN THE PAST PRICE HISTORY OF THE MARKET.

ALTERNATIVES TO THE EFFICIENT MARKET HYPOTHESIS

- Adaptive markets hypothesis
- Fractal markets hypothesis
- Long term memory

DATA (I)

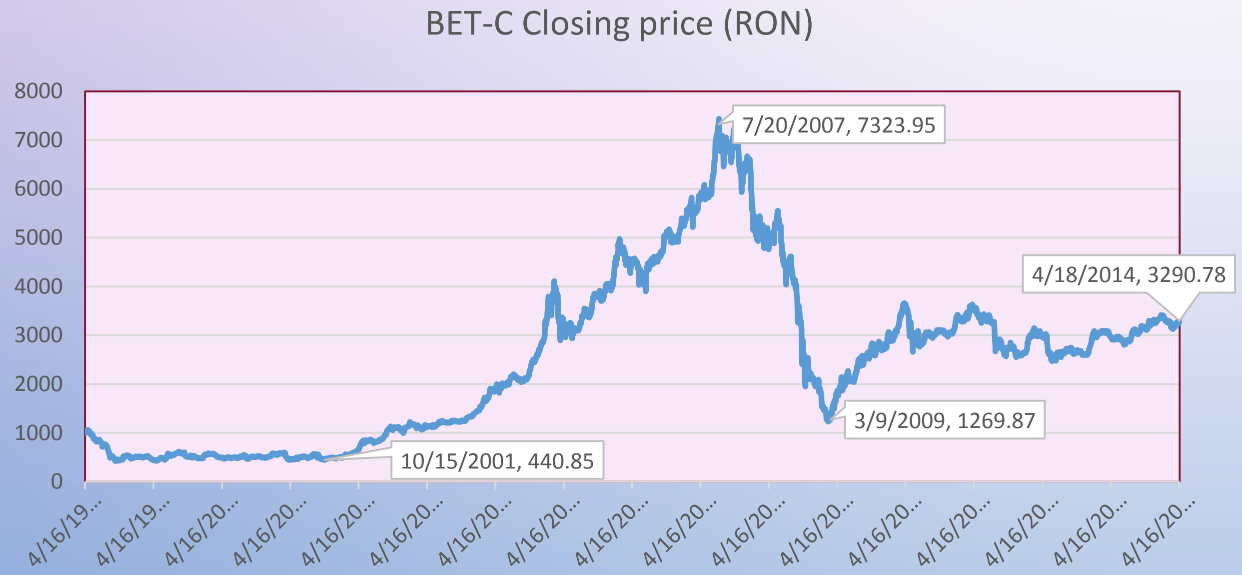
Index composition 5/21/2014	
Symbol	**Company Name**
TLV	BANCA TRANSILVANIA S.A.
FP	FONDUL PROPRIETATEA
SNG	S.N.G.N. ROMGAZ S.A.
SNP	OMV PETROM S.A.
BRD	BRD GROUP SOCIETE GENERALE S.A.
TGN	S.N.T.G.N TRANSGAZ S.A.
TEL	C.N.T.E.E. TRANSELECTRICA
SNN	S.N. NUCLEARELECTRICA S.A.
BVB	BURSA DE VALORI BUCURESTI SA
BRK	S.S.I.F. BROKER S.A.

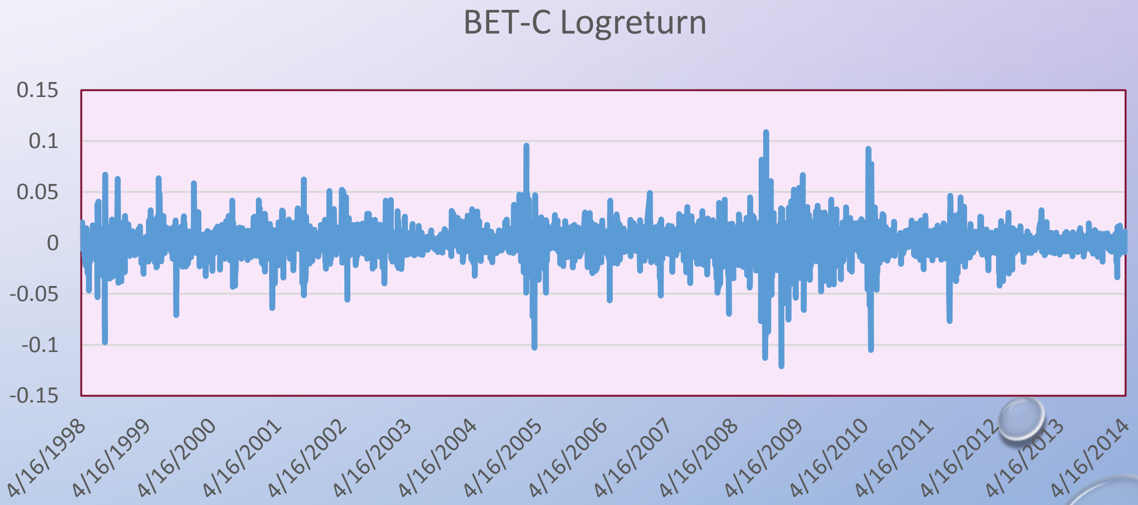


Data source: www.bvb.ro

DATA (II)

- BET-C index was launched on April 16, 1998, being the second index developed BSE. BET-C is a composite index and reflects the evolution of all the companies listed on BSE regulated market, I-st, II-nd and 3-rd category, excepting the financial investment companies.
- At the moment, the index includes 75 companies.





DATA (III)

Descriptive statistics for BET and BET-C log returns

	BET logreturn	BET-C logreturn
Mean	0.000452	0.000298
Median	0.00051	0.000604
Maximum	0.105645	0.108906
Minimum	-0.017675	-0.121184
Std. Dev.	0.131168	0.015213
Skeness	-0.345334	-0.571474
Kurtisis	9.645448	11.06562
Jarque-Bera	7700.32	11080.10
Probability	0.0000	0.0000

Stationarity → Serial correlation → Normal distribution → Variance ratio

- **TESTING THE LINEAR DEPENDENCE OF DAILY RETURNS**

$$\ln(P_t) = \mu + \rho \ln(P_{t-1}) + \varepsilon_t$$

$$\varepsilon_t = c(1) + c(2)\, \varepsilon_{t-1}$$

Is c(2) significant?

- **TESTING FOR NON–LINEAR DEPENDENCE IN DAILY RETURN**
- Engle's ARCH model has the following specification:

$$r_t = \mu + \varepsilon_t$$

$$\varepsilon_t = z_t \sigma_t$$

$$\sigma_t^2 = \omega + \alpha_1 \varepsilon_{t-1}^2 + \ldots + \alpha_q \varepsilon_{t-q}^2 = \omega + \sum_{i=1}^{q} \alpha_i\, \varepsilon_{t-i}^2$$

- Bollerslev (1986) generalized this model and transformed it into an GARCH (Generalised Autoregressive Conditional Heteroskedasticity) model of order p and q

$$\sigma_t^2 = \omega + \alpha_1 \varepsilon_{t-1}^2 + \ldots + \alpha_q \varepsilon_{t-q}^2 + \beta_1 \sigma_{t-1}^2 + \ldots + \beta_p \sigma_{t-p}^2 = \omega + \sum_{i=1}^{q} \alpha_i\, \varepsilon_{t-i}^2 + \sum_{j=1}^{p} \beta_j\, \sigma_{t-j}^2$$

α_i represents the speed at which the volatility reacts to market shocks;

β_i represents the persistence of volatility

BET – GARCH models

	1			2			q / p
	Normal	Student-t	GED	Normal	Student-t	GED	
Akaike	-5.655417	-5.722252	-5.718533	-5.6686	-5.730849	-5.727518	1
Schwarz	-5.647773	-5.713079	-5.709359	-5.659427	-5.720147	-5.716815	
Log likelihood	11708.89	11848.2	11840.5	11737.17	11866.99	11860.1	
R-squared	0.03091	0.030539	0.030736	0.030592	0.030556	0.030576	
Akaike	-5.662725	-5.726902	-5.723281	-5.672922	**-5.734613**	-5.73077	2
Schwarz	-5.653551	-5.7162	-5.712578	-5.662219	**-5.722382**	-5.718539	
Log likelihood	11725.01	11858.82	11851.33	11747.11	**11875.78**	11867.83	
R-squared	0.030455	0.030283	0.03043	0.031043	**0.030703**	0.030782	

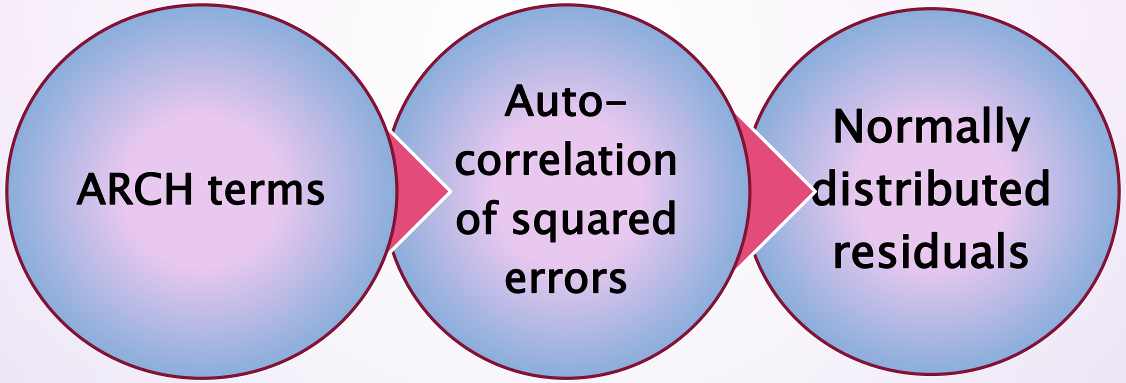
BET-C – GARCH models

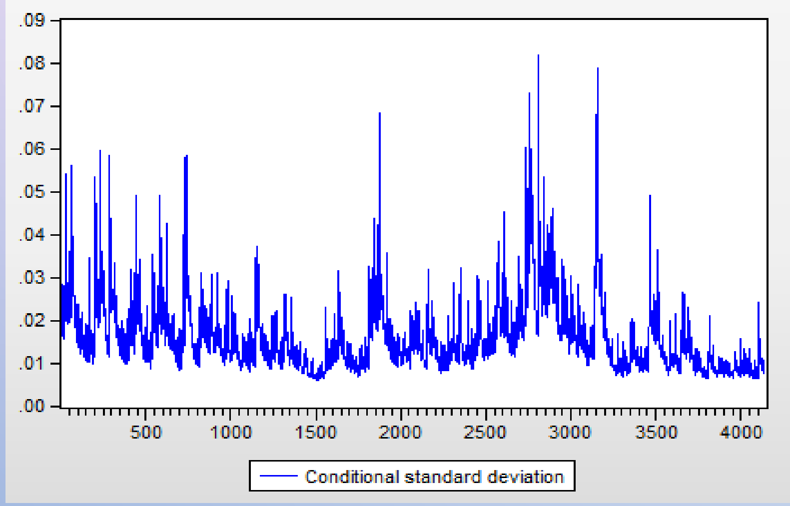
	1			2			q / p
	Normal	Student-t	GED	Normal	Student-t	GED	
Akaike	-5.96175	-6.026266	-6.021744	-5.974408	-6.036981	-6.03121	1
Schwarz	-5.952307	-6.015249	-6.010727	-5.963391	-6.024391	-6.018619	
Log likelihood	11926.52	12056.52	12047.48	11952.83	12078.94	12067.4	
R-squared	0.030514	0.027426	0.032435	0.031807	0.032191	0.032436	
Akaike	-5.966628	-6.031111	-6.018703	-5.984538	**-6.042488**	-6.036877	2
Schwarz	-5.955611	-6.01852	-6.006113	-5.971948	**-6.028324**	-6.022713	
Log likelihood	11937.27	12067.21	12042.4	11974.08	**12090.96**	12079.74	
R-squared	0.031243	0.032154	0.028917	0.03182	**0.03219**	0.032422	

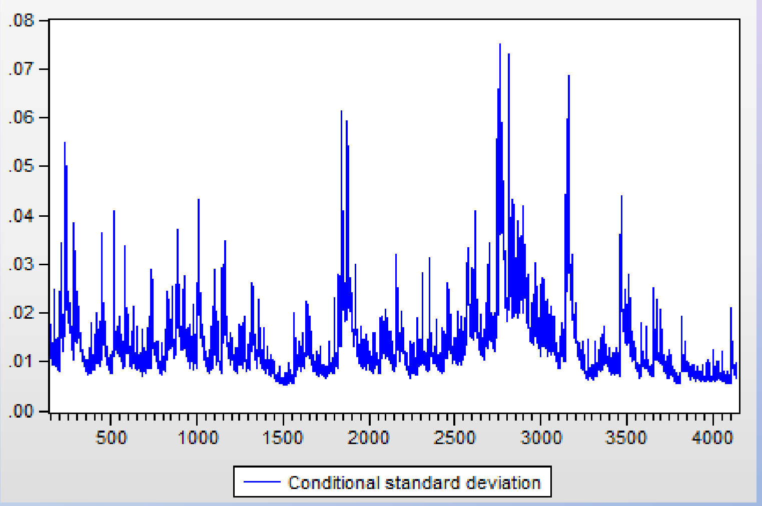
BET	GARCH-M	EGARCH	TGARCH
Akaike info criterion	-5.720702	-5.72391	-5.7214
Schwarz criterion	-5.711528	-5.71473	-5.71223
Log likelihood	11844.99	11851.62	11846.44
R-squared	0.029569	0.030377	0.030659

BET-C	GARCH-M	EGARCH	TGARCH
Akaike info criterion	-6.028141	-6.02745	-6.02769
Schwarz criterion	-6.01555	-6.01486	-6.0151
Log likelihood	12061.27	12059.88	12060.37
R-squared	0.02526	0.032045	0.027458

Sum of coefficients almost 1 -> persistence







Conditional standard deviations for BET and BET-C

ALTERNATIVES TO THE EFFICIENT MARKET HYPOTHESIS

- LONG MEMORY, OR LONG-TERM DEPENDENCE, DESCRIBES THE CORRELATION STRUCTURE OF A SERIES AT LONG LAGS. IF A SERIES EXHIBITS LONG MEMORY (OR THE "BIASED RANDOM WALK"), THERE IS PERSISTENT TEMPORAL DEPENDENCE EVEN BETWEEN DISTANT OBSERVATIONS. SUCH SERIES ARE CHARACTERIZED BY DISTINCT BUT NON-PERIODIC CYCLICAL PATTERNS.

- THE PRESENCE OF LONG-MEMORY DYNAMICS IN ASSET PRICES WOULD PROVIDE EVIDENCE AGAINST THE WEAK FORM OF MARKET EFFICIENCY.

R/S analysis

-
- Begin with a time series x_i (i = 1,M) which in Hurst's case was annual discharges of the Nile River. For markets it can be the daily changes in the price of a stock index. Concert it into a time series of length N = M – 1 of logarithmic ratios.
- Divide this time period into A contiguous subperiods of length n, such that A * n = N. We label each subperiod I_a, with a = 1, 2, 3, … , A, so that each element in I_a is labeled $N_{k,a}$ with k = 1, 2, 3, …, n. For each I_a of length n compute the average value defined as :

e_a = (1/n) * $\sum_{k=1}^{n} N_{k,a}$

- The time series of accumulated departures $(X_{k,a})$ from the mean value for each subperiod C is defined as:

$X_{k,a} = \sum_{i=1}^{n}(N_{i,a} - e_a)$, k = 1, 2, 3, …, n

- The range is defined as the maximum minus the minimum value of $X_{k,a}$ within each subperiod I_a:

R_{I_a} = max $(X_{k,a}) - \min\ (X_{k,a})$, where 1 ≤ k ≤ n

- The sample standard deviation calculated for each subperiod I_a is:

$S_{I_a} = ((\frac{1}{n}) * \sum_{k=1}^{n}(N_{k,a} - e_a^2))^{0.50}$

- Each range R_{I_a} is now normalized by deviding by the S_{I_a} corresponding to it. Therefore, the rescaled range for each I_a subperiod is equal to R_{I_a} / S_{I_a}. As we had A contiguous subperiods of length n, the average R/S value for length n is defined as:

$$(\frac{R}{S})_n = (1/A) * \sum_{a=1}^{A}(\frac{R_{I_a}}{S_{I_a}})$$

- The length n is increased to the next higher value and (M-1)/n is an integer value. The above steps are repeated until n= (M-1_/2. Finaly, we perform an ordinary least squares regression on log (n) as the independent variable and log$(\frac{R}{S})_n$ as the dependent variable. The intercept is the estimate for log(c), the constant. The slope of the equation is the estimate of the Hurst value.
- Einstein's equation R=$T^{0.5}$ only applies to series that are in Brownian motion. Hurst's contribution was to generalize this equation to $(\frac{R}{S})_n$ = c * n^H
- So Hurst exponent can be approximated from the equation

Log $(\frac{R}{S})_n$ = log (c) + H * log (n)

Interpreting Hurst exponent

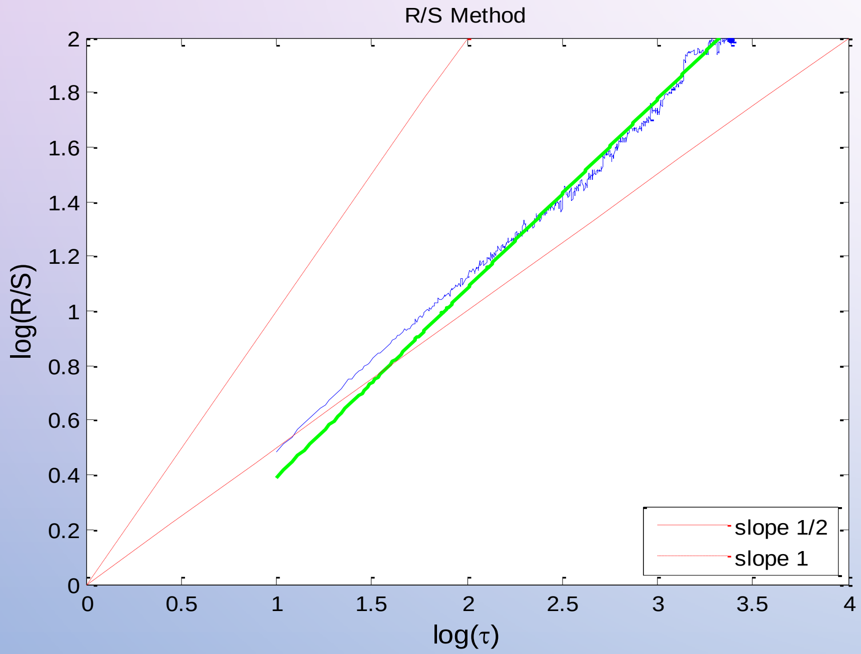
- H = 0.5 is consistent with an independently distributed system

- 0.5 < H <1 auto-covariances of the process are positive at all lags so that the process is called long-range dependent with positive correlations (Embrechts & Maejima, 2002) or persistent (Mandelbrot & van Ness, 1968). The auto-covariances are hyperbolically decaying and non-summable so that $\sum_{k=0}^{\infty} \gamma(k) = \infty$ (Beran, 1994). Theoretically, what happens today will ultimately have a lasting effect on the futurethe

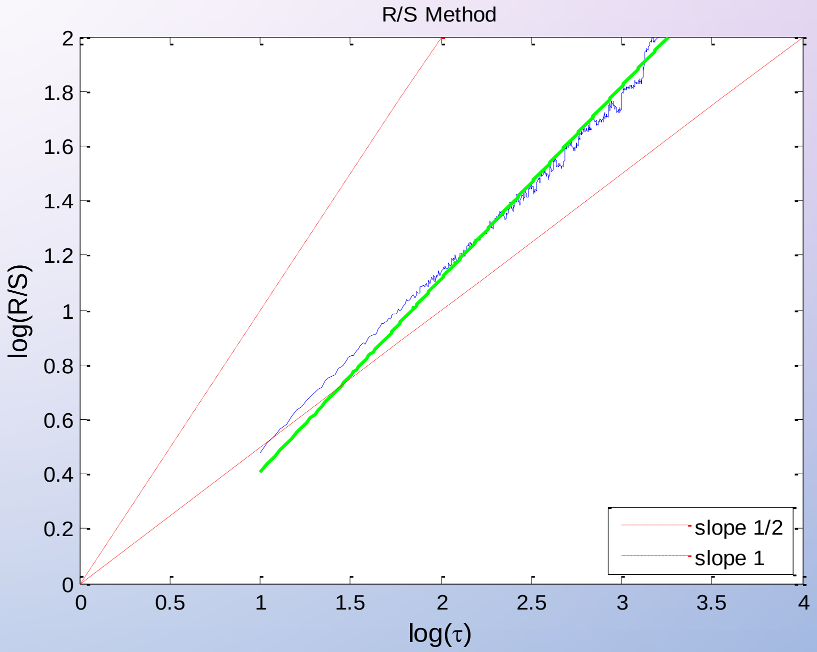
- 0 < H <0.5 the auto-covariances are significantly negative at all lags and the process is said to be long-range dependent with negative correlations (Embrechts & Maejima, 2002) or anti-persistent (Mandelbrot & van Ness, 1968). Similarly to the previous case, the auto-covariances are hyperbolically decaying but summable so that $0 < \sum_{k=0}^{\infty} \gamma(k) < \infty$ (Embrechts & Maejima, 2002). For a system to cover less distance, it must reverse itself more often than a random process

- The persistent process implies that a positive movement is statistically more likely to be followed by another positive movement or vice versa. On the other hand, the anti-persistent process implies that a positive movement is more statistically probable to be followed by a negative movement and vice versa (Vandewalle, Ausloos & Boveroux, 1997).

- I COMPUTED THE HURST EXPONENTS FOR THE RETURNS OF BET AND BET-C IN MATLAB R2013A. THE RESULT OBTAINED FOR BET RETURNS SERIES IS H = 0.6903, WHILE FOR BET-C RETURNS I GOT AN EXPONENT H = 0.7039.



R/S Analysis for BET log returns



R/S Analysis for BET-C log returns

R/S analysis for the realized volatility

- $S_t = \ln\left(\frac{P_t}{P_{t-1}}\right)$, where:

S_t = log return at time t,

P_t = price at time t.

- The volatility is the standard deviation of contiguous 20-day increments of S_t. These increments are non-overlapping and independent

$V_n = \left(\frac{1}{n-1}\right) * \sum_{t=1}^{n}(S_t - \hat{S})^2$, where

V_n = variance over n days,

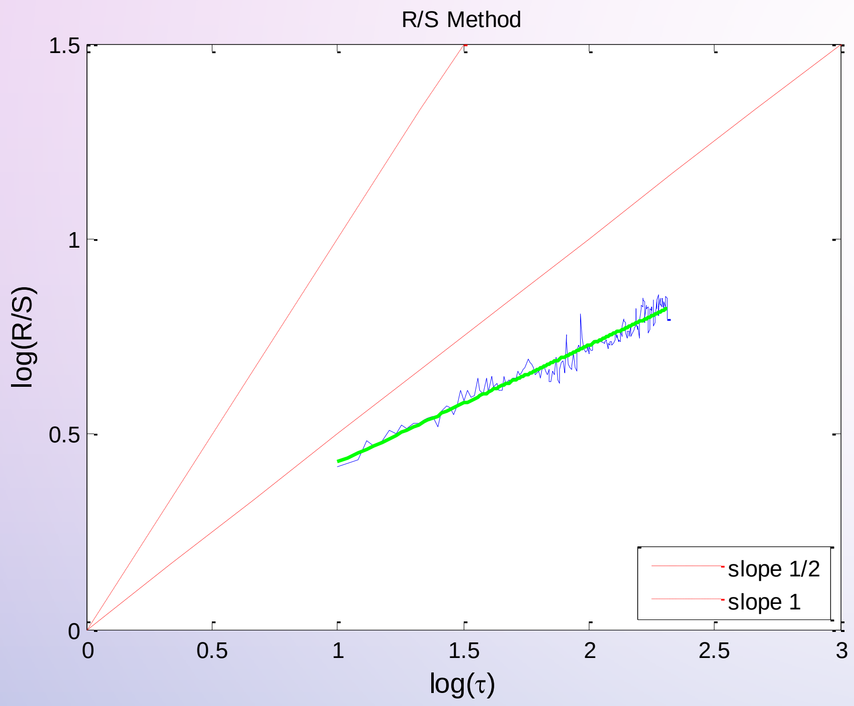
$\hat{S}$ = average value of S.

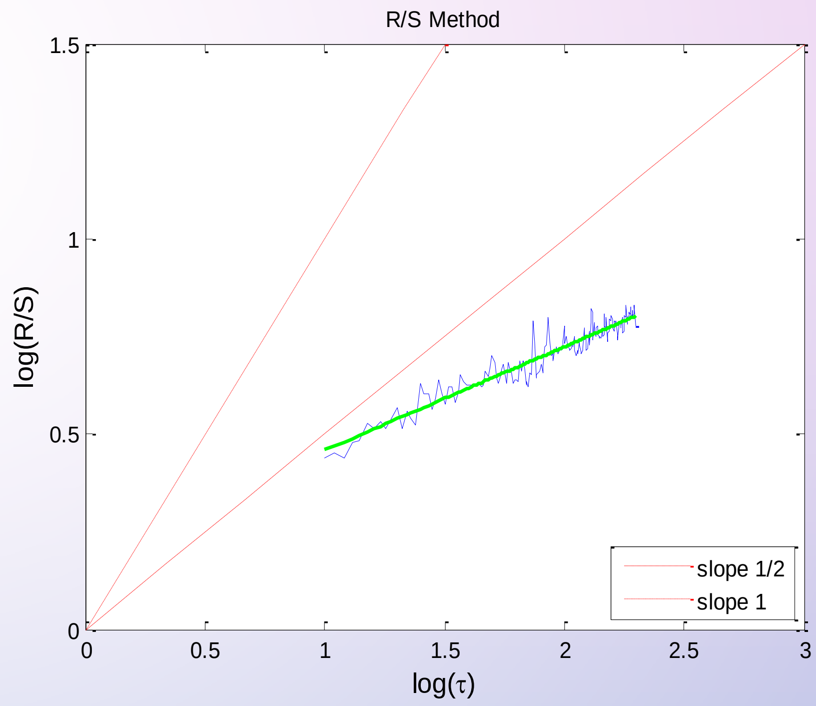
- The log changes are calculated as:

$L_n = \ln\left(\frac{V_n}{V_{n-1}}\right)$,

L_n = change in volatility at time n.

Perform R/S analysis on the volatility series





R/S Analysis for BET volatility

R/S Analysis for BET-C volatility

The realized volatility of BET has a Hurst exponent H = 0.2993, while for BET-C I obtained H = 0.2639.

Antipersistence says that the system reverses itself more often than a random one would. A large increase in volatility has a high probability of being followed by a decrease, but its magnitude is unknown. The reversal is equally likely to be smaller as larger than the increase. There is no guarantee that the eventual reversal will be big enough to offset previous losses.

CONCLUSIONS, LIMITATIONS AND FURTHER RESEARCH

- HURST COEFFICIENT MAY NOT BE RELIABLE FOR THE SHORT OR NOISY TIME SERIES (ARNEODO ET AL., 1995; SIMONSEN ET AL., 1998; KATSEV AND HEUREUX, 2003)
- HURST EXPONENT COMPUTED USING R/S STATISTIC MAY BE INFLUENCED BY THE SHORT TERM DEPENDENCE.
- DETRENDED ﬂUCTUATION ANALYSIS (DFA), DETRENDING MOVING AVERAGE (DMA) OR HEIGHT-HEIGHT CORRELATION ANALYSIS (HHCA)
- RELATIVE EFFICIENCY
- "FAMA'S 1965 INSIGHT—COMBINING SIMPLE COMPETITIVE ECONOMIC THEORY WITH AN INFORMATION-BASED VIEW OF SECURITY PRICES—IRREVERSIBLY CHANGED THE WAY WE LOOK AT FINANCIAL MARKETS. LIKE ALL IMPORTANT INSIGHTS, THIS IS THE CASE EVEN IF IT IS NOT A COMPLETE REPRESENTATION OF HOW MARKETS BEHAVE. THE IMPACT OF THE THEORY OF EFFICIENT MARKETS HAS PROVEN TO BE DURABLE, AND SEEMS LIKELY TO CONTINUE TO BE SO, DESPITE ITS INEVITABLE AND PAINFULLY OBVIOUS LIMITATIONS." (RAY BALL (2009) "THE GLOBAL FINANCIAL CRISIS AND THE EFFICIENT MARKET HYPOTHESIS: WHAT HAVE WE LEARNED?")

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THANK YOU!