B A D A N I A   O P E R A C Y J N E   I   D E C Y Z J E

Nr 1 2006

Jana HANČLOVA*
Eva RUBLIKOVA**

TESTING THE WEAK FORM OF EFFICIENCY ON CZECH AND SLOVAK STOCK MARKET

The article deals with the testing of the weak form of efficiency on Czech and Slovak stock market during the period 2000–2004 based on daily returns representing index PX50 and SAX30 in the form of martingale as well as in the form of random walk. Concerning functional model forms of conditional variance, the linear and nonlinear volatility models have been estimated and half-life of the variance on the markets, presence of leverage effect or risk aversion have been evaluated.

Keywords: *Stock market efficiency, GARCH models, martingale form of efficiency, random walk, Czech and Slovak stock market, testing the weak form of efficiency*

1. Introduction

The theory of efficient markets explains the failure of many analysts to predict the future development of stock returns. It says that share prices change at random and hence the analyses cannot predict the future development, regardless of how good they are. The experience of developed markets validates this hypothesis.

The semi-strong form of market efficiency exhibits the random walk of share price changes. A share price development cannot be predicted just on the basis of the last information (and hence of the last price, too). When testing the weak form of market efficiency, it is assumed that the returns are governed by the random walk model or by the martingale.

* Faculty of Economics, Technical University of Ostrava, Sokolská třída 33, Ostrava 1, 701 21, Czech Republic. jana.hanclova@vsb.cz

** Department of Statistics, Faculty of Economic Informatics, Economic University of Bratislava, Dolnozemská 1/b, 852 35 Bratislava 5, Slovak Republic. rublik@euba.sk

As with other financial time series, it is necessary to cope with the variance variation of series, in this case, too. A number of Autoregressive Conditional Heteroskedasticity (ARCH) models have been designed to deal with this problem. The variance of dependent variable is modeled as a function of past values of the dependent variable and independent, or exogenous, variables. ARCH models were introduced by Engle (1982) and generalized as GARCH (Generalized ARCH) by Bollerslev (1986) and Taylor (1986).

The aim of this paper is to test the weak form of efficiency of Czech and Slovak stock market based on the daily data analysis of their indices PX50 and SAX30 over the time period from March 20, 2000 to March 18, 2004.

The weak form of efficiency, being in the form of the random walk and the martingale, is investigated for:

- aggregated 4-year period,
- divided time periods:
  - March 20, 2000 – March 18, 2002 and
  - March 19, 2002 – March 18, 2004.

Applying the ARCH models enables us to estimate the half-life of the variance on the markets and to test for the existence of the leverage effect and risk aversion of these markets.

The structure of the paper fully corresponds with the objective aligned. Section 2 briefly describes the efficient market theory, particularly focusing on determination of the forms of effectiveness. Section 3 shows the approaches to testing the weak form of effectiveness and Section 4 gives a summary of existing results from tests of the effectiveness of Czech and Slovak stock market. Empirical studies on testing weak form of effectiveness of Czech and Slovak stock market for different time periods form the fundamental parts of the report. The conclusions present the evaluations of results.

2. Efficient Market Hypothesis (EMH)

In the past a number of personalities have attempted to correctly estimate the future returns. Eugene Fama is considered to be the father of the efficient market theory. In the years 1965–1970 he formulated this theory:

"An efficient stock market reflects all the information that is significant and possible to know. There exist neither underestimated nor overestimated securities".

(All the strategies striving to get better knowledge of prices than the one offered by the market fail).

We discriminate between three efficiency forms of capital market:

Weak efficiency – the impossibility to achieve systematic returns using the methods of technical analysis. The information set comprises all the current and past realizations of the price system. Share price changes manifest the random walk, no trends existing.

Semi-strong efficiency – the share price comprises the historical data as well as the current public information; it is impossible to achieve above-average returns, not even with the help of the fundamental analysis.

Strong efficiency – the present share price comprises, in addition to the information mentioned above, the inside (nonpublic) information. This form has not been spotted even in the case of the developed markets.

Martingale behavior of the price assumes that returns do not systematically change over time but it is not possible to predict the future deviations from expected returns.

3. Approaches to testing the weak form of efficiency

In the next part of paper we will pay attention to the testing of the weak form efficiency. These tests can be divided into two groups – those testing the independence of stock market changes and others consisting of tests of successfulness of the business and investment strategies.

Tests of independence of changes in share prices:

Correlation tests (a strive to spot the statistically insignificant autocorrelations).

Simulation tests (a comparison of the random file (the one being simulated) with the real file).

Run tests (a connection of the two types mentioned above, disposing its disadvantages, such as danger of extreme values appearance and their excessive influence).

Distribution models (based on comparisons of differentiation between share price movement and Gauss normal partition).

Returns modelling The use of autoregressive models in order to trace a potential trend, which opposes the EMH models. The correlation of returns itself is not sufficient. Nevertheless, it will at least serve for determining the regressors of the AR model. If these regressors are statistically significant, a potential influence of the use of the model being found is evaluated and hence the EMH is rejected. The ARCH models represent an improved version of AR models.

4. Existing results of testing the Czech market efficiency

Existing results of testing the Czech stock or more precisely Slovak market efficiency are digestibly summarized in the next part:

Filáček–Kapička–Vošvrda (1998) – testing the EHM:

• *Data* – daily values of the PX50 index over the time period of 5.1.1995–3.10.1997.

• *Methods* – autocorrelations, random walk, GARCH models.

• *Conclusion* – rejections of the weak form of efficiency, autocorrelation of the degrees 1,2,10 indicates the dependence of the returns.

Kvasnička (1997) – applicability of the technical analysis of the stocks on the Czech market:

• *Data*–Stock prices 6.3.1995–21.3.1997.

• *Methods* – successfulness of the technical analysis indicators.

• *Conclusion* – the Czech market is ineffective.

Horská (2003) – efficiency of Czech stock market and the macroeconomic consequences:

• Monthly *data* PX50, January 1995 – the middle of 2003.

• *Methods* – random walk tested by the Error Correction Model, test of filters, test of the semi-strong efficiency in relation to the macroeconomic factors.

• *Conclusion* – the weak form of efficiency is not rejected, the semi-strong form is rejected.

Gazda–Výrost (2003) – Volatility of the Slovak market index SAX:

• *Data* – daily SAX30, 1.8.1997–27.9.2002.

• *Methods*: test of the martingale, autocorrelations, ARCH models.

• *Conclusions* – SAX follows the martingale, i.e., the weak form of efficiency is not rejected.

5. Characteristics of the Czech stock market and its weak efficiency testing

In this part, we will characterize the evolution of Czech stock market during the period under consideration and we will test its weak efficiency form with the help of GARCH models for the whole time period between 2000–2004 and also for its divided periods mentioned above.

After the establishment of Czech stock market (via the so-called coupon privatization), a large number of stocks were traded on the nontransparent market. Oscillations on the market were frequently exceeding 10% on the daily basis and even 50% were not an exception. Experienced foreign investors were profiting from the situation (making the advantage of the situation that many of the DIKs strived to sell the easily-gained stocks). Bursting of the speculative bubble meant a harsh fall (the crash of Czech Stock Exchange) – the PX50 index plummeted to the half of its former value during 3 months (March–May, 1994). A period of the lack of interest in stock trading has come after (the collapse of the Mexican stock exchange has brought about the distrust of the foreign investors in new markets). The year 1995 was the second wave of the privatization process and it was followed by the third wave (fight for majority stakes of some companies' shares). The years following the second wave of privatization process were in token of strengthening the legislative system, fluctuation of the stock prices because of, among other factors, the changes in the home affairs (Russian crisis). At present time, the integration of the Czech Republic into the EU proceeds – trading in stocks of those Czech companies which enjoy no interest on the foreign stock exchanges.

The representative of Czech stock market is PX50 index. It is calculated on the basis of standard methodology IFC. The index basis consists of 50 emissions with the biggest share on the stock market (according to March, 2004) such as Komerční banka, Erste Bank, ČEZ and Český Telecom. Figure 1 shows the daily progress of index PX50, where the influences mentioned can be seen.

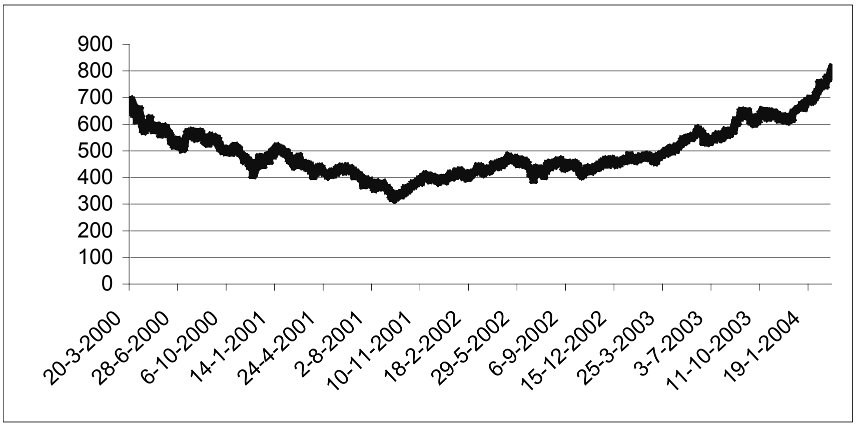

Fig. 1. The progress of Czech stock market during the time period 2000–2004

While testing the weak form of efficiency of Czech stock market, we will result from the daily returns defined by the following equation:

$$r_t = \ln P_t - \ln P_{t-1} \quad (1)$$

where:

r_t – daily share price index returns,

P_t – share price index value at the moment t.

Figure 2 characterizes the daily returns development on Czech stock market and we will attend to basic statistic values of this variable.

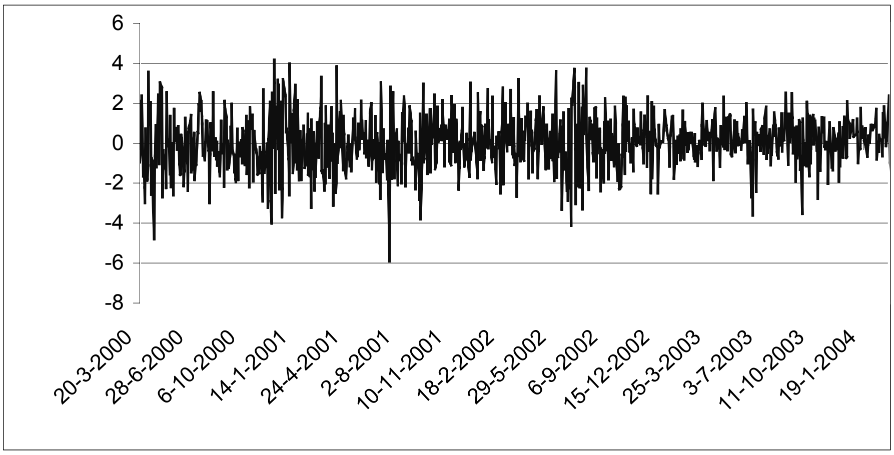

Fig. 2. Daily returns development on Czech stock market during the years 2000–2004

It can be reasoned from the histogram in Figure 3 that the distribution of returns is not normal, especially in the case of higher kurtosis (3.72 >3) and negative skewness, which is typical of many financial time series. We reject the normality distribution of returns also in terms of high value of Jarque–Bera statistic.

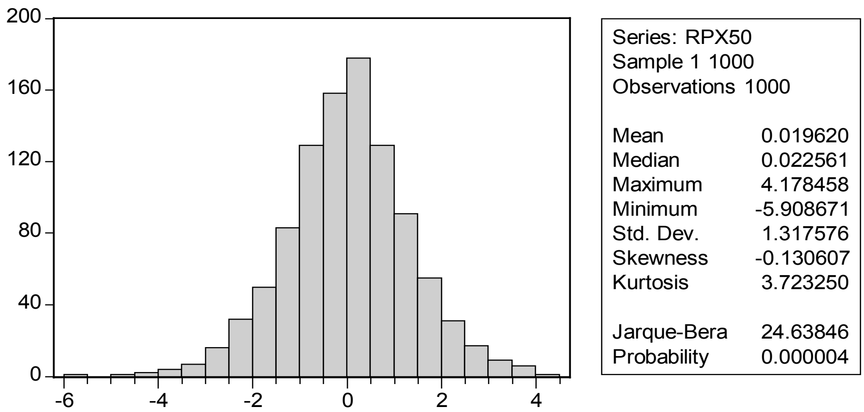

Fig. 3. PX50 daily returns normality testing

We continue with testing the stationarity of returns series based on Augmented Dickey–Fuller's test. The test equation includes linear trend and intercept or only intercept or none. These results are shown in Table 1. Values exceed the MacKinn critical value. We reject the hypothesis of nonstationarity of the returns series at all significance levels, which is in compliance with the weak form of the EMH of the unit root.

Table 1

ADF test results for PX50 daily returns

ADF(4) of returns	ADF trend+const.	ADF with constant	ADF
ADF Test Statistic	**–30.729**	**–30.397**	**–30.406**
1% Critical Value	–3.967	–3.437	–2.567
5% Critical Value	–3.414	–2.864	–1.941
10% Critical Value	–3.129	–2.568	–1.165

The next step is the autocorrelation analysis. Possible statistically significant autocorrelations would be rejecting the validity of the weak form of the EMH.

Table 2

Testing of PX50 daily returns autocorrelation – correlogram of RPX50

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
.| |	.| |	1	0.037	0.037	1.3390	0.247
.| |	.| |	2	0.020	0.019	1.7427	0.418
.| |	.| |	3	–0.039	–0.041	3.2978	0.348
.| |	.| |	4	0.035	0.038	4.5577	0.336
.| |	.| |	5	–0.038	–0.039	5.9862	0.308
.| |	.| |	6	0.047	0.048	8.2484	0.220
.| |	.| |	7	0.013	0.014	8.4192	0.297
.| |	.| |	8	–0.012	–0.020	8.5722	0.380
.| |	.| |	9	–0.037	–0.030	9.9376	0.356
.| |	.| |	10	–0.008	–0.009	10.001	0.440

Testing the autocorrelation on the basis of the returns correlogram has declared the returns to be uncorrelated – it is in compliance with the weak form of the EMH.

On the basis of existing results we will be able to model Czech stock market daily returns during the years 2000–2004 using the formula:

$$RPX50_t = c + \varepsilon_t \,. \tag{2}$$

Table 3

Modelling Czech stock market returns according to equation (2)

Variable	Coefficient	Std. Error	*t*-Statistic	Prob.
C	0.019620	0.041665	0.470887	0.6378
R-squared	0.000000	Mean dependent var		0.019620
Adjusted R-squared	0.000000	S.D. dependent var		1.317576
S.E. of regression	1.317576	Akaike info criterion		3.390464
Sum squared resid	1734.271	Schwarz criterion		3.395372
Log likelihood	–1694.232	Durbin–Watson stat		1.923163

Table 3 summarizes estimation results using least squared methods, where the statistically insignificant level constant is included. Residues autocorrelation has not been liquidated on a 5% significance level. The residues are neither normally distributed, which is evidently caused by variable dispersion. This was found through square residuals autocorrelation provided by ARCH LM test (see more in Tab. 4 and Tab. 5).

Table 4

Correlogram of Residuals Squared

Autocorrelation	Partial Correlation		AC	PAC	*Q*-Stat	Prob
.|* |	.|* |	1	0.125	0.125	15.752	0.000
.|* |	.|* |	2	0.137	0.123	34.468	0.000
.|* |	.|* |	3	0.152	0.126	57.779	0.000
.|* |	.|* |	4	0.125	0.084	73.423	0.000
.|* |	.|* |	5	0.183	0.138	107.12	0.000
.|* |	.|* |	6	0.131	0.069	124.40	0.000
.|* |	.| |	7	0.115	0.047	137.75	0.000
.|* |	.| |	8	0.127	0.055	153.92	0.000
.|* |	.| |	9	0.072	–0.003	159.19	0.000
.|* |	.|* |	10	0.136	0.067	177.96	0.000

Table 5

ARCH LM(4) test

F-statistic	13.79331	Probability	0.000000	
Obs*R-squared	52.52720	Probability	0.000000	
Variable	Coefficient	Std. Error	*t*-Statistic	Prob.
C	1.066643	0.126644	8.422346	0.0000
RESID^2(–1)	0.084841	0.031687	2.677422	0.0075
RESID^2(–2)	0.099878	0.031561	3.164638	0.0016
RESID^2(–3)	0.117753	0.031557	3.731409	0.0002
RESID^2(–4)	0.083478	0.031673	2.635627	0.0085

In the next part, we will use the models with conditional heteroscedasticity, however it can be already stated as a fact that we reject the weak EMH form in the form of random walk for abnormally distributed residuals.

Table 6 summarizes the results of a group of ARCH models.

Table 6

ARCH models for RPX50 (2000–2004)

	Akaike criterion	Schwarz criterion	Normality of residuals prob. of JB	Autocorrelation (at 5% level of sign.)	Heteroscedasticity (at 5% level of sign.)
ARCH(1)	3.374	3.389	0.000003	No	Yes
GARCH(1,1)	3.303	3.323	0.0016	No	No
GARCH(1,2)	3.304	3.329	0.0043	No	No
GARCH(2,1)	3.304	3.329	0.0038	No	No
GARCH(2,2)	3.306	3.336	0.0037	No	No
GARCH(1,1)-M(var)	3.304	3.328	0.0012	No	No
GARCH(1,1)-M(std)	3.302	3.327	0.0012	No	No
TARCH(1,1)	3.286	3.311	0.0008	No	No
EGARCH(1,1)	**3.286**	**3.309**	0.063	**No**	**No**

By virtue of maximum predicative ability of the model according to Akaike info criterion and Schwarz criterion the EGARCH (1,1) model (see Tab. 7) seems to be suitable.

Table 7

EGARCH (1,1) model

	Coefficient	Std. Error	z-Statistic	Prob.
C	0.057257	0.038933	1.470673	0.1414
	Variance equation			
C	–0.076675	0.026997	–2.840162	0.0045
|RES|/SQR[GARCH](1)	0.124616	0.037412	3.330881	0.0009
RES/SQR[GARCH](1)	**–0.081722**	**0.018581**	**–4.398205**	**0.0000**
EGARCH(1)	0.944862	0.014544	64.96794	0.0000
R-squared	–0.000817	Mean dependent var		0.019620
Adjusted R-squared	–0.004840	S.D. dependent var		1.317576
S.E. of regression	1.320761	Akaike info criterion		3.284145
Sum squared resid	1735.687	Schwarz criterion		3.308684
Log likelihood	–1637.073	Durbin–Watson stat		1.921593

EGARCH(1,1) model contains a constant in the returns equation which is not statistically significant, all the estimated coefficients of the variation equation are significant. The item in bold letters represents significant leverage effect (negative information causes higher volatility than the positive one. Residuals are not autocorrelated and distribution of residuals is normal and residuals are homoscedastical.

Partial conclusion: We do not reject a weak form of the EMH on Czech stock market in the form of martingale.

EGARCH(1,1)-M model (see Tab. 8) incorporates into returns equation statistically significant level constant and also regressor GARCH, being is all negative, which indicates, that the return is decreasing with growing volatility, which does not correspond to the aversion towards risk.

Table 8

EGARCH(1,1)-M model

	Coefficient	Std. Error	z-Statistic	Prob.
GARCH	–0.136636	0.055438	–2.464684	**0.0137**
C	0.260287	0.085650	3.038951	**0.0024**
Variance Equation				
C	–0.078883	0.024433	–3.228485	0.0012
|RES|/SQR[GARCH](1)	0.119317	0.034220	3.486805	0.0005
RES/SQR[GARCH](1)	–0.083036	0.017715	–4.687345	0.0000
EGARCH(1)	0.960147	0.013367	71.82847	0.0000

On the basis of GARCH (1,1) model, the half-life of the variation is set to be equal to 26 days.

The technique of modelling taking advantage of ARCH models was also applied to two-year periods of PX50 daily returns:

○ March 20,2000–March 18,2002 and

○ March 19,2002–March 18,2004.

The results from the first period (2000–2002) can be summarized in the following steps:

• Returns are stationary, uncorrelated and normally distributed, hence we reject neither the weak form of EMH in the form of random walk and nor in the form of martingale.

• As the most appropriate model (see Tab. 9) uses the TARCH(1,1) model (see Tab. 10), in which the residuals are uncorrelated, homoscedastical, normally distributed, the existence of the leverage effect has been confirmed.

• The half-life of variance according to the GARCH(1,1) model is about 12 days.

• TARCH(1,1)-M model has not confirmed the existence of the risk aversion of the market due to the statistical insignificance of the variance coefficient.

The results of Czech stock market returns model for the years 2002–2004 can be accordingly resumed as:

• PX50 returns are stationary, uncorrelated but they are not normally distributed. We do not reject the weak form of EMH in the form of martingale (on the basis of non-existence of any significant autocorrelation).

• The most appropriate are the TARCH(1,1) and GARCH(2,2) models (see Tab. 11).

• The existence of the leverage effect has not been confirmed, neither was the risk aversion of the market.

• The half-life of the variance is 15 days.

Table 9

ARCH models for RPX50 (2000–2002)

	Akaike criterion	Schwarz criterion	Normality of residuals prob. of JB	Autocorrelation (at 5% level of sign.)	Heteroscedasticity (at 5% level of sign.)
GARCH(1,1)	3.555	3.589	0.228	No	No
GARCH(1,2)	3.555	3.597	0.340	No	No
GARCH(2,1)	3.590	3.632	0.133	No	No
GARCH(2,2)	3.559	3.609	0.326	No	No
GARCH(1,1)-M(var)	3.556	3.597	0.219	No	No
TARCH(1,1)	**3.525**	**3.567**	**0.961**	**No**	**No**
TARCH(1,1)-M(var)	3.527	3.577	0.937	No	No
EGARCH(1,1)	3.526	3.568	0.784	No	No
EGARCH(1,1)-M(var)	3.530	3.580	0.781	No	No

Table 10

TARCH(1,1) for PX50 returns modelling in years 2000–2002

	Coefficient	Std. Error	z-Statistic	Prob.
C	–0.097023	0.061281	–1.583240	0.1134
	Variance Equation			
C	0.108063	0.050313	2.147807	0.0317
ARCH(1)	–0.024147	0.024146	–1.000048	0.3173
(RESID<0)*ARCH(1)	0.157045	0.048629	3.229437	0.0012
GARCH(1)	0.896272	0.044958	19.93568	0.0000
R-squared	–0.000058	Mean dependent var		–0.085927
Adjusted R-squared	–0.008075	S.D. dependent var		1.453704
S.E. of regression	1.459561	Akaike info criterion		3.524959
Sum squared resid	1063.029	Schwarz criterion		3.566850
Log likelihood	–883.2897	Durbin-Watson stat		1.955061

Table 11

ARCH models for RPX50 (2002–2004)

	Akaike criterion	Schwarz criterion	Normality of residuals prob. of JB	Autocorrelation (at 5% level of sign.)	Heteroscedasticity (at 5% level of sign.)
GARCH(1,1)	3.028	3.062	0.00117	No	No
GARCH(1,2)	3.030	3.072	0.0032	No	No
GARCH(2,1)	3.027	3.0692	0.0123	No	No
GARCH(2,2)	**3.020**	3.071	0.0161	No	No
GARCH(1,1)-M(var)	3.034	3.076	0.0014	No	No
TARCH(1,1)	3.027	**3.0689**	0.002	No	No
TARCH(1,1)-M(var)	3.033	3.084	0.0024	No	No
EGARCH(1,1)	3.028	3.071	0.004	No	No
EGARCH(1,1)-M(var)	3.043	3.085	0.0045	No	No

6. Characteristics of Slovak stock market and its weak form efficiency testing

Similarly as in the case of the Czech Republic, the first wave of privatization had different consequences. Slovak market did not offer as good liquidity as Czech stock market did. The second wave of privatization (1994–1997) was realized mainly through the direct sales and transfers. The returns during the government led by Čarnogurský and first Mečiar's government exceeded the book value of the assets. Since 1996 the privatization process for just fractional prices had been pursued, (e.g., Slovnaft, VSŽ, Nafta Gbely). Overall dissatisfaction with the state property sale initiated the complementary method of the second wave of privatization. However, this method had brought about just chaos, small amount of emissions as well as small trading volume and low trusts on the market. Since 2004 the Slovak market has been facing another blow – the withdrawal of the VSZ stocks.

Determinants mentioned above affected SAX30 share price index (see Fig. 4), which represents Slovak stock market. The biggest share in SAX30 in March 2004 had the share prices of Slovnaft a.s., Všeobecná úvěrová banka a.s. and Nafta a.s.

Figure 5 characterizes the development of daily returns on Slovak stock market. We will again pay attention to basic statistical variables:

The distribution of returns is not normal – (very high kurtosis (**8.18**>3), negative skewness.

We reject the normality of returns distribution accordingly to the high value of Jarque-Bera statistic.

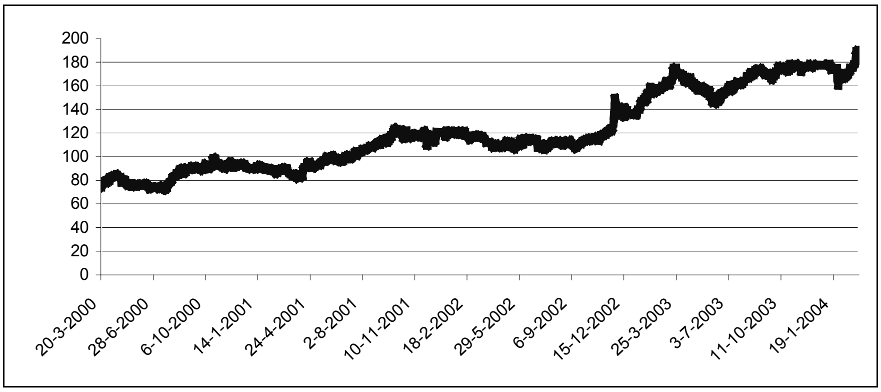

Fig. 4. Index SAX30 development (2000–2004)

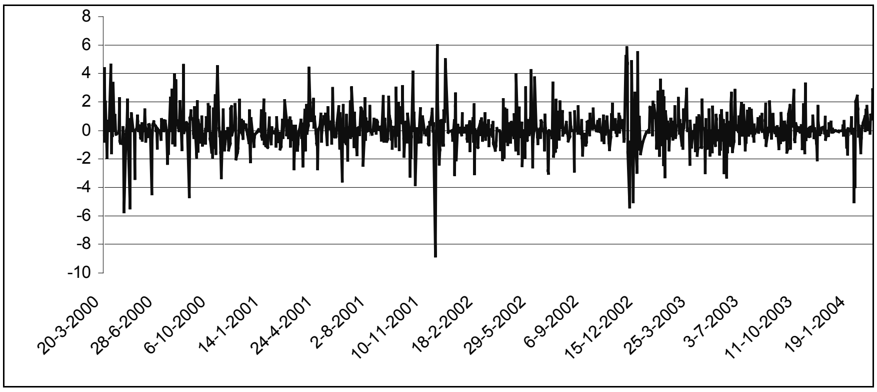

Fig. 5. Daily Returns of SAX30 Development

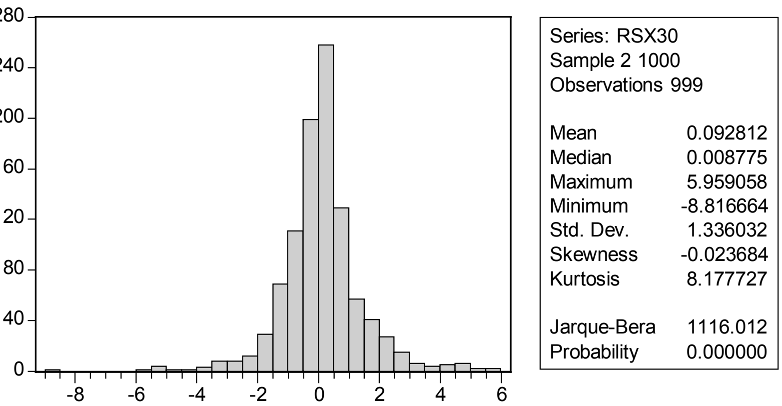

Fig. 6. Testing of SAX30 daily returns normality (2000–2004)

For Slovak stock index returns SAX30 modeling **(2000–2004**) the same technique was applied as for Czech stock market, which has lead to the following conclusions:

– The returns are stationary and there is a high autocorrelation of the degree four.

– After including the returns lagging by 4 days to return equation, the estimated parameters were statistically significant, the autocorrelation of the residuals was eliminated, however, it remained heteroscedastical.

– Applying a family of ARCH models (see Tab. 12) the GARCH (1,1) model was evaluated as the most appropriate one according to the AIC and SIC (see Tab. 13):

– The residuals do not manifest heteroscedasticity, they are not autocorrelated, they tend to the normal distribution.

– Estimated coefficients of regressors are significant.

– Half-life of the variance is 6.34 days.

Table 12

ARCH models for RSAX30 (2000–2004)

	Akaike criterion	Schwarz criterion	Normality of residuals prob. of JB	Autocorrelation (at 5% level of sign.)	Heteroscedasticity (at 5% level of sign.)
ARCH(1)	3.375	3.972	0	No	Yes
GARCH(1,1)	3.326	**3.351**	0	No	No
GARCH(1,2)	**3.324**	3.354	0	No	No
GARCH(2,1)	3.327	3.357	0	No	No
GARCH(2,2)	3.326	3.360	0	No	No
GARCH(1,1)-M(var)	3.329	3.359	0	No	No
TARCH(1,1)	3.328	3.357	0	No	No
EGARCH(1,1)	3.329	3.358	0	No	No

Table 13

Estimation of GARCH(1,1) model for RSAX30 (2000–2004)

	Coefficient	Std. Error	z-Statistic	Prob.
C	0.084903	0.040154	2.114419	0.0345
RSX30(-4)	–0.087191	0.037426	–2.329695	0.0198
	Variance Equation			
C	0.209990	0.029949	7.011658	0.0000
ARCH(1)	0.092360	0.014116	6.542945	0.0000
GARCH(1)	0.785952	0.025804	30.45886	0.0000
R-squared	0.011741	Mean dependent var		0.087760
Adjusted R-squared	0.007748	S.D. dependent var		1.330243
S.E. of regression	1.325080	Akaike info criterion		3.325995
Sum squared resid	1738.278	Schwarz criterion		3.350632
Log likelihood	–1649.683	F-statistic		2.940476
Durbin–Watson stat	2.033541	Prob(F-statistic)		0.019690

• The TARCH (1,1) model has higher reliability in comparison with the models capturing the asymmetrical reaction to information. The existence of the leverage effect has not been confirmed.

• GARCH(1,1)-M model has not confirmed the existence of the risk premium.

Partial conclusion: We reject the weak form EMH in the form of martingale as well as in the form of random walk on Slovak stock market.

Then we succeeded with efficiency test for two divided time periods on Slovak stock market. Output results can be characterized as:

The results for a two-year time period – Slovak stock market (2000–2002) are:

• SAX30 returns are stationary, they are not normally distributed (see Fig. 7).

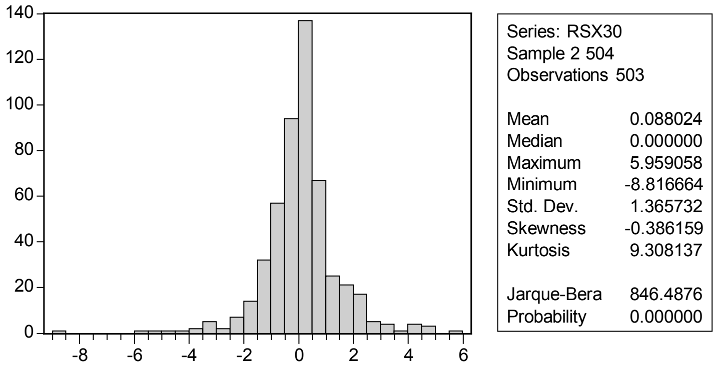

Fig. 7. The testing of SAX30 daily returns normality (2000–2002)

• The residuals of the autoregression model are heteroscedastical.

Due to the distribution of returns, which do not show normal distribution, we reject the weak form of EMH in the form of random walk.

Table 14

Correlogram – the testing of SAX30 daily returns autocorrelation (2000–2004)

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
*|. |	*|. |	1	–0.058	–0.058	1.6984	0.192
.|* |	.|* |	2	0.076	0.073	4.5892	0.101
.|. |	.|. |	3	–0.021	–0.013	4.8120	0.186
*|. |	*|. |	4	–0.147	–0.155	15.594	0.004
.|. |	.|. |	5	0.024	0.010	15.877	0.007
.|. |	.|. |	6	–0.007	0.019	15.905	0.014
.|. |	.|. |	7	0.034	0.027	16.505	0.021
.|. |	.|. |	8	0.048	0.030	17.691	0.024
.|. |	.|. |	9	–0.021	–0.017	17.919	0.036
.|. |	.|. |	10	0.052	0.047	19.269	0.037

• Among the ARCH models the GARCH (2,1) is the most appropriate – the residuals are uncorrelated, they are homoscedastical, not normally distributed.

On the basis of the GARCH(2,1) model we do not reject the weak form of EMH in the form of martingale.

• According to the GARCH(1,1) model the half-life of the variance on the market is about 13 days.

• EGARCH(1,1) model has confirmed the presence of the leverage effect.

Results for a two-year time period – Slovak stock market **(2002–2004)** are:

• SAX30 returns are stationary, they comprise significant autocorrelation of the degree four (see Tab. 14) and their distribution is not normal. We reject the weak form of EMH in the form of random walk. The residuals include heteroscedasticity.

• The GARCH (1,1) model has given the best results from all the models with conditional heteroscedasticity. Residuals are uncorrelated and homoscedastical, but they do not have the normal distribution. The constant as well as the regressor $RSAX30_{t-4}$ are statistically significant, i.e., we reject the weak form of EMH in the form of martingale.

• The half-life of 5 days has been estimated from the GARCH (1,1) model.

• The existence of the leverage effect has failed to be confirmed by the TARCH (1,1) model.

• The GARCH(1,1)-M model has not confirmed the risk aversion either.

Table 15

ARCH models for RSAX30 (2002–2004)

	Akaike criterion	Schwarz criterion	Normality of residuals prob. of JB	Autocorrelation (at 5% level of sign.)	Heteroscedasticity (at 5% level of sign.)
GARCH(1,1)	**3.193**	**3.235**	**0**	**No**	**Yes**
GARCH(1,2)	3.196	3.247	0	No	No
GARCH(2,1)	3.196	3.247	0	No	No
GARCH(2,2)	3.199	3.258	0	No	No
GARCH(1,1)-M(var)	3.200	3.250	0	No	No
TARCH(1,1)	3.194	3.244	0	No	No
TARCH(1,1))-M(var)	3.200	3.260	0	No	No
EGARCH(1,1)	3.196	3.247	0	No	No
EGARCH(1,1))-M(var)	3.204	3.263	0	No	No

7. Conclusions

The Conclusions for Czech stock market are:

- Evaluated as the WEAKLY EFFICIENT MARKET.
- The weak form of efficiency has not been rejected in any of the periods.
- In the time period of 2000–2002 the weak form was not rejected even in the form of the random walk.
- Leverage effect is apparent and good utilizability of the nonlinear models is related to this.
- Risk aversion has failed to be proved.
- Half-life of variance differed for the different periods.

The conclusions for Slovak stock market are:

- Evaluated as more or less INEFFICIENT; only in the time period of 2000–2002 the martingale form of efficiency was not rejected.
- Leverage effect has failed to be proved with the exception of the period 2000–2002.
- Risk aversion has failed to be proved.
- Half-life of variance was fluctuating around the value of 6 days.

General conclusions

- The choice of the testing period length has an impact on the test results.
- The comparison of the Czech and Slovak market from the efficiency perspective is definitely in favour of the Czech market.
- On the weakly-efficient market, the stock prices reflect all the relevant information, and hence it is not possible to find badly-estimated securities by using the methods of technical analysis. The returns cannot be predicted because of being random.

References

[1] ARLT J., ARLTOVÁ M., *Finanční časové řady (Vlastnosti, metody modelování, příklady a aplikace)*, 1. vyd. Praha, Grada Publishing, 2003, 220 s. ISBN 80-247-0330-0.

[2] BOLLERSLEV T., *Generalized Autoregressive Conditional Heteroskedasticity*, Journal of Econometrics, 1986, 31, pp. 307–327.

[3] ENGLE R.F., *Autoregressive Conditional Heteroskedasticity with Estimates of the Variance of U.K. Inflation*, Econometrica, 1982, 50, pp. 987–1008.

[4] FILÁČEK J., KAPIČKA M., VOŠVRDA M., *Testování hypotézy efektivního trhu na BCPP*, Finance a úvěr, 1998, roč. 48, č. 9. str. 554.

[5] GAZDA V., VÝROST T., *Applicant of GARCH Models in Forecasting the Volatility of the Slovak Share Index (SAX)*, BIATEC, 2003, Vol. XI, No. 2, pp. 17–20.

[6] HORSKÁ H., *Český akciový trh – jeho efektivnost a makroekonomické souvislosti*, VŠE, Praha 2003.

Analiza słabych form efektywności na giełdzie Czech i Słowacji

Artykuł dotyczy analizy słabych form efektywności giełdy Czech i Słowacji w latach 2000–2004 na podstawie dziennych zwrotów reprezentujących indeksy PX50 i SAX30 w formie martyngałów oraz w formie błądzenia losowego. W odniesieniu do modelu funkcjonalnego wariancji warunkowej rynku liniowe i nieliniowe modele zmienności zostały estymowane oraz oszacowano połowiczną wariancję na rynkach, obecność efektu dźwigni i unikanie ryzyka. Wyniki oszacowania giełdy czeskiej w omawianym okresie określają ją jako słabo efektywną. Giełda słowacka została oszacowana jako bardziej lub mniej nieefektywna, jedynie w latach 2000–2002 martyngałowa forma efektywności nie została odrzucona.

Słowa kluczowe: *efektywność giełdy, modele GARCH, martyngałowa forma efektywności, losowe błądzenie, czeska i słowacka giełda, testowanie słabej formy efektywności*