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Abstract

This study examines the existence of rational speculative bubbles in selected Central European stock markets. We employed the duration dependence test for bubble detection, which we believe provides reliable results for the specific properties of the markets studied. In addition to the stock market indices the prices of individual stocks with the highest capitalization were investigated in order to identify the source of bubble. In contrast to the findings of previous studies on bubbles in emerging markets, no significant bubbles in asset prices were reveiled, except for the Polish stocks of chemical companies from 2004-2007 and Czech and Hungarian stocks of new and prospective sectors.

Keywords: rational speculative bubble, Central European stock markets, duration dependence test
JEL classification: C52, G12

Introduction

Asset bubbles are one of the basic concepts of the financial theory that has developed over the past half-century. Currently, there is no deliberate and conventional empirical solution for detection and prediction of these bubbles. Since the 1980s, bubbles have been investigated with the application of time series econometric analysis. However, the use of this mathematical approach raises the question of whether an econometric test can truly detect a bubble or just discover an error in the market evaluation of assets. Hence, the choice of test used should be based on growth patterns of stock returns (associated with dramatic price increases), rather than simply time dependencies. For this reason, we analyzed bubble test theory to choose a procedure with fewer limitations,

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which would empirically correspond to the common rational speculative bubble model.

Emerging markets are of greater interest to global investors, since they usually outperform developed markets. Large financial inflows into fast growing markets create a situation in which the emergence of speculative bubbles becomes more feasible and likely to occur. Even if it is initially seen as an indication of investor's expectations of high future dividends, investors begin to hold such assets. Investors simply believe that they can sell the asset at a higher price and gain a greater than usual return, while knowing that the actual spot price exceeds the assets fundamental value. In fact, several empirical studies report evidence of asset bubbles in emerging markets, such as China (Lehkonen, 2010), countries of the MENA region (Yu and Hassan, 2010) and Thailand (Watanapalachaikul and Islam, 2007). European emerging markets have also undergone a period of rapid growth in recent years, however the research on investor's speculative behavior in these markets is limited.

The aim of this study is to test the existence of rational speculative bubbles in stock markets of three Central European countries, the Czech Republic, Poland and Hungary, which provide the strength behind the progress of European emerging markets. Over the last twenty years these Central European countries went through an economic transformation that resulted in remarkable economic growth and financial maturity. Fast financial development was supported by the accession of these countries to the European Union in 2004, after which stock prices had a massive upswing, but later declined due to the global financial crisis which started in the summer of 2007. It is important to examine whether this strong growth was a result of an increase in a company's' fundamental value or the speculative behavior of investors. With this uncertainty in mind, it is not clear if the steep decline in asset prices during the financial crisis was due to a slow burst of the bubble or a significant shrinkage. Additionally, the assumption of bubble existence is also supported by frequently reported inefficiencies of Central European stock markets (e.g., Todea and Zoicas-Ienciu, 2008), since asset bubbles involve rapid price fluctuations.

Our survey fills a gap in the empirical literature on asset bubbles in European emerging markets. This study expands the possibility of employing bubble testing on individual stocks, thus raising an awareness of investor overconfidence in stocks of companies with novel technologies.

Rational speculative bubble model

The most common theoretical model of rational speculative bubbles in stock markets is built on the axiom that stock prices constantly deviate from their fundamental values without assuming irrationality in investor's behavior[1]. It is

[1] For the general discussion on bubble models see Brunnermeier (2008) and Kubicová and Komárek (2011)

based on a simple efficient market condition, which implies that the expected return of an asset is equal to the required return:

$$E(R_{t+1}) = r_{t+1}, \tag{1}$$

where $E_t(.)$ denotes mathematical expectation given the information set at time t. R_{t+1} is the return of an asset at time t+1 and r_{t+1} is the time-varying required rate of return. A stock return is defined by the following equation (here d_{t+1} is the sum of dividends paid at time $t+1$):

$$R_{t+1} = \frac{p_{t+1} - p_t + d_{t+1}}{p_t}, \tag{2}$$

which after the rearrangement according to the previous condition implies that the current price of the stock p_t equals the sum of the expected future price p_{t+1} and the dividends discounted at the return required by investors:

$$p_t = \frac{E_t(p_{t+1} + d_{t+1})}{1 + r_{t+1}}. \tag{3}$$

But current stock price established by the fundamental value of an asset should correspond to its profitability in the indefinite future, hence, allowing for multi-period horizons:

$$p_t = \sum_{i=1}^{\infty} \frac{E_t(p_{t+i} + d_{t+i})}{\prod_{j=1}^{i}(1+r_{t+j})}. \tag{4}$$

To achieve an equilibrium condition, we assume that the expected discount value of a stock in the indefinite future converges to zero:

$$\lim \frac{E_t(p_{t+i})}{\prod_{j=1}^{i}(1 + r_{t+j})} = 0. \tag{5}$$

With this assumption, there is one solution to the equilibrium condition to find a fundamental value of a stock determined by the future payments of dividends (discounted value of the future cash flows):

$$p_t = \sum_{i=1}^{\infty} \frac{E_t(d_{t+i})}{\prod_{j=1}^{i}(1+r_{t+j})}. \tag{6}$$

However, rejecting the assumption of zero convergence leads to an infinite number of solutions. Blanchard and Watson (1982) noted that any price of the form

$$p_t = p_t^* + b_t, \text{ where } E_t(b_{t+1}) = (1 + r_t)b_t, \tag{7}$$

is a solution to the equilibrium condition as well. It represents the notion that the market price of the stock can deviate from its fundamental value by a rational speculative bubble factor b_t, if on average, the factor grows at the required rate of return. It also eliminates the possibility of indefinite negative growth or negative bubble, since total stock price could not be negative. The theoretical potential for positive, but not negative, bubbles suggests that bubble tests should allow for non-linearity (McQueen and Thorley, 1994).

The rational speculative bubble model allows for price changes $\varepsilon_{t+1} = R_{t+1} - r_{t+1}$ that emerge from two unobservable sources:

- changes in fundamental value ($\mu_{t+1} = p^*_{t+1} + d_{t+1} - (1 + r_{t+1})p^*_t$) and
- changes in the size of bubble ($\eta_{t+1} = b_{t+1} - (1 + r_{t+1})b_t$).

Given the certain probability π, the observable price change $\varepsilon_{t+1} = \mu_{t+1} + \eta_{t+1}$ equals the sum of the change in fundamental value and change of the bubble size:

$$\begin{aligned} \varepsilon_{t+1} &= \mu_{t+1} + \tfrac{\pi}{1-\pi}((1 + r_{t+1})b_t - a_o) \quad \text{with probability } \pi \\ &= \mu_{t+1} + (1 + r_{t+1})b_t + a_o \quad \text{with probability } 1 - \pi, \end{aligned} \tag{8}$$

where $a_0 \geq 0$ is an initial bubble value, which allows for continuously repeating periods of bubble shrinkage and expansion. Such formulation of price changes with possible bubble innovations is consistent with basic attributes of a speculative bubble: positive excess returns (persistent explosive price change) causing positive autocorrelation, negative skewness and leptokurtosis in time series. As bubble components grow, it begins to dominate the fundamental component. Negative abnormal returns become less likely and occur only when the bubble bursts, even if incomplete.

Empirical tests of stock bubbles

In the context of a financial time series analysis there are several test procedures usually utilized for bubble detection in asset markets. However, it is still not obvious if any of those tests achieve a satisfactory degree of certainty in the results. We carefully studied the most common test techniques consistent with the model of rational speculative bubbles in stock markets with symmetric information, while trying to evaluate the limitations and possibilities for application on the chosen markets. Table 1 reports our findings. The majority of tests directly compare actual prices with fundamentals. Effectivity of these tests largely depends on the specification of fundamentals. Gurkaynak (2005) argued that for almost every study that finds a bubble, there is another that relaxes some assumption on the fundamentals and fits the data equally well without resorting to a bubble. Thus, the most appropriate tests are those independent of assumptions on specific fundamentals or, in other words, those not determined to capture fundamental values accurately.

In our opinion, the non-parametric duration dependence test originally developed by McQueen and Thorley (1994) is the most reliable bubble detection

Table 1: Empirical tests of stock market bubbles

Test type	Test description	Reference	Limitations
Probability distribution	Stock returns exhibit fat tails, negative skewness, leptokurtosis	Blanchard and Watson (1982) Lux and Sornette (2002)	Attributes of time series are not unique to bubbles (may also explain the changes in the fundamental value of an asset)
Variance bound test	Rational price does not fluctuate as the observed price due to forecast errors of expected dividends	Shiller (1981) LeRoy and Porter (1981) Kleidon (1986) Cochrane (1992)	Linearity in changes of prices and dividends Requires stationarity of dividends and stock prices Assumes expected return to be constant over time
Two-step test	Two estimations of model parameters are compared: (1) regression of p_t on $p_{t+1} + d_{t+1}$ with d_t as an instrument (estimation without the bubble) and (2) dividends follow a stationary AR(n) process (estimation with the bubble)	West (1987) Dezhbakhsh and Demirguc-Kunt (1990)	Linearity in changes of prices and dividends Long time data of dividends are needed Problems in implementation (see West (1988) or Gurkaynak (2008) for discussion)
Cointegration test	Dividends and prices should be cointegrated stationary processes	Campbell and Shiller (1987) Diba and Grossman (1988) Nasseh and Strauss (2004) Bohl et al. (2003)	Stationarity of dividends is required Long series of observations are required Does not allow for periodically collapsing bubbles Possibly inconclusive results (for more information see Evans (1991), Charemza and Deadman (1991) and Waters (2008))
Regime switching test	Switching regimes depends on the relative size of the bubble and of the measure of abnormal returns or trading volume	Hamilton (1989) van Norden (1996) Hall et al. (1999)	Precision in measurements of fundamental values is required
Duration dependence test	The presence of bubbles implies negative duration dependence in runs of positive abnormal returns	McQueen and Thorley (1994) Harman and Zuehlke (2004)	Sensitive to model specifications used to generate the sequence of abnormal returns
Kalman filter	Bubble is an unobserved state vector in the state-space model estimated by the Kalman filter	Wu (1997)	Produce negative values for bubble variable, which theoretically is impossible
Hurst persistence test	Long-term dependence (memory) in the stock market volatility	Mandelbrot (1972) Rejichi and Aloui (2012)	Estimation of the fundamental value via VAR model can indicate the substantial volatility instead of bubble existence

Note: Tests based on behavioral models are not included.

technique. The duration dependence test can overcome the limitations of traditional bubble tests, since it addresses non-linearity of abnormal returns without requiring their accurate assessment.

The duration dependence test is a classical statistical procedure frequently utilized in the survival analysis. In this case, it requires little revision to follow the logic behind the rational speculative bubble model, while providing the evidence of non-random behavior of returns. If security prices exhibit bubble behavior, then runs of positive abnormal returns will reveal negative duration dependence with a run ending and the length of the run. Mathematically, it means that the probability of a negative price change is conditional on the sequence of i prior positive price changes $h_i = P(\varepsilon_t < 0 \,|\, \varepsilon_{t-1} > 0, \varepsilon_{t-2} > 0, \ldots, \varepsilon_{t-i} > 0, \varepsilon_{t-i-1} < 0)$ decreases with i, i.e., conditional probability of the positive run ending is decreasing with time ($h_{i+1} < h_i$). Since bubble behavior could not be detected in negative returns, a similar inequality does not hold for runs of negative abnormal returns.

To detect duration dependence, the time series of abnormal returns should be transformed into two series of run lengths of positive and negative abnormal returns. In other words, we consider the length of the sequence of abnormal returns of the same sign. Then the number of runs of a particular length i usually denoted as N_i are counted and the number of runs with a length greater than i is denoted as M_i. The sample hazard rate for each run length i could be calculated by $\hat{h}_i = N_i/(N_i + M_i)$.

In the framework of statistical analysis, the set of run lengths of positive (negative) abnormal returns S_T obtained consists of T observations on the random run length I, which is a positive discrete random variable generated by some discrete density function $f_i = P(I < i)$ and a corresponding cumulative density function $F_i = P(I < i)$. Hazard function $h_i = P(I = i \,|\, I \geq i)$ is defined by $h_i = f_i/(1 - F_i)$. Hence, log-likelihood can be expressed as

$$L(\Theta|S_T) = \sum_{i=1}^{\infty} N_i \ln f_i + M_i \ln(1 - F_i) \tag{9}$$

or using the hazard function

$$L(\Theta|S_T) = \sum_{i=1}^{\infty} N_i \ln h_i + M_i \ln(1 - h_i). \tag{10}$$

To perform the duration dependence test, we first chose a specific form of the hazard function. The hazard function might be specified with an exponential, Weibull or extreme-value distribution. Empirically they yield similar results (Harman and Zuehlke, 2004). Since we follow the classic duration dependence test procedure of McQueen and Thorley (1994), we consider the logistic transformation of the log of i:

$$h_i = \frac{1}{1 + e^{-(\alpha + \beta \ln i)}}. \tag{11}$$

The duration dependence test is performed by substituting equation (11) into (10) and maximizing the log-likelihood function with respect to parameters α and β. The parameters are estimated via logit regression, in which the independent variable is the log of the current length of the run and the dependent variable is 1 if the run ends in the next period and 0 if it does not. The null hypothesis of no duration dependence H_0: $\beta = 0$ (constant hazard rate) implies randomness in the occurrence of positive or negative abnormal returns. The alternative bubble hypothesis H_1: $\beta < 0$ (decreasing hazard rate) suggests that a positive run end decreases with run length. The likelihood ratio test of $\beta = 0$ is asymptotically distributed χ^2 with one degree of freedom.

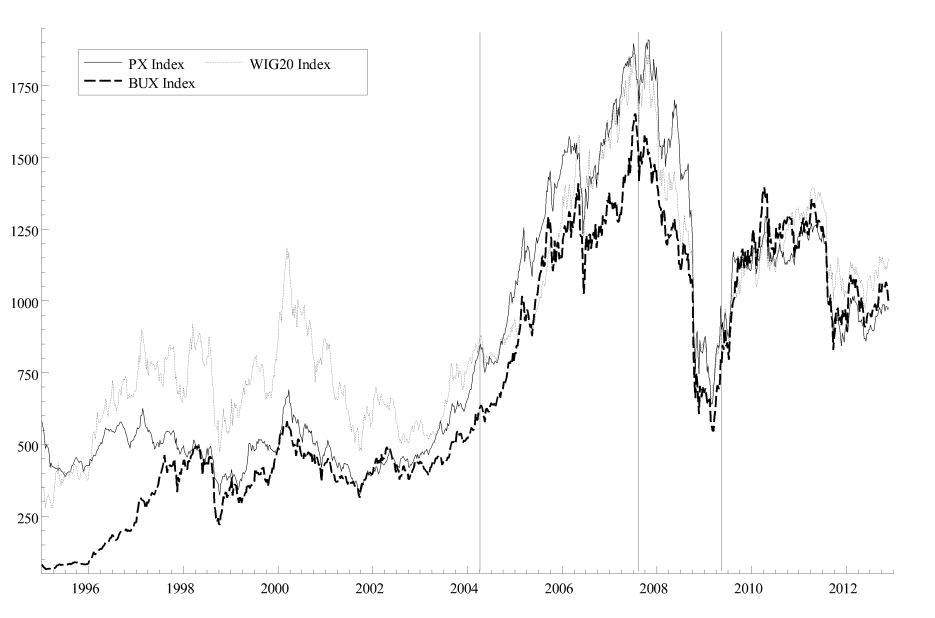
Data and methodology

Results from several empirical studies are contradictory in that they indicate that the duration dependence test is sensitive to the choice of sample period, the method by which abnormal returns are identified, stocks' weights in portfolios or indices chosen to represent the market, and the use of daily, weekly or monthly returns. Moreover, the properties of the selected Central European financial markets pose several additional complications to the choice of methodology: (1) only short span data are available (1995-2012) and (2) companies pay dividends infrequently. Therefore, the dataset was constructed in a way that would overcome test limitations and reflect qualities of the studied markets.

In pioneer papers on bubble testing (Shiller 1981, Blanchard 1982, McQueen and Thorley 1994 and others), data were collected on a monthly basis, which implied significant aggregation of returns within the month. Apparently, substantial changes in the current securities trading environment due to the usage of information technology and faster information sharing require empirical research of financial markets to be based on more frequent data. On the other hand, daily returns exhibit high noise terms, which would make detection of bubbles nearly impossible. Weekly data would bring the exact blend of short-term and long-term tendencies that are needed. However, it is not clear how to construct weekly observations: taking Friday closing prices would not capture within-the-week dynamics, but would affect the empirical results. Therefore, it is more rational to base our analysis on weekly returns calculated as an arithmetic mean of within-the-week daily returns.

The initial dataset consists of prices and dividend yields for country indices (PX in the Czech Republic, WIG20 in Poland and BUX in Hungary) as well as stocks traded on the markets that were studied. All data expressed in local currency for the time interval of January 4, 1995 to November 16, 2012 were obtained from Bloomberg. Prices were then transformed into continuously compounded returns. Consistent with the presence of bubbles, all return series exhibit significant negative skewness, excess kurtosis and first-order autocorrelation (see Table 2 for statistics on stock indices).

Figure 1: PX, WIG20 and BUX index movements (scaled)



Source: Bloomberg

Table 2: Descriptive statistics of weekly returns for stock indices

Statistic	Czech Republic (PX)	Poland (WIG20)	Hungary (BUX)
N	930	933	932
Mean	0.000555	0.001232	0.002733
SD	0.027113	0.334441	0.033831
Minimum	-0.169218	-0.143565	-0.181111
Maximum	0.105085	0.125497	0.131273
Skewness	-0.885842	-0.239749	-0.769759
Kurtosis	4.1214	1.3871	4.1556
Q-statistic(4) (p-value)	87.891 (0.0001)	57.480 (0.0001)	76.767 (0.0001)

To determine abnormal returns we ran an autoregressive model $AR(p)^2$ on normal returns with dividend-price ratio as an additional independent variable to reflect a fundamental value of a stock or portfolio. We computed dividend-price ratio by dividing the sum of the prior twelve month dividends by the current price. Error terms from the autoregressive model represent abnormal returns, the sign of which rather than value is of particular interest in our study. On the basis of the sign of abnormal returns and their particular sequence two run (or duration) series for positive and negative abnormal returns are obtained. Actual run counts do not include partial runs occurring at the beginning or end of the investigated period.

We first ran duration dependence test on the full sample period. And in order to address the sensitivity of the duration dependence test to the time interval studied, we divided the full sample into four sub-periods according to the clearly observed trends in price movements (see Figure 1). The sub-periods are labled as transition period (January 4, 1995 – April 30, 2004), pre-crisis period (May 1, 2004 – July 31, 2007), crisis period (August 1, 2007 – March 31, 2009) and post-crisis period (April 1, 2009 – November 16, 2012). The beginning of the pre-crisis period (or the period of spectacular growth) coincides with an accession of the countries studied to the European Union. We chose not to start the crisis period with the Lehman Brothers bankruptcy and major panic in the markets. Instead we wanted to capture an earlier market, which would be when the 2007 banking crisis changed from high expectations to the fear of a looming sovereign debt crisis.

Empirical results

The results of the duration dependence test for the stock market indices studied are summarized in Table 3. The first panel of the table contains the number of total, positive, and negative weekly returns for fifteen test specifications. The second panel reports run counts in each test horizon. The longest run of positive innovations (10 weeks) is found for the Czech Republic and Hungary in the transition period. Finally, the last two panels of the table cover the results of the maximum likelihood estimates of the log-logistic function parameters α and β separately for positive and negative runs. Duration dependence in runs implies a changing hazard rate or statistically significant estimation of parameter β. In the case of a rational speculative bubble, the probability of a positive run ending should decrease with run length, hence, we should observe decreasing hazard rates, exemplified by negative values of parameter β. The null hypothesis of no bubble implies a constant hazard rate (β=0) and is examined by the likelihood ratio test of Chi-squared asymptotic distribution with one degree of freedom (LRT estimations also include p-value as a marginal significance level).

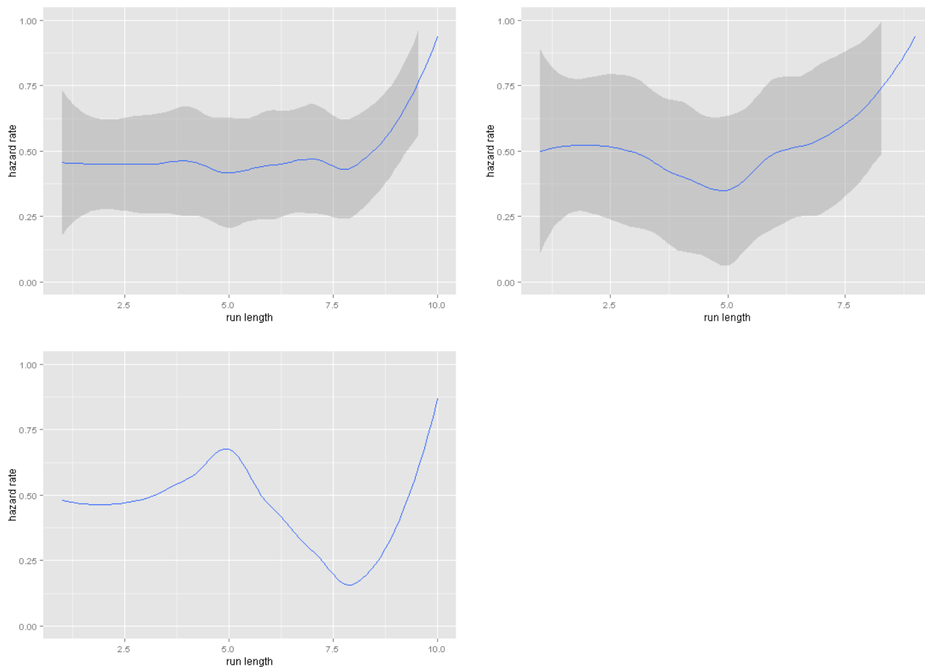
[2]Order of p is defined by autocorrelation function

Table 3: Results of duration dependence test for stock market indices

Dataset	Czech Republic					Poland					Hungary				
	Full period	Transition	Pre-crisis	Crisis	Post-crisis	Full period	Tran-sition	Pre-crisis	Crisis	Post-crisis	Full period	Tran-sition	Pre-crisis	Crisis	Post-crisis
Number of returns															
Positive	227	111	40	20	50	241	120	44	24	47	228	110	48	21	53
Negative	228	112	41	20	50	240	120	45	25	46	229	111	48	21	53
Total	455	223	81	40	100	481	240	89	49	93	457	221	96	42	106
Actual run counts for each run length (positive/negative)															
1	108/116	52/53	15/22	9/9	28/27	122/123	57/55	26/27	13/14	26/20	112/111	43/49	30/31	11/11	29/29
2	50/61	23/28	13/12	5/6	12/10	59/63	33/37	8/9	6/6	12/13	51/60	33/28	6/11	4/4	11/12
3	28/24	18/10	4/2	0/2	5/8	33/32	15/14	4/6	3/3	3/8	32/28	18/18	4/3	2/3	9/9
4	22/18	9/14	2/1	2/3	2/2	10/14	6/8	1/2	0/2	2/3	17/14	7/7	4/0	2/2	4/1
5	7/7	3/3	4/4	3/0	0/1	6/3	2/3	2/0	2/0	1/1	11/9	5/5	2/2	1/1	0/1
6	5/1	2/2	1/0	1/0	3/2	5/4	4/2	1/0	-	1/0	3/4	1/2	2/1	0/0	0/1
7	4/1	2/1	1/0	-	-	4/0	2/0	0/1	-	2/0	0/2	1/1	-	0/0	-
8	1/0	1/1	-	-	-	1/0	1/0	1/0	-	0/0	1/0	1/1	-	1/0	-
9	1/0	0/0	-	-	-	1/1	0/1	1/0	-	0/1	0/1	0/0	-	-	-
10	1/0	1/0	-	-	-	-	-	-	-	-	1/0	1/0	-	-	-
Positive run test															
α	-0.149	-0.172	-0.464	-0.342	0.238	0.032	-0.064	**0.299**	0.146	0.233	-0.089	-0.358	0.316	0.006	0.067
β	-0.061	-0.052	0.268	0.009	-0.186	-0.078	-0.001	**-0.610**	0.084	-0.359	0.065	0.239	-0.449	-0.299	0.498
LRT(β=0)	0.175	0.063	0.587	0.004	0.252	0.255	0	**3.720**	0.021	1.104	0.165	1.248	1.564	0.419	1.236
(p-value)	0.675	0.802	0.443	0.985	0.616	0.614	0.997	**0.053**	0.885	0.293	0.685	0.264	0.211	0.519	0.266
Negative run test															
α	0.009	-0.152	0.169	-0.263	0.086	0.052	-0.105	0.375	0.168	-0.155	-0.063	-0.257	0.621	-0.046	0.147
β	0.254	0.077	-0.023	0.717	-0.006	0.196	0.233	-0.156	0.446	0.095	0.081	0.209	-0.393	0.202	0.209
LRT(β=0)	1.840	0.118	0.003	1.175	0.004	1.185	0.985	0.131	0.437	0.080	0.244	0.860	0.793	0.115	0.259
(p-value)	0.175	0.731	0.957	0.278	0.986	0.276	0.321	0.717	0.508	0.777	0.621	0.358	0.373	0.735	0.610

Note: Significant results are highlighted in bold.

Figure 2: Smoothed hazard functions (with 90% confidence bounds) for stock indices PX, WIG20 and BUX



We did not find any evidence of rational speculative bubbles in the Czech Republic and Hungary in any of the time periods examined (the null hypothesis of constant hazard rate is accepted). As for the Polish market, we discovered the existence of a speculative stock bubble during the period of tremendous market growth after the accession to the European Union and before the global financial crisis. The negative β coefficient of -0.61 indicates a significant speculative bubble in the Polish stock market. The null hypothesis is rejected at the 5% significance level. Consistent with the rational speculative bubble model, there is no duration dependence in runs of negative abnormal returns.

Calculations of run counts for each run length allow us to specify hazard functions for market indices, which are depicted in Figure 2. The hazard function for the market with a speculative bubble is a convex function, which declines as run length extends, but grows for the longest run due to construction of the test (by definition the hazard rate for the longest observed run equals 1). The hazard function for the WIG20 index is an example of such function. Hazard function for the market without a bubble is a constant function, which will appear as almost a straight line, but then grows for the longest run. In our case, that would be the hazard function for the PX index. There is certainly no sign of speculative bubble behavior in the Czech stock market. As for the hazard function for the BUX index, it could not be considered as one of our theoretical cases (constant or convex) and hence be unequivocally interpreted in terms of bubble existence.

It should be noted that investigation of indices for bubble testing gives the most general view on the problem. Indices studied are capitalization-weighted and usually dominated only by few companies. Investigation of individual stocks provides more sophisticated outcomes. Table 4 reports selected results of the duration dependence test on returns for individual stocks. As previously stated, we ran the test procedure for the full sample, starting with the date that stocks of particular company began trading, as well as for sub-periods.

In the Czech stock market, bubble behavior is detected for the stock of KIT Digital (IT company). However, this stock has been traded for only three years and the company has not yet paid dividends, which is typical for the internet sector. From the investigation of bubbles in Polish stocks, we were able to narrow down the previously discovered speculative bubbles in the pre-crisis period to the chemical stock (Boryszew and PKN Orlen) and telecommunication stock (TVN) sectors. In the Hungarian stock market, energy sector companies exhibit bubble behavior. These companies are adopting and developing technologies of energy efficiency (EST Media) and renewable energy resources (PannErgy). This situation might not be true of the Hungarian market only, it could indicate a global trend. As international stock markets became integrated to a greater extent, bubbles in the most influential stock markets could be contagious for smaller markets. Further investigation for stocks of similar companies is clearly needed.

Comparing our results with previous findings on bubbles in emerging markets, it is likely that the creation of bubbles in the Central European markets studied was probably prevented by the availability of Czech, Polish and Hungarian highly capitalized stocks in the more developed stock markets, such as US, UK and Germany. Therefore, any anomalies were subsequently arbitraged away. Moreover, stocks discovered with bubble behavior in prices are traded in their market of origin only.

Conclusions

The study examines the existence of rational speculative bubbles in stock markets of Central European countries. The presence of speculative bubbles was tested by the duration dependence test, which in our opinion, provides the most feasible tool for testing asset bubbles when the estimation of fundamental values and consequently abnormal returns is more difficult.

The rapid growth of studied markets for years 2004-2007 led to investor's overconfidence in revenue possibilities and could have easily resulted in a speculative bubble. However, the steep decline of stock prices triggered by the global financial crisis prevented these markets from overheating. Nevertheless, certain European emerging markets, in recent history, are not completely free of bubbles. We presented evidence of the existence of a rational speculative bubble in the Polish stock market in the period of its biggest growth to date

Table 4: Results of duration dependence test for individual stocks

	Stock	Period		Number of returns			Positive run test			
		Start	End	Total	Positive	Negative	α	β	LRT(β=0)	(p-value)
Czech Republic	AAA Auto Group	24.9.2007	16.11.2012	142	71	71	0.179	-0.215	0.513	0.474
	CETV	27.6.2005	16.11.2012	208	104	104	0.037	-0.140	0.373	0.541
	CEZ AS	26.7.1995	16.11.2012	435	217	218	0.035	-0.178	1.309	0.253
	Fortuna	21.10.2010	16.11.2012	60	30	30	0.190	0.320	0.288	0.591
	KIT Digital	**25.1.2010**	**15.11.2012**	**74**	**37**	**37**	**0.396**	**-0.693**	**3.546**	**0.059**
	KB	26.7.1995	16.11.2012	443	221	222	-0.130	0.066	0.167	0.682
	NWR	6.5.2008	16.11.2012	114	57	57	-0.206	0.167	0.275	0.599
	Orco Property	1.2.2005	16.11.2012	167	84	83	-0.386	-0.027	0.017	0.896
	Pegas Nonwovens	15.12.2006	16.11.2012	154	77	77	-0.186	0.268	0.865	0.352
	ErsteGroup	1.10.2002	16.11.2012	275	137	138	-0.020	0.189	0.686	0.408
	Philip Morris CR	26.07.1995	16.11.2012	439	219	220	0.003	-0.182	1.498	0.221
	Unipetrol	29.08.1997	16.11.2012	387	193	194	0.014	-0.145	0.771	0.379
	Vienna Insurance	5.2.2008	15.11.2012	143	71	72	0.306	0.118	0.102	0.749
Poland	Asseco Poland	2.6.1998	16.11.2012	376	188	188	-0.131	0.175	0.927	0.336
	Bank Handlowy	30.6.1997	16.11.2012	405	203	202	-0.005	0.269	1.869	0.172
	BRE Bank	2.1.1995	16.11.2012	473	237	236	0.071	-0.082	0.255	0.614
	Boryszew	**20.5.1996**	**16.11.2012**	**263**	**131**	**132**	**0.024**	**-0.573**	**22.801**	**0.0001**
	Globe Trade	5.5.2004	16.11.2012	225	112	113	-0.021	0.099	0.167	0.683
	Jasterzebska SW	5.7.2011	16.11.2012	38	19	19	0.589	-0.593	1.158	0.282
	Kernel Holding	22.11.2007	16.11.2012	146	73	73	0.268	0.137	0.138	0.711
	KGHM Miedz	14.7.1997	16.11.2012	404	202	202	-0.003	-0.032	0.034	0.854
	Grupa Lotos	8.6.2005	16.11.2012	200	100	100	-0.059	0.077	0.091	0.763
	LWB	21.7.2009	16.11.2012	91	46	45	0.042	0.363	0.698	0.403
	Bank Pekao	30.6.1998	16.11.2012	366	183	183	-0.141	0.204	1.203	0.273
	PGE	14.12.2009	16.11.2012	73	37	36	-0.184	-0.123	0.123	0.728
	PGNIG	20.10.2005	16.11.2012	187	94	93	-0.053	0.205	0.550	0.458
	PKN Orlen	26.11.1999	16.11.2012	345	173	172	0.131	-0.176	0.888	0.346
	PKN Orlen	**4.5.2004**	**28.12.2007**	**96**	**48**	**48**	**0.418**	**-0.581**	**3.067**	**0.079**
	PKO Bank Polski	9.11.2004	16.11.2012	228	114	114	0.090	0.190	0.499	0.480
	PZU	11.5.2010	16.11.2012	69	34	35	0.205	-0.284	0.459	0.498
	Synthos	20.12.2004	16.11.2012	196	98	98	0.042	-0.244	1.183	0.277
	Tauron	29.06.2010	16.11.2012	50	25	25	-0.585	0.058	0.024	0.876
	Telekomunikacja	18.11.1998	16.11.2012	388	194	194	0.102	0.041	0.046	0.830
	TVN	6.12.2004	16.11.2012	201	101	100	0.112	-0.195	0.704	0.401
	TVN	**6.12.2004**	**31.07.2007**	**67**	**34**	**33**	**0.584**	**-0.736**	**3.662**	**0.056**
Hungary	Appeninn Holding	2.7.2010	16.11.2012	69	35	34	0.368	0.148	0.067	0.795
	EGIS	4.9.1995	16.11.2012	436	218	218	-0.119	0.092	0.321	0.571
	E-STAR	2.10.2007	16.11.2012	126	65	64	-0.244	0.564	2.708	0.099
	ESTMEDIA	**5.12.2000**	**16.11.2012**	**261**	**131**	**130**	**-0.025**	**-0.309**	**2.996**	**0.083**
	FHB Mortgage	21.11.2003	16.11.2012	243	212	122	0.080	-0.059	0.067	0.796
	MOL	28.11.1995	16.11.2012	439	219	220	0.023	-0.094	0.346	0.556
	Magyar Telekom	14.11.1997	16.11.2012	383	192	191	-0.127	0.181	0.973	0.324
	OTP Bank	4.9.1995	16.11.2012	439	220	219	-0.082	0.055	0.112	0.738
	PannErgy	**4.9.1995**	**16.11.2012**	**434**	**217**	**217**	**0.381**	**-0.465**	**7.929**	**0.005**
	CIG Pannonia	5.11.2010	15.11.2012	59	29	30	-0.030	0.426	0.582	0.445
	Richter Gedeon	4.9.1995	16.11.2012	455	227	228	0.107	0.043	0.058	0.809
	Synergon IS	5.5.1999	16.11.2012	330	165	165	-0.104	0.042	0.052	0.820

Note: Significant results are highlighted in bold.

and narrowed it down to the chemical sector. Bubbles are also found in stocks representing new business sectors, such as cloud-based software and services, renewable energy resources, and energy efficiency technologies.

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