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The effect of financial, macroeconomic and sentimental factors on stock market volatility

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Abstract. The aim of this paper is to find economic factors that could be helpful in explaining the market's shifts between periods of prosperity and crisis. The study took into account the main stock indices from developed markets of the USA, Germany and Great Britain, and from two emerging markets, i.e. Poland and Turkey. The analysis confirms the existence of two different states of volatility in these markets, namely the state with a positive returns' mean and low volatility, and the state with a negative or insignificant mean and high volatility. The Markov-switching model with a dynamic probability matrix was applied in the study. The subject of the analysis was the impact of domestic and global factors, such as VIX and TED spread, oil prices, sentiment indices (ZEW), and macroeconomic indices (unemployment, long-term interest rate, CPI), on the probability of switching between the states. The authors concluded that in all the examined countries, changes in long-term interest rates have an influence on market returns. However, the direction of this impact is different for developed and emerging markets. As regards developed markets, high prices of oil, 10-year bonds, and the ZEW index can suggest a high probability of the countries remaining in the first state, whereas an increase in the VIX index and the TED spread significantly reduces the probability of staying in this state. The other studied factors proved to be rather local in nature.

Keywords: regime shift, equity volatility, macroeconomic factors, sentimental factors, financial markets, TVPMS model

JEL: C52, G11, G15, G32

1. Introduction

Understanding the stock market's mood is crucial for investors and policymakers. The diversification strategies created to reduce investment risks are closely tied to a given stock market's nature. After the global financial crisis, theorists and practitioners began to take notice of the volatility of international stock markets. A 'volatility shift' means that volatility transitions from a low to a high level, usually corresponding to crisis periods (Aloy et al., 2014). From the practical point of view, it is worth knowing what impact various indicators have on the markets.

A lot of research has been conducted on the factors which interact with financial markets, such as political events, the economic situation and investors' expectations (Huang et al., 2005). As the stock market is a part of the economy and stock prices are often determined on a cash-flow basis, fundamental macroeconomic indicators can

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influence stock market prices and they tend to be included in the portfolio investment decision-making process (Chen, 2009; Haq & Larson, 2016; Pilinkus, 2010). Rapach et al. (2005) presented evidence that stock returns can be predicted on the basis of macroeconomic variables. Chen (2009) investigated whether macroeconomic variables can predict a recession in the stock market. The author evaluated series such as interest rate spreads, inflation rates, money stocks, aggregated output, unemployment rates, federal funds rates, federal government debt, and nominal exchange rates, and concluded that bear markets can be easily predicted on the basis of macroeconomic variables. The relationships between stock prices and chosen economic variables were discussed by a variety of scientists, including Mahmood & Dinniah (2009). Chang (2009) and Humpe & Macmillan (2007) approach this issue using the Markov-switching mechanism. Nasseh & Strauss (2000) proved the existence of a long-run relationship between stock prices and the macroeconomic activity in six major European countries. They concluded that stock markets were driven by economic fundamentals and a number of interrelated factors, such as production, business expectations, interest rates and the CPI. The existence of long-run equilibrium relationships among stock prices, industrial production, real exchange rates, interest rates and inflation in the United States was investigated by Kim (2003). Celebi & Hönig (2019) demonstrated that the impact of external factors on stock prices in Germany is stronger in times of crisis than in the pre- or post-crisis periods. Research on the developing Vietnamese stock market (Nasir et al., 2020) also showed a link between macroeconomic variables and stock prices. Real economic growth and easy crediting had a positive impact on the stock market, whereas inflation caused long-term negative effects. The impact of sentiment indicators, based on the expectations of analysts and investors, was discussed for example by Kvietkauskienė & Plakys (2017) and many others (see Algaba et al., 2020). The German Zentrum für Europäische Wirtschaftsforschung (ZEW) Economic Sentiment Index proved to have predictive power for technology-oriented stock companies in Germany (Homolka & Pavelková, 2018). Also, the tone of the economic news in the media (García, 2013; Lischka, 2015) or the overall mood of Facebook users (Siganos et al., 2014) were found to be good indicators for stock markets about the general economic situation, especially during recession.

This paper examines the effect of various indicators on stock market returns. A selection of developed markets was analysed: the USA, Germany and Great Britain, as well as two emerging markets, i.e. Poland[1] and Turkey. Research was

[1] A leading global index provider, FTSE Russell promoted Poland from the status of an Emerging Market to the status of a Developed Market on 24 September 2018.

performed on monthly returns of the main stock indices of the considered countries (SPX, DAX, WIG, XU, FTM) and monthly data of the exogenous variables from the period of January 2001 to January 2019. The research revealed the existence of volatility shifts from a low to a high level, usually corresponding to prosperity and crisis periods, respectively. Subsequently, an attempt was made to determine which of the indicators – global or domestic – could be of use in explaining or predicting volatility shifts.

The applied methodology is based on the Markov-switching model (Hamilton, 1990). The regime switching models with a Markov switching mechanism for modelling financial time series were discussed by Chollete et al. (2009), Jondeau & Rockinger (2006), Rodriguez (2007) and others. Switching models were also analysed by Czapkiewicz (2018), Doman (2011) and Doman & Doman (2014). In order to verify the impact of financial, macroeconomic and sentimental factors on the stock market volatility, we adopted the Copula-GARCH model with Markov switching with a time-varying transition probability matrix. A time-varying transition probability Markov-switching (TVPMS) framework was originally proposed by Filardo (Filardo, 1994) and further developed by Kim et al. (2008). This approach has already been applied by researchers to verify the influence of selected indicators on the behaviour of some financial time series. For example, Boudt et al. (2012) used the TVPMS mechanism to study the impact of the VIX or TED spread on the dependencies between weekly returns on the US headquartered bank holding companies. Aloy et al. (2014) showed volatility shifts between tranquil and crisis periods in the East Asian equity markets. Dufrénot et al. (2014) applied this method to study the impact of the anticipated macroeconomic fundamentals on the Eurozone sovereign spreads, while Toparlı et al. (2019) used it to study the impact of oil prices on the stock returns in Turkey. The TVPMS model is discussed in detail also in a monograph by Czapkiewicz (2018).

This article considers only three developed markets and only two developing markets; nevertheless, some observations could be made. The relationship between financial and macroeconomic factors and market volatility is the subject of numerous articles. However, the specific contribution of this paper is the verification of the thesis that both global factors such as the VIX, TED spread, oil prices, the ZEW index, and chosen macroeconomic variables, including the consumer price index, long-term interest rates and unemployment rates, may be crucial for the state of the volatility of markets (emerging or developed). Particular attention is devoted to the impact of the ZEW sentiment factor on the markets. To the authors' best knowledge, this factor has not been widely studied yet. The paper attempts to investigate what variables may affect regime shifts and seeks an answer to the questions whether sentimental factors matter and weather it is only macroeconomic and financial data that impact regime shifts.

The TVPMS model was defined by Filardo (1994), but the financial literature fails to provide any further information on its usage. There are no ready-to-use procedure libraries, thus using this model in practice requires the implementation of one's own algorithms. In addition, the applied methodology makes it possible to study the impact of these factors on market volatility in each of the states (prosperity or crisis) considered separately. This model applied in practice shows whether the examined factors are of greater importance in the period of prosperity or in the period of crisis. To the best of the authors' knowledge, such a study has not been conducted for the Polish nor Turkish market.

This paper further contains the following parts: Section 2 describes the model's specifications and its estimation procedure, Section 3 presents the results of the empirical study, while the conclusions are provided in the last, fourth, section of the paper.

2. Econometric framework

2.1. The TVPMS model

Let us consider a process $(S_t, R_t)_{t\in\mathbb{N}}$, where $(R_t)_{t\in\mathbb{N}}$ is a returns time series, $(S_t)_{t\in\mathbb{N}}$ is a hidden Markov process with transition matrix P_t and with two states, i.e. $s_t \epsilon \{1,2\}$. The matrix of the transition probabilities is defined as follows:

$$P_t = \begin{bmatrix} p_t^{11} = \dfrac{exp(x_{t-1}^T\beta_1)}{1 + exp(x_{t-1}^T\beta_1)} & p_t^{12} = 1 - \dfrac{exp(x_{t-1}^T\beta_1)}{1 + exp(x_{t-1}^T\beta_1)} \\ p_t^{21} = 1 - \dfrac{exp(x_{t-1}^T\beta_2)}{1 + exp(x_{t-1}^T\beta_2)} & p_t^{22} = \dfrac{exp(x_{t-1}^T\beta_2)}{1 + exp(x_{t-1}^T\beta_2)} \end{bmatrix},$$

where $p_t^{ij} = P(S_t = j | S_{t-1} = i)$ is a time-varying transition probability (model TVPMS), evolving as a logistic function of $x_{t-1}^T\beta_i$, and matrix x_{t-1}^T (or x_t^T) contains variables that affect transition probabilities. We assume that:

$$R_t = \mu_{s_t} + b_{s_t}R_{t-1} + \varepsilon_t \quad \text{and} \quad \varepsilon_i \sim N(0, \sigma_{s_t}). \tag{1}$$

If there is no statistically meaningful impact of the exogenous variables x_t^T on returns, then the TVPMS model converges to the Markov-switching model with fixed transition probabilities (MS model). In this case, the LM test statistic could be applied to test the null hypothesis, which assumes that the considered models are equivalent against the alternative hypothesis which assumes that the dynamic model is better (Vuong, 1989). This statistic takes the following form:

$$LM = 2\big(l(\theta) - l_F(\theta_1)\big), \tag{2}$$

where $l(\theta)$ and $l_F(\theta_1)$ are the log-likelihood functions of the models with time-varying and fixed transition probabilities, respectively. Despite the fact that in this test the classical regularity conditions are not fulfilled, the asymptotic distribution of LM is the central chi-square distribution (Czapkiewicz, 2018; Vuong, 1989; White & Domiwitz, 1984).

2.2. The procedure of estimating the Markov-switching model parameters

The estimation of the unknown model parameters is performed on the basis of the Hamilton filters (Hamilton, 1990). Let θ denote the collected parameters $(\mu_1, \mu_2, b_1, b_2, \sigma_1, \sigma_2)$ from (1) and parameters of the transition probabilities: $\beta_1 = (\beta_{01}, \beta_{11})$, $\beta_2 = (\beta_{02}, \beta_{12})$. The log-likelihood function takes the following form:

$$l(\theta) = \sum_{t=1}^{T} \log\Big(\sum_{j=1}^{2} f_{s_t}(r_t|\Omega_{t-1};\theta)\, P(S_t = s_t|\Omega_{t-1};\theta)\Big), \tag{3}$$

where $f_{s_t}(\cdot)$ is the distribution of the random variable R_t conditional on the information set Ω_{t-1} in the $\mathrm{s_t}$ state, $s_t \epsilon \{1, 2\}$, and r_t is the observable of return at time t. Let η_t denote a vector of two densities governed by the Markov process at date t:

$$\eta_t = [f_1(r_t|\Omega_{t-1};\theta), f_2(r_t|\Omega_{t-1};\theta)]^T, \tag{4}$$

and let $\hat{\xi}_{t|t-1}$ denote the collected conditional probabilities $P(S_t = j|\Omega_{t-1};\theta)$:

$$\hat{\xi}_{t|t-1} = [P(S_t = 1|\Omega_{t-1};\theta), P(S_t = 2|\Omega_{t-1};\theta)]^T. \tag{5}$$

The optimal inference and forecast for each t in the sample can be found by iteration, using the following pair of equations:

$$\hat{\xi}_{t|t} = \frac{\hat{\xi}_{t|t-1} \odot \eta_t}{1^T(\hat{\xi}_{t|t-1} \odot \eta_t)},$$

$$\hat{\xi}_{t|t+1} = P_t \hat{\xi}_{t|t}.$$

Hence, the symbol $\odot$ denotes an element-by-element multiplication. The log-likelihood function takes now the form presented below:

$$l(\theta) = \sum_{t=1}^{T} \log\left(1^T\left(\hat{\xi}_{t|t-1} \odot \eta_t\right)\right).$$

The parameter estimates of the standard Markov-switching model (MS) are performed in the same way, but instead of the time-varying transition matrix, we take a matrix with fixed transition probabilities. To evaluate the model's goodness-of-fit, we use the diagnostic test proposed by Diebold et al. (1998). Let F be the conditional cumulative distribution functions of R_t. If a distribution is correctly specified, $u_t = F(r_t | R_{t-1}; \theta_1)$ should be i.i.d. uniform [0, 1] distributed.

3. Empirical study

3.1. Data

The research concerns five countries: the USA, Germany, the United Kingdom (as developed markets), and Poland and Turkey (as East European, emerging markets). The US stock exchange is the one with the largest capitalisation in the world, Germany has the strongest economy in Europe, whereas the London Stock Exchange is the largest stock market in Europe. The Warsaw Stock Exchange represents the stock markets of Eastern Europe and has long been part of the group of developing markets. The Turkish stock exchange represents behaviour typical for developing markets. We consider monthly returns of main stock indices, computed as $r_{it} = \ln \frac{P_{i,t}}{P_{i,t-1}}$, where $P_{i,t}$ is the closing price of i-th index in t, and $P_{i,t-1}$ is the closing price in the previous month (i.e. the closing price of the last session in a given month). The following indices were considered: WIG (Poland), DAX (Germany), FTM (UK), XU (Turkey), and SPX (S&P500, the USA). Monthly data values of the indices came from the period of January 2001 to January 2019. We decided to use monthly data, as the selected exogenous variables are noted on a monthly basis. Table 1 presents the basic descriptive statistics for all indices' returns: mean, median and standard deviation. The mean of the returns ranges from 0.2 to 1.1 percent. The largest mean is for Turkey, whereas the lowest – for Germany. The mean of the Polish index's returns is 0.06 percent which situates it in second place (after Turkey). In all the cases, the median is higher than the mean, which is also reflected in negative skewness. Kurtosis is high, compared to the value of 3 for normal distribution. All things considered, the return rates of these indices come from distributions typical for financial data: with most of the values very small, but positives, and some rare, but severe losses. The standard deviation is the largest for Turkey. All the series were also tested with the Dickey-Fuller test, which confirmed their stationarity (p-value < 0.01).

Table 1. Descriptive statistics of indices' returns

Country (index)	Mean	Median	Standard deviation	Skewness	Kurtosis
The US (SPX)	0.003	0.009	0.042	−0.457	16.432
Germany (DAX)	0.002	0.008	0.060	−0.166	9.788
The UK (FTM)	0.005	0.008	0.048	−0.585	10.734
Poland (WIG)	0.006	0.007	0.061	−0.692	10.337
Turkey (XU)	0.011	0.015	0.095	−0.227	8.064

Note. The table reports descriptive statistics of monthly indices' returns from January 2001 to January 2019. All means are insignificant.
Source: authors' calculation.

We consider financial, sentiment and macroeconomic factors to investigate their co-movement with stock indices. As financial factors, we take into account the VIX and TED spread indices. The VIX is a volatility index, often referred to as 'fear index'. It was first introduced by the Chicago Board Options Exchange (CBOE) in 1993 to measure expectations of the volatility of the S&P500 index's options. The price of an option represents the expectations of a 30-day forward-looking volatility. The TED spread is computed as the difference between the three-month U.S. government Treasury bill and the three-month LIBOR and is considered to be an indicator of credit risk. High values mean that investors are prone to allocating money into secure government treasury bills, rather than lending them to banks.

As a sentiment factor, we consider the ZEW Index. The German Zentrum für Europäische Wirtschaftsforschung (ZEW) Economic Sentiment Index is based on a survey of German institutional investors and analysts. Positive values indicate optimism, whereas negative ones are a sign of pessimism.

The considered macroeconomic factors (such as the consumer price index, long-term interest rate, and the unemployment rate) are defined for each country separately. As the long-term interest rate, we consider the price of 10-year bonds. We also included the price of oil, as it is well known for its importance for financial markets.

3.2. Results of the study

First of all, we have considered the MS model. Table 2 presents the estimation results, from which we can assume the existence of two states. The first state, which can be identified as prosperity, is characterised by positive mean and a relatively small standard deviation. The second one, identified as a crisis, has usually a twice as big standard deviation and an insignificant or negative mean. Only for the UK, we observe a significant b_2 in the state of high volatility, so a negative return in a $(t-1)$ is going to be exaggerated in the next t, deepening the crisis. In the state of prosperity, the autoregressive parameter is significant only in the USA. Its negative value suggests that in times of prosperity downs follow ups and vice versa, impeding a chain-reaction effect. In the period of prosperity, the average rate of return remained at the same level, although the highest was in Germany (1.4%), the lowest – in Poland (1.1%). On the other hand, during crisis, the average of returns was the lowest in Germany (–1.7%), and the highest in Turkey (0.05%), although they weren't significant. At the same time, we should note a very high variance in both regimes on the Turkish market (6.5% and 14%, respectively).

Table 2. Estimated parameters of the Markov-switching model with fixed transition parameters

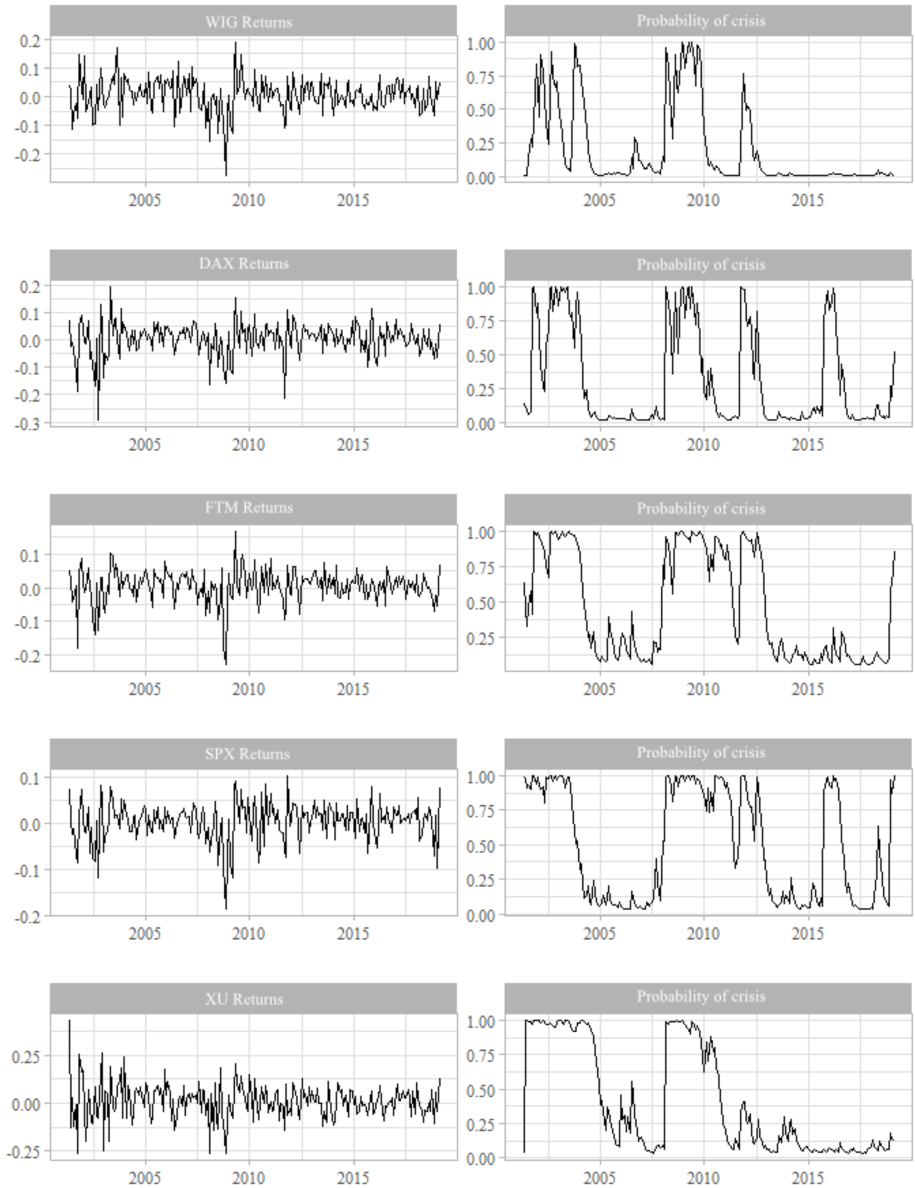
Country	μ_1	b_1	σ_1	μ_2	b_2	σ_2
Poland	0.011***	–0.081	0.043***	–0.001	0.157	0.088***
Germany	0.014***	–0.050	0.035***	–0.017	0.066	0.088***
The UK	0.012***	–0.040	0.032***	–0.007*	0.206**	0.068***
The US	0.013***	–0.167***	0.022***	–0.005	0.167	0.055***
Turkey	0.012***	0.053	0.065***	0.005	–0.202	0.140***

Note. The results of the Markov-switching model parameters, estimated using Hamilton filtering. The model switches between two AR(1) processes, each described by constant μ, an autoregressive parameter b, and a standard deviation of errors σ. The significant parameters at 1% are marked by ***, at 5% by **, at 10% by *.

Source: authors' calculation.

To verify the assumption that the volatility of returns during the crisis period is much greater than in the prosperity period, a restrictive test was performed. As these states are identified primarily by the change in variance, LM tests were performed against models with the restriction that standard deviations in both states are equal. In each country, the difference turned out to be significant (p-value < 0.01). In each case, the null hypothesis of homogeneity of variance was rejected. This proves that returns come from two distributions with significantly different variances. Subsequently, in order to evaluate the goodness-of-fit of the MS model, the test described in the previous section was carried out. For all cases we obtained a p-value ≥ 0.05, so the Markov-switching between the two AR(1) models is here an appropriate description.

Figure 1. Returns' volatility (left panel) and conditional probabilities of being in the second regime (associated with crisis) from the MS model (right panel)



Source: authors' calculation.

Figure 1 shows the volatility of returns (left panel) and the conditional probability of being in the second regime obtained from the MS model (right panel). The graphs in Figure 1 allow the conclusion that the high values of conditional probability indicate the periods when high volatility is observed. The financial literature suggests that the high return volatility is driven mainly by a rising uncertainty in the stock market (Ang & Bekaert, 2002; Forbes & Chinn, 2004; Longin & Solnik, 1995; Ramchand & Susmel, 1998). Therefore, the states display a close link with the mood on stock markets.

The first common period of high volatility can be related to the crash of the dot-com bubble, which was caused by excessive speculation in internet-based companies at the end of the 20th century. After a few peaceful years, the conditional probability of being in the second regime has increased around 2007, which marked the beginning of the world-wide financial crisis, followed by a severe recession. The strong, conditional probability of being in this regime peaked around 2008 when the volatility of returns was particularly high, which was connected with the bankruptcy of the Lehman Bank. The years 2010–2012 was also a period of high volatility in effect of the fiscal problems in the EU.

Table 3. Correlations between indices' returns and exogenous variables

Index	VIX	TED spread	ZEW	Unemployment	CPI	Oil price returns	Long-term interest rate
WIG	–0.495***	–0.071	0.238***	–0.041	0.024	0.259***	–0.268***
SPX	–0.758***	–0.091	0.142*	–0.171**	0.092	0.289***	0.358***
XU	–0.355***	–0.103	0.128*	–0.097	0.005	0.148*	–0.586**
DAX	–0.619***	–0.076	0.115*	–0.120**	0.044	0.158*	0.304***
FTM	–0.672***	–0.202**	0.178**	–0.029	0.079	0.291**	0.125**

Note. The table presents the correlations between indices' returns and exogenous variables. The stationarity of the exogenous data has been verified by means of the ADF test. As they are not stationary (except ZEW), the difference of the first order is used. The significant parameters at 1% are marked by ***, at 5% by **, at 10% by *.

Source: authors' calculation.

Table 3 presents the correlations between the increments of the VIX, TED spread, the ZEW, unemployment, the CPI, oil price returns, and long-term interest rates, with return rates of stock indices. These correlations may serve as an initial step in the analysis, suggesting what can be expected of the coefficients in the final models. A relatively high (as an absolute value) negative correlation can be observed between the VIX and all the considered indices' returns. This correlation is higher for developed markets than for emerging ones. The correlation coefficients with TED spread are rather small (ranging from –0.202 to –0.071) and insignificant (except for the FTM). The correlation coefficients with the ZEW index are moderate (from 0.115 to 0.178).

The lowest coefficient is observed for the DAX index, while the highest for the WIG. This may mean that when the consumer sentiment in Germany is optimistic, the rates of return on the Polish stock exchange are likely to increase relatively more than in Germany. The negative correlation coefficients with increments of the unemployment rate are insignificant. The highest one (as an absolute value) is for the SPX. Insignificant correlation coefficients are obtained for the CPI factor. The oil price returns are relatively highly correlated with stock market indices (the highest correlation coefficient is for the UK and the US, while the lowest for Turkey). Long-term interest rates seem to be the second most important factor (after VIX). The data indicate a positive correlation for developed markets, while a negative one for Poland and Turkey. Moreover, for the latter, it seems to be the most strongly correlated factor (-0.586).

In the next stage of the research, we verify which of the factors affect the transition between states. For this purpose, we use the Markov-switching model with a time-varying matrix transition probability, where transition probabilities p_t^{ii}, $(i = 1, 2)$, are the logistic function of $x_t^T \beta_i$, where: $x_t^T \beta_i = \beta_{0i} + \beta_{1i} Z_t$, and Z_t denotes a given factor. If there is no statistically meaningful impact of this factor on the stock market, then the TVPMS model converges to the Markov-switching model with fixed transition parameters. Therefore, for each case, we tested the null hypothesis of the Markov-switching model with fixed transition parameters against the alternative of the model with time-varying transition parameters.

Table 4. Estimated parameters of the TVPMS model and LM statistics

Factors	μ_1	b_1	σ_1	μ_2	b_2	σ_2	β_{01}	β_{11}	β_{02}	β_{12}	LM
Poland											
VIX	0.019	−0.164	0.049	−0.071	0.232	0.078	8.681	**−2.099**	−4.193	2.300	**39.658**
	0.000	0.048	0.000	0.190	0.078	0.000	0.061	**0.070**	0.503	0.469	**0.000**
TED SPREAD	0.012	−0.170	0.041	−0.007	0.308	0.086	4.847	**−0.317**	0.810	−0.037	**14.411**
	0.002	0.148	0.000	0.381	0.107	0.000	0.008	**0.082**	0.320	0.107	**0.000**
ZEW	0.012	−0.065	0.043	−0.004	0.159	0.084	4.357	**0.128**	2.764	−0.009	**7.465**
	0.003	0.469	0.000	0.729	0.231	0.000	0.015	**0.098**	0.017	0.738	**0.024**
Unemploy-ment	0.013	−0.076	0.044	−0.009	0.179	0.087	3.309	30.511	1.885	**37.295**	**5.582**
	0.003	0.442	0.000	0.560	0.241	0.000	0.000	0.254	0.017	**0.022**	**0.061**
CPI	0.013	−0.074	0.044	−0.008	0.166	0.085	4.262	**11.072**	2.113	0.984	2.066
	0.003	0.442	0.000	0.535	0.266	0.000	0.013	**0.098**	0.009	0.701	0.355
Oil	0.011	−0.050	0.042	−0.005	0.169	0.088	2.871	−3.006	3.887	−6.527	0.439
	0.006	0.546	0.000	0.722	0.255	0.000	0.013	0.412	0.014	0.850	0.803
Interest rate	0.011	−0.076	0.043	−0.005	0.155	0.087	3.662	**−1.963**	2.079	−0.387	**53.034**
	0.018	0.921	0.000	0.722	0.368	0.000	0.001	**0.004**	0.012	0.837	**0.000**

Table 4. Estimated parameters of the TVPMS model and LM statistics (cont.)

Factors	μ_1	b_1	σ_1	μ_2	b_2	σ_2	β_{01}	β_{11}	β_{02}	β_{12}	LM
USA											
VIX	0.022	−0.091	0.025	−0.045	0.319	0.034	4.901	**−2.059**	−0.401	**0.768**	**81.388**
	0.000	0.055	0.000	0.000	0.002	0.000	0.004	**0.003**	0.251	**0.003**	**0.000**
TED SPREAD	0.013	−0.093	0.023	−0.013	0.144	0.061	4.161	**−0.244**	1.451	−0.098	**9.639**
	0.000	0.284	0.000	0.177	0.324	0.000	0.002	**0.012**	0.016	0.241	**0.008**
ZEW	0.012	−0.117	0.023	−0.005	0.174	0.057	3.003	**0.068**	2.576	0.016	**5.363**
	0.000	0.257	0.000	0.406	0.116	0.000	0.000	**0.055**	0.000	0.387	**0.068**
Unemploy-	0.013	−0.166	0.023	−0.004	0.166	0.054	4.602	−22.807	2.935	3.407	4.020
ment	0.000	0.118	0.000	0.543	0.121	0.000	0.080	0.165	0.000	0.768	0.133
CPI	0.011	−0.158	0.022	−0.004	0.172	0.056	3.462	0.150	2.836	0.053	2.004
	0.000	0.143	0.000	0.510	0.132	0.000	0.000	0.381	0.000	0.814	0.367
Oil	0.014	−0.106	0.023	−0.011	0.113	0.058	5.264	**29.204**	1.939	−13.066	**9.272**
	0.000	0.254	0.000	0.189	0.410	0.000	0.001	**0.016**	0.004	0.203	**0.009**
Interest rate	0.019	−0.173	0.028	−0.039	0.211	0.043	4.694	**18.273**	−0.213	**−3.117**	**11.189**
	0.000	0.013	0.000	0.000	0.156	0.000	0.013	**0.019**	0.677	**0.044**	**0.004**
Turkey											
VIX	0.013	0.062	0.066	0.001	−0.218	0.147	4.190	−0.130	3.729	0.256	1.810
	0.015	0.442	0.000	0.949	0.120	0.000	0.000	0.755	0.004	0.186	0.405
TED SPREAD	0.013	0.064	0.066	−0.001	−0.212	0.144	28.397	−0.946	3.618	0.036	**14.634**
	0.014	0.431	0.000	0.945	0.117	0.000	0.829	0.787	0.000	0.203	**0.002**
ZEW	0.012	0.015	0.065	0.009	−0.171	0.144	4.414	**0.052**	4.585	−0.036	**4.678**
	0.030	0.866	0.000	0.660	0.206	0.000	0.000	**0.092**	0.079	0.438	**0.096**
Unemploy-	0.009	0.057	0.067	−0.075	−0.416	0.124	14.944	−23.89	4.903	0.157	4.414
ment	0.026	0.380	0.000	0.072	0.180	0.000	0.547	0.657	0.000	0.804	0.110
CPI	0.012	0.074	0.066	0.002	−0.019	0.136	4.602	−0.790	2.115	3.720	3.464
	0.016	0.656	0.000	0.908	0.164	0.000	0.000	0.864	0.012	0.266	0.176
Oil	0.013	0.041	0.066	0.002	−0.192	0.143	4.484	2.005	6.440	−31.925	3.387
	0.020	0.791	0.000	0.878	0.144	0.000	0.000	0.972	0.034	0.109	0.183
Interest rate	0.050	−0.325	0.034	−0.045	−0.139	0.040	14.312	−42.08	0.814	**2.509**	**41.575**
	0.000	0.001	0.000	0.000	0.736	0.000	0.862	0.734	0.244	**0.070**	0.000
Germany											
VIX	0.025	−0.097	0.039	−0.067	0.151	0.061	4.293	**−1.458**	−0.192	**0.493**	**43.752**
	0.000	0.387	0.000	0.000	0.020	0.000	0.001	**0.004**	0.119	**0.027**	**0.000**
TED SPREAD	0.013	−0.038	0.035	−0.017	0.065	0.090	3.542	**−0.038**	2.060	−0.003	2.219
	0.000	0.274	0.000	0.083	0.252	0.000	0.000	**0.034**	0.000	0.862	0.329
ZEW	0.013	−0.047	0.036	−0.018	0.070	0.090	3.075	**0.071**	2.704	−0.006	**7.299**
	0.000	0.298	0.000	0.075	0.289	0.000	0.000	**0.038**	0.001	0.756	**0.026**
Unemploy-	0.012	−0.007	0.036	−0.018	0.075	0.094	3.958	17.331	2.545	**28.959**	**5.720**
ment	0.000	0.925	0.000	0.188	0.581	0.000	0.001	0.135	0.009	**0.023**	**0.057**
CPI	0.012	−0.016	0.036	−0.017	0.061	0.093	3.004	1.000	4.618	**−6.356**	**5.032**
	0.000	0.850	0.000	0.163	0.635	0.000	0.000	0.491	0.065	**0.093**	**0.080**
Oil	0.013	−0.029	0.038	−0.024	0.041	0.093	3.538	15.226	4.345	−16.230	**5.075**
	0.000	0.711	0.000	0.124	0.779	0.000	0.000	0.122	0.018	0.130	**0.079**
Interest rate	0.012	−0.024	0.037	−0.019	0.068	0.093	4.741	**13.112**	2.388	−0.810	**6.701**
	0.001	0.768	0.000	0.176	0.611	0.000	0.000	0.034	0.000	0.848	**0.035**

Table 4. Estimated parameters of the TVPMS model and LM statistics (cont.)

Factors	μ_1	b_1	σ_1	μ_2	b_2	σ_2	β_{01}	β_{11}	β_{02}	β_{12}	LM
						UK					
VIX	0.022	0.055	0.032	−0.049	0.603	0.043	2.744	**−2.080**	−2.169	1.091	**70.155**
	0.000	0.116	0.000	0.000	0.000	0.000	0.007	0.041	0.052	0.232	**0.000**
TED SPREAD	0.012	0.027	0.035	−0.046	0.632	0.075	2.725	**−0.137**	−0.829	−0.006	**10.513**
	0.000	0.737	0.000	0.071	0.014	0.000	0.003	0.038	0.271	0.9877	**0.005**
ZEW	0.012	−0.002	0.032	−0.007	0.210	0.072	4.901	**0.177**	3.168	0.089	3.949
	0.000	0.620	0.000	0.000	0.100	0.000	0.856	0.078	0.104	0.204	0.138
Unemployment	0.010	0.001	0.033	−0.036	0.753	0.072	2.505	−15.242	2.284	3.575	2.832
	0.002	0.826	0.000	0.081	0.045	0.000	0.045	0.189	0.004	0.785	0.243
CPI	0.011	0.0041	0.032	−0.010	0.188	0.072	1.195	0.009	−1.526	−0.610	3.203
	0.000	0.981	0.000	0.007	0.001	0.000	0.195	0.574	0.059	0.122	0.202
Oil	0.014	−0.014	0.031	−0.032	0.739	0.064	1.213	**9.384**	−1.606	−6.604	**6.686**
	0.000	0.665	0.000	0.017	0.012	0.000	0.069	0.098	0.032	0.101	**0.035**
Interest rate	0.012	−0.047	0.034	−0.019	0.178	0.080	6.071	**24.711**	−0.287	−1.723	**9.707**
	0.000	0.692	0.000	0.343	0.292	0.000	0.006	0.034	0.324	0.473	**0.007**

Note. The table shows the TVPMS model parameters with their p-values, estimated using Hamilton filtering. The model switches between two AR(1) processes, each described by a constant μ, an autoregressive parameter b, and a standard deviation of errors σ. The transition probabilities matrix is described by parameters $\beta_1 = [\beta_{01}, \beta_{11}]$, $\beta_2 = [\beta_{02}, \beta_{12}]$. LM is a test statistic, used to compare models from Table 4 against respective models with fixed transition probabilities, presented in Table 2. The significant beta parameters and high LM values are marked in **bold**.

Source: authors' calculation.

The full set of the estimated model parameters with corresponding p-values is presented in Table 4. For all cases, we obtained statistically significant volatility parameters $\sigma_{i,}(i = 1, 2)$. We want to pay special attention to columns β_{11}, β_{12}, and LM. Parameter β_{11} provides information on how the values of the exogenous variable affect the probability of staying in the first state (prosperity), whereas β_{12} – in the second state (crisis). A significant LM statistic indicated that the adoption of a dynamic transition probability matrix, based on the exogenous variable, actually improved the model.

When analysing the results presented in Table 4, it can be noticed that, in general, the factor of the greatest importance is the VIX. For almost every country we obtained a high value of the LM statistic and p-value $= 0.000$. It turned out insignificant only for the Turkish market. The statistical significance of the β_{11} or β_{12} coefficients shows the influence of this factor on probabilities p_t^{11} or p_t^{22}. For the USA and Germany, the VIX impacts both p_t^{11} and p_t^{22}. The negative sign of parameter β_{11} indicates that an increase in the VIX values weakens the probability of staying in the first regime, whereas the positive sign of parameter β_{12} indicates that a decrease in the VIX values weakens the probability of staying in the second state. In the USA and Germany, a rising VIX index not only indicates a high probability of an oncoming crisis in the state of prosperity but also a low probability of rebounding in the state of crisis. For the Polish and British markets, only parameter β_{11} proves significant.

For all the studied countries, we also performed tests for Granger's causality and found that the value of the VIX has an impact on transition probabilities in the following month.

Similar results were obtained for the TED spread factor. As noted in Table 3, the increases in this indicator are very weakly correlated with returns. Despite this, when analysing results collected in Table 4, we observed a relatively high value of the LM statistic and p-value < 0.05 in most of the countries. However, the fact that only β_{11} is significant, shows that it affects only the p_t^{11} probability, i.e. the probability of staying in the first regime. The negative sign of this parameter implies that an increase in the TED spread values weakens this probability.

In other words: an increasing 'fear index' or credit risk is a sign that the market is more likely to shift into a state of crisis. For the Turkish market, we have not observed the TED spread factor's importance on probabilities p_t^{11} or p_t^{22}. However, the inclusion of this indicator in the model significantly improves the parameter estimation ($LM = 14.634$, p-value < 0.05).

The results presented in Table 4 indicate that also the ZEW index plays an important role in market volatility modelling. We can notice that β_{11} differs significantly from zero for all the analysed markets. The positive sign of this parameter indicates that the higher the expectations, the greater the probability that the market will remain in the first state. This means that, in general, investors and analysts have accurate information at their disposal on the state of the economy. The highest β_{11} parameters were observed for Poland and the UK. However, in the case of the UK, an additional inclusion of the ZEW index in the model does not significantly improve the accuracy of the parameter estimation ($LM = 3.949$, p-value $= 0.138$).

As regards the macroeconomic factors, it should be noted that the unemployment rate was important only in Poland and Germany, while CPI solely in Germany. In Poland, unemployment seems to have a significant positive impact on the probability of staying in the second state ($\beta_{12} = 37.295$). In Germany, a similar pattern is observed, i.e. parameter β_{12} also significantly diverges from zero ($\beta_{12} = 28.96$). The estimates of these parameters suggest that when the unemployment rate decreases, the probability of staying in crisis also decreases. For the remaining countries, both beta parameters are insignificant, but signs of their estimates reveal the fact that unemployment has a negative impact on the markets. This trend is common among all the countries, which corresponds with the theoretical expectations. Unemployment is a strong determinant of the condition of an economy and its rapid growth may indicate an economic downturn.

In Poland, the CPI seems to have a positive impact on the probability of staying in the first regime, although the overall model is not significantly better than the MS. In Germany, a considerably negative parameter β_{12} signifies that when the inflation rate decreases, the probability of remaining in the second state increases. The same direction was observed for other developed markets, but both beta parameters are insignificant. Summing up, the CPI growth seems to have a favourable impact on stock exchanges.

This part of the paper is devoted to a discussion on the impact of the oil prices returns on the stock market. This factor is important for all of the analysed developed markets. As we can notice, oil prices returns have a significantly positive impact on the probability of staying in the first state in the USA,[2] Germany and the UK. Oil prices returns also have a slightly negative impact on the probability of remaining in the second state, as expected. The existing positive relationship between oil prices and assets prices was documented by Apergis & Miller (2009), Ferson & Harvey (1994), Huang et al. (1996), Kilian & Park (2009), Narayan & Narayan (2010) and others.

For all the analysed developed markets, long-term interest rates are also important. Statistically significant parameters β_{11} (for the USA $\beta_{11} = 18.273$; for Germany $\beta_{11} = 13.122$; for the UK – $\beta_{11} = 17.711$) indicate a positive impact on the probability of remaining in the first state. For the USA, the rise in long-term rates is related to the decreasing probability of staying in the state of crisis. For other developed markets, negative parameter β_{12} suggests the direction of change in the probability of being in the second state; however, these parameters seem to be insignificant.

We also found long-term interest rates important for the modelling of emerging markets. However, the direction of this relationship is quite the opposite to that of the developed economies. For the Turkish market returns, parameter β_{12} is significantly greater than zero, and parameter β_{11} less than zero, but it is insignificant. This means that interest rates negatively impact the market, especially in bad economic times. Poland follows a similar pattern, however here parameter β_{11} equals significantly less than zero and parameter β_{12} (estimate is greater than zero) is insignificant, so in this case, the relationship in the first regime, i.e. in the period of prosperity, is more meaningful.

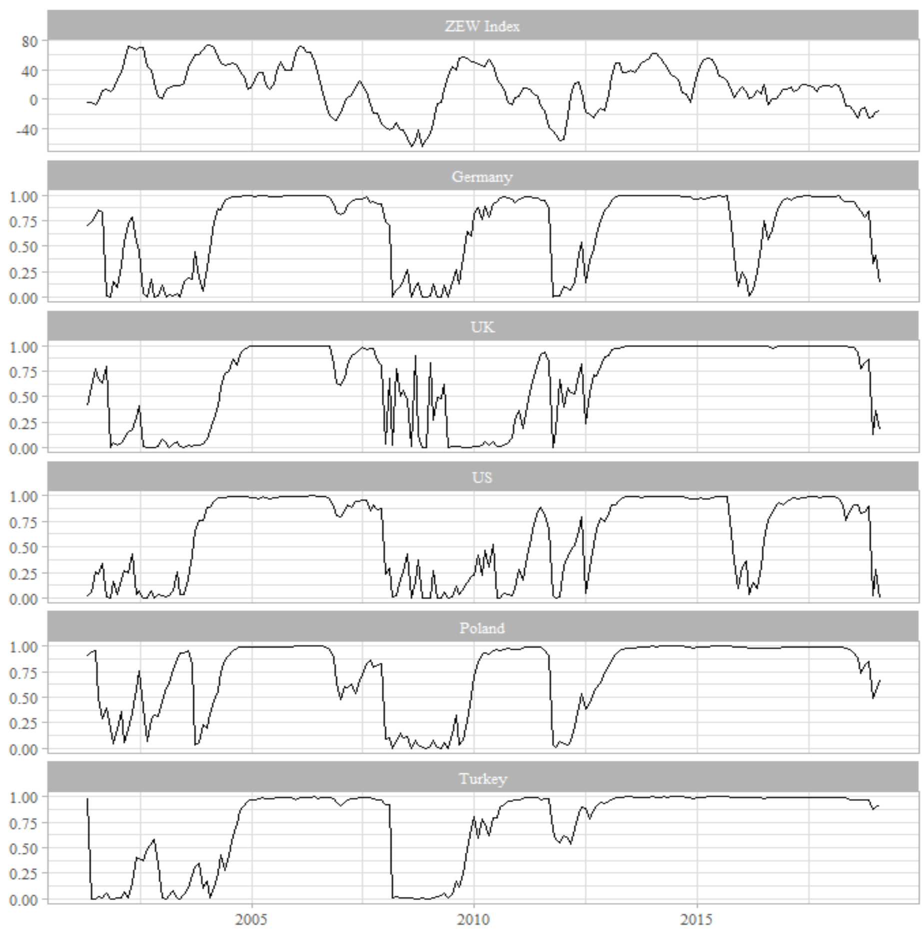
To sum up, most factors are important for developed markets. We have found that high prices of oil, 10-year bonds, and the ZEW index can be connected with a high probability of staying in the first state, whereas an increase in the VIX index

[2] These results are similar to the findings of Chen et al. (1986), according to which the growth rate of oil prices impacts positively the expected returns (however, a significant impact was observed only between 1956-67).

and the TED spread significantly reduces the probability of staying in this state. The ZEW and LTI factors are also important for both emerging markets. Furthermore, for the Polish stock market, as well as for German, domestic macroeconomic factors are significant. A high unemployment rate indicates a high probability of a crisis persisting, whereas a high inflation rate can be connected with a more probable recovery.

Figure 2 shows changes in the ZEW index, compared to the probabilities of staying in the first regime. We can notice that the ZEW index is associated with the probabilities for all the analysed markets. We have noted that the decline in the ZEW index is reflected in the decreases in the probability of staying in the first regime.

Figure 2. The ZEW index and the probability of staying in the first regime (associated with prosperity), obtained from a TVPMS model with the ZEW index as an exogenous variable



Source: authors' calculations.

As expected, in the case of Germany a very high similarity is observed in the changes of the ZEW index and the probability of remaining in the first state. The largest drop in the ZEW index was noted in 2007–2009 and 2001–2012. There was a decrease in the value of this index after 2015 and 2018. These decreases were reflected in the decrease in the probability of remaining in the first regime. A similar pattern of the relationship occurred for the USA, Poland and Turkey.

4. Conclusions

The aim of the study was to check which variables affect regime shifts. Its contribution is the verification of the thesis that both global factors (such as the VIX, TED spread, oil prices, the ZEW index) and selected macroeconomic variables (e.g. the consumer price index, long-term interest rates or the unemployment rate) may be important for the state of volatility of markets. Particular attention has been devoted to the impact of the ZEW sentiment factor on the markets. To the authors' best knowledge, this factor has not been widely examined yet. The applied methodology allowed the analysis of the importance of the factors in each state (prosperity or crisis) separately. The application of the TVPMS model in practice enabled the determination whether the examined factors are of greater importance in the period of prosperity or in the period of crisis. And again, as far as the authors know, such study has not been conducted for the Polish or Turkish market before. There has also been very little research done on the ZEW index so far.

The analysis revealed that there is no uniform and general set of indicators influencing market volatility. In the case of large, developed markets such as the USA, Great Britain or Germany, a wide range of the considered exogenous indicators have some impact on the returns dynamic. We have discovered that high returns of prices of oil, 10-year bonds, and the ZEW index can be related to the high probability of staying in the first state, whereas an increase in the VIX index and the TED spread significantly reduces the probability of remaining in this state. The positive impact of 10-year bonds and the ZEW index on the market was discussed by Hüfner & Schröder (2002), Kvietkauskienė & Plakys (2017) and others.

The ZEW and 10-year bonds indicators have proven important not only for the developed markets that were analysed in this study, but also for the two emerging ones. Although the research showed a positive impact of the ZEW index on market volatility, it also indicated the opposite relationship between 10-year bonds and rates of return than in the case of the developed markets.

Domestic macroeconomic factors play an important role for the Polish and German stock markets. A high unemployment rate indicates a strong probability of a crisis persisting, whereas a high inflation rate usually signals a greater probability of economic recovery.

The article considered three developed and two emerging markets. On their basis, some observations could have been made. However, the formulation of a more general conclusion (relating to the difference between developing and developed markets) requires a much wider study, which the authors decided to carry out in their subsequent research.

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