WEAK EFFICIENCY AND LINEAR REGRESSION OF CENTRAL AND EASTERN EUROPEAN MARKETS

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Abstract: *The deepening of financial integration in the EU has accelerated in the last decade. The expansion of trade relations, intensification of investment flows and capital market development evidence strengthening of financial integration processes. Particularly, the large number of foreign companies listed on domestic equity market enhances financial integration. In this regard, the enlargement of stock markets of Central and Eastern European (CEE) countries and efficient capital allocation define further integration prospects.*
The stock market efficiency depends mainly on adequate pricing of capital and risk. The rational investment expectations and information efficiency positively impact trading strategies and eliminates the presence of undervalued and overvalued assets. This leads to the high competitiveness of stock market and decreases the likelihood of abnormal profits.
Studies of stock market efficiency of CEE countries and the correlations of CEE capital markets with Western European markets have a significant importance owing to the ongoing financial integration and impact of financial crisis. I run two tests to check the capital market efficiency of CEE countries taking into account the perspectives of CEE countries to enter the euro area.
The aim of this quantitative empirical research is twofold: first, it investigates the weak form of market efficiency for the period from 2nd of September 2005 to 31st of August 2011 by using the Augmented Dickey-Fuller and Kwiatkowski-Phillips-Schmidt-Shin unit root procedures. Second, it checks the existence of linear correlation between CEE countries and Western European markets.
The results assume that the stock markets of some CEE countries follow a unit root. The linear regression model evidences different correlation patterns between CEE and EU old capital markets.
Those findings can be used for deeper investigation of market efficiency by highlighting convergence processes of CEE countries with EU old member states. Also effective capital allocation channels, institutional foundations of markets and strengthening of corporate governance should be highlighted. Finally, the outcomes of my paper will be useful for researchers in the field of finance.

Keywords: *stock markets; unit root; random walk; market efficiency; stock returns*

JEL classification: *G10; G14*

Introduction

The financial integration of CEE markets fosters the strengthening of information efficiency in these markets. This factor improves the risk-sharing and diversification of capital. In other words, market efficiency shows the degree of development of equity market assuming effective asset allocation, pricing and good governance. In market efficiency environment investors have an opportunity to largely diversify their

funds. Market efficiency fosters effective investment decisions in real economy which support an economic development of country. Basse (2010) assumes that under conditions of market inefficiencies, designing (high cost) sophisticated trading rules based on publicly available information will systematically yield significantly positive abnormal returns to investors.
Following section covers empirical methodology. I discussed in detail the Augmented Dickey-Fuller and Kwiatkowski-Phillips-Schmidt-Shin tests. The third section reports the results of study. The last section concludes.
I emphasize the findings of other authors. In particular, Rockinger and Urga (2000) show that both Czech and Hungarian stock returns were mostly correlated with German market movements. Nivet (1997) supposes that the Polish stock market do not follow a random walk. A similar study was carried out by Divis and Teply (2006) for testing the random walk hypothesis for CEE markets. They assume that Hungarian, Polish, Czech and Slovakian stock markets show a random walk. Ratkovicova (1999) approves the strong correlation of Hungarian stock prices with DAX. Besides, the reported results assume the presence of unit root of Hungarian, Polish and Slovakian indices except for the Czech index. Hasanov and Omay (2007) find that stock prices of Bulgarian, Czech, Hungarian, Polish, Romanian and Slovakian markets show a weak form efficiency. Those authors also indicate that nonlinear unit root test results assume the acceptance of unit root test at conventional levels for the Bulgarian, Czech, Slovakian and Hungarian stock prices. The ADF test conducted by Omay and Karadagli (2012) indicate that Bulgarian, Hungarian, Russian, Polish, Slovenian and Romanian stock price series follow unit root.

Empirical Methodology

Any sequance that contains one or more characteristic roots that are equal to one is called a unit root process. The simplest model that may contain a unit root is the AR(1) model.
Ssekuma (2011) thinks over the autoregressive process of order one as:

$$Y_t = \text{ø} Y_{t-1} + \varepsilon_t \qquad (1)$$

where ε_t denotes a serially uncorrelated white noise error term with a mean of zero and a constant variance.
If ø=1, equation (1) becomes a random walk without drift model that is, a nonstationary process. When this happens, we face what is known as the unit root problem. This means that we are faced with a situation of nonstationarity in the series. As Ssekuma (2011) finds that if ø<1, then the series Y_t is stationary. On the other hand, Yule (1989) supposes that the stationarity of the series is imporatnt because correlation could persist in nonstationary time series even if the sample is very large and may result in what is called spurious (or nonsense) regression.
The presence of serial correlation in the residuals of the Dickey-Fuller test biases the results. For that reason the ADF test was developed. The idea is to include enough lagged dependent variables to rid the residuals of serial correlation (Mahadeva and Robinson, 2004). The basic idea behind the augmented Dickey-Fuller (ADF) test for nonstationarity is to simply regress Y_t on its (one period) lagged value Y_{t-1} and find out if the estimated ø is statistically equal to 1 or not. Equation (1) can be manipulated by subtracting Y_{t-1} from both sides to obtain (Ssekuma, 2011):

$$Y_t - Y_{t-1} = (ø-1)\ Y_{t-1} + \varepsilon_t \qquad (2)$$

which can be written as:

$$\Delta Y_t = \delta Y_{t-1} + \varepsilon_t \qquad (3)$$

where $\delta=(ø-1)$, and Δ is the first difference operator.
In practice, instead of estimating equation (1), we shall estimate equation (3) and test for the null hypothesis of $\delta=0$ against the alternative of $\delta\neq0$. If $\delta=0$, then $\delta\neq1$, meaning that we have a unit root problem and the series under consideration is nonstationary (Ssekuma, 2011). Erdogdu (2007) assumes that under the null hypothesis $\delta=0$, the t-value of the estimated coefficient of Y_{t-1} does not follow the t-distribution even in large samples. This means that the t-value does not have an asymptotic normal distribution. The decisioon to reject the null hypothesis of $\delta=0$ is based on the Dickey-Fuller (DF) critical values of the τ (tau) statisitc. The DF test is based on an assumption that the errors of term ε_t are uncorrelated (Ssekuma, 2011).
Syczewska (2010) indicates that the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test has a null of stationarity of a series around either mean or a linear trend; and the alternative assumes that a series is non-stationary due to presence of a unit root. Moreover, in the KPSS model, series of observations is represented as a sum of three components: deterministic trend, a random walk and a stationary error term. The model has the following form (Syczewska, 2010):

$$y_t = \xi t + r_t + \varepsilon_t$$

$$r_t = r_{t-1} + u_t \qquad (4)$$

where y_t, $t=1,2,...,T$ denotes series of observations of variable of interest, t – deterministic trend, r_t – random walk process, ε_t – error term of the first equation, by assumption is stationary, u_t denotes an error term of second equation.
Syczewska (2010) shows that the null hypothesis of stationarity is equivalent to the assumption that the variance σ_u^2 of the random walk process r_t in equation (4), equals zero. In case when $\xi=0$, the null means that y_t is stationary around r_0. If $\xi\neq0$, then the null means that y_t is stationary around a linear trend. If the variance σ_u^2 is greater than zero, then y_t is non-stationary (as sum of a trend and random walk), due to presence of a unit root.
Syczewska (2010) substracts y_t from both sides of the first equation in equation (4) and obtain:

$$\Delta y_t = \xi + u_t + \Delta\varepsilon_t = \xi + w_t$$

where w_t, due to assumption that ε_t, and u_t, are independently distributed random variables, is generated by an autoregressive process AR(1) (Kwiatkowski et al., 1992): $w_t = v_t + \theta v_{t-1}$. Hence Syczewska (2010) mentions that the KPSS model may be expressed in the following form:

$$y_t = \xi + \beta y_{t-1} + w_t,$$

$$w_t = v_t + \theta v_{t-1},\ \beta=1$$

According to Tranmer and Elliot (2008), the multiple linear regression represents p explanatory variables, and the relationship between the dependent variable and the explanatory variables is represented by the following equation:

$$y_i = \beta_0 + \beta_1 x_{1i} + \beta_2 x_{2i} + \ldots + \beta_p x_{pi} + \varepsilon_i$$

where β_0 is the constant term and β_1 to β_p are the coefficients relating the p explanatory variables to the variables of interest.

I emphasize the main characteristics of the linear regression model. The latter includes (Nathans et al., 2012):

- The correlation coefficient reflects both the magnitude and direction of the relationship between two independent variables. If a correlation coefficient is negative, tha value of the variables that are correlated are inversely related; as one variable's scores increase the other variable's scores decrease. If a correlation coefficient is positive, an increase (or decrease) in one variable is related to an increase (or decrease) in the other variable in the coefficient.
- The closer the value of the correlation coefficient is an absolute value of 1.0, the larger the magnitude of the relationship is between the two variables. If the value of the correlation coefficient is zero, there is no relationship between the two variables.
- It is important to note that the strength/magnitude of a correlational relationship is not related to the sign of the correlation coefficient; thus, equivalent predicitve power can be attributed to correlations of equivalent magnitude but different signs.

Empirical Findings

In this study I use stock market data (from 2nd of September 2005 to 31st of August 2011) of CEE countries and EU old member states. Particularly, I examined the ADF and KPSS tests for Bulgarian (SOFIX), Hungarian (BUX), Polish (WIG), Romanian (BET) stock markets.

The results of ADF and KPSS tests for CEE stock market returns are shown in tables 1-8. As can be seen the null hypothesis of random walk is accepted for BET, WIG and BUX stock indices. I reject the null hypothesis for SOFIX.

I find different correlation patterns between the old and new stock markets of the EU (Table 9). In particular, some of CEE markets are negatively correlated with EU old capital markets. This mainly refers to BUX and BET. BET is in negative relationship with CAC40, DAX and IBEX. WIG and SOFIX are not correlated with most of developed markets.

Conclusion

This paper investigates the random walk hypothesis of CEE stock markets by using the Augmented Dickey-Fuller (ADF) and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) tests. Besides, we checked linear regression between CEE and EU old member countries' markets.

From the ADF and KPSS tests I get mixed results. Particularly, BET, WIG and BUX follow a random walk hence these markets are weak efficient. The null hypothesis of random walk is rejected for SOFIX.

I assume that CEE markets have different correlation patterns with Western European markets. The CEE markets are negatively correlated or not correlated with Euroepan developed markets.

The outcomes of my study can be summerized as follows: Romanian, Polish and Hungarian stock returns follow a random walk according to the ADF and KPSS tests and WIG, BET, BUX and SOFIX are not positively correlated with European developed markets.

I find that the deepening of capital markets assumes a high transparency of market information and robust relations between market players. In this regard, the information efficiency depends on several factors. Particularly, the introduction of new trading platforms and systems enhances the efficiency of firm-level and market-level efficiency of firm-level and market-level information. By contrast, restrictions imposed on short sales and price limits hinder information efficiency. Market efficiency is also conditioned by the relationships of managers and investors. Thus, the intention of managers disclose or not firm-specific information impacts credibility of investors.

In general, it appears that the weak efficiency of Polish, Romanian and Hungarian equity markets is conditioned by good supporting institutions and governance and developing investor protection regulation and increasing transparency. On the contrary, the capital market infrastructure of Bulgaria seems to be underdeveloped which undermines the stock market efficiency.

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Table 1 ADF test for BET

Null Hypothesis: CLOSE has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic-based on SIC, maxlag=22)

	t-Statistic	Prob*
Augmented Dickey-Fuller test statistic	-0.952309	0.7716
Test critical values: 1% level	-3.435279	
5% level	-2.863604	
10% level	-2.567919	

*MacKinnon (1996) one-sided p-values

Table 2 KPSS test for BET

Null Hypothesis: CLOSE is stationary
Exogenous: Constant
Bandwidth: 1.27e+003 (Andrews automatic) using Quadratic Spectral kernel

	LM-Stat.
Kwiatkowski-Phillips-Schmidt-Shin test statistic	0.7022
Asymptotic critical values*: 1% level	0.739
5% level	0.463
10% level	0.347
Residual variance (no correction)	415165
HAC corrected variance (Quadratic Spectral kernel)	3.48E+08

*Kwiatkowski-Phillips-Schmidt-Shin (1992, Table1)

Table 3 ADF test for WIG

Null Hypothesis: CLOSE has a unit root
Exogenous: Constant

Lag Length: 0 (Automatic-based on SIC, maxlag=22)

	t-Statistic	Prob*
Augmented Dickey-Fuller test statistic	-1.537833	0.5142
Test critical values: 1% level	-3.435279	
5% level	-2.863604	
10% level	-2.567919	

*MacKinnon (1996) one-sided p-values

Table 4 **KPSS test for WIG**

Null Hypothesis: CLOSE is stationary

Exogenous: Constant

Bandwidth: 653 (Andrews automatic) using Quadratic Spectral kernel

	LM-Stat.
Kwiatkowski-Phillips-Schmidt-Shin test statistic	0.290164
Asymptotic critical values*: 1% level	0.739
5% level	0.463
10% level	0.347
Residual variance (no correction)	322851.9
HAC corrected variance (Quadratic Spectral kernel)	4.21E+07

*Kwiatkowski-Phillips-Schmidt-Shin (1992, Table1)

Table 5 **ADF test for BUX**

Null Hypothesis: CLOSE has a unit root

Exogenous: Constant

Lag Length: 0 (Automatic-based on SIC, maxlag=22)

	t-Statistic	Prob*
Augmented Dickey-Fuller test statistic	-1.649759	0.4567
Test critical values: 1% level	-3.435279	
5% level	-2.863604	
10% level	-2.567919	

*MacKinnon (1996) one-sided p-values

Table 6 **KPSS test for BUX**

Null Hypothesis: CLOSE is stationary

Exogenous: Constant

Bandwidth: 551 (Andrews automatic) using Quadratic Spectral kernel

	LM-Stat.
Kwiatkowski-Phillips-Schmidt-Shin test statistic	0.251372
Asymptotic critical values*: 1% level	0.739
5% level	0.463
10% level	0.347
Residual variance (no correction)	1585617 0
HAC corrected variance (Quadratic Spectral kernel)	1.13E+09

*Kwiatkowski-Phillips-Schmidt-Shin (1992, Table1)

Table 7 **ADF test for SOFIX**

Null Hypothesis: CLOSE has a unit root

Exogenous: Constant

Lag Length: 3 (Automatic-based on SIC, maxlag=22)

	t-Statistic	Prob*
Augmented Dickey-Fuller test statistic	-0.437986	0.9002
Test critical values: 1% level	-3.435291	
5% level	-2.86361	
10% level	-2.567922	

*MacKinnon (1996) one-sided p-values

Table 8 **KPSS test for SOFIX**

Null Hypothesis: CLOSE is stationary

Exogenous: Constant

Bandwidth: 7.77e+003 (Andrews automatic) using Quadratic Spectral kernel

	LM-Stat.
Kwiatkowski-Phillips-Schmidt-Shin test statistic	20.9764
Asymptotic critical values*: 1% level	0.739
5% level	0.463
10% level	0.347
Residual variance (no correction)	204476
HAC corrected variance (Quadratic Spectral kernel)	6.96E+0 5

*Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1)

Table 9 **Linear regression (full simple)**

Dependent variables	Independent variables	CAC 40	DAX	IBEX	FTSE 100	FTSE MIB	WIG	BUX	BET	SOFIX
CAC40	1		NC	NC	NC	NC	P	NC	N	NC
DAX	2	NC		NC	NC	N	P	N	N	NC
IBEX	3	N	NC		N	NC	N	N	N	P
FTSE100	4	NC	NC	N		NC	NC	NC	NC	N
FTSE MIB	5	P	N	NC	NC		P	N	NC	N
WIG	6	NC	NC	N	NC	NC		NC	NC	NC
BUX	7	NC	N	N	NC	N	P		P	N
BET	8	N	N	N	NC	NC	NC	P		P
SOFIX	9	NC	NC	NC	N	N	NC	N	NC	

Notes: P – positive correlation, N – negative correlation, NC – no correlation