

Time series analysis

Lecture 13. Hypothesis testing on market efficiency.

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1. Defining capital market efficiency

There are three types of market efficiency:

- - when prices are determined in a way that equates the marginal rates of return (adjusted for risk) for all producers and savers, market is said to be *allocationally efficient*;
- - when the cost of transferring funds is “reasonable”, market is said to be *operationally efficient*;
- - when prices fully reflect all available information, market is said to be *informationally efficient*.

Major contributions in developing “the market efficiency” concept:

Bachelier (1900): In the opening paragraph of his dissertation paper, he recognises that: *“past, present and even discounted future events are reflected in market price, but often show no apparent relation to price changes”*.

Samuelson (1965): In his article, “Proof that properly anticipated prices fluctuate randomly”, he asserted that: *“...competitive prices must display price changes...that perform a random walk with no predictable bias.”* Therefore, price changes must be unforecastable if they are properly anticipated.

Major contributions in developing “the market efficiency” concept:

Fama (1969): First definition of “efficient market”=“a market which adjust rapidly to new information”

Fama (1970): *“A market in which prices always “fully reflect” available information is called “efficient”.”*

Rubinstein (1975) and Latham (1985) have extended the definition of market efficiency. The market is said to be efficient with regard to an informational event if the information causes no portofolio changes.

Major contributions in developing “the market efficiency” concept:

Jensen (1978): says that prices reflect information up to the point where the marginal benefits of acting on the information (the expected profits to be made) do not exceed the marginal costs of collecting it.

Malkiel (1992): offered the following definition:

“A capital market is said to be efficient if it fully and correctly reflects all relevant information in determining security prices. Formally, the market is said to be efficient with respect to some information set...if security price would be unaffected by revealing that information to all participants. Moreover, efficiency with respect to an informational set ...implies that it is impossible to make economic profits by trading on the basis of (that informational set).”

Reproaches to “market efficiency”

Grossman (1976) and **Grossman and Stiglitz (1980)** argue that perfectly informationally efficient markets are an *impossibility*, for if markets are perfectly efficient, the return to gathering information is nil, in which case there would be little reason to trade and markets would eventually collapse.

Campbell, Lo and MacKinlay (1997): share the same opinion. They are in favour of the notion of relative efficiency – the efficiency of one market measured against another.

Reproaches to market efficiency

Lo and MacKinlay (1999): say: “...*the Efficient Markets Hypothesis, by itself, is not a well-defined and empirically refutable hypothesis. To make it operational, one must specify additional structure, e.g., investors’ preferences, information structure, business conditions, etc. But then a test of the Efficient Markets Hypothesis becomes a test of several auxiliary hypotheses as well, and a rejection of such a joint hypothesis tells us little about which aspect of the joint hypothesis is inconsistent with the data.*”

The “Bad Model” problem: Efficiency per se is not testable. It must be tested jointly with some model of equilibrium. When we find anomalous evidence on behavior of returns, the way it should be split between market inefficiency or a bad model of market equilibrium is ambiguous (Fama-1991)

Types of market efficiency:

Weak-form efficiency: the information set includes only the history of prices or returns themselves. A capital market is said to satisfy weak-form efficiency if it fully incorporate the information in past stock prices.

Semistrong-form efficiency: the information set includes all information known to all market participants (*publicly available information*). A market is semi-strong efficient if prices reflect all publicly available information.

Strong-form efficiency: the information set includes all information known to any market participant (*private information*). This form says that anything that is pertinent to the value of the stock and that is known to at least one investor is, in fact fully incorporated into the stock value.

Tests of market efficiency:

- one must specify the information set used;
- one must specify a model of normal returns (the classic assumption is that normal returns are constant over time);
- abnormal returns are computed as difference between the return on a security and its normal return, and forecast of the abnormal return are constructed using the chosen information set. If abnormal return is unforecastable, and in this sense “random”, then the hypothesis of market efficiency is not rejected.

Testing for Romanian capital market efficiency

The aim of this paper is to investigate if Romanian capital market is weak-form efficient.

There is a wide consensus that capital markets in emerging countries are not semistrong-form efficient, nor strong-form efficient, and in most of the cases not even weak-form efficient, due to the lack of financial development.

Participants are not well informed and behave irrationally, comparing with well-organised developed markets.

The uncertainty about the future is claiming it's rights!

Tests of market efficiency – Weak-form tests

The question is: **How well do past returns predict future returns?**

The main assumption is that there should be no pattern in the time series of returns.

Three theories of time series behaviour of prices can be found in the literature:

- the fair-game model;
- the martingale or submartingale model;
- the random walk model.

Tests of market efficiency – Weak-form tests

The fair-game model

Is based on the behaviour of average returns.

$$E(\varepsilon_{j,t+1}) = E[r_{j,t+1} - E(r_{j,t+1} | \Omega_t)] = 0$$

A fair-game means that, on average, across a large number of samples, the expected return on a security equals its actual return.

Tests of market efficiency – Weak-form tests

The martingale model

Is also a fair game, where tomorrow's price is expected to be the same as today (the expected return is zero).

$$E(P_{j,t+1} | \Omega_t) = P_{j,t}$$

The submartingale model

Is a fair game with positive returns.

$$E(P_{j,t+1} | \Omega_t) > P_{j,t}$$

Tests of market efficiency – Weak-form tests

The random walk model

The simplest form version is the independently and identically distributed increments case, in which the dynamics of prices are given by the equation:

$$P_t = \mu + P_{t-1} + \varepsilon_t \quad \varepsilon_t \sim IID(0, \sigma^2)$$

The independence of increments implies not only that increments are uncorelated, but that any nonlinear functions of the increments are uncorelated. This model is known as **random walk 1 (RW1)**.

Tests of market efficiency – Weak-form tests

The assumption of identically distributed increments is not plausible for financial asset prices over long time spans, due to changes in the economic, social, technological, institutional and regulatory environment in which stock prices are determined.

By relaxing the assumptions of RW1 to include processes with independent but not identically distributed (INID) returns we have **Random Walk 2**.

RW2 still retains the most interesting property of RW1: **Any arbitrary transformation of future price increments is unforecastable using any arbitrary transformation of past price increments.**

Testing for market efficiency – Weak-form tests

By relaxing the independence assumption of RW2 to include processes with dependent but uncorelated increments we obtain the weakest form of random walk, **RW3**.

Data and methodology:

The data employed consists from logarithm daily, weekly and monthly returns of four Romanian indices, three indices from Bucharest Stock Exchange and one from Rasdaq OTC:

- BET (Bucharest Exchange Trading)

- BET-Composite

- BET-FI

- RASDAQ-Composite

Data series:

<i>SYMBOL</i>	<i>SEMNIIFICATION</i>	<i>Nr.observations</i>
<i>RBETZ</i>	Daily log-returns of BET	1139
<i>RBETW</i>	Weekly log-returns of BET	230
<i>RBETM</i>	Monthly log-returns of BET	56
<i>RBETFZ</i>	Daily log-returns of BET-FI	352
<i>RBETFW</i>	Weekly log-returns of BET-FI	72
<i>RBETFM</i>	Monthly log-returns of BET-FI	18
<i>RBETCZ</i>	Daily log-returns of BET-C	1000
<i>RBETCW</i>	Weekly log-returns of BET-C	203
<i>RBETCM</i>	Monthly log-returns of BET-C	48
<i>RRSDZ</i>	Daily log-returns of RASDAQ-C	925
<i>RRSDRW</i>	Weekly log-returns of RASDAQ-C	188
<i>RRSDM</i>	Monthly log-returns of RASDAQ-C	45

Hypotheses: this paper seeks evidence whether the Romanian capital market follows the random walk model or the market is weak-form efficient. So the tested hypotheses are:

H_{01} : Prices in Romanian capital market follow random walk process;

H_{02} : The Romanian capital market is weak-form efficient.

*“If the random walk hypothesis holds, the weak-form of the efficient market hypothesis must hold, but **not vice versa**. Thus, evidence supporting the random walk model is the evidence of market efficiency. But violation of the random walk model need not be evidence of market inefficiency in the weak form”. (Ko and Lee – 1991)*

Autocorrelation coefficients test

One of the most direct and intuitive test of random walk is to check for serial correlation (Fama 1965). If stock prices exhibit a random walk, the returns of stocks are uncorrelated at all leads and lags.

























$$\rho(k) = \frac{\text{COV}(r_t, r_{t+k})}{\sqrt{\text{var}[r_t] * \text{var}[r_{t+k}]}} = \frac{\text{COV}(r_t, r_{t+k})}{\text{var}[r_t]}$$

To test the joint hypothesis that all the serial correlation coefficients, are simultaneously equal to zero, the Ljung and Box Q statistic is applied:

$$Q'_m \equiv T(T+2) \sum_{k=1}^m \frac{\rho^2(k)}{T-k}$$























Correlogram of RBETIZ

Date: 06/06/02 Time: 14:14
 Sample: 1 1200
 Included observations: 1138

Autocorrelation	Partial Correlation	AC	PAC	Q-Stat	Prob	
		1	0.301	0.301	103.52	0.000
		2	0.065	-0.028	108.38	0.000
		3	0.031	0.021	109.47	0.000
		4	0.029	0.017	110.45	0.000
		5	0.011	-0.004	110.58	0.000
		6	0.002	-0.001	110.59	0.000
		7	0.014	0.015	110.83	0.000
		8	-0.019	-0.031	111.23	0.000
		9	-0.016	-0.003	111.54	0.000
		10	-0.025	-0.021	112.27	0.000
		11	0.021	0.038	112.76	0.000
		12	0.007	-0.009	112.82	0.000




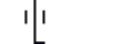

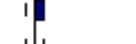

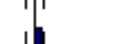

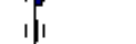



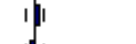

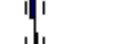

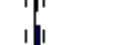






Correlogram of RBETFZ

Date: 06/06/02 Time: 14:16
 Sample: 1 1200
 Included observations: 351

Autocorrelation	Partial Correlation	AC	PAC	Q-Stat	Prob	
		1	0.165	0.165	9.6859	0.002
		2	-0.087	-0.117	12.356	0.002
		3	0.003	0.040	12.359	0.006
		4	0.086	0.071	15.002	0.005
		5	0.034	0.010	15.427	0.009
		6	0.031	0.041	15.771	0.015
		7	0.033	0.023	16.152	0.024
		8	-0.052	-0.065	17.122	0.029
		9	0.025	0.050	17.340	0.044
		10	0.086	0.058	20.055	0.029
		11	0.035	0.011	20.501	0.039
		12	-0.030	-0.018	20.837	0.053























Correlogram of RBETCZ

Date: 06/06/02 Time: 14:03
 Sample: 1 1200
 Included observations: 999

Autocorrelation	Partial Correlation	AC	PAC	Q-Stat	Prob	
		1	0.288	0.288	83.198	0.000
		2	0.079	-0.004	89.462	0.000
		3	0.082	0.066	96.237	0.000
		4	0.042	0.001	98.008	0.000
		5	0.053	0.041	100.88	0.000
		6	0.052	0.023	103.60	0.000
		7	0.026	0.001	104.28	0.000
		8	0.045	0.033	106.28	0.000
		9	-0.008	-0.038	106.34	0.000
		10	0.013	0.023	106.50	0.000
		11	0.040	0.027	108.14	0.000
		12	0.024	0.006	108.73	0.000

























Correlogram of RRSZ

Date: 06/06/02 Time: 14:17
 Sample: 1 1200
 Included observations: 924

Autocorrelation	Partial Correlation	AC	PAC	Q-Stat	Prob	
		1	-0.398	-0.398	147.12	0.000
		2	-0.086	-0.290	153.91	0.000
		3	0.147	-0.017	173.92	0.000
		4	-0.150	-0.138	194.93	0.000
		5	0.118	0.035	207.82	0.000
		6	0.044	0.092	209.65	0.000
		7	-0.022	0.115	210.09	0.000
		8	-0.005	0.047	210.11	0.000
		9	-0.039	-0.017	211.56	0.000
		10	0.138	0.143	229.48	0.000
		11	-0.078	0.034	235.23	0.000
		12	-0.151	-0.196	256.70	0.000

























Correlogram of RBETIW

Date: 06/06/02 Time: 15:15
 Sample: 1 1200
 Included observations: 229

Autocorrelation	Partial Correlation	AC	PAC	Q-Stat	Prob
		1 0.058	0.058	0.7923	0.373
		2 0.019	0.016	0.8799	0.644
		3 -0.034	-0.037	1.1580	0.763
		4 0.062	0.067	2.0747	0.722
		5 0.035	0.029	2.3659	0.797
		6 0.023	0.016	2.4960	0.869
		7 -0.003	-0.001	2.4976	0.927
		8 -0.067	-0.070	3.5746	0.893
		9 0.000	0.006	3.5746	0.937
		10 0.049	0.049	4.1585	0.940
		11 -0.014	-0.027	4.2093	0.963
		12 -0.035	-0.026	4.5073	0.972

























Correlogram of RBETCW

Date: 06/06/02 Time: 15:17
 Sample: 1 1200
 Included observations: 202

Autocorrelation	Partial Correlation	AC	PAC	Q-Stat	Prob
		1 0.214	0.214	9.3850	0.002
		2 0.042	-0.004	9.7530	0.008
		3 -0.020	-0.030	9.8389	0.020
		4 0.107	0.123	12.203	0.016
		5 0.067	0.021	13.139	0.022
		6 -0.017	-0.045	13.201	0.040
		7 -0.041	-0.022	13.549	0.060
		8 -0.046	-0.042	14.008	0.082
		9 -0.014	-0.008	14.051	0.121
		10 0.053	0.066	14.649	0.145
		11 -0.006	-0.025	14.655	0.199
		12 -0.068	-0.060	15.670	0.207

























Correlogram of RBETFW

Date: 06/06/02 Time: 15:18
 Sample: 1 1200
 Included observations: 71

Autocorrelation	Partial Correlation	AC	PAC	Q-Stat	Prob
		1 0.063	0.063	0.2931	0.588
		2 0.165	0.162	2.3356	0.311
		3 0.155	0.140	4.1601	0.245
		4 0.023	-0.017	4.2012	0.379
		5 -0.045	-0.097	4.3618	0.499
		6 0.095	0.082	5.0876	0.533
		7 -0.067	-0.054	5.4472	0.606
		8 -0.024	-0.028	5.4929	0.704
		9 -0.125	-0.137	6.7911	0.659
		10 -0.062	-0.033	7.1151	0.715
		11 -0.014	0.056	7.1323	0.788
		12 0.055	0.100	7.3964	0.830

Correlogram of RRSDW

Date: 06/06/02 Time: 15:20
 Sample: 1 1200
 Included observations: 187

Autocorrelation	Partial Correlation	AC	PAC	Q-Stat	Prob
		1 -0.137	-0.137	3.5745	0.059
		2 0.056	0.038	4.1737	0.124
		3 0.070	0.085	5.1204	0.163
		4 0.010	0.029	5.1388	0.273
		5 -0.197	-0.205	12.644	0.027
		6 0.182	0.129	19.082	0.004
		7 -0.122	-0.068	22.011	0.003
		8 0.007	-0.001	22.020	0.005
		9 0.040	0.031	22.342	0.008
		10 0.061	0.050	23.079	0.010
		11 -0.024	0.044	23.190	0.017
		12 -0.086	-0.170	24.684	0.016

Correlogram of RBETIM

Date: 06/06/02 Time: 15:29
 Sample: 1 1200
 Included observations: 55

Autocorrelation	Partial Correlation	AC	PAC	Q-Stat	Prob
		1 0.104	0.104	0.6307	0.427
		2 -0.053	-0.065	0.7971	0.671
		3 -0.060	-0.048	1.0109	0.799
		4 0.039	0.048	1.1048	0.894
		5 -0.030	-0.046	1.1595	0.949
		6 -0.019	-0.010	1.1833	0.978
		7 0.104	0.110	1.8830	0.966
		8 0.145	0.117	3.2900	0.915
		9 0.017	0.001	3.3097	0.951
		10 -0.157	-0.139	5.0226	0.890
		11 0.109	0.154	5.8655	0.882
		12 -0.233	-0.305	9.8405	0.630

Correlogram of RBETCM

Date: 06/06/02 Time: 15:39
 Sample: 1 1200
 Included observations: 47

Autocorrelation	Partial Correlation	AC	PAC	Q-Stat	Prob
		1 0.185	0.185	1.7147	0.190
		2 -0.102	-0.141	2.2474	0.325
		3 -0.031	0.017	2.2989	0.513
		4 0.016	0.005	2.3123	0.679
		5 -0.034	-0.044	2.3767	0.795
		6 -0.038	-0.020	2.4587	0.873
		7 0.212	0.228	5.0538	0.653
		8 0.088	-0.014	5.5122	0.702
		9 -0.141	-0.119	6.7131	0.667
		10 -0.254	-0.206	10.727	0.379
		11 0.005	0.073	10.728	0.466
		12 -0.081	-0.158	11.165	0.515

Correlogram of RBETFM

Date: 06/06/02 Time: 15:35
 Sample: 1 1200
 Included observations: 17

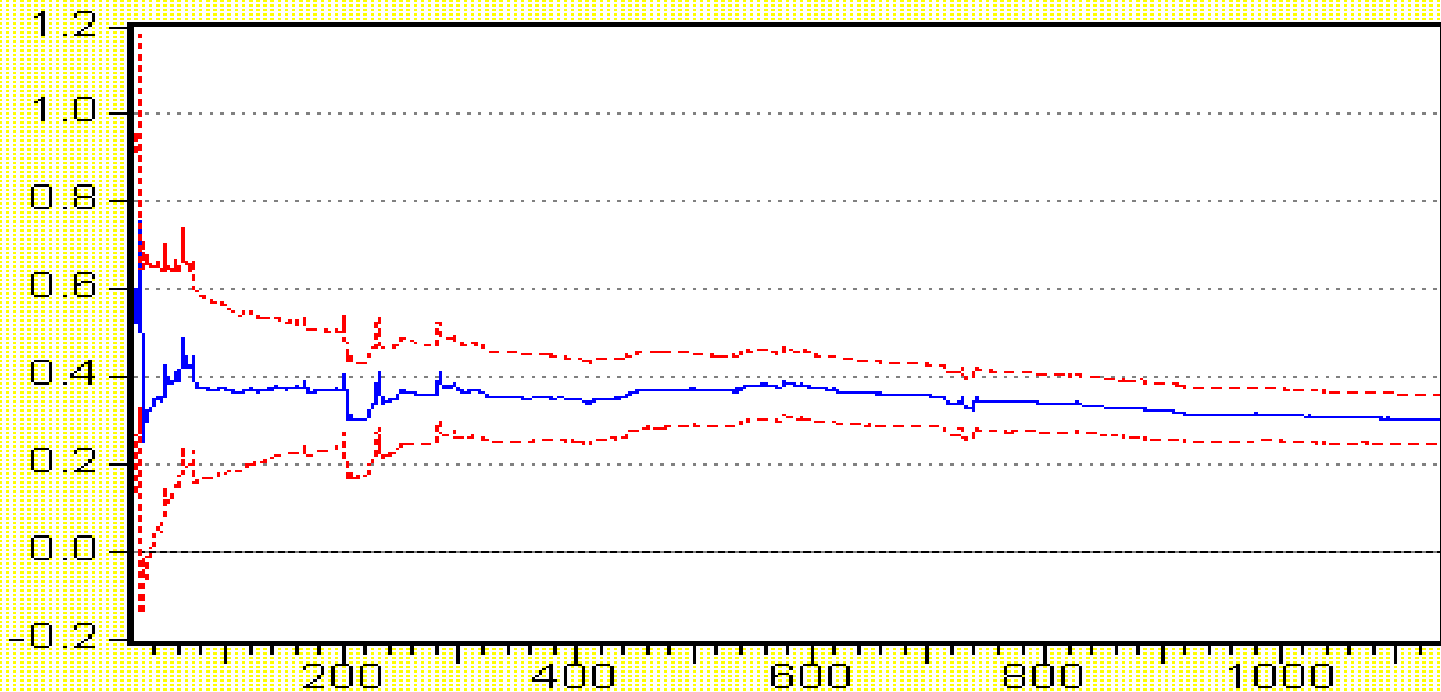
Autocorrelation	Partial Correlation	AC	PAC	Q-Stat	Prob
		1 0.184	0.184	0.6814	0.409
		2 -0.096	-0.134	0.8803	0.644
		3 0.000	0.047	0.8803	0.830
		4 -0.209	-0.244	1.9628	0.743
		5 -0.284	-0.205	4.1342	0.530
		6 -0.256	-0.258	6.0569	0.417
		7 -0.034	-0.018	6.0952	0.529
		8 0.057	-0.054	6.2132	0.623
		9 -0.155	-0.313	7.1798	0.618
		10 0.189	0.108	8.8323	0.548
		11 0.225	-0.039	11.562	0.397
		12 -0.066	-0.153	11.841	0.459

Correlogram of RRSDEM

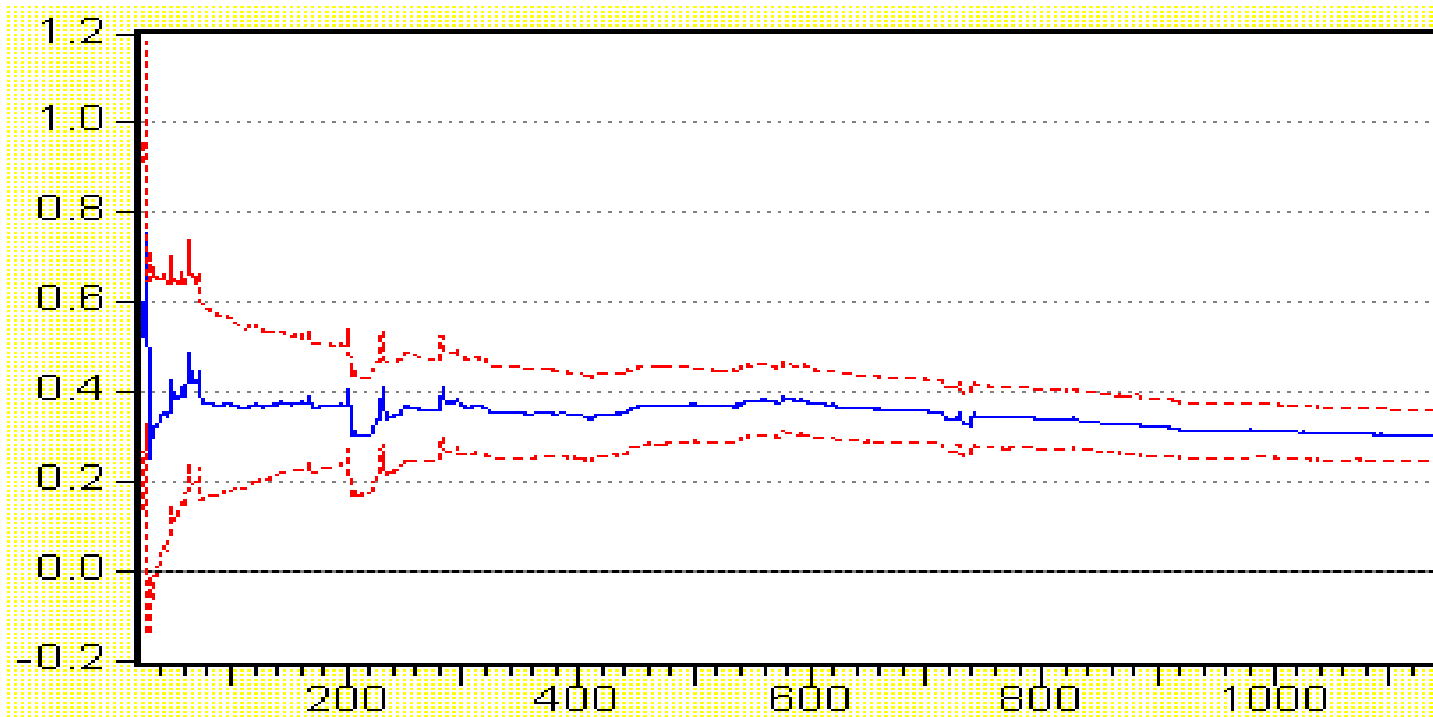
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 Sample: 1 1200
 Included observations: 44

Autocorrelation	Partial Correlation	AC	PAC	Q-Stat	Prob
		1 -0.310	-0.310	4.5339	0.033
		2 0.066	-0.034	4.7430	0.093
		3 -0.072	-0.068	4.9991	0.172
		4 0.009	-0.035	5.0035	0.287
		5 -0.051	-0.065	5.1401	0.399
		6 -0.034	-0.081	5.2011	0.518
		7 -0.034	-0.080	5.2626	0.628
		8 0.018	-0.028	5.2812	0.727
		9 0.109	0.109	5.9702	0.743
		10 -0.237	-0.206	9.3060	0.503
		11 0.159	0.018	10.851	0.456
		12 -0.046	0.011	10.987	0.530

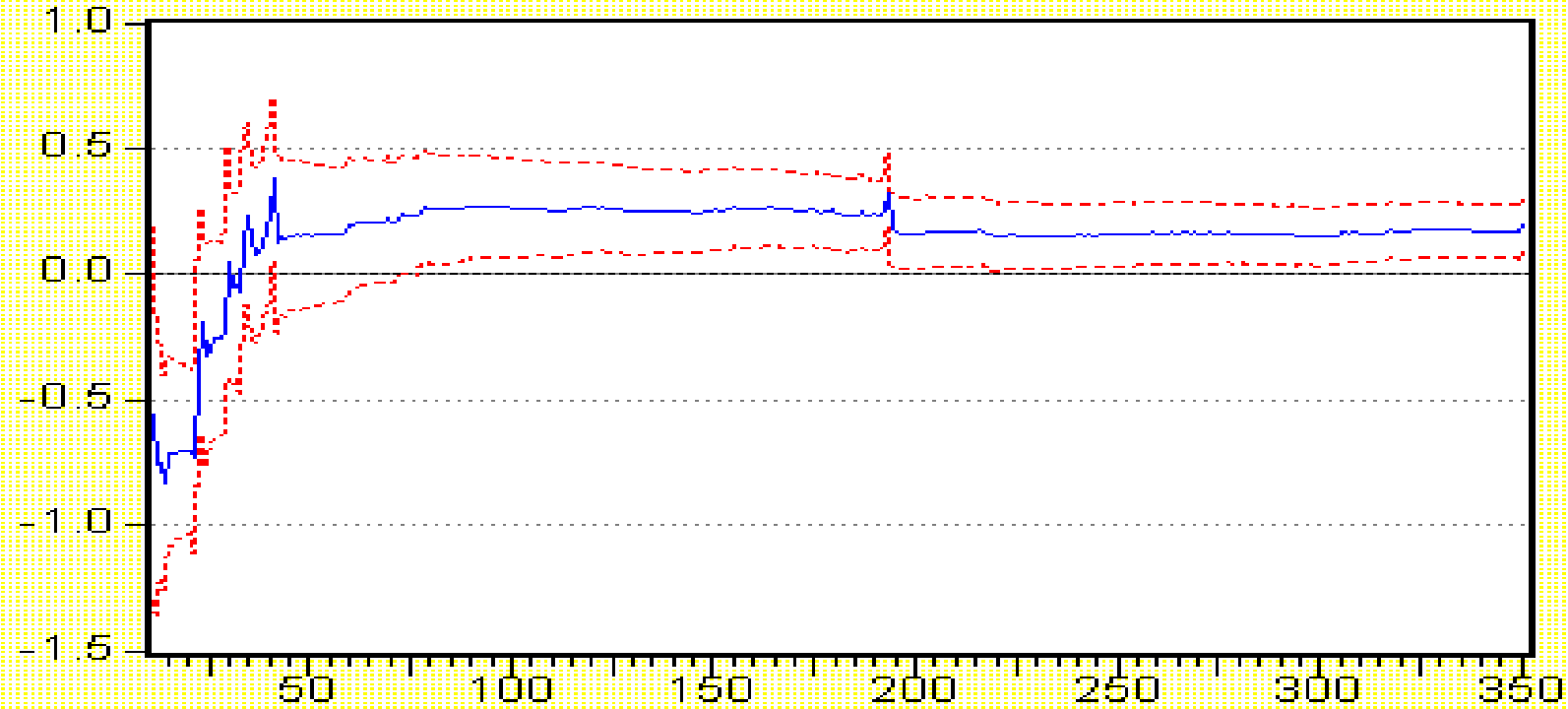
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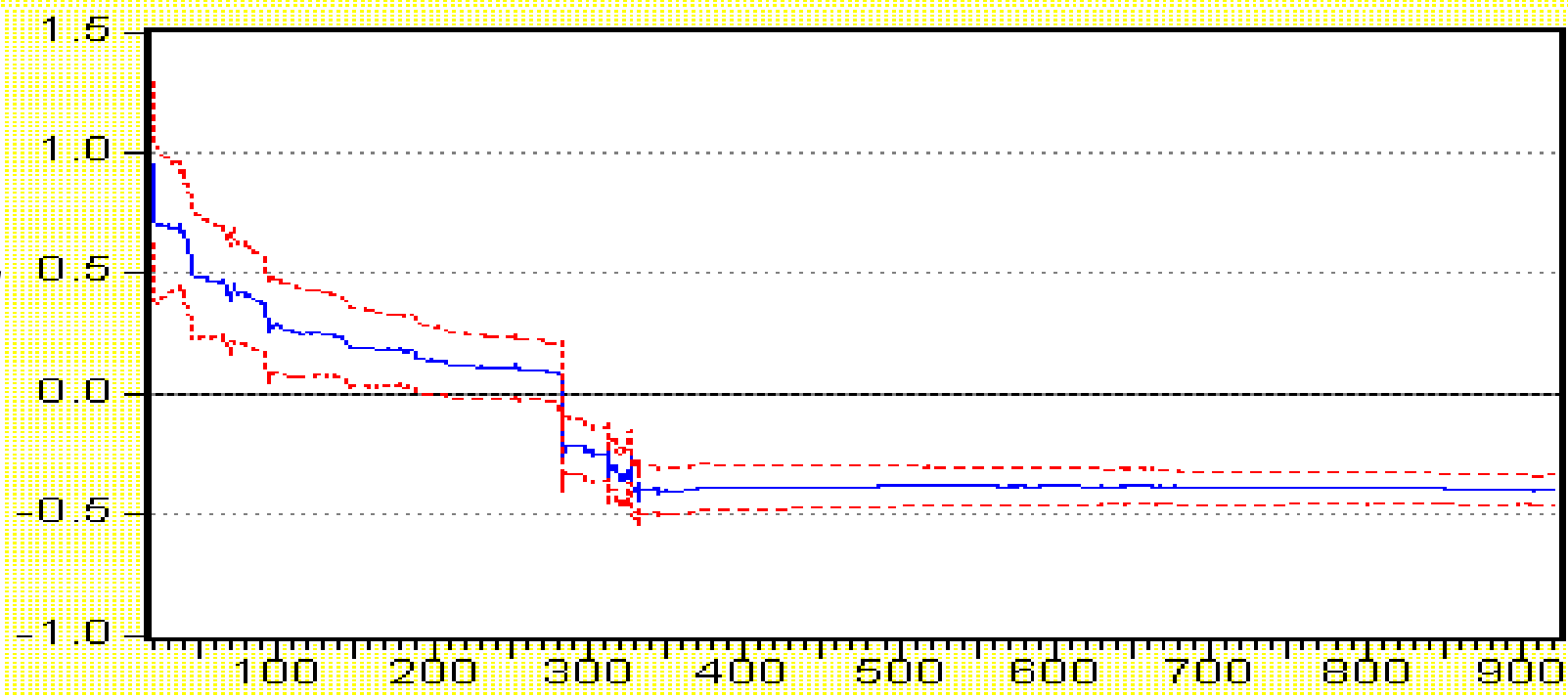
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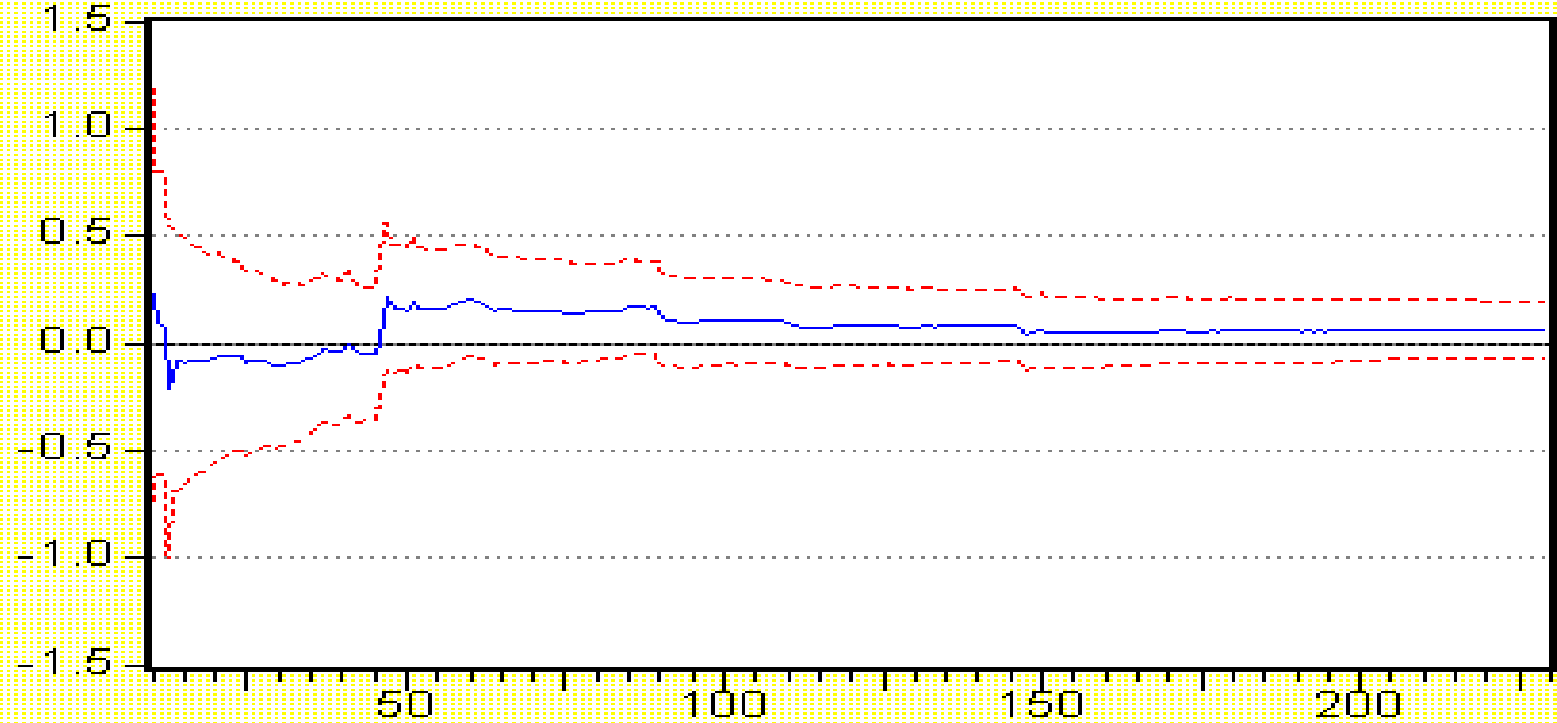
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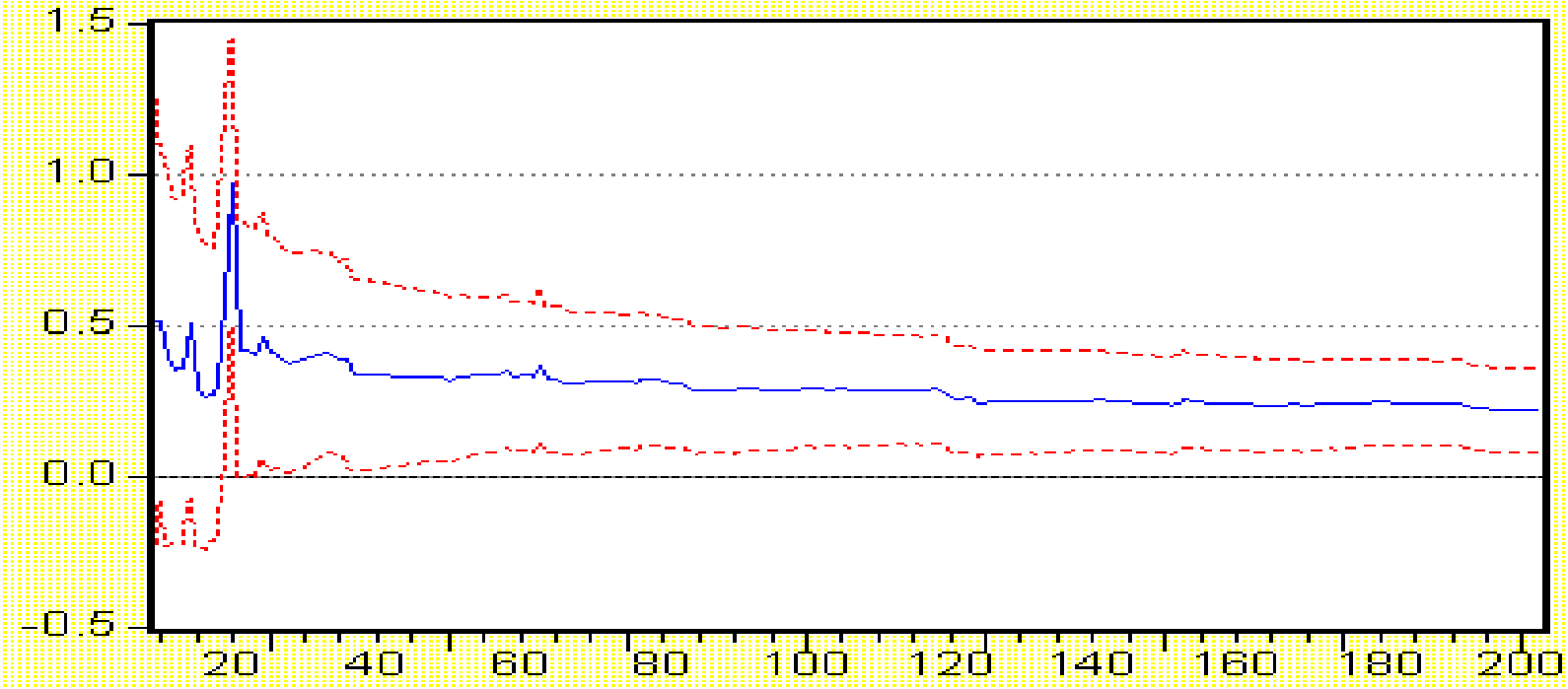
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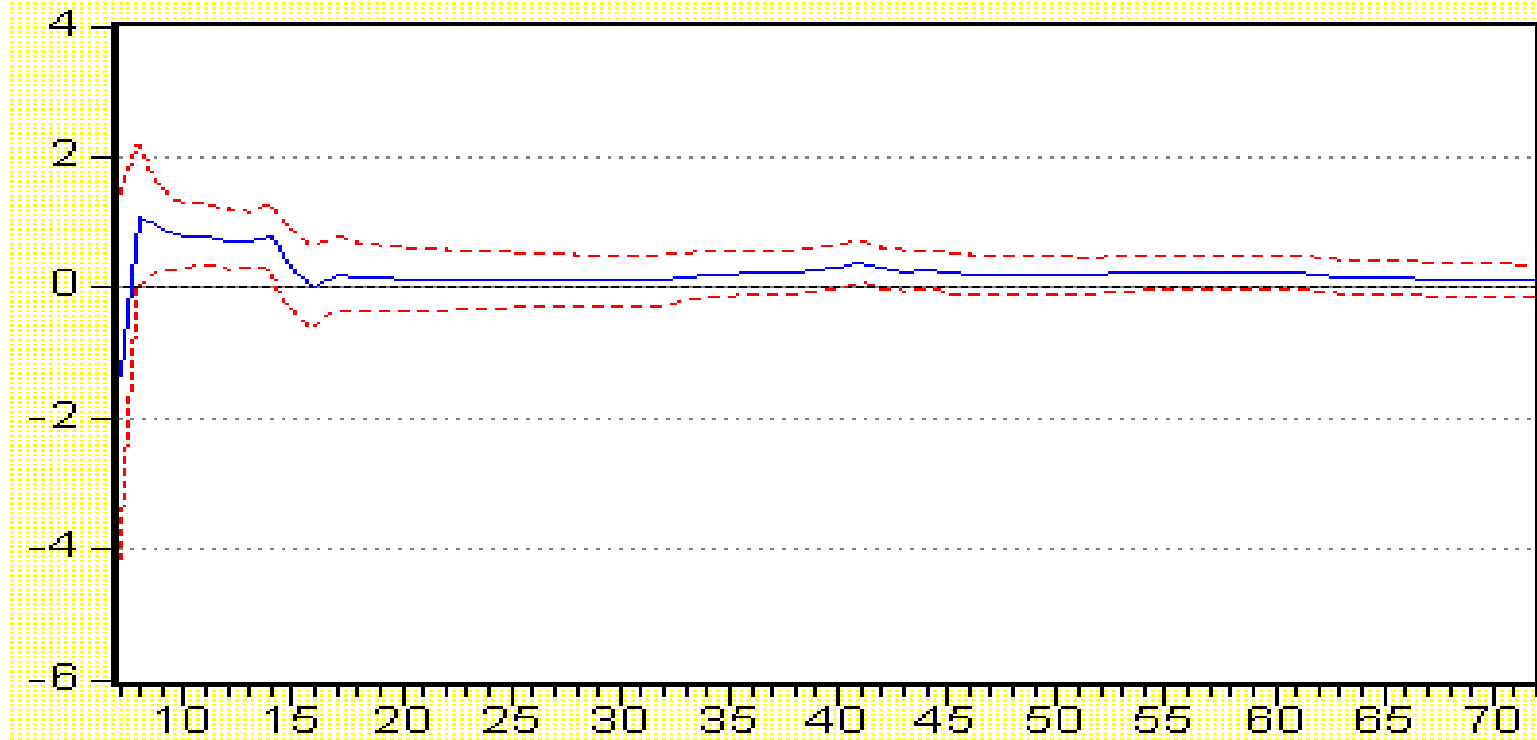
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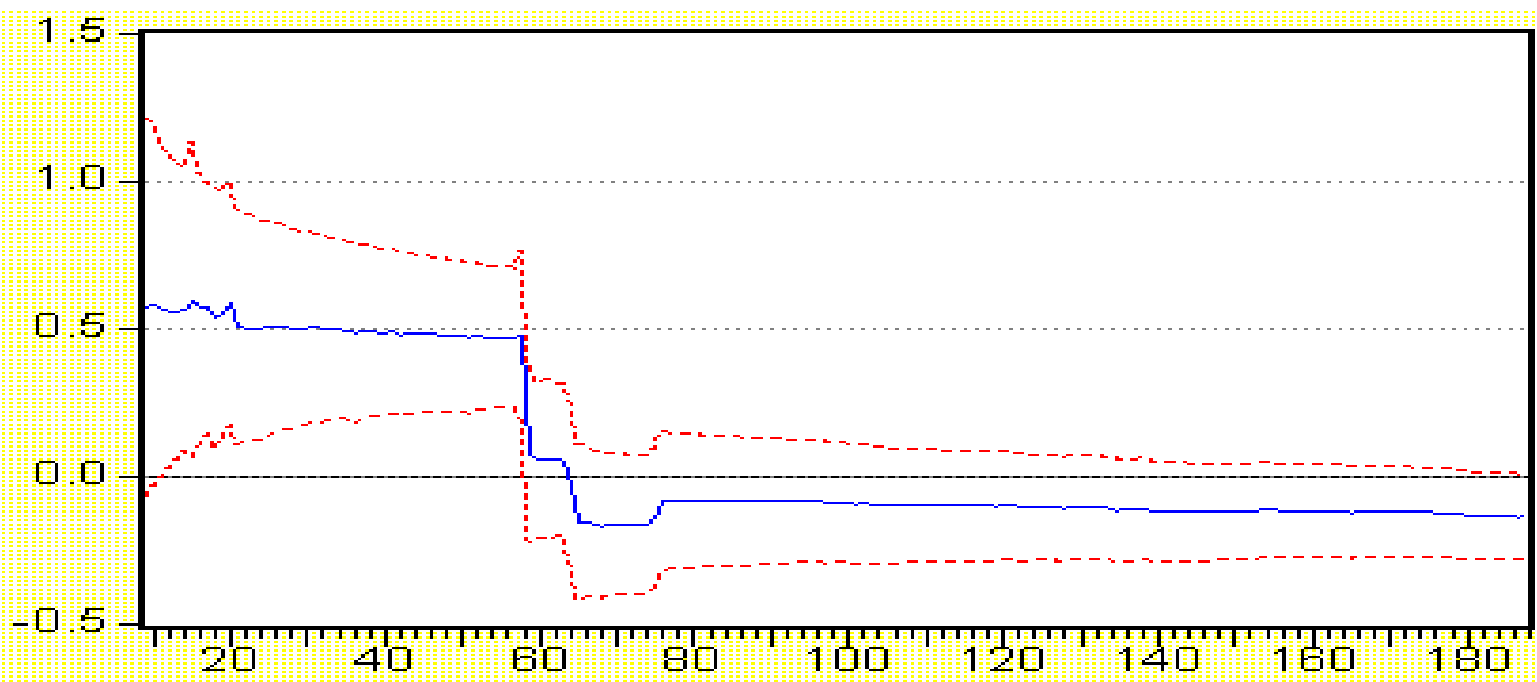
RBETCW



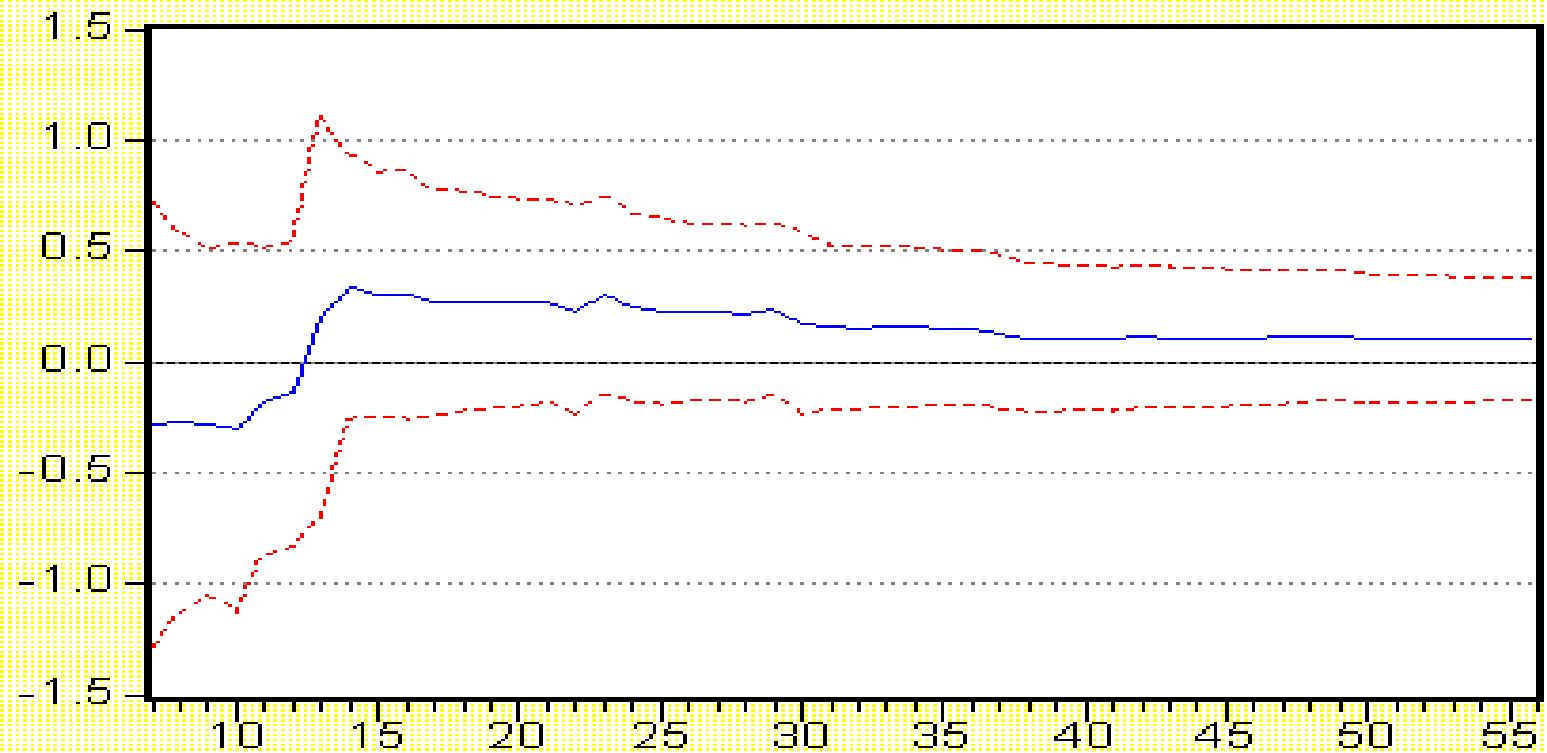
RBETFW



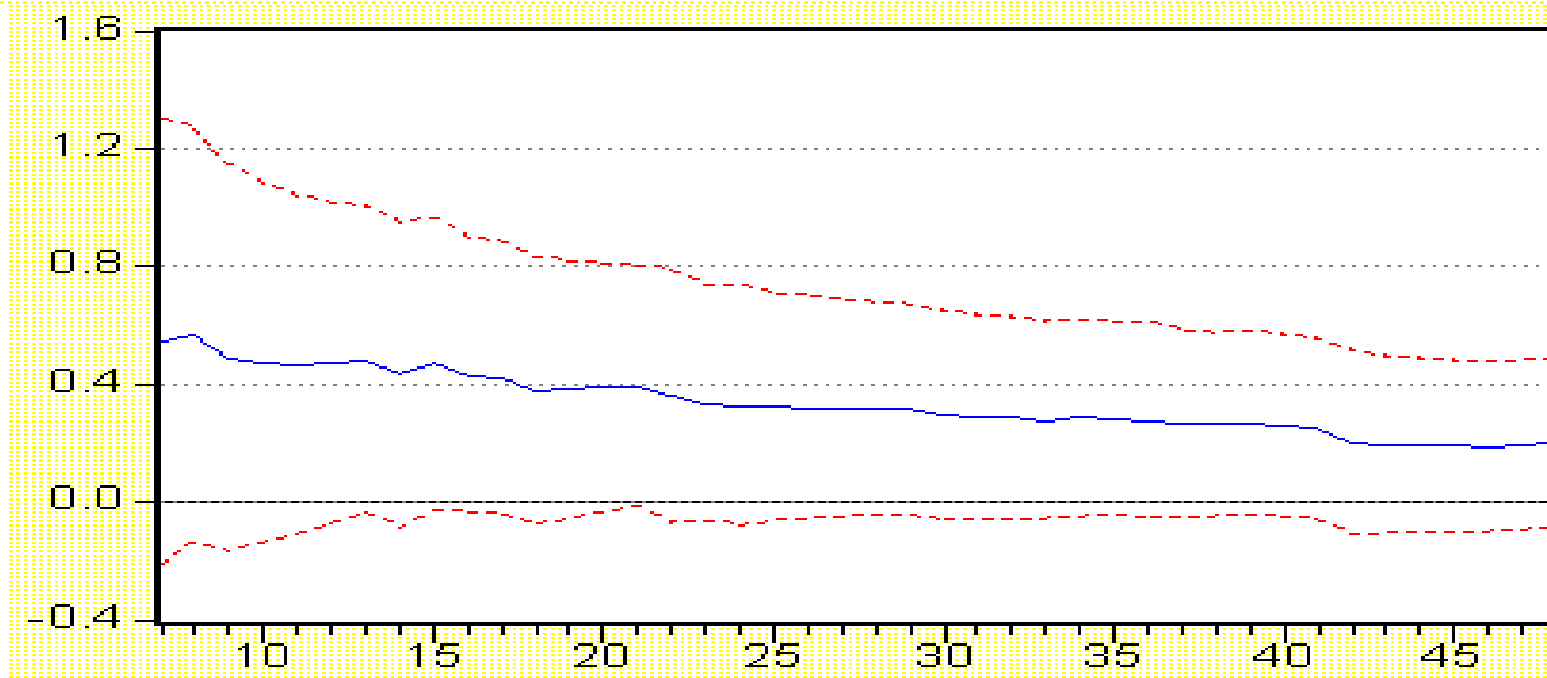
RRSDW



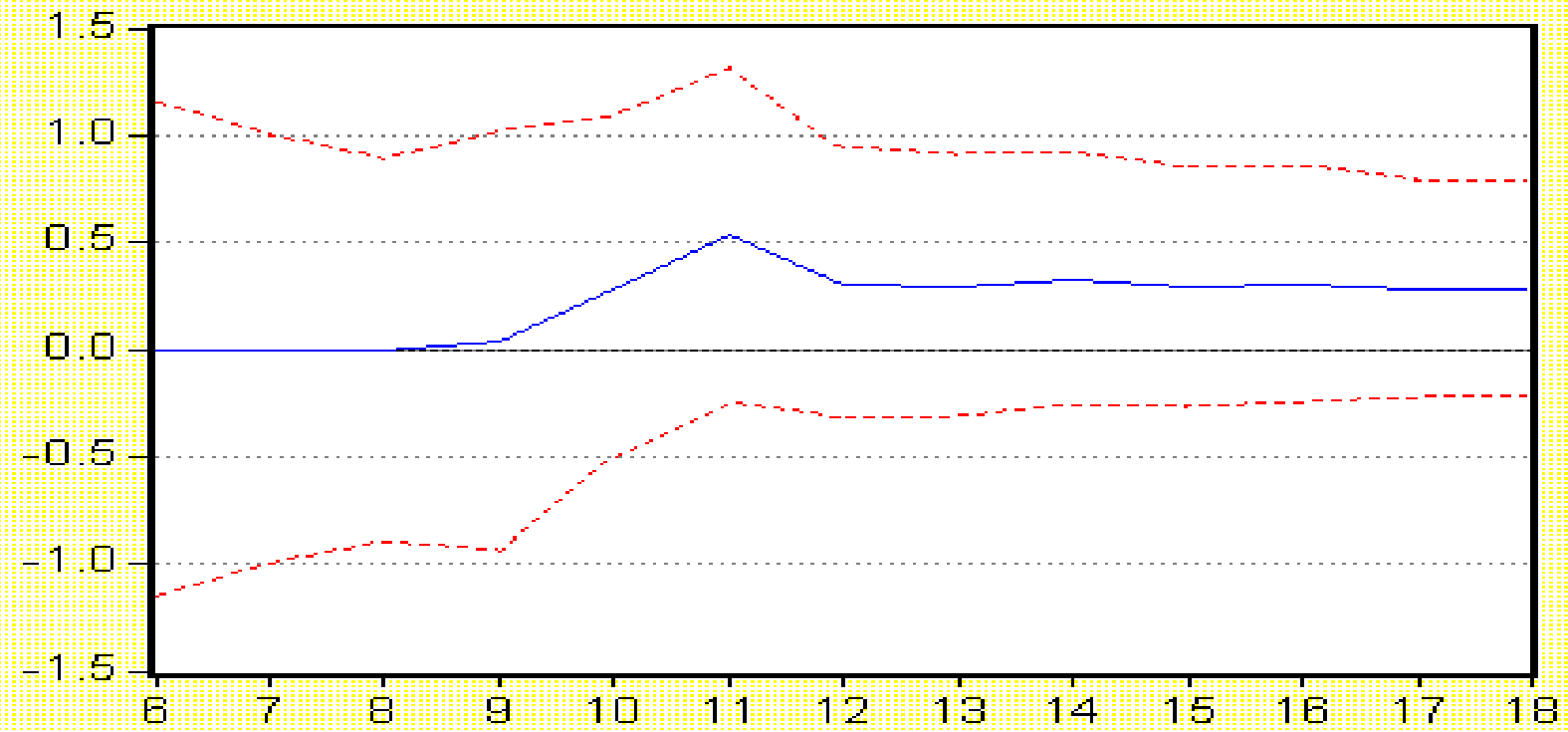
RBETIM



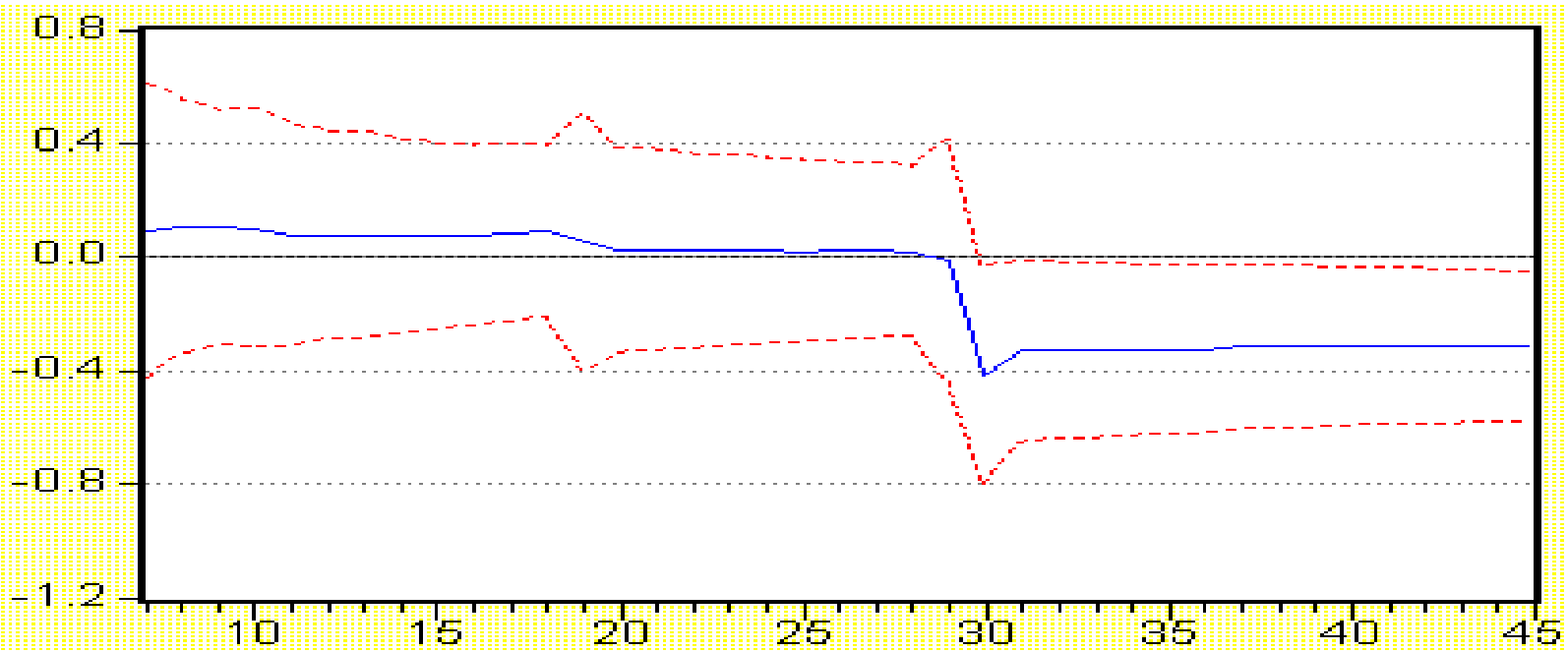
RBETCM



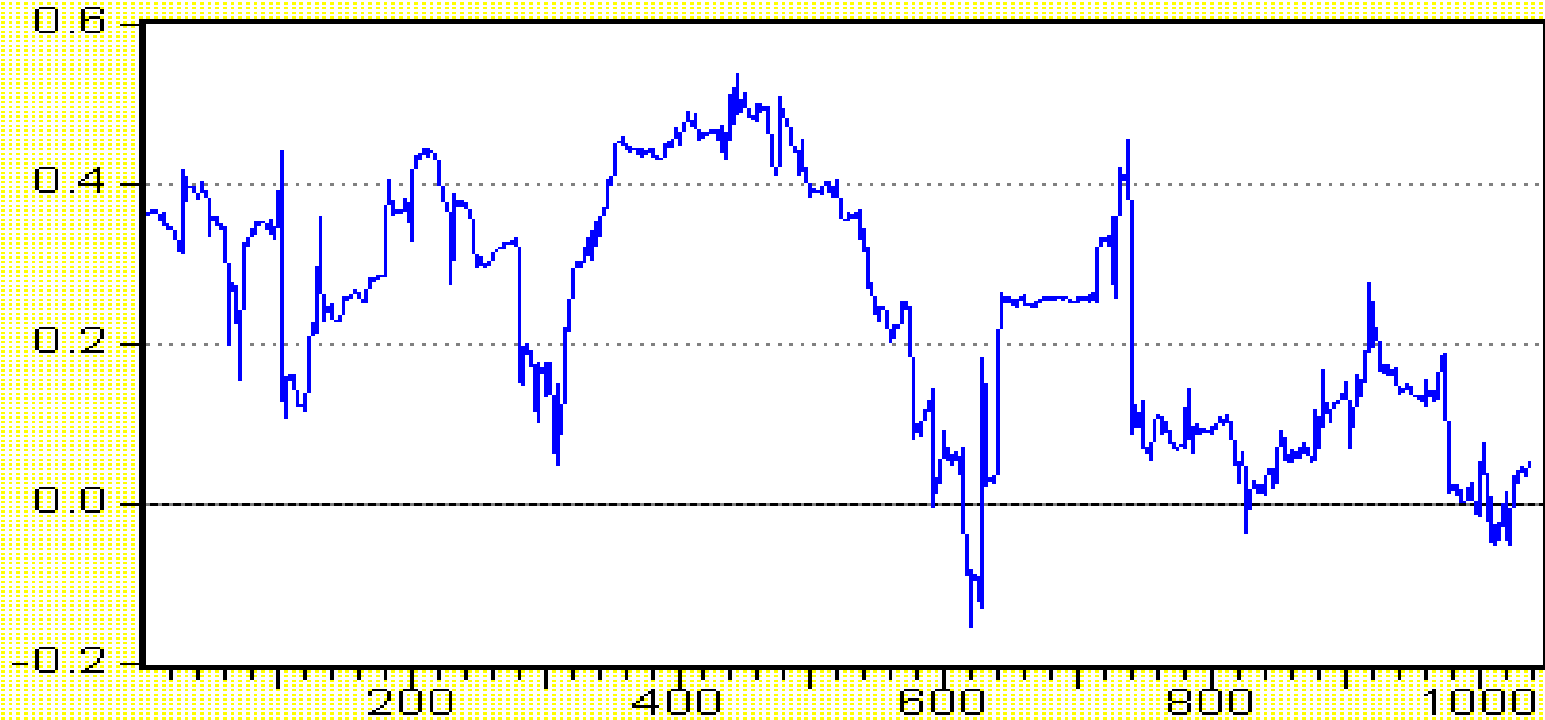
RBETFM



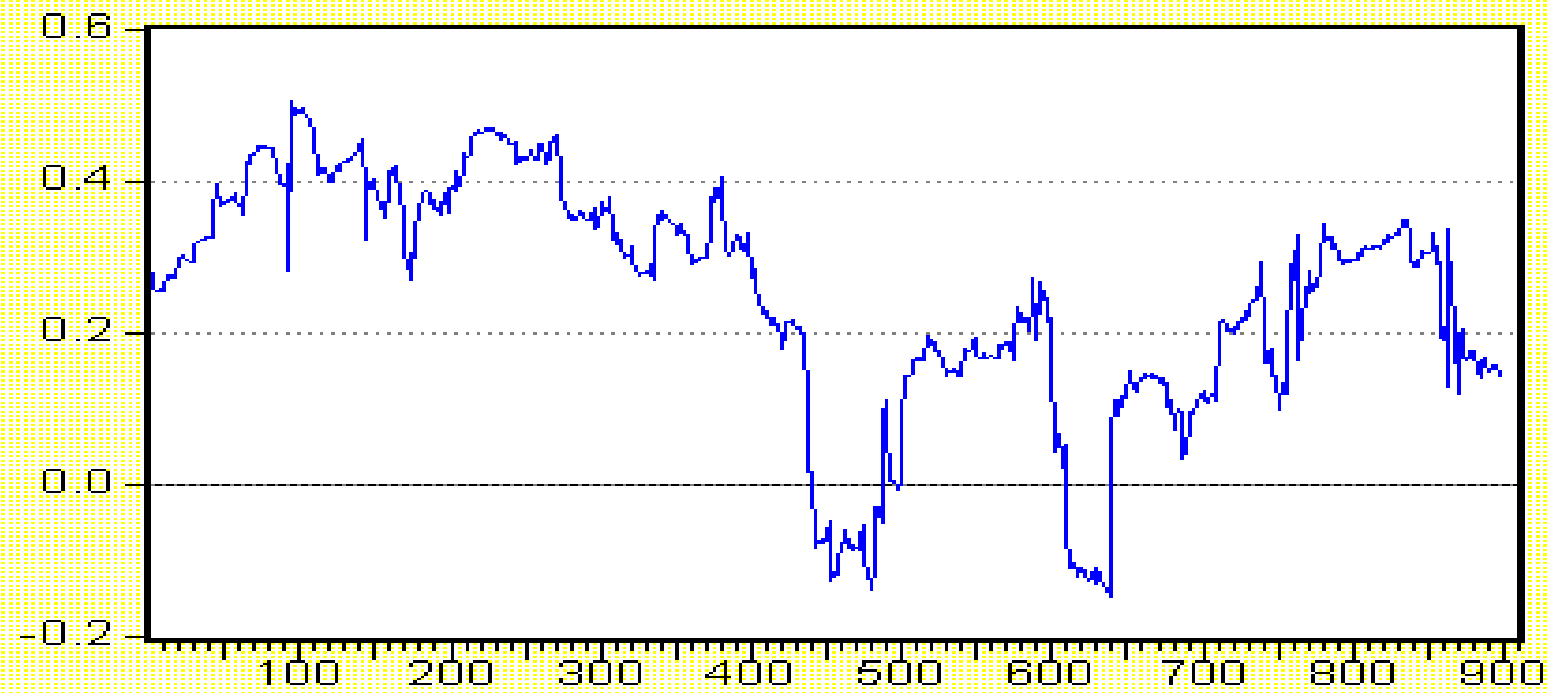
RRSDM



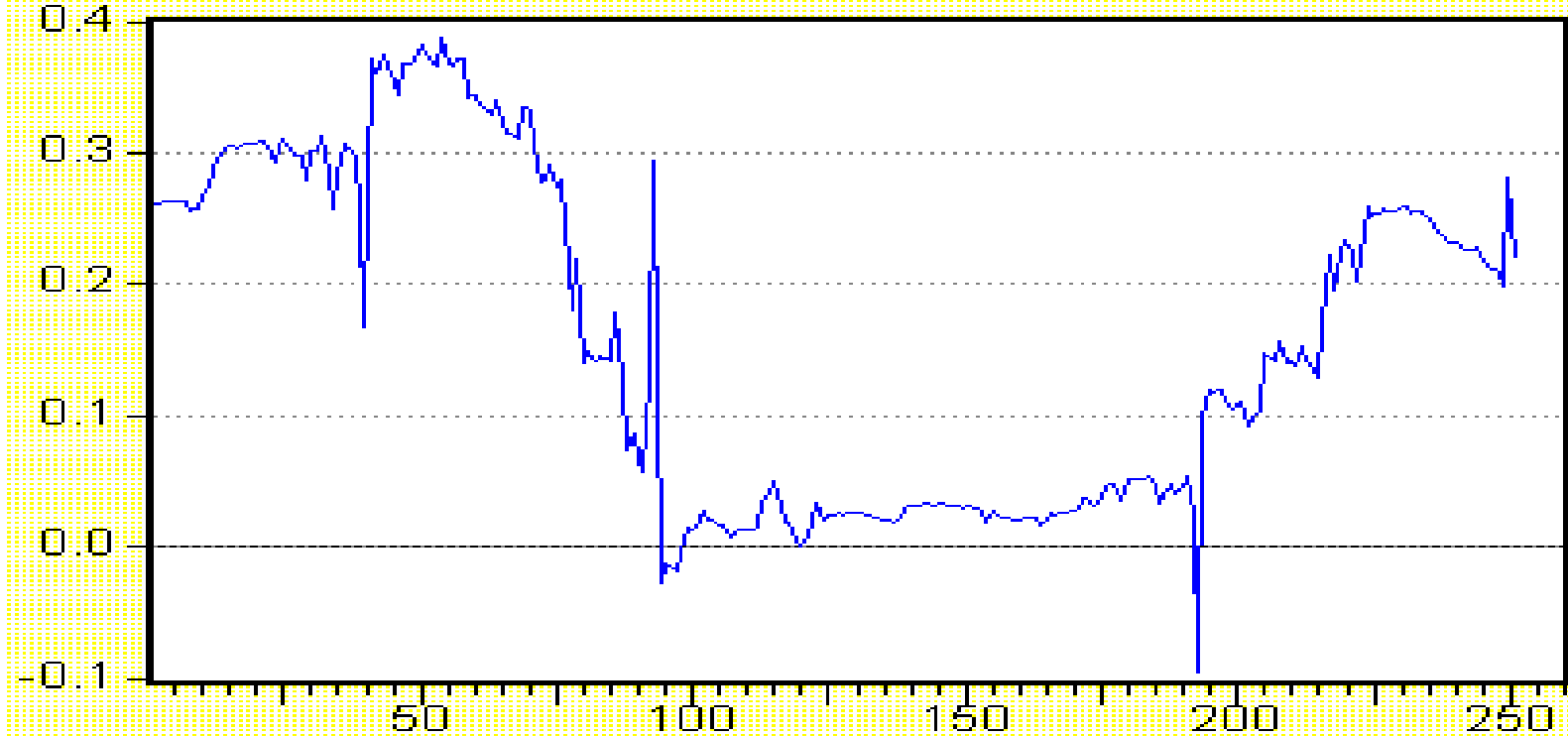
RBETIZ



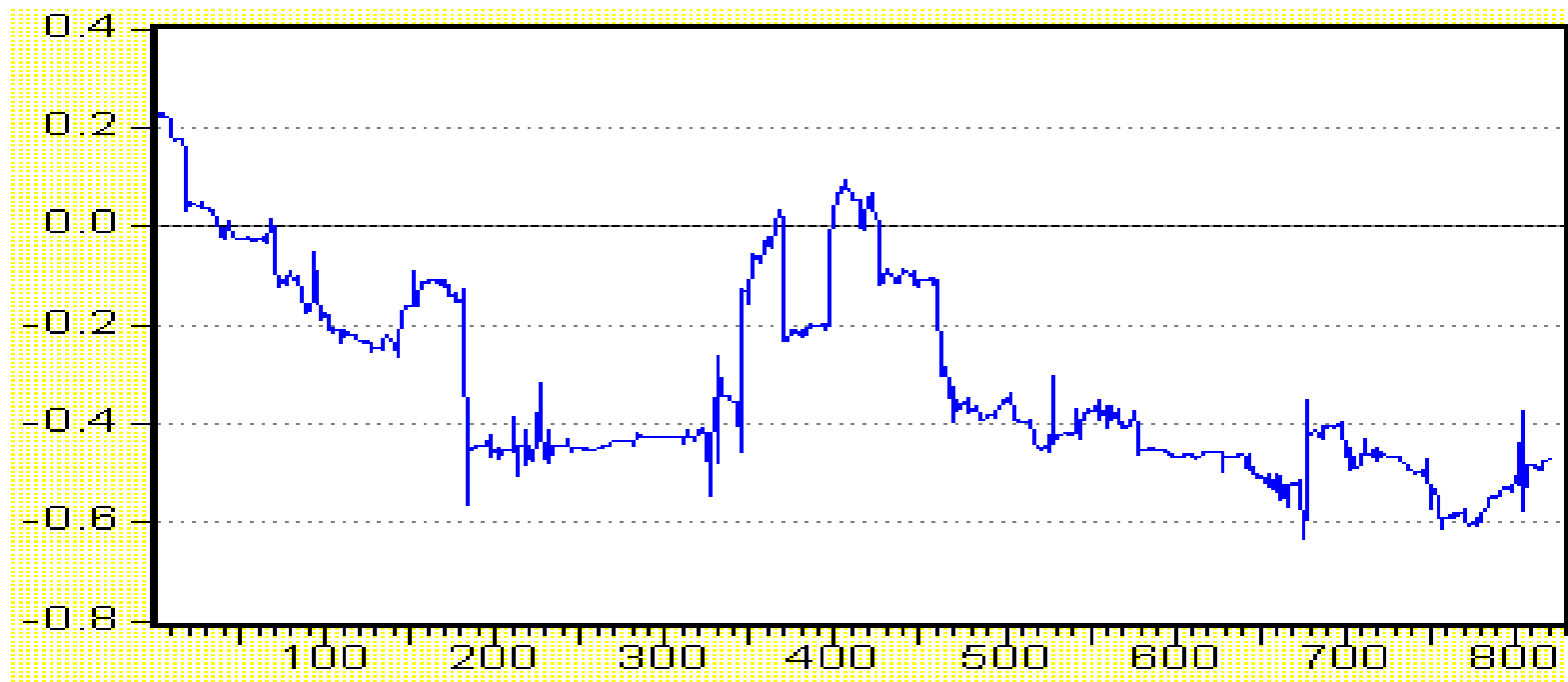
RBETCZ



RBETFZ



RRSDZ



Variance ratio test

This test was developed by Lo and MacKinlay (1988) who showed that the variance ratio test is more powerful than „autocorrelation coefficient” test. An important property of all three random walk hypotheses is that the variance of increments must be a linear function of the time interval.

Specifically, the variance estimated from the q-period returns should be q times as large as the variance estimated from one-period return.

$$VR(q) = \frac{Var[r_t(q)]}{qVar[r_t]} = 1 + 2 \sum_{k=1}^{q-1} \left(1 - \frac{k}{q}\right) \rho(k)$$

$$VR(2) = \frac{Var[r_t(2)]}{2 \cdot Var[r_t]} = \frac{Var[r_t + r_{t-1}]}{2 \cdot Var[r_t]} = \frac{2 \cdot Var[r_t] + 2 \cdot Cov[r_t, r_{t-1}]}{2 \cdot Var[r_t]} = 1 + \rho(1)$$

The standard normal statistics for the variance ratio test under the assumption of homoscedasticity $Z(q)$ and heteroscedasticity $Z'(q)$ are respectively:

$$Z(q) = \frac{VR(q) - 1}{\sqrt{\Phi(q)}} \sim N(0, 1)$$

$$Z'(q) = \frac{VR(q) - 1}{\sqrt{\Phi'(q)}} \sim N(0, 1)$$

Daily returns:

Series	Observation	Indicators	$q=2$	$q=4$	$q=8$
<i>RBETIZ</i>	1139	VR(q)	1,302	1,533	1,709
		Z(q)	10,195***	9,62***	8,093***
		Z'(q)	5,591***	5,521***	5,151***
<i>RBETCZ</i>	1000	VR(q)	1,288	1,551	1,842
		Z(q)	9,121***	9,315***	8,998***
		Z'(q)	4,966***	5,301***	5,657***
<i>RBETFZ</i>	352	VR(q)	1,166	1,154	1,281
		Z(q)	3,111***	1,542	1,785*
		Z'(q)	1,715*	0,941	1,233
<i>RRSDZ</i>	925	VR(q)	0,601	0,39	0,31
		Z(q)	-12,102***	-9,911***	-7,066***
		Z'(q)	-3,276***	-2,76***	-2,061**

Weekly returns:

<i>Series</i>	<i>Observations</i>	<i>Indicators</i>	<i>q=2</i>	<i>q=4</i>	<i>q=8</i>
<i>RBETIW</i>	230	VR(q)	1,062	1,098	1,209
		Z(q)	0,938	0,795	1,069
		Z'(q)	0,808	0,684	0,9
<i>RBETCW</i>	203	VR(q)	1,213	1,358	1,563
		Z(q)	3,039***	2,725***	2,706***
		Z'(q)	1,995**	1,979**	2,134**
<i>RBETFW</i>	72	VR(q)	1,056	1,366	1,709
		Z(q)	0,479	1,649*	2,021**
		Z'(q)	0,416	1,461	1,879*
<i>RRSDW</i>	188	VR(q)	0,861	0,809	0,658
		Z(q)	-1,289	-0,947	-1,076
		Z'(q)	-0,531	-0,48	-0,718

Monthly returns:

Series	Observations	Indicators	$q=2$	$q=4$	$q=8$
RBETIM	56	VR(q)	1,118	1,096	1,124
		Z(q)	0,876	0,315	0,311
		Z'(q)	0,779	0,36	0,312
RBETCM	48	VR(q)	1,168	1,096	0,535
		Z(q)	1,536	0,53	-1,075
		Z'(q)	1,109	0,36	-1,176
RBETFM	18	VR(q)	1,249	1,332	0,313
		Z(q)	1,028	0,733	-0,957
		Z'(q)	1,28	0,859	-1,126
RRSDM	45	VR(q)	0,613	0,384	0,313
		Z(q)	-2,565***	-2,181**	-1,716*
		Z'(q)	-1,362	-1,422	-1,462

Calendar anomalies

One way to investigate the predictability of future returns is to check for market anomalies.

The anomalies investigated here are:

- A. The January or Turn-of-the-Year Effect
- B. The Weekend Effect
- C. Turn-of-the-month Effect
- D. Pre-holiday Effect
- E. Serial Correlation Patterns

Model 1

$$\begin{aligned} R_t = & a_0 + a_1 \cdot WD_t + b_1 \cdot M_t \cdot R_{t-1} + b_2 \cdot Tu_t \cdot R_{t-1} + b_3 \cdot W_t \cdot R_{t-1} \\ & + b_4 \cdot Th_t \cdot R_{t-1} + b_5 \cdot F_t \cdot R_{t-1} + b_6 \cdot POSTH_t \cdot R_{t-1} + d \cdot PH_t \\ & + e \cdot JAN_t + f \cdot TOM_t + u_t \end{aligned}$$

Model 2

$$\begin{aligned} R_t = & \alpha_0 + \alpha_1 \cdot WD_t + \beta_1 \cdot M_t \cdot R_{t-1} + \beta_2 \cdot Tu_t \cdot R_{t-1} + \beta_3 \cdot W_t \cdot R_{t-1} + \beta_4 \cdot Th_t \cdot R_{t-1} + \beta_5 \cdot F_t \cdot R_{t-1} \\ & + \beta_6 \cdot POSTH_t \cdot R_{t-1} + \delta \cdot PH1_t + \gamma \cdot TOY_t + \lambda \cdot TOMR_t + \varepsilon_t \end{aligned}$$

We will accept the existence of these anomalies if:

<i>Calendar anomalies</i>	<i>Model 1</i>	<i>Model 2</i>
The January Effect	$e > 0$	
Turn-of-the-Year Effect		$\gamma > 0$
<i>Week-end Effect</i>	$a_1 < 0$	$\alpha_1 < 0$
<i>Pre-Holiday Effect</i>	$d > 0$	$\delta > 0$
<i>Turn-of-the-Month Effect</i>	$f > 0$	$\lambda > 0$

Dependent Variable: RBETIZ
 Method: Least Squares
 Date: 05/30/02 Time: 13:24
 Sample(adjusted): 3 1138
 Included observations: 1136 after adjusting endpoints
 Newey-West HAC Standard Errors & Covariance (lag truncation=6)
 RBETIZ=C(1)+C(2)*BET_IWDA12+C(3)*BET_IMA12*RBETIZ(-1)
 +C(4)*BET_ITUA12*RBETIZ(-1)+C(5)*BET_IWA12*RBETIZ(-1)
 +C(6)*BET_ITHA12*RBETIZ(-1)+C(7)*BET_IFA12*RBETIZ(-1)
 +C(8)*BET_IPOSTHA12*RBETIZ(-1)+C(9)*BET_IPHA12+
 C(10)*BET_IJANA12+C(11)*BET_ITOMA12

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	-0.001178	0.000794	-1.482223	0.1386
C(2)	0.002463	0.001534	1.605633	0.1086
C(3)	0.356300	0.123645	2.881638	0.0040
C(4)	0.211294	0.096843	2.181812	0.0293
C(5)	0.293457	0.091667	3.201349	0.0014
C(6)	0.313611	0.136625	2.295415	0.0219
C(7)	0.355466	0.086937	4.088761	0.0000
C(8)	-0.626260	0.343588	-1.822708	0.0686
C(9)	0.007875	0.004023	1.957746	0.0505
C(10)	0.002746	0.001852	1.482258	0.1386
C(11)	0.001886	0.001272	1.482286	0.1385

R-squared	0.104509	Mean dependent var	-8.57E-05
Adjusted R-squared	0.096549	S.D. dependent var	0.020032
S.E. of regression	0.019041	Akaike info criterion	-5.074834
Sum squared resid	0.407869	Schwarz criterion	-5.026077
Log likelihood	2893.506	F-statistic	13.12937
Durbin-Watson stat	1.979859	Prob(F-statistic)	0.000000

Dependent Variable: RBETIZ
 Method: Least Squares
 Date: 05/30/02 Time: 13:25
 Sample(adjusted): 3 1138
 Included observations: 1136 after adjusting endpoints
 Newey-West HAC Standard Errors & Covariance (lag truncation=6)
 RBETIZ=C(1)+C(2)*BET_IWDA12+C(3)*BET_IMA12*RBETIZ(-1)
 +C(4)*BET_ITUA12*RBETIZ(-1)+C(5)*BET_IWA12*RBETIZ(-1)
 +C(6)*BET_ITHA12*RBETIZ(-1)+C(7)*BET_IFA12*RBETIZ(-1)
 +C(8)*BET_IPOSTHA12*RBETIZ(-1)+C(9)*BET_IPH1A2+
 C(10)*BET_ITOYA2+C(11)*BET_ITOMRA2

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	-0.001020	0.000750	-1.359027	0.1744
C(2)	0.002487	0.001529	1.626229	0.1042
C(3)	0.346898	0.123869	2.800520	0.0052
C(4)	0.207756	0.097292	2.135396	0.0329
C(5)	0.295442	0.091547	3.227225	0.0013
C(6)	0.313178	0.136446	2.295242	0.0219
C(7)	0.342533	0.087570	3.911530	0.0001
C(8)	-0.639279	0.366654	-1.743547	0.0815
C(9)	0.007648	0.003770	2.028814	0.0427
C(10)	0.007554	0.003849	1.962726	0.0499
C(11)	0.001442	0.001230	1.172457	0.2413

R-squared	0.106168	Mean dependent var	-8.57E-05
Adjusted R-squared	0.098222	S.D. dependent var	0.020032
S.E. of regression	0.019023	Akaike info criterion	-5.076688
Sum squared resid	0.407114	Schwarz criterion	-5.027931
Log likelihood	2894.559	F-statistic	13.36251
Durbin-Watson stat	1.980019	Prob(F-statistic)	0.000000

Dependent Variable: RBETCZ
 Method: Least Squares
 Date: 05/30/02 Time: 13:23
 Sample(adjusted): 3 999
 Included observations: 997 after adjusting endpoints
 Newey-West HAC Standard Errors & Covariance (lag truncation=6)
 RBETCZ=C(1)+C(2)*BET_CWDA12+C(3)*BET_CMA12*RBETCZ(-1)
 +C(4)*BET_CTUA12*RBETCZ(-1)+C(5)*BET_CWA12*RBETCZ(-1)
 +C(6)*BET_CTHA12*RBETCZ(-1)+C(7)*BET_CFA12*RBETCZ(-1)
 +C(8)*BET_CPOSTHA12*RBETCZ(-1)+C(9)*BET_CPHA12+C(10)*BET_CJANA12
 +C(11)*BET_CTOMA12

Dependent Variable: RBETCZ
 Method: Least Squares
 Date: 05/30/02 Time: 13:27
 Sample(adjusted): 3 999
 Included observations: 997 after adjusting endpoints
 Newey-West HAC Standard Errors & Covariance (lag truncation=6)
 RBETCZ=C(1)+C(2)*BET_CWDA12+C(3)*BET_CMA12*RBETCZ(-1)
 +C(4)*BET_CTUA12*RBETCZ(-1)+C(5)*BET_CWA12*RBETCZ(-1)
 +C(6)*BET_CTHA12*RBETCZ(-1)+C(7)*BET_CFA12*RBETCZ(-1)
 +C(8)*BET_CPOSTHA12*RBETCZ(-1)+C(9)*BET_CPH1A2+C(10)*BET_CTOYA2
 +C(11)*BET_C TOMRA2

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	-0.001224	0.000601	-2.035522	0.0421
C(2)	0.001862	0.001313	1.418458	0.1564
C(3)	0.262926	0.139619	1.883170	0.0600
C(4)	0.139254	0.088613	1.571485	0.1164
C(5)	0.278416	0.100415	2.772660	0.0057
C(6)	0.478288	0.129428	3.695396	0.0002
C(7)	0.276904	0.143428	1.930615	0.0538
C(8)	-0.081651	0.259818	-0.314261	0.7534
C(9)	0.004330	0.002296	1.885919	0.0596
C(10)	0.004343	0.001632	2.661473	0.0079
C(11)	0.000793	0.001197	0.662029	0.5081

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	-0.000968	0.000576	-1.680677	0.0931
C(2)	0.001867	0.001306	1.429349	0.1532
C(3)	0.249948	0.138743	1.801519	0.0719
C(4)	0.135128	0.088519	1.526546	0.1272
C(5)	0.284103	0.100222	2.834747	0.0047
C(6)	0.478722	0.129351	3.700955	0.0002
C(7)	0.273191	0.142354	1.919101	0.0553
C(8)	-0.086079	0.251653	-0.342053	0.7324
C(9)	0.001855	0.002959	0.626935	0.5308
C(10)	0.009507	0.002648	3.590605	0.0003
C(11)	0.000323	0.001215	0.266237	0.7901

R-squared	0.105352	Mean dependent var	-0.000493
Adjusted R-squared	0.096278	S.D. dependent var	0.014841
S.E. of regression	0.014108	Akaike info criterion	-5.673125
Sum squared resid	0.196260	Schwarz criterion	-5.619010
Log likelihood	2839.053	F-statistic	11.61091
Durbin-Watson stat	2.002555	Prob(F-statistic)	0.000000

R-squared	0.107639	Mean dependent var	-0.000493
Adjusted R-squared	0.098588	S.D. dependent var	0.014841
S.E. of regression	0.014090	Akaike info criterion	-5.675684
Sum squared resid	0.195758	Schwarz criterion	-5.621569
Log likelihood	2840.328	F-statistic	11.89335
Durbin-Watson stat	2.010495	Prob(F-statistic)	0.000000

Dependent Variable: RBETFZ
 Method: Least Squares
 Date: 06/10/02 Time: 16:19
 Sample(adjusted): 3 351
 Included observations: 349 after adjusting endpoints
 Newey-West HAC Standard Errors & Covariance (lag truncation=5)

$$RBETFZ=C(1)+C(2)*BET_FWDA12+C(3)*BET_FMA12*RBETFZ(-1)+C(4)*BET_FTUA12*RBETFZ(-1)+C(5)*BET_FWA12*RBETFZ(-1)+C(6)*BET_FTHA12*RBETFZ(-1)+C(7)*BET_FFA12*RBETFZ(-1)+C(8)*BET_FPOSTHA12*RBETFZ(-1)+C(9)*BET_FPHA1+C(10)*BET_FJANA1+C(11)*BET_FTOMA1$$

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	0.002843	0.001629	1.744808	0.0819
C(2)	-0.000924	0.002981	-0.310081	0.7567
C(3)	0.383730	0.152839	2.510678	0.0125
C(4)	0.369963	0.287891	1.285080	0.1996
C(5)	-0.004604	0.217960	-0.021124	0.9832
C(6)	-0.047066	0.098869	-0.476041	0.6344
C(7)	0.438555	0.156703	2.798638	0.0054
C(8)	0.475617	0.191938	2.477973	0.0137
C(9)	-0.006819	0.010880	-0.626734	0.5313
C(10)	-0.005751	0.004004	-1.436223	0.1519
C(11)	0.002095	0.003406	0.615276	0.5388

R-squared	0.080286	Mean dependent var	0.002883
Adjusted R-squared	0.053076	S.D. dependent var	0.025958
S.E. of regression	0.025259	Akaike info criterion	-4.488221
Sum squared resid	0.215658	Schwarz criterion	-4.366715
Log likelihood	794.1946	F-statistic	2.950556
Durbin-Watson stat	1.942735	Prob(F-statistic)	0.001435

Dependent Variable: RBETFZ
 Method: Least Squares
 Date: 05/30/02 Time: 13:34
 Sample(adjusted): 3 351
 Included observations: 349 after adjusting endpoints
 Newey-West HAC Standard Errors & Covariance (lag truncation=5)

$$RBETFZ=C(1)+C(2)*BET_FWDA12+C(3)*BET_FMA12*RBETFZ(-1)+C(4)*BET_FTUA12*RBETFZ(-1)+C(5)*BET_FWA12*RBETFZ(-1)+C(6)*BET_FTHA12*RBETFZ(-1)+C(7)*BET_FFA12*RBETFZ(-1)+C(8)*BET_FPOSTHA12*RBETFZ(-1)+C(9)*BET_FPH1A2+C(10)*BET_FTOYA2+C(11)*BET_FTOMRA2$$

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	0.002397	0.001457	1.644772	0.1009
C(2)	-0.000720	0.002969	-0.242576	0.8085
C(3)	0.342028	0.142038	2.408004	0.0166
C(4)	0.350905	0.301175	1.165119	0.2448
C(5)	0.004260	0.218200	0.019522	0.9844
C(6)	-0.035215	0.091847	-0.383407	0.7017
C(7)	0.430288	0.156528	2.748956	0.0063
C(8)	0.346093	0.282813	1.223752	0.2219
C(9)	-0.007457	0.009105	-0.819036	0.4133
C(10)	0.005359	0.010069	0.532238	0.5949
C(11)	-0.000101	0.003385	-0.029920	0.9761

R-squared	0.075532	Mean dependent var	0.002883
Adjusted R-squared	0.048181	S.D. dependent var	0.025958
S.E. of regression	0.025325	Akaike info criterion	-4.483066
Sum squared resid	0.216772	Schwarz criterion	-4.361559
Log likelihood	793.2950	F-statistic	2.761574
Durbin-Watson stat	1.926535	Prob(F-statistic)	0.002744

Dependent Variable: RRSDZ
 Method: Least Squares
 Date: 05/30/02 Time: 13:44
 Sample(adjusted): 3 924
 Included observations: 922 after adjusting endpoints
 Newey-West HAC Standard Errors & Covariance (lag truncation=6)
 RRSDZ=C(1)+C(2)*RSD_WDA12+C(3)*RSD_MA12*RRSDZ(-1)+C(4)*RSD_TUA12*RRSDZ(-1)+C(5)*RSD_WA12*RRSDZ(-1)+C(6)*RSD_THA12*RRSDZ(-1)+C(7)*RSD_FA12*RRSDZ(-1)+C(8)*RSD_POSTHA12*RRSDZ(-1)+C(9)*RSD_PHA1+C(10)*RSD_JANA1+C(11)*RSD_TOMA1

Dependent Variable: RRSDZ
 Method: Least Squares
 Date: 05/30/02 Time: 13:46
 Sample(adjusted): 3 924
 Included observations: 922 after adjusting endpoints
 Newey-West HAC Standard Errors & Covariance (lag truncation=6)
 RRSDZ=C(1)+C(2)*RSD_WDA12+C(3)*RSD_MA12*RRSDZ(-1)+C(4)*RSD_TUA12*RRSDZ(-1)+C(5)*RSD_WA12*RRSDZ(-1)+C(6)*RSD_THA12*RRSDZ(-1)+C(7)*RSD_FA12*RRSDZ(-1)+C(8)*RSD_POSTHA12*RRSDZ(-1)+C(9)*RSD_PH1A2+C(10)*RSD_TOYA2+C(11)*RSD_TOMRA2

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	0.000168	0.000764	0.219854	0.8260
C(2)	-0.000690	0.001442	-0.478178	0.6326
C(3)	-0.407636	0.150658	-2.705694	0.0069
C(4)	-0.388113	0.098309	-3.947893	0.0001
C(5)	-0.105938	0.228255	-0.464120	0.6427
C(6)	-0.657630	0.235875	-2.788042	0.0054
C(7)	-0.419329	0.131397	-3.191323	0.0015
C(8)	-0.003326	0.250329	-0.013287	0.9894
C(9)	-3.81E-05	0.004336	-0.008776	0.9930
C(10)	-0.002161	0.003096	-0.697962	0.4854
C(11)	-0.000841	0.001340	-0.627326	0.5306

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	0.000138	0.000790	0.175274	0.8609
C(2)	-0.000645	0.001449	-0.445162	0.6563
C(3)	-0.405754	0.150564	-2.694883	0.0072
C(4)	-0.390223	0.097724	-3.993098	0.0001
C(5)	-0.107642	0.228561	-0.470954	0.6378
C(6)	-0.657148	0.236068	-2.783724	0.0055
C(7)	-0.420582	0.131158	-3.206673	0.0014
C(8)	-0.001995	0.252357	-0.007906	0.9937
C(9)	0.002379	0.005322	0.447094	0.6549
C(10)	-0.005659	0.003477	-1.627701	0.1039
C(11)	-0.001193	0.001396	-0.854712	0.3929

R-squared	0.186813	Mean dependent var	-0.000256
Adjusted R-squared	0.177886	S.D. dependent var	0.023773
S.E. of regression	0.021555	Akaike info criterion	-4.824584
Sum squared resid	0.423256	Schwarz criterion	-4.767001
Log likelihood	2235.133	F-statistic	20.92831
Durbin-Watson stat	2.192325	Prob(F-statistic)	0.000000

R-squared	0.187702	Mean dependent var	-0.000256
Adjusted R-squared	0.178785	S.D. dependent var	0.023773
S.E. of regression	0.021543	Akaike info criterion	-4.825679
Sum squared resid	0.422793	Schwarz criterion	-4.768095
Log likelihood	2235.638	F-statistic	21.05095
Durbin-Watson stat	2.193749	Prob(F-statistic)	0.000000

Conclusions

<i>Series</i>	<i>Autocorrelation coefficients</i>	<i>Variance ratio</i>	<i>Calendar anomalies</i>
<i>RBETZ</i>	N	N	**
<i>RBETW</i>	D	D	-
<i>RBETM</i>	D	D	-
<i>RBETFZ</i>	N	N	*
<i>RBETFW</i>	D	D	-
<i>RBETFM</i>	D	D	-
<i>RBETCZ</i>	N	N	***
<i>RBETCW</i>	N	N	-
<i>RBETCM</i>	D	D	-
<i>RRSDZ</i>	N	N	*
<i>RRSDRW</i>	N	D	-
<i>RRSDM</i>	N	N	-

Possible explanations for the high autocorrelation:

- The non-trading effect
- The cross-effect
- The correlated trading strategies of institutional investors
- The noise-trading effect

As Samuelson noted, randomness is achieved through the active participation of many investors seeking greater wealth. In their quest to exploit every information, by trading on the basis of it, they automatically incorporate that information in the price.

For daily series, there is a clear violation of the randomness conditions, and this violation last even for some of weekly series, and even for onen monthly series.

In assuming my conclusion about market efficiency, I take into account especially the results for daily series (it is difficult to reject efficiency for weekly and monthly data on many markets).

My conclusion is that the Romanian capital market is not weak-form efficient, and the most important causes is the low number of investors on this markets.

Due to the incertity about the future, many potential investors stay out of this market, seeking the safeness of bank deposits.

The implications of inefficiency:

- The perception that prices do not fully reflect some information can lead the investors to adopting portfolio strategies designed to reap abnormal profits by exploiting the informational inefficiency.
- On the other hand, the investors may be unwilling to trade in securities if it is felt that the information is possessed by others. They might leave these markets to invest elsewhere, or they might reduce the total amount invested.
- The information intermediaries will gather information and make profits, because there will exist a big demand for information, as the information is not reflected in prices as it should be.
- Firms should not expect to receive the fair value for securities they sell (price will not always reflect the present value for securities they issue). There even might exist the opportunity to “fool” investors.

Reference and source:

1. Multivariate Time Series Analysis: With R and Financial Applications by Ruey S. Tsay
2. Time Series Analysis by James Douglas Hamilton
3. The Analysis of Time Series: An Introduction with R (Chapman & Hall/CRC Texts in Statistical Science)
4. Machine Learning for Time Series Forecasting with Python by Francesca Lazzeri
5. Time Series Analysis for the Social Sciences (Analytical Methods for Social Research) Part of: Analytical Methods for Social Research (14 Books)
6. Introduction to Probability, Statistics, and Random Processes by Hossein Pishro-Nik
7. Introduction to Time Series and Forecasting (Springer Texts in Statistics) Part of: Springer Texts in Statistics