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Stock price volatility and fundamental value: evidence from Central and Eastern European countries[1]

***Jerzy Gajdka*[2], *Piotr Pietraszewski*[3]**

Abstract: The paper deals with the problem of the discrepancy between fundamental values of shares in the stock market and their market prices. In particular it discusses the problem of the excessive volatility of stock prices compared with changes in their fundamental value determined as the present value of dividends paid by the company. The results of research on this issue for the US market initiated and popularized by Robert Shiller provided strong arguments against the hypothesis of capital market efficiency stating that stock prices immediately account for any new information affecting the fundamental value of assets. This problem has been studied neither for the Polish stock market nor for other post-communist countries in Central and Eastern Europe. The paper presents preliminary results of research into these stock markets.

Keywords: present value model, fundamental value, efficient market hypothesis, CEE countries.

JEL codes: G12, G14, E44.

Introduction

One of most popular concepts in finance is the present value model for pricing shares traded on the stock market. According to this model the stock price reflects the market consensus on the expected present value of future dividends paid to stock-holders. Robert Shiller, the 2013 Nobel Memorial Prize laureate in Economics, was the first to use this model to verify the veracity of the efficient market hypothesis. The informational efficiency of capital markets means that all relevant information released into the investment community

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is immediately incorporated in prices.[4] The hypothesis also assumes that investors do not make systematic mistakes. Both these imply that market prices constitute the optimal forecast of future cash flows received by holders of financial assets or what is called their fundamental values. In numerous studies Shiller has proved that changes of financial asset prices were excessive considering the observed fluctuations in fundamental values. With regard to the stock market, Shiller compared historical stock prices with fundamental values, calculated *ex post* as a sum of discounted actual dividends paid after the moment for which the valuation was carried out. In fact a historical *ex post* fundamental value of shares is never known and should be assessed because a time series of dividends always ends at the time the calculations are made, making it necessary to make assume what the future amounts of dividends will be. However, because the discount factors decline exponentially into the future (under an assumption of a constant discount rate), for sufficiently long historical time series of dividends already paid, the value of future dividends, yet unknown, becomes relatively unimportant in determining the fundamental value. According to Shiller (1981, 1984, 2003), the present value (PV) model of pricing shares implies that stock price volatility on an effective market should not be greater than the variability of such defined fundamental values. However, his research has shown that the observed volatility of historical stock prices is several times larger than the variability of their fundamental values. Some authors raised some methodological issues questioning the results of Shiller's pioneering work (see e.g.: Copeland, 1983; Flavin, 1983; Kleidon, 1986; Marsh & Merton, 1986). Most importantly his volatility tests require a strong assumption that prices and dividends have constant finite variances (are stationary around a time trend). Nevertheless Shiller's key findings and conclusions were confirmed in subsequent studies for the US stock market that he (Campbell & Shiller, 1988) and other researchers (e.g.: Mankiw, Romer & Shapiro, 1985; West, 1988) conducted with usage of more sophisticated quantitative methods, mainly the cointegration framework, taking the observed non-stationarity of prices and dividends into account. Furthermore the basic version of the efficient markets PV-model assumes a constant expected rate of return (discount rate) over time. However there is much evidence supporting the predictability and time-variation of expected stock returns (Campbell, 2000;

[4] The informational efficiency of capital markets has been debated by its proponents and opponents since the early 1980s. Based on the wide body of evidence contradicting this theory, new trends in financial science such as behavioural finance and neurofinance have been developed. The significance of the debate over stock market efficiency for the development of financial and economic sciences has recently been acknowledged by the Nobel Committee, when the 2013 Nobel Prize in economics was awarded to Eugen F. Fama and Robert J. Shiller, two economists representing opposing views in this long-lasting scientific battle. Robert J. Shiller's research has made a significant contribution to undermining the veracity of the efficient market hypothesis that Fama defended consistently.

Campbell, Lo & MacKinlay, 1997; Campbell & Shiller, 1988; Fama & French, 1988). Therefore the validity of the PV-model, assuming a time-varying discount rate, has been also investigated with ambiguous results. Many authors found the model invalid for an explanation of stock prices' volatility (Balke & Wohar, 2002; Campbell & Shiller, 1988a, 1988b; Craine, 1993; Lamont, 1998). More recently, McLemore, Woodward and Zwirlein (2015) have found that introducing time-varying discount rates reduces reported prediction errors of the model, especially over more turbulent periods in the market. There is also some evidence in favour of a long-term relationship (cointegration) between log dividends and stock prices, predicted by the dividend-discount model with a time-varying discount rate (Bohl & Sicklos, 2004; Horvath & Watson, 1995; Nasseh & Strauss, 2004; Polimenis & Neokosmidis, 2016), but Shirvani, Delcoure and Wilbratte (2011) prove something opposite. The problem was also studied for other developed countries with mixed results, eg.: in Kanas (2005) for Germany, United Kingdom and Japan, in McMillan (2007) for thirteen countries, including G7 countries (Canada, France, Germany, Italy, Japan, UK and US), Belgium, Denmark, Ireland and the Netherlands and finally two South-East Asian economies Hong Kong and Singapore, and more recently, in Black, McMillan and McMillan (2015) for 29 markets.

A significant volume of papers analyzes the informational efficiency of stock markets in the post-communist Central and Eastern European (CEE) countries. There is a diversity of approaches. The most commonly used are those that analyze the random-walk hypothesis or capital market anomalies (day-of-the-week effect, month-of-the-year effect, small-firm effect, among others). A comprehensive overview of these studies is presented in Dragota, Tilica (2014) and Smith (2012). The studies of interest in this paper regarding the validity of the efficient-market dividend-discount model are typically long-term. This may explain why the investigations of R. Shiller and other researchers in this area are relatively little known in Poland and similar studies have not been performed on the Polish capital market and the capital markets of other post-communist CEE countries.

This article sets out to provide an insight into the results of our preliminary study on the discrepancy between market stock prices and their fundamental values, and the problem of the excessive volatility of prices in the selected CEE stock markets. The countries under investigation include Poland, Russia, the Czech Republic, Hungary, Slovakia and Latvia and this choice was limited by the length of the available data series (for more details, see footnote). We apply basic methodology of calculating the *ex post* rational prices (fundamental values) and comparing their variance with the variance of market prices, similar to that used by Shiller in many publications (Shiller, 1981, 1984, 2003). With annual data we use the available data series which are too short to apply more advanced quantitative methods. The remainder of the paper is as follows. Section 1 reviews the theoretical underpinning of research into the price

volatility of stocks in relation to changes in their fundamental value. Section 2 supports the details of the methodology. It also presents the main results of Shiller's use of it in the empirical studies for the US stock market. This makes the point of direct reference for the results of our own study. Sections 3 and 4 provide an insight into the results of our preliminary research involving stock markets in the CEE countries selected. The analysis is carried out in two stages . Firstly, a constant discount rate is assumed, following the main and most popular interpretation of the efficient market PV-model assuming that expected returns on the market are constant through time (section 3). Secondly, we admit time-varying discount rates that in turn correspond to varying interest rates (section 4). Discussion of the results and closing remarks end the paper.

1. Stock price volatility in the light of the efficient market hypothesis

According to Shiller (1981, 1984, 2003) the efficient markets' model can be described by taking that price P_t of a share (or of a portfolio of shares making up an index) equals the mathematical expectation, conditional on all available information, of the present value P_t^* of subsequent dividends accruing to that share (or a portfolio of shares). It can also be represented by the equation:

$$P_t = E_t P_t^*,$$

where E_t denotes the mathematical expectation conditional on information available at time t. According to this model, all stock price movements can be attributed to new information about the fundamental value P_t^*.

P_t^* is not known at time t, so it has to be forecast . In the efficient markets' model price P_t is given by the optimal forecast of P_t^*. The relationship between the market price P_t and the fundamental value P_t^* can also be described as $P_t^* = P_t + U_t$, where U_t is the forecast error. U_t must not be correlated with any information available at time t for the forecast to be optimal; otherwise some information will be unaccounted for in the forecast. Since the price P_t itself is information at time t, the forecast error U_t and the forecast P_t must be uncorrelated with each other. It is known from elementary statistics that the variance of the sum of two uncorrelated variables is the sum of their variances, i.e. $\text{var}(P^*) = \text{var}(P) + \text{var}(U)$. Since variances cannot be negative, we have:

$$\text{var}(P) \leq \text{var}(P^*). \tag{1}$$

This inequality is yet another exemplification of the general principle of optimal forecasting stating that the forecast must be less variable than the variable being forecast. Otherwise, high forecasts would point to the overvalua-

tion of the forecast variable, and low forecasts to its undervaluation. Then, just smoothing out the forecast values over time would improve the quality of the forecasts. The maximum possible variance of the forecast is the variance of the forecast variable only if the forecaster has perfect foresight.

Numerous studies by Schiller and other authors (see e.g. Craine, 1993; Lamont, 1998; Campbell & Shiller, 1987, 1988a, 1988b; Shiller, 1981, 1981a, 1984; West, 1988) show that the volatility of stock prices P_t is many times higher than the volatility of their fundamental values P_t^*. The section below contains a description of the basic methodological issues of this research and presents some of Shiller's results.

The financial literature provides also a number of plausible explanations for the high volatility of stock prices, using to this end the traditional theory of finance building on the assumption of rational investors, as well as the framework of behavioural finance that questions its validity. The focus of the first approach is on the likely changes in the level of investors' risk aversion that affect the level of discount rates and consequently alter the valuation of shares (Campbell & Cochrane, 1999), as well as on the investors' limited access to information contributing to errors in the forecasts of cash flows for shareholders (Ackert, 1994; Brennan & Xia, 2001; Lewellen & Shanken, 2002). The behavioural factors include factors arising from investors' irrational beliefs (overreaction to new information, the short-series error, the extrapolation error and excessive trust in the trend, underestimation of the law of regression to the mean, overconfidence combined with selective attribution, money illusion, etc.) and from the irrational instability of preferences. A discussion of these factors and a review of formal theoretical models can be found in Szyszka (2009, pp. 162-165).

2. Methodological issues and the results of empirical research received by Shiller

As already mentioned, a simple efficient markets model can be written as:

$$P_t = \sum_{k=1}^{\infty} \gamma^k E_t D_{t+k} = E_t P_t^*, \tag{2}$$

where P_t denotes the real price of a share (or a portfolio of shares) at the end of period t, just after last dividend was paid, D_t is the real dividend paid at the end of period t, γ denotes the constant discount factor and $P_t^* = \sum_{k=1}^{\infty} \gamma^k D_{t+k}$ is the perfect foresight or the *ex post* rational price, not known at the end of period t. E_t denotes a mathematical expectation conditional on information available at

the end of period *t*, including current and lagged values of P_t and D_t and other variables. A constant real discount factor γ corresponds to a constant discount rate *r* according to the equation: $\gamma = (1 + r)^{-1}$. It is easy to show that in the model (2) the discount rate *r* is equal to the expected one-period rate of return $H_t = \frac{P_{t+1} - P_t + D_t}{P_t}$, meaning that the equality $E_t H_t = r$ holds. The assumption that *r* is constant in time corresponds to an efficient markets' assumption that the expected returns on the market are constant in time, so there is no good or bad time to enter the stock market as far as the predictability of returns is concerned (Shiller, 2005, p. 260).

To compute the dividend present value (the *ex post* rational price or the fundamental value P_t^*) for any given time, two problems need to be solved. The first one involves the determination of the discount rate *r*. The second problem is due to the fact that the summation of dividends in the formula for the fundamental value P_t^* extends to infinity. At the same time it is not known what dividends will be paid after the last year for which data are available, so an assumption must be made as to their future values. This solution is equivalent to choosing an arbitrary value for the residual value P_t^*. In the next step the fundamental values of shares in the earlier periods are calculated recursively with $P_t^* = \gamma(P_{t+1}^* + D_t)$. That an assumption has to be made about the residual value implies that the estimates of the fundamental values remain uncertain – we never have a P_t^* without some error. However, two things are noteworthy. Firstly, the importance of the chosen residual value declines as we move backward from the terminal date, because the discount factors decrease exponentially. Secondly, if a different residual value were chosen the exponential trend would have to be added or subtracted from fundamental values P_t^*, which would not cause any changes in the fluctuations of these values.

Shiller's pioneering work (1981) provides the following solutions to these issues. First of all, the exponential trend is removed from the price data. According to Shiller (1981a), this way the heteroscedasticity arising from the gradually increasing size of the market is eliminated. The growth rate of the exponential trend *b* is estimated with the regression equation $\ln P_t = a + bt + \xi_t$. The model (2) can be restated in terms of price and dividend series scaled with the growth factor $\lambda = e^b$, i.e. $p_t = \frac{P_t}{\lambda^{t-t_0}}$, $d_t = \frac{D_t}{\lambda^{t-t_0}}$, where t_0 denotes an arbitrary chosen base time period for which $p_t = P_t$, $d_t = D_t$.[5] By dividing both sides of (2) by λ^{t-t_0} and by making some rearrangements, we have:

[5] When time is indexed from 0 and base time period t_0 is chosen as the first period in the time series than λ^{t-t_0} simplifies to λ^t. The choice of the base time period and the way of indexing time do not matter for the results because both prices and dividends in the period *t* are divided by the same trend factor.

$$p_t = \sum_{k=1}^{\infty} (\lambda\gamma)^k E_t d_{t+k} = \sum_{k=1}^{\infty} \overline{\gamma}^{-k} E_t d_{t+k} = E_t p_t^{\star}, \tag{3}$$

where $\overline{\gamma} = \lambda\gamma$ and $p_t^{\star} = \sum_{k=1}^{\infty} \overline{\gamma}^{k} d_{t+k}$.

Let $\overline{r}$ given by $\overline{\gamma} = (1+\overline{r})^{-1}$ stand for a discount rate appropriate for the scaled p_t and d_t. Then the model implies that the discount rate $\overline{r}$ equals just the mean dividend d_t divided by the mean price p_t:

$$\overline{r} = \frac{E(d)}{E(p)}, \tag{4}$$

where E denotes the mathematical (unconditional) expectation. It is so because the equation (3) implies that $\overline{r} = \frac{E(d)}{E(p)} E(p_t) = \sum_{k=1}^{\infty} \overline{\gamma}^{k} E(d) = \frac{\overline{\gamma}}{1-\overline{\gamma}} E(d)$; then from this and from the definition of $\overline{r}$ one gets (4). To determine the series of $p_t^{\star}$, we also need to make assumptions about the residual value $p_T^{\star}$, the sum of discounted dividends d_t that will be paid in the future. Shiller (1981) assumes that $p_T^{\star}$ equals the average historical price (scaled with the growth factor), that is $p_T^{\star} = E(p_t)$.

With this methodology, Shiller 1981 computed the series of fundamental values for the Standard and Poor's Composite Stock Price Index in the years 1871-1979 and the Dow Jones Industrial Average Index in the years 1928-1979. He showed that the volatility (measured with variance) of the detrended market values of the Standard and Poor's Index (adjusted for inflation with CPI) was more than 31 times in excess of the volatility of the fundamental values. For the Dow Jones the appropriate variance ratio was 176.

In his later works (1982, 1989, 2003, 2005), Shiller presented an alternative approach to determining the discount rate and the residual value $P_T^{\star}$. He discounted dividends using the geometric-average real total return (capital gain plus dividend) for the entire sample. Dividends after the last year for which data were known were assumed to be growing at the geometric-average historical growth rate for dividends. To compute future dividends the value of dividends in the last year of the sample was adjusted to a level at which the dividend payout rate (dividends as a fraction of ten-year moving average earnings) equalled its historical average for the whole period of analysis.

As already mentioned, the assumption about a constant discount rate amounts to an efficient markets assumption stating that expected returns on the market are constant in time. However there are also some more sophisticated versions of the efficient markets' hypothesis, which allow the discount rate to vary over time, implying that the returns on the stock market are forecastable (Campbell, 2000; Shiller, 2003, pp. 87-88, 2005, p. 260). The first of the versions that Schiller considered defines the discount rate for period t as the

sum of the interest rate for period t plus the risk premium (constant in time) defined as a difference between the geometric-average market return and the geometric-average interest rate. The dividend present value P_t^* is then computed according to the formula:

$$P_t^* = \sum_{\tau=t+1}^{T} \left(D_\tau \prod_{j=t+1}^{\tau} \frac{1}{1+r_j+\phi} \right) + P_T^* \prod_{j=t+1}^{T} \frac{1}{1+r_j+\phi},$$

where ϕ denotes a constant risk premium.

The time-varying discount rate considered by Shiller is alternatively determined by deriving the discount rate from the data on aggregate *per capita* consumption, as proposed by the models of valuation of financial assets in the effective market of Lucas (1978), Breeden (1979), Grossman and Shiller (1981). In these models, which maximize the intertemporal utility of consumption, the discount rate is equal to the marginal rate of intertemporal substitution of consumption. The formula for calculating the present value of future dividends, assuming that the coefficient of relative risk aversion of the representative consumer is 3, is the following (Grossman & Shiller, 1981; Shiller, 1982):

$$P_t^* = \sum_{\tau=t+1}^{T} \left(\frac{C_t}{C_\tau} \right)^3 D_\tau + \left(\frac{C_t}{C_T} \right)^3 P_T^*,$$

where C_t denotes aggregated *per capita* consumption at time t.

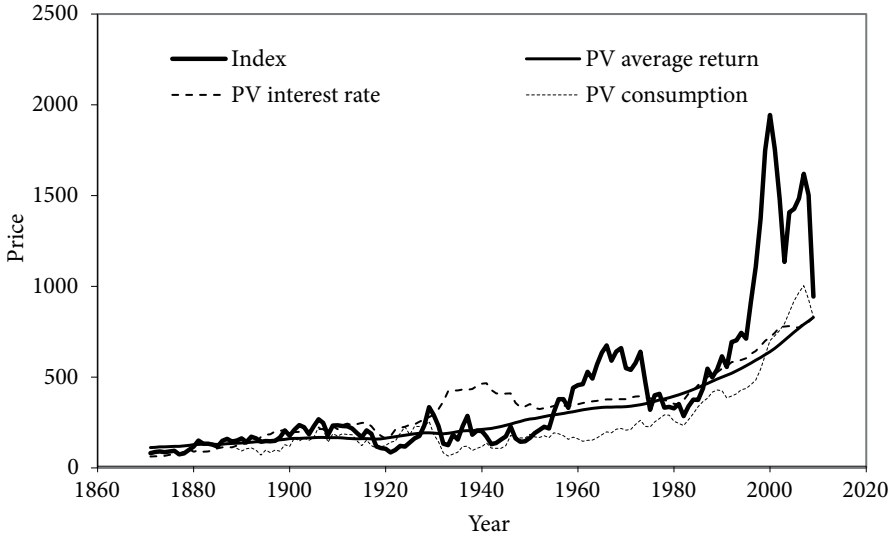

Figure 1. Real Standard & Poor's Composite Stock Price Index and present value of dividends, 1871-2002

Source: Developed by the authors with data and calculations available on http://x\uw.econ.yale.edu/-shiller.

Figure 1 presents the real Standard & Poor's Composite Stock Price Index in the years 1871-2002 and the time series of fundamental values (present values of dividends) that Shiller obtained with the above methods of determining the discount rate and the assumption that dividends after 2001 will grow at an historical average growth rate.

In the graph that was created by Shiller the present value of dividends calculated with the constant discount rate (the same as the geometric-average real total return over the period of analysis) behave remarkably like a stable trend, whereas the market values of the index that gyrate around it show very strong fluctuations. Using the time-varying interest rates to discount dividends does not change the behaviour of present value much, especially in the last half-century. Moreover changes in the present value have little resemblance as to how the market prices behave, which is particularly evident during the depression years in the 1930s, when the present value was extremely high, while prices remained at the lowest levels. Even the model based on consumption that bears some resemblance to changes in stock prices fails to explain the extent of their volatility.

3. Results of empirical research into stock markets in CEE countries assuming a constant discount factor

Studies on the volatility of US stock market indices, as well as stock indices in other countries, have provided a strong argument that asset prices show much greater volatility than predicted by the efficient-markets-present-value models. This aspect has not been investigated with regard to the Polish stock market or other Central and Eastern European (CEE) stock markets. The sample consists of six post-communist countries (Poland, Russia, the Czech Republic, Hungary, Slovakia, Latvia), which are located in the same geographical region and have shared the experience of having launched large-scale systemic reforms after 1990 to introduce a market economy and its institutions. Their capital markets are fairly new compared with those in highly-developed countries. This implies they are relatively "tight", less liquid and less transparent and presumably less efficient, which increases the probability of faulty valuations. To a large extent foreign investors used to perceive these markets as the one, relatively homogenous group and they are still considered rather speculative. There are also some differences within the group, lots of them coming from different origins and different paths of further development (see e.g. Koke & Schroder, 2002; Schroder, 2001).

The research uses Bloomberg's data on the MSCI indices (Morgan Stanley Capital Index) and aggregated annual dividends per share for these indices from

the period between the end of 1994 and the end of 2015.[6] The wide range of MSCI indices are calculated by the American investment bank Morgan Stanley since 1970. The indices we use here cover approximately 85% of the country's equity universe. They are very useful for international comparisons because they apply the same methodology for all countries and particularly useful for the analysis we perform here because dividends per share are calculated and published for all of them. The nominal price and dividend series have been adjusted for inflation using the CPI (2010 = 1). The inflation data have been obtained from the OECD database.

We calculate the *ex post* rational price (fundamental value) at time t using the time series of dividends paid in the succeeding periods and the assumed residual value. Then we calculate the ratio of the variances of the detrended market prices and fundamental values and test the equality of these variances. The details of this methodology are described in section 2. There is no good choice for the residual value. According to Schiller (1981), the detrended residual value, $p_T^\star$, has been set to equal the average historical detrended index value, so $p_T^\star = E(p_t)$. The detrended price is assumed to return to its mean. Any other choice of $p_T^\star$ would be just as arbitrary as this one. Fortunately, as already mentioned in section 2, the particular choice of $p_T^\star$ is of very limited importance for the results in which we are interested. It is because if a different residual value were chosen, the exponential trend would be added or subtracted from fundamental values $P_t^\star$, which would not cause any changes in the fluctuations of these values. That is why we have not examined different scenarios for the residual value. In this section the discount rates are assumed to be constant over time and have been determined with the formula (4): $\overline{r} = E(d)/E(p)$. Prior to plotting the data, the exponential trend, previously removed, has now been restored. In Figure 2, the time series of the real fundamental values for MSCI indices are plotted with dotted lines and the real market values of the indices are represented by solid lines. All values in this Figure are at 2010 prices.

Figure 2 is consistent with the conclusions Schiller obtained for the US market. In the case of each country the series of fundamental values calculated with the fixed discount rate seem to form a consistent trend, while the market values show considerable fluctuations around it. Further, all charts making up Figure 2 appear to point to a significant overvaluation of shares in the countries analysed before the financial crisis erupted in 2007. On the other hand, however, there were also periods when shares were undervalued, which followed the Russian crisis and the burst of the Internet bubble (in Russia, Poland, the Czech Republic and Hungary; the time series for Slovakia and Latvia start after this period), but in recent years. Moreover some interesting differences

[6] Unfortunately the time series available for other CEE countries are too short (below 10 years) to make the analysis sensible. The authors wish to acknowledge their gratitude to dr hab. Janusz Brzeszczyński for his assistance in obtaining Bloomberg's data.

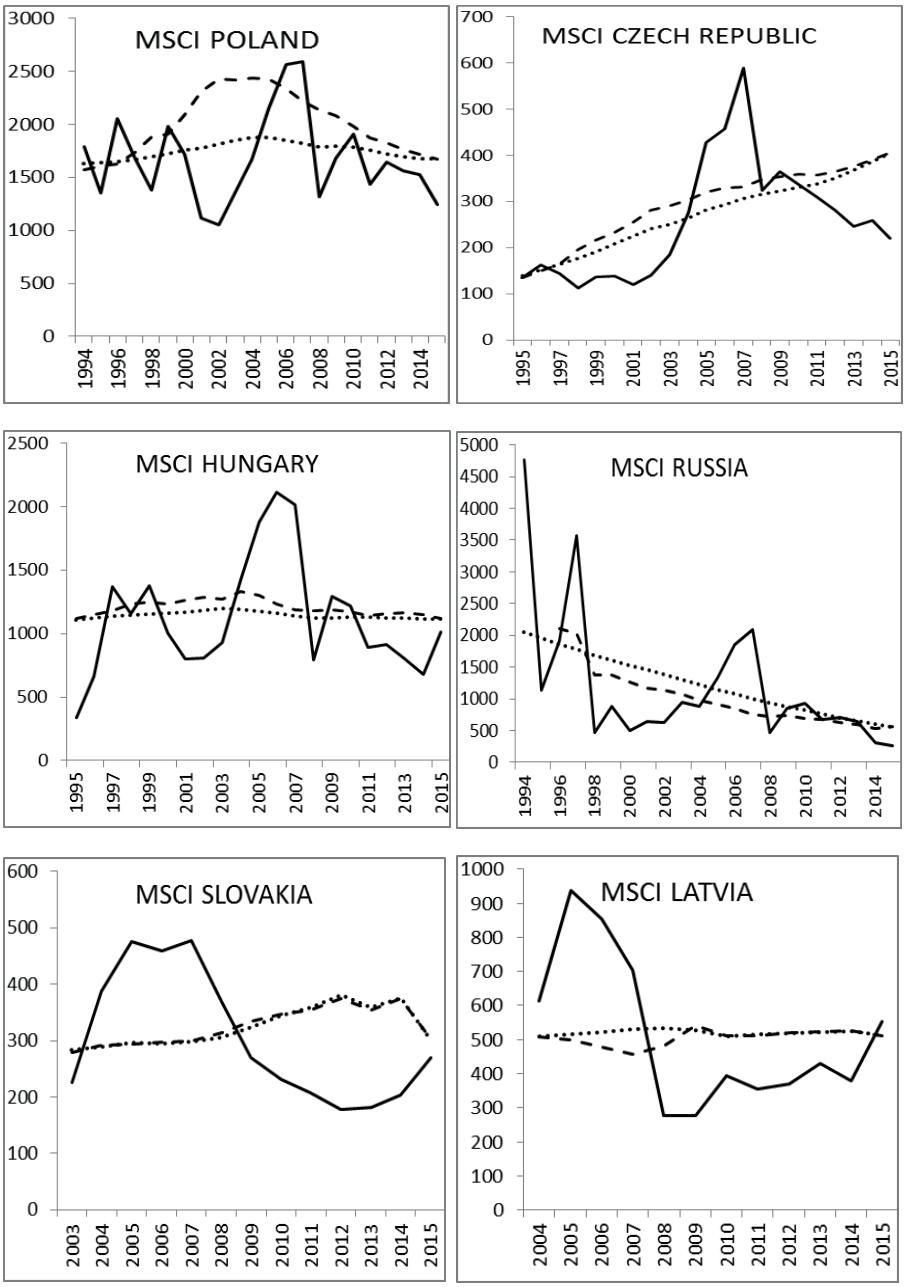

Figure 2. Real MSCI and present value of real dividends in CEE countries, 1994-2015

Source: Developed by the authors using Bloomberg and OECD data.

can be observed in the long-run behaviour of the fundamental values and stock prices between countries. While in Poland, Hungary and Latvia none of them displays any clear upward or downward trend, the fundamental values in Russia decline steadily in time and in the Czech Republic they keep rising. The case of Slovakia is less clear because the estimates are biased by an extremely high dividend payout in the last year of the analysis, although the overall trend tends to be rising over time. Let us note, however, that the calculations of fundamental values as presented here, especially for recent years, are significantly influenced by the choice of the residual value. Therefore the above findings, particularly those concerning recent years, should be treated with some caution. This particularly applies to Slovakia and Latvia, for which the available time series, and consequently the period of the analysis, are particularly short.

Table 1 presents the ratios between the variance of real market prices (index values) and the variance of corresponding fundamental values.[7] Ratios greater than 1 indicate that inequality (1) resulting from the effective market model is not satisfied. In the third row of the table the *p*-values in the *F*-test verifying the null hypothesis H0 : var(p) ≥ var(p^*) against the alternative H1 : var(p) > var(p^*) were also presented.[8]

Table 1. The ratios of market volatility to fundamental volatility (constant discount rates)

Country	Poland	Russia	Hungary	Czech Republic	Slovakia	Latvia
Years	1994-2015	1994-2015	1995-2015	1995-2015	2003-2015	2004-2015
Variance ratio var(p) / var(p^*)	27	266	289	39	11	770
(*p-value*)	(<0,0001)	(<0,0001)	(<0,0001)	(<0,0001)	(0,0001)	(<0,0001)

Source: Developed by the authors using Bloomberg and OECD data.

The numbers in Table 1 are consistent with the conclusions drawn from the analysis of Figure 1. The high values of variance ratios correspond to the results that Shiller obtained for the US market (the variance ratios for the Standard and Poor's Index and the Dow Jones were 31 and 176, respectively; see above).

[7] To be precise, it is a variance ratio between the detrended index, var(p), and the present value of subsequent detrended dividends var(p^*), i.e. variance ration = var(p)/var(p^*). As already mentioned, removing the trend from the data eliminates heteroscedasticity.

[8] The *F*-test requires the normal distributions of both variables. We have tested the normality of the detrended market prices p and their *ex post* rational counterparts p^* using the Jacque-Bera test. The test fails to reject the null hypothesis stating the normality of both p and p^* at any acceptable significance level for all countries. However because the numer of observations is fairly scarce, especially for Latvia and Slovakia, one should be very careful with these results.

4. Results of empirical research into stock markets in CEE countries assuming a time-varying discount factor

For the purposes of the above analysis we assumed a constant discount factor for dividends following the most basic and most popular interpretation of the efficient market theory that expected returns on the market are constant in time, so in terms of return predictability there is no good or bad time to enter the stock market. According to this theory price changes represent the efficient discounting of "new information" that always relates to future dividends rather than future returns. The assumption that a discount rate is constant in time is apparently the first step, as more sophisticated versions of the efficient markets' hypothesis allow the rate to vary over time, implying the predictability of stock returns (Campbell, 2000).

As the research findings suggest that dividends do not vary enough to justify fluctuations of stock indices let us consider in the next step the movements can be attributed to information about discount factors that correspond to interest rates. We assume therefore that the forecasts of future interest rates for investors may determine, for mere reasons of arbitrage, the expected returns on stocks, with which investors discount expected dividends in equity valuation. The efficient markets' model with a time-varying discount rate can now be written as (cf. 2):

$$P_t = \sum_{k=1}^{\infty} E_t \left(D_{t+k} \prod_{j=1}^{k} \gamma_{t+j} \right), \tag{5}$$

where γ_t denotes the real discount factor appropriate for period t and $P_t^{\star} = \sum_{k=1}^{\infty} \left(D_{t+k} \prod_{j=1}^{k} \gamma_{t+j} \right)$ is the perfect foresight or the *ex post* rational price. The discount factor γ_t corresponds to the real discount rate r_t appropriate for period t according to the equation: $\gamma_t = (1 + r_t)$.

Using the same methodology as before, we remove the exponential trend from the price data to avoid heteroscedasticity. Dividing both sides of (5) by the growth factor λ^{t-t_0} and substituting $p_t = \frac{P_t}{\lambda^{t-t_0}}$, $d_t = \frac{D_t}{\lambda^{t-t_0}}$, we get:

$$p_t = \sum_{k=1}^{\infty} E_t \left(d_{t+k} \lambda^k \prod_{j=1}^{k} \gamma_{t+j} \right) = \sum_{k=1}^{\infty} E_t \left(d_{t+k} \prod_{j=1}^{k} \overline{\gamma}_{t+j} \right) = E_t p_t^{\star},$$

where $\overline{\gamma}_t = \lambda \gamma_t$ and $p_t^{\star} = \sum_{k=1}^{\infty} \left(d_{t+k} \prod_{j=1}^{k} \overline{\gamma}_{t+j} \right)$. Let $\overline{r}_t$, given by $\overline{\gamma}_t = (1 + \overline{r}_t)^{-1}$, stand for a discount rate appropriate for scaled data p_t and d_t. Taking $\overline{\gamma}_t = \lambda \gamma_t$ and substituting discount rates r_t and $\overline{r}_t$ one finds:

$$1+\overline{r}_t = \frac{1+r_t}{\lambda}. \tag{6}$$

To determine the series of *ex post* rational prices (fundamental values), we assume that the discount rate r_t for period t equals the real one-year interest rate i_t plus a risk premium ϕ that is constant over time, so $r_t = i_t + \phi$. From this and (6) it follows that $\overline{r}_t = i_t + \overline{\phi}$, where $\overline{i}_t$ is defined by $1+\overline{i}_t = \frac{1+i_t}{\lambda}$ and $\overline{\phi} = \phi/\lambda$. To make sure that this new analysis is compatible with the earlier one the risk premium $\overline{\phi}$ (scaled with the growth factor) will be calculated as a difference between the value of the previously used constant discount rate, $\overline{r} = \frac{E(d)}{E(p)}$, and the average real one-year interest rate (also scaled), $\overline{i} = E(\overline{i})$, that is:

$$\overline{\phi} = \frac{E(d)}{E(p)} - E(\overline{i}).$$

It is now straightforward to find: $E(\overline{r}) = E(\overline{i}) + (\overline{\phi}) = \frac{E(d)}{E(p)}$, i.e. the average discount rate that equals the constant discount rate used in our previous study. We also assume that the residual value p_T^* still equals the average historical index value, $p_T^* = E(p)$. Having made these assumptions, we can directly compare the "new" and "old" results in order to assess the bare impact of time-varying discount rates on the volatility of the fundamental values and the efficient markets' model better fit to the real data.

In our calculations we used the annualized short-term interest rates from the OECD database that are described therein as the rates at which short-term borrowings are effected between financial institutions or as the rates at which short-term government papers are issued or traded on the market. These rates are based on three-month money market rates where available (OECD, 2016). In our calculations the rates were adjusted for inflation using the CPI.

In Figure 2 the series of fundamental values for MSCI indices calculated with time-varying interest rates are marked as dashed lines. Table 2 contains the new variance ratios and the new *p*-values in the *F*-test corresponding to those presented in Table 1.[9]

When compared with the results of previous analysis assuming a constant discount rate (see Table 1), allowing for time-varying interest rates in the present value formula, increased the volatility of fundamental values, consequently reducing the variance ratios (with the exception of Slovakia). In case of Poland

[9] The normal distribution of the new *ex post* rational prices p^* was tested using the Jacque-Bera statistic. The null cannot be rejected at any acceptable significance level for any country except Russia. See footnote 5 for more details.

Table 2. The ratio of market volatility to fundamental volatility (time-varying discount rates)

Country	Poland	Russia	Hungary	Czech Republic	Slovakia	Latvia
Years	1994-2015	1994-2015	1995-2015	1995-2015	2003-2015	2004-2015
Variance ratio var(p) / var(p^*)	2	39	57	10	12	90
(*p-value*)	0,07556	<0,0001	<0,0001	<0,0001	0,0001	<0,0001

Source: developed by the authors using Bloomberg and OECD data.

the null hypothesis that the variance of market prices does not exceed the variance of fundamental values cannot be rejected at the 5% significance level. This speaks in favour of the PV-model with time-varying discount rates as more reliable in tracking the market behaviour of stock prices in the CEE countries analysed. However, when looking at the charts in Figure 2, one finds little resemblance between the present value and the stock prices in the way they change in time. The difference is the most evident, but also most interesting, in the case of Poland, where the behaviour of the *ex post* rational values of the stock index changed significantly following the introduction of the time-varying interest rates. Even though the stock market prices in Poland dropped dramatically after the Internet bubble in the USA burst at the turn of the century the fundamental values continued to rise until they peaked in 2004 and then they started to decline to the residual value. The simulations performed by the authors show that this behaviour of fundamental values (an initial rise followed by a decline) is observed regardless of which residual value is used in calculations. Undoubtedly its main cause is changes in the level of real interest rates that were significantly lower after 2002-2003 than before. Another contributing factor is changes in dividends per share that after 2004 were consistently higher than in the previous years. The relative significance of these two factors can be determined by comparing the series of fundamental values calculated with a constant discount rate (a dotted line) and with varying discount rates (a slashed line). A similar pattern of fundamental values' behaviour, however less distinct, is observed for the Czech Republic and Hungary.

Conclusions

The question as to whether the market prices of shares really track fundamental values has been studied since Robert Shiller's pioneering works at the beginning of the 1980s. A standard efficient market present-value model, a cornerstone of finance theory, states that real stock prices equal the present value of

rationally expected or optimally forecast future real dividends, with a constant discount rate. According to this model, the movements in stock prices are fully attributed to changes in dividends. The more reliable version of this model allows for time-varying discount rates, according to empirical evidence supporting the predictability and time-variation of expected stock returns. Using historical data on prices and dividends one can check the model's key prediction that the variance of actual market prices should be bounded by the variance of the *ex post* rational prices defined as the present values of all dividends paid after the moment at which the market valuation had been done. The results of such an analysis, employing the MSCI stock indices (covering approximately 85% of the country's equity) for six post-communist countries in Central and Eastern Europe are referred to in the paper. The capital markets in these countries launched after 1990 on the wave of large-scale systemic reforms introducing a market economy and its institutions, are fairly new compared with those in highly-developed countries. This implies they are relatively "tight", less liquid and less transparent and presumably less efficient, which increases the probability of faulty valuations. That is why they are still considered rather speculative by foreign investors.

The results confirm in general a commonly observed and long-discussed anomaly of stock prices' excessive volatility, i.e. a greater volatility of stock prices than the changes in their fundamental values could explain. With constant discount rates the variance ratios between actual prices and their *ex post* rational counterparts obtained are very high, ranging from 11 for Slovakia up to an extreme 770 for Latvia. Allowing for time-varying discount rates corresponding to the real one-year interest rates that can be rationally predicted by investors, increased the volatility of fundamental values, consequently reducing the variance ratios between market prices and fundamental values (with the exception of Slovakia), ranging now from 2 for Poland up to 90 for Latvia. In the case of Poland the change is so significant that the applied *F*-test failed to reject the null hypothesis that the variance of market prices does not exceed the variance of fundamental values. These results seem to speak in favour of the PV-model with time-varying discount rates as more reliable in tracking movements of market prices. Some interesting conclusions were also drawn from the graphs on which the time series of market prices and calculated fundamental values are plotted. In all countries the results reveal significant overvaluation of shares before the financial crisis erupted in 2007. This points to the wave of speculation, discussed in literature, induced mainly by foreign capital seeking attractive places to raise high profits in the late phase of the cycle. This effect is least evident in Poland when time-varying discount rates are assumed. On the other hand, there were also periods when shares were undervalued, which followed the Russian crisis and the burst of the Internet bubble (in Russia, Poland, the Czech Republic and Hungary), but also the case in recent years. Moreover some interesting differences can be observed in the long-term behaviour of real

prices and fundamental values between countries. While in Poland, Hungary and Latvia they do not display any clear upward or downward trend, in the Czech Republic they keep rising and in Russia declining steadily, due to persistent high inflation throughout the whole a period analysed (in 2015 prices were about 72 times higher than in 1994). The case of Slovakia is less clear because the estimates are biased by an extremely high dividend payout in the last year of the analysis, although the overall trend tends to be rising over time. Although these differences are very interesting and sometimes a little bit confusing, the analysis such as this performed in the paper cannot give any reasons for this varied behaviour of real values. Each case deserves much more detailed, both qualitative and quantitative, study.

Undoubtedly, the problem in empirical research into these relatively new capital markets is that the available time series, especially of annual frequency, are fairly short, which impedes the usage of more advanced econometric techniques. Although the results presented in this paper are very preliminary they bring some new evidence that stock prices do not track fundamental values in the emerging markets of Central and Eastern Europe and the observable violation of stock prices is too high to be justified by changes in fundamental factors. More rigorous studies would require longer time series and would be done, at least for some countries, with data of higher frequency.

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