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Abstract

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1. Introduction

If prices in any market reflect all available information, that market is said to be an efficient market and stock market is no exception. Fama (1970) identified three different types of market efficiency depending upon types of information available in the market. Since information available in the market is changing over time and it is not possible to incorporate all of them in making a decision, the weak form of market efficiency which uses information from the past and is known as Efficient Market Hypothesis (EMH) has received the most attention.[1]

Considering stock markets, if such markets are to be efficient, any shock to share prices due to news or political events must be transitory, resulting in a random-walk process. Since a random walk process is usually a non-stationary process, establishing non-stationarity of stock prices or unit root amounts to establishing market efficiency. When markets are efficient, investors cannot enjoy excess returns to their investment.

Different studies have applied different unit root tests to test the Efficient Market Hypothesis and have provided mixed results. Examples include Kemp and Reid (1971), Conard and Juttner (1973), McInish and Puglisi (1982), Groenewold and Kang (1993), Macdonald (1994), Ang and Pohlman (1978), D'Ambrosio (1980), Gandi *et al*. (1980), Wong and Kwong (1984), Panas (1990), Dickinson and Murago, 1994), and Fawson et al. (1996).

However, standard unit root tests applied to test EMH usually focus on the average behavior of stock prices without considering the influence of various sizes of shocks on them. In other words, the speed of adjustment in stock prices towards its equilibrium is usually assumed to be constant, no matter how big or what sign the shock is. As a result, conventional unit root tests possibly lead to a widespread failure in the rejection of unit-root null hypothesis in stock prices. We try to resolve this issue by using the newly developed quantile unit root test by Koenker and Xiao (2004) to enhance estimation accuracy. As argued by Hosseinkouchack and Wolters (2013) quantile unit root test has several advantages. First, it allows shocks of different sign and magnitude have a different impact on the variable of our choice, stock prices in our case. Second, it is not restricted to a specific number of regimes. Indeed, it accounts for differences in the transmission of shocks. Third, it reduces estimation uncertainty by avoiding to estimate additional regime parameters. Finally, the test has higher power than conventional unit root tests as shown by Koenker and Xiao

[1] In this study, we attempt to test the weak-form efficient market hypothesis for transition countries. A random walk process is a necessary condition for the weak-form efficient market to hold true.

(2004).[2]

The main purpose of this study is to test the efficient market hypothesis in the stock markets of transition countries (i.e., Bulgaria, Croatia, Czech Republic, Hungary, Lithuania, Poland, Romania, and Russia) by using quantile unit root test and weekly data over the 2000/10/26 to 2015/4/23 periods. The major policy implications of our empirical findings are that non-stationarity of share prices in the 5 out of 8 transition countries support the weak-form efficient market hypothesis and imply that fund managers and investors can not enjoy excess returns from their investment in these five markets (i.e., Croatia, Czech Republic, Hungary, Lithuania, and Poland).

The transition countries have recently moved from centrally planned economies toward market driven economies that motivate us to investigate the behavior of share prices in these countries. To that end, we review data sources and definition of variables in Section 2. Section 3 first briefly describes the quantile unit root test and then presents the empirical results. Section 4 concludes the paper and presents its policy implications.

2. Data

Our sample includes eight transition countries: Bulgaria, Croatia, the Czech Republic, Hungary, Lithuania, Poland, Romanian, and Russia. We employ weekly data in our empirical study and the time span is from 2000/10/26~ 2015/4/23. A total of 757 weekly data points for each country. All stock price indices, i.e., BULGARIA SE SOFIX (Bulgaria), PRAGUE SE PX (the Czech Republic), BUDAPEST - BUX (Hungarian), OMX VILNIUS - OMXV (Lithuanian), WARSAW GENERAL INDEX (Poland), ROMANIA BET (L) (Romanian), and RUSSIA RTS INDEX (Russian), respectively, are taken from the Datastream. Each of the stock price series was transformed into natural logarithms before performing the econometric analysis.

3. Methodology and Empirical Results

3.1 Quantile Autoregressive Unit Root Test[3]

Let stp_t denote the log of weekly stock price and ε_t , a serially uncorrelated error term. An autoregressive process of order q for our variable with drift term a and

[2] Quantile unit root is also said to be superior to standard unit root tests in case of departure from Gaussian residuals.

[3] This section closely follows Bahmani-Oskooee and Ranjbar (2016).

deterministic trend t is given by:

$$stp_t = a + \beta t + \sum_{i=1}^{q} \gamma_i stp_{t-1} + \varepsilon_t, \quad t = q+1, q+2, ..., n. \tag{1}$$

The sum of the autoregressive coefficients is $\alpha = \sum_{i=1}^{q} \gamma_i$ which is known as measure of persistence that we will focus on in our study. We can rewrite Equation (1) as follows:

$$\Delta stp_t = \alpha stp_{t-1} + \beta t + a + \sum_{i=1}^{q-1} \phi_i \Delta stp_{t-i} + \varepsilon_t \tag{2}$$

which is similar to the ADF test. Once (2) is estimated, if estimate of $\alpha = 1$, then the stock price has a unit root and, therefore, shocks have permanent effects on stock price. ε_t is a serially uncorrelated error term. If estimate of $\alpha < 1$, then stock price is stationary. In this case shocks have only temporary effects on stock market.

To gain more detailed estimates to analyze persistence we estimate (2) using quantile autoregression methods. The $\tau - th$ conditional quantile is defined as the value $Q_\tau(stp_t \mid stp_{t-1}, ..., stp_{t-q})$ such that the probability that output conditional on its recent and past history will be less than $Q_\tau(stp_t \mid stp_{t-1}, ..., stp_{t-q})$ is τ. For example, if stock price is very high (low) relative to recent stock price level this means that a large positive (negative) shock has occurred and that stp_t is located above (below) the mean conditional on past observations $stp_{t-1}, ..., stp_{t-q}$ somewhere in the upper (lower) conditional quantiles.

The AR(q) process of *stp* at quantile τ can be written as:

$$Q_\tau(stp_t \mid stp_{t-1}, ..., stp_{t-q}) = \alpha(\tau) stp_{t-1} + a(\tau) + b(\tau)t + \sum_{i=1}^{q-1} \phi_i(\tau) \Delta stp_{t-i} . + \varepsilon_t \tag{3}$$

By estimating Equation (3) at different quantiles $\tau \in (0,1)$ we can get a set of estimates of the persistence measure as $\alpha(\tau)$. ε_t is a serially uncorrelated error term. We can test $\alpha(\tau) = 1$ at different values of τ to analyze the persistence of the stock price impact of positive and negative shocks and shocks of different magnitude using the quantile autoregression based unit root test proposed by Koenker and Xiao (2004).

Let $\alpha(\tau)$ be the quantile regression estimator. To test $H_0 : \alpha(\tau) = 1$ we use the t-stat for $\alpha(\tau)$ as proposed by Koenker and Xiao (2004) which can be written as

$$t_n(\tau) = \frac{f(F^{-1}(\tau))}{\sqrt{\tau(1-\tau)}} (stp_{-1}^{'} M_Z stp_{-1})^{1/2} (\alpha(\tau) - 1), \tag{4}$$

where $f(u)$ and $F(u)$ are the probability and cumulative density functions of ε_t , stp_{-1} is the vector of lagged log stock price and M_z is the projection matrix onto the space orthogonal to $Z = (1, t, \Delta stp_{t-1}, \Delta stp_{t-2}, ..., \Delta stp_{t-q+1})$. We use the results derived by Koenker and Xiao (2004) to find the critical values of $t_n(\tau)$ for different quantile levels. We can estimate $f\left(F^{-1}(\tau)\right)$ following the rule given in Koenker and Xiao (2004).

Furthermore, we try to get a more complete inference of the unit root process by exploring the unit root property across a range of quantiles. Koenker and Xiao (2004) suggest using the Quantile Kolmogorov–Smirnov (*QKS*) test outlined by equation (5):

$$QKS = \sup_{\tau \in \Gamma} |t_n(\tau)| \qquad (5)$$

where $t_n(\tau)$ is given by Equation (4) and $\Gamma = (0.1, 0.2, ...0.9)'$ in our later applications. In other words, we first calculate $t_n(\tau)$ for all τ_s in Γ, and then construct the *QKS* test statistic by selecting the maximum value across Γ. While the limiting distributions of both $t_n(\tau)$ and *QKS* tests are nonstandard, Koenker and Xiao (2004) suggest the use of a resampling (Number of bootstrap =10,000 in our case) procedure to approximate their small-sample distributions.

3.2 **Empirical results**

For comparison purpose, we first apply three conventional unit root tests – ADF, PP and KPSS tests. The results in Table 1 clearly indicate that both the ADF and the PP tests fail to reject the null of non-stationarity in stock prices in all eight transition countries and KPSS test also get similar results, indicating that stock price are non-stationary in these countries.

Next, we shift to quantile unit root test results. To test the null of $\alpha(\tau) = 1$ for $\tau = 0.1, 0.2, 0.3, 04, ..., 0.9$ more formally, we use the t-statistic ($t_n(\tau)$) based on Eq. (4). Tables 2-9 show the point estimates, the t-statistics, the critical values, Half-Life of a shock, and *QKS* for each transition markets. We find that $H_0 : \alpha(\tau) = 1$ can be rejected at the 10% significance level over the whole conditional stock price distribution using *QKS* test in 3 out of 8 countries (i.e., Bulgaria, Romania, and Russia). The test result confirms that all types of shocks to stock price lead to temporary effects in these three transition markets.

Tables 2-9 also show the persistent estimates of $\alpha(\tau)$ for $\tau = 0.1, 0.2, 0.3, ..., 0.9$ in each transition markets. The persistence parameter estimates are close to one for all the quantiles considered in Bulgaria, Czech Republic, Hungary, Lithuania, Poland, and Croatia. The persistent point estimate is slightly above one at the upper tail quantile for Hungary and Croatia, and lower tail quantile for Bulgaria, Czech Republic, Poland, and Russia. Overall the parameter estimates are relatively homogeneous over the conditional stock price distribution. Because we find stock price in 3 out of 8 transition markets (i.e., Bulgaria, Romania, and Russia) to be stationary, in Tables 2, 7, and 8 we also calculate Half-Life of a shock for those 3 markets. We find that the estimated half-life based on quantile autoregressive model is about 52-120 weeks (about 1-2 year). Empirical results from our study are of great importance to global fund investors who may be planning to invest in these markets.

4. Conclusions

A market is said to be efficient if prices in that market reflect all available information, hence any shock to prices must be permanently and eventually follow a random walk process and be non-stationary. Stock markets are no exception on this regard. Thus, it is a common practice to apply unit root test to share prices in order to test the efficient market hypothesis.

Unlike previous research that relied upon standard unit root tests, in this paper we test the weak form efficient-market hypothesis (EMH) using quantile unit root test and weekly data form stock markets of transition countries over the period 2000–2015. Our empirical results indicate the stock markets of only Bulgaria, Romania, and Russia are stationary. Non-stationarity of share prices in the remaining five countries support the weak-from of efficient market hypothesis and imply that fund managers and investors can not enjoy excess returns from their investment in the five markets (i.e., Croatia, Czech Republic, Hungary, Lithuania, and Poland).

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Table 1. Univariate unit root tests (2000/10/26 - 2015/4/23) Weekly Data

	Level			1st difference		
	ADF	**PP**	**KPSS**	**ADF**	**PP**	**KPSS**
Bulgarian	-1.839(3)	-1.828(15)	0.847(22)***	-12.158(2)***	-25.590(15)***	0.361(15)*
Czech	-1.440(0)	-1.514(12)	1.338(22)***	-25.387(0)***	-25.546(12)***	0.223(12)
Hungarian	-1.446(0)	-1.496(9)	1.831(22)***	-26.329(0)***	-26.352(8)***	0.122(9)
Lithuanian	-2.028(4)	-2.136(18)	1.057(22)***	-14.758(3)***	-28.156(18)***	0.240(19)
Poland	-1.096(0)	-1.155(6)	2.368(22)***	-25.451(0)***	-25.502(5)***	0.108(6)
Romanian	-2.633(3)	-2.562(12)	1.808(22)***	-12.279(2)***	-25.612(12)***	0.452(12)*
Russian	-2.237(0)	-2.213(14)	2.092(22)***	-25.792(0)***	-26.256(14)***	0.285(14)
Croatia	-1.745(3)	-1.866(11)	1.049(22)***	-12.299(2)***	-24.890(10)***	0.292(11)

Note: ***, ** and * indicate significance at the 0.01, 0.05 and 0.1 level, respectively. The number in parenthesis indicates the lag order selected based on the recursive t-statistic, as suggested by Perron (1989). The number in the brackets indicates the truncation for the Bartlett Kernel, as suggested by the Newey-West test (1987). N =757.

Table 2. Quantile Unit Root Test Results –BULGARIA SE SOFIX - Bulgaria

Quantile	α(τ)	t-statistics	Critical Value	H-L	QKS test
0.10	1.0054	1.0994	-2.5506		
0.20	0.9996	-0.1297	-2.5673		
0.30	0.9990	-0.6137	-2.6130		
0.40	1.0000	-0.0172	-2.5886		
0.50	0.9985	-1.0616	-2.5049		
0.60	0.9967	-2.3127	-2.4486		
0.70	**0.9952**	**-2.7038**	**-2.5006**	**144.059**	**2.8378**
0.80	0.9934	-2.3787	-2.4011		
0.90	**0.9870**	**-2.8378**	**-2.3356**	**52.972**	**2.8378**

Notes: The table shows point estimates, t-statistics and critical values for the 5% significance level. If the t-statistic is numerically smaller than the critical value then we reject the null hypothesis of α(τ) = 1 at the 5% level. QKS is the quantile Kolmogorov–Smirnov test. 2.7769 is 5 % critical value for QKS based on 10000 bootstrapping simulations. Here, HL=ln(0.5)/ln(α(τ)).

Table 3. Quantile Unit Root Test Results –PRAGUE SE PX - Czech Republic

Quantile	α(τ)	t-statistics	Critical Value	H-L	QKS test
0.10	0.9995	-0.0715	-2.5046		2.3314
0.20	1.0015	0.3690	-2.6205		
0.30	0.9976	-0.7774	-2.6171		
0.40	0.9976	-0.8755	-2.5636		
0.50	0.9966	-1.3944	-2.6122		
0.60	0.9959	-1.6430	-2.5622		
0.70	0.9950	-2.0733	-2.5490		
0.80	0.9942	-2.3314	-2.4338		
0.90	0.9953	-1.3321	-2.3009		

Notes: The table shows point estimates, t-statistics and critical values for the 5% significance level. If the t-statistic is numerically smaller than the critical value then we reject the null hypothesis of α(τ) = 1 at the 5% level. QKS is the quantile Kolmogorov–Smirnov test. 2.7905 is 5 % critical value for QKS based on 10000 bootstrapping simulations.

Table 4. Quantile Unit Root Test Results –BUDAPEST (BUX)- Hungary

Quantile	α(τ)	t-statistics	Critical Value	H-L	QKS test
0.10	0.9910	-1.4016	-2.3396		1.6530
0.20	0.9953	-1.0196	-2.4237		
0.30	0.9952	-1.2985	-2.5396		
0.40	0.9957	-1.3545	-2.5749		
0.50	0.9979	-0.6947	-2.6019		
0.60	0.9950	-1.6530	-2.6021		
0.70	0.9946	-1.6469	-2.5626		
0.80	0.9954	-1.1645	-2.5455		
0.90	1.0002	0.0317	-2.4917		

Notes: The table shows point estimates, t-statistics and critical values for the 5% significance level. If the t-statistic is numerically smaller than the critical value then we reject the null hypothesis of α(τ) = 1 at the 5% level. QKS is the quantile Kolmogorov–Smirnov test. 2.7791 is 5 % critical value for QKS based on 10000 bootstrapping simulations.

Table 5. Quantile Unit Root Test Results –OMX VILNIUS (OMXV) - Lithuania

Quantile	α(τ)	t-statistics	Critical Value	H-L	QKS test
0.10	0.9986	-0.1790	-2.7223		
0.20	0.9959	-1.3171	-2.5971		
0.30	0.9967	-1.3185	-2.5811		
0.40	0.9986	-0.7084	-2.5559		
0.50	0.9983	-0.8372	-2.5432		
0.60	0.9968	-1.4901	-2.4579		
0.70	**0.9942**	**-2.4792**	**-2.4537**	**119.161**	2.4972
0.80	0.9940	-2.2581	-2.3080		
0.90	0.9917	-1.6290	-2.2347		

Notes: The table shows point estimates, t-statistics and critical values for the 5% significance level. If the t-statistic is numerically smaller than the critical value then we reject the null hypothesis of α(τ) = 1 at the 5% level. QKS is the quantile Kolmogorov–Smirnov test. 2.7889 is 5 % critical value for QKS based on 10000 bootstrapping simulations. Here, HL=ln(0.5)/ln(α(τ)).

Table 6. Quantile Unit Root Test Results –WARSAW GENERAL INDEX - Poland

Quantile	α(τ)	t-statistics	Critical Value	H-L	QKS test
0.10	0.9980	-0.3307	-2.5284		2.3748
0.20	0.9995	-0.1196	-2.5993		
0.30	1.0011	0.3413	-2.5726		
0.40	0.9998	-0.0905	-2.5690		
0.50	0.9976	-1.0857	-2.5929		
0.60	0.9969	-1.4513	-2.5402		
0.70	0.9943	-2.3748	-2.5167		
0.80	0.9945	-1.9208	-2.4629		
0.90	0.9946	-1.1645	-2.3166		

Notes: The table shows point estimates, t-statistics and critical values for the 5% significance level. If the t-statistic is numerically smaller than the critical value then we reject the null hypothesis of α(τ) = 1 at the 5% level. QKS is the quantile Kolmogorov–Smirnov test. 2.7562 is 5 % critical value for QKS based on 10000 bootstrapping simulations.

Table 7. Quantile Unit Root Test Results –ROMANIA BET (L) - Romania

Quantile	α(τ)	t-statistics	Critical Value	H-L	QKS test
0.10	0.9998	-0.0397	-2.5653		
0.20	0.9984	-0.5764	-2.5305		
0.30	0.9969	-1.6987	-2.5801		
0.40	0.9974	-1.7394	-2.5670		
0.50	0.9975	-1.6548	-2.5366		
0.60	**0.9960**	**-2.5294**	**-2.5091**	**172.940**	**3.4915**
0.70	**0.9941**	**-2.8901**	**-2.5302**	**117.136**	**3.4915**
0.80	**0.9910**	**-3.4915**	**-2.4936**	**76.670**	**3.4915**
0.90	**0.9892**	**-2.8308**	**-2.2356**	**63.833**	**3.4915**

Notes: The table shows point estimates, t-statistics and critical values for the 5% significance level. If the t-statistic is numerically smaller than the critical value then we reject the null hypothesis of α(τ) = 1 at the 5% level. QKS is the quantile Kolmogorov–Smirnov test. 2.7995 is 5 % critical value for QKS based on 10000 bootstrapping simulations. Here, HL=ln(0.5)/ln(α(τ)).

Table 8. Quantile Unit Root Test Results –RUSSIA RTS INDEX - Russia

Quantile	α(τ)	t-statistics	Critical Value	H-L	QKS test
0.10	1.0025	0.3884	-2.5407		
0.20	1.0003	0.0637	-2.5476		
0.30	0.9983	-0.5011	-2.6659		
0.40	0.9959	-1.4799	-2.6609		
0.50	0.9966	-1.3059	-2.6215		
0.60	0.9944	-2.2221	-2.5791		
0.70	**0.9898**	**-3.7511**	**-2.5390**	**67.608**	**4.1505**
0.80	**0.9865**	**-4.1505**	**-2.3750**	**50.100**	**4.1505**
0.90	**0.9849**	**-3.9332**	**-2.2275**	**45.556**	**4.1505**

Notes: The table shows point estimates, t-statistics and critical values for the 5% significance level. If the t-statistic is numerically smaller than the critical value then we reject the null hypothesis of α(τ) = 1 at the 5% level. QKS is the quantile Kolmogorov–Smirnov test. 2.8047 is 5 % critical value for QKS based on 10000 bootstrapping simulations. Here, HL=ln(0.5)/ln(α(τ)).

Table 9. Quantile Unit Root Test Results –CROATIA CROBEX - Croatia

Quantile	α(τ)	t-statistics	Critical Value	H-L	QKS test
0.10	0.9899	-1.7112	-2.5022		2.2411
0.20	0.9953	-1.4452	-2.5257		
0.30	0.9946	-2.2411	-2.5521		
0.40	0.9969	-1.5293	-2.5180		
0.50	0.9959	-1.9992	-2.5576		
0.60	0.9965	-1.6222	-2.5396		
0.70	0.9985	-0.6300	-2.5270		
0.80	0.9975	-0.7557	-2.5233		
0.90	1.0040	0.6637	-2.3147		

Notes: The table shows point estimates, t-statistics and critical values for the 5% significance level. If the t-statistic is numerically smaller than the critical value then we reject the null hypothesis of α(τ) = 1 at the 5% level. QKS is the quantile Kolmogorov–Smirnov test. 2.7817 is 5 % critical value for QKS based on 10000 bootstrapping simulations.