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Asymmetric stochastic volatility in central and eastern European stock markets

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Abstract. *The goal of this paper is to investigate the asymmetric impact of innovations on volatility and the relationship between the stock return and volatility dynamics in the case of Central and Eastern European (CEE) markets using the framework of asymmetric stochastic volatility models. The empirical findings provide weak evidence of asymmetry, a significant and high volatility persistence in the stock markets of the CEE region. The most interesting and different results obtained from the present paper are that there are both of a high variability of volatility and a high volatility persistence in the stock markets of Poland and Lithuania. Additionally, the stock markets of the Czech Republic and Hungary, which have leverage effect, have lower variability of volatility and in these markets the future volatility is relatively certain as compared to the other stock markets from the CEE region.*

Keywords: Asymmetric Stochastic Volatility, MCMC, Central and Eastern European Markets.

JEL Classification: C11, G10.

1. Introduction

The volatility of asset returns is still one of the major issues of financial econometrics. The understanding of volatility in stock markets matters because volatility has an important role in option pricing, portfolio management and asset allocation. It is well known that stock market volatility, defined as the conditional variance or standard deviation of stock returns, changes over time.

The relationship between a stock market index (or a stock price) and its volatility has been studied widely in market economies and also it is well documented that a negative shock increases the stock market volatility more than the positive shock at the same magnitude and this circumstance is described as “asymmetry”. As mentioned in Cappiello et al. (2006), asymmetric volatility could be handled in two ways: “leverage effect” and “volatility feedback effect”. The leverage effect is described as the notion that a fall in stock price causes an increase in the debt-equity ratio (financial leverage) of the firm and the risk (volatility) of the firm increases right after (Selçuk, 2005). On the other hand, volatility feedback effect is specified as the notion that once volatility is priced, an expected increase in volatility enhances the required return on equity, leading to an urgent stock price downfall. The main difference between leverage effect and volatility feedback effect is the direction of causality between stock returns and volatility. In the leverage effect, the direction of causality is running from the stock returns to volatility whilst the volatility feedback effect implies that the causality running from the volatility to stock returns.

The main goal of the present paper is to investigate the asymmetric impact of innovations on volatility and the relationship between the stock return and volatility dynamics in the case of Central and Eastern European (CEE) markets, which have been researched far less than the other markets, using univariate asymmetric stochastic volatility approach. Although stock return and its volatility in advanced markets has been well studied, there exist relatively few contributions to return and volatility dynamics in the transition markets of the CEE region.

The stock markets of the CEE countries are known as comparatively young markets and the volatility in the CEE stock markets tends to be relatively higher in comparison with advanced stock markets. Also, the trading volume and the number of traded firms of the CEE stock markets are narrow but are growing at a greater rate than advanced markets.

The present paper differs from the extant literature in the following way: to the best of our knowledge, it is the first study that examines the stock returns and volatility dynamics and asymmetric innovations to volatility in the stock markets from the CEE region using the framework of the asymmetric stochastic volatility models.

The remainder of the paper is organized as follows: in section 2 we discuss the literature review and in section 3 we present the econometric methodology. Section 4 contains the data description and empirical results of the study. The 5th and last section includes conclusions.

2. Literature Review

As mentioned above, there exist fewer empirical studies on the transition markets of the CEE region and the empirical findings on asymmetric volatility are conflicted. Shields (1997) investigated the volatility in the stock markets of CEE region, i.e. Poland and Hungary using GARCH model and its extensions and reported that no asymmetry in the volatility of returns was found.

Kasch-Haroutounian and Price (2001) used GARCH model and its extensions in their empirical study and found out weak evidence of asymmetric volatility in the stock markets of the Czech Republic, Hungary, Poland and Slovakia in the CEE region.

Murinde and Poshakwale (2001) examined volatility in the stock markets from the CEE region, i.e. Croatia, the Czech Republic, Hungary, Poland, Russia and Slovakia using the traditional GARCH model and its extensions. They reached the findings on the persistency of volatility and also the findings on no asymmetric impact of innovation on volatility for the most of markets.

Harrison and Moore (2012) analysed the volatility in ten stock markets of CEE countries, i.e. Bulgaria, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovenia and Slovak Republic, using the traditional GARCH model and its extensions. They also concluded that the asymmetric volatility exists in the stock markets of CEE region.

Olbryś (2013) explored the volatility in the CEE stock markets, i.e. Poland, the Czech Republic, and Hungary using EGARCH model and reported that negative innovations have a higher impact on volatility than positive innovations, so the asymmetric volatility exists in the stock markets of Poland, the Czech Republic, and Hungary.

Okičić (2014) also used GARCH models and its extensions to investigate the stock markets of Bosnia and Herzegovina, Bulgaria, Croatia, the Czech Republic, Hungary, Macedonia, Montenegro, Poland, Romania, Serbia, Slovakia and Slovenia and found out evidence of asymmetric volatility and leverage effect in the CEE stock markets.

3. Econometric Methodology

A general representation of a volatility model for a stationary series of returns r_t takes the form:

$$r_t = \mu_t + y_t$$
$$y_t = \sigma_t \varepsilon_t \tag{1}$$

where ε_t is i.i.d. random variable with zero mean and unit variance and σ_t is either a deterministic of stochastic random process which depends on the past values of returns. μ_t denotes either a constant or an autoregressive variable with a parameter close to zero and y_t denotes a stochastic process i.e. demeaned returns.

The main issue is related to which process σ_t follows; if σ_t is expressed as a deterministic function of lagged (squared) returns, we are within the ARCH models (Engle, 1982; Bollerslev, 1986), which have achieved widespread popularity in applied empirical research (Pellegrini and Rodriguez, 2007). On the other hand, when σ_t is expressed as a stochastic function of an unobserved latent variable, we introduce the stochastic volatility model proposed by Taylor (1986). Stochastic volatility models are attractive because they are close to the models often used in Financial Theory to represent the behaviour of financial prices and their statistical properties are easy to derive using well-known results on log-normal distributions (Broto and Luiz, 2004). The main relative advantages of stochastic volatility models are discussed by Carnero et al. (2004) and also Das et al. (2011) emphasise that stochastic volatility models have the capability to provide one-step-ahead prediction and to better harmonise with excess kurtosis and leverage effects compared to GARCH models.

The stochastic volatility model is represented as the following form;

$$y_t = \exp\left(h_t / 2\right)\varepsilon_t$$
$$h_t = \gamma + \phi h_{t-1} + \eta_t \tag{2}$$

where h_t is latent stochastic volatility which equals to $\ln \sigma_t^2$. ε_t is i.i.d. random variable with zero mean and unit variance and also η_t is i.i.d. random variable with zero mean and variance σ_η^2 , independent of ε_t. σ_η^2 indicates the volatility (variability) of volatility and measures the uncertainty about future volatility. The parameter ϕ is described as a measure of the persistence of shocks to the volatility. There is such a trade-off relationship between σ_η^2 and ϕ; namely when ϕ approximates to one, σ_η^2 tends to approximate to zero.

As mentioned Ghysels et al. (1996), it can be noticed that if ε_t and η_t are allowed to be correlated with each other, the model can pick up the kind of asymmetric behaviour. Indeed a negative correlation between ε_t and η_t induces a leverage effect. Harvey and Shephard (1996), propose a specification which considers contemporaneous dependence and allows the correlation between ε_t and η_t as $corr(\varepsilon_t, \eta_t) = \rho$. In other respects, Jacquier et al. (2004) propose a specification which considers intertemporal dependence and allows the correlation between ε_t and η_{t-1} as $corr(\varepsilon_t, \eta_{t-1}) = \rho$.

Asai and McAleer (2005) present a specification that captures asymmetry in "dynamic leverage" model through the direct negative correlation between returns and volatility innovations as the following form:

$$
\begin{aligned}
& y_t = \exp(h_t / 2)\varepsilon_t \\
& h_{t+1} = \mu + \phi h_t + \eta_t \qquad \varepsilon_t \sim \mathrm{N}(0,1) \qquad \eta_t \sim \mathrm{N}(0, \sigma_\eta^2) \\
& E(\varepsilon_t \eta_t) = \rho \sigma_\eta
\end{aligned} \tag{3}
$$

We could describe this type of asymmetry, namely when $\rho < 0$, as the Dynamic Leverage Stochastic Volatility model. When $\rho = 0$, there exists no dynamic leverage between the innovations to returns and volatility (Asai and McAleer, 2005).

4. Data and Empirical Results

The data set involves daily closing price indices of nine CEE countries (due to data availability) for the period from January 26, 2010 to January 23, 2015, a total of 1,304 observations and consists of stock indices of Bulgaria, Croatia, the Czech Republic, Estonia, Hungary, Lithuania, Poland, Romania and Slovenia. The source of data is the Morgan Stanley Capital Index (MSCI) database and the stock indices are the MSCI indices of selected countries. Furthermore, according to MSCI classification, Bulgaria, Croatia, Estonia, Lithuania, Romania and Slovenia are described as the frontier markets and on the other hand, the Czech Republic, Hungary and Poland are classified as the emerging markets. Finally, we calculate the stock returns from the stock market indices of the selected countries using the $\ln(P_t / P_{t-1}) \times 100$ formula where P_t denotes the value of the stock price indices of each country at time t.

The descriptive statistics for the stock returns of each stock market indices are reported in Table 1. All of the stock return series have small mean and the standard deviations of the stock returns are greater than the means of stock returns, indicating that the stock market of CEE countries follow a random walk process.

Except for Estonia and Hungary, the other returns series have negative skewness. Additionally, the excess kurtosis for each is significantly positive, indicating that they have heavy tails relative to the normal distribution, which is also typical in these financial data (Ding and Vo, 2012).

The stochastic volatility models can be estimated using different techniques. The most popular approaches are the quasi-maximum likelihood method as proposed by Harvey and Shephard (1996) and the Markov Chain Monte Carlo (MCMC) method, which was introduced by Jacquier et al. (1994). In this study, we employ the MCMC approach for estimating Dynamic Leverage model and we use the code provided by Yasuhiro Omori[(1)] utilized for the WinBUGS software. In MCMC estimation strategy, we determine the prior values as μ~Inverse-Normal$\left(\text{-}10,1\right)$, ρ~Inverse-Uniform$\left(\text{-}1,1\right)$, σ_η^2~Inverse-Gamma$\left(2.5,0.025\right)$ and ϕ~Inverse-Beta$\left(20,1.5\right)$ following Yasuhiro Omori and MCMC sampler is also initialized by setting the values $\mu = -9$, $\sigma_\eta^2 = 100$, $\phi = 0.95$ and $\rho = -0.4$ following also Yasuhiro Omori. We obtain the posterior means of the coefficients ignoring the first 10.000 iterations and utilizing the following 90.000 iterations in all cases. The posterior means of parameter estimates with 95% posterior credibility intervals are presented in Table 2.

The estimation results shown in Table 2 indicate that the volatility persistence coefficients ϕ are in between 0.798 (Croatia) and 0.997 (Poland) and except for Croatia and Slovenia, the empirical findings imply that there exists a remarkable volatility persistence and strong evidence of volatility clustering in the CEE stock markets.

Table 1. *Descriptive Statistics of the Stock Returns*

	Bulgaria	Croatia	Czech Republic	Estonia	Hungary	Lithuania	Poland	Romania	Slovenia
Mean	-0.035	-0.041	-0.044	-0.004	-0.066	-0.005	-0.018	0.006	-0.037
Median	0.000	0.000	0.000	-0.045	-0.024	0.000	0.001	0.025	-0.035
Maximum	5.321	7.332	6.958	9.175	16.257	5.375	10.590	11.397	5.087
Minimum	-6.743	-6.997	-6.872	-6.764	-10.671	-9.160	-11.221	-13.946	-6.484
Std. Dev.	1.485	0.985	1.454	1.545	2.204	1.110	1.813	1.679	1.211
Skewness	-0.066	-0.515	-0.252	0.142	0.081	-0.887	-0.377	-0.384	-0.139
Kurtosis	4.383	10.544	5.055	6.421	7.056	12.554	7.073	11.469	4.585
Jarque-Bera	104.81	3147.78	243.10	639.82	894.43	5126.96	931.56	3925.89	140.57
Probability	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Observations	1303	1303	1303	1303	1303	1303	1303	1303	1303

The posterior means of the coefficient $\hat{\rho}$, indicating the correlation between innovations to returns and volatility, are negative and statistically significant at the 5% level for only three out of CEE stock markets which are the Czech Republic, Hungary and Poland. The smallest value is -0.23 for the Czech Republic and the highest value is -0.397 for Hungary. It can be concluded that there is a leverage effect in the stock markets of the Czech Republic, Hungary and Poland so a negative shock increases the stock market volatility more than the positive shock at the same magnitude in these markets. These findings are consistent with the findings of Kasch-Haroutounian and Price (2001), Murinde and Poshakwale (2001) and Olbryś (2013).

In other respects, the posterior means of the volatility of volatility coefficient $\hat{\sigma}_\eta$, indicating the measure of uncertainty about the future volatility are within the range of 0.135 (Hungary) and 0.514 (Lithuania). Except for the Czech Republic, Hungary and Romania, it can be concluded that the CEE stock markets exhibit a high variability of volatility and also the future volatility is uncertain in these stock markets.

Table 2. *The Estimation Results of the Posterior Means of Parameters*

	$\hat{\mu}$		$\hat{\phi}$		$\hat{\rho}$		$\hat{\sigma}_\eta$	
Bulgaria	-8.704*		0.894*		-0.082		0.330*	
	(0.102)		(0.033)		(0.079)		(0.063)	
	[-8.904	-8.500]	[0.821	0.948]	[-0.237	0.071]	[0.221	0.457]
Croatia	-9.578*		0.798*		0.024		0.444*	
	(0.081)		(0.067)		(0.083)		(0.083)	
	[-9.733	-9.414]	[0.641	0.904]	[-0.139	0.187]	[0.294	0.620]
Czech Republic	-8.692*		0.962*		-0.230*		0.151*	
	(0.134)		(0.018)		(0.112)		(0.039)	
	[8.959	-8.438]	[0.920	0.988]	[-0.443	-0.002]	[0.092	0.238]
Estonia	-8.804*		0.953*		-0.036		0.294*	
	(0.196)		(0.017)		(0.088)		(0.055)	
	[-9.195	-8.422]	[0.915	0.983]	[-0.209	0.133]	[0.177	0.402]
Hungary	-8.158*		0.983*		-0.397*		0.135*	
	(0.325)		(0.009)		(0.113)		(0.029)	
	[-8.966	-7.703]	[0.962	0.996]	[-0.619	-0.174]	[0.093	0.203]
Lithuania	-9.479*		0.992*		-0.095		0.514*	
	(0.898)		(0.003)		(0.071)		(0.035)	
	[-11.300	-7.774]	[0.986	0.998]	[-0.233	0.043]	[0.447	0.586]
Poland	-9.600*		0.997*		-0.289*		0.412*	
	(0.990)		(0.001)		(0.081)		(0.034)	
	[-11.560	-7.670]	[0.994	0.999]	[-0.441	-0.123]	[0.348	0.481]
Romania	-8.650*		0.973*		-0.121		0.190*	
	(0.230)		(0.011)		(0.107)		(0.033)	
	[-9.129	-8.226]	[0.949	0.990]	[-0.325	0.091]	[0.137	0.261]
Slovenia	-9.033*		0.806*		-0.103		0.354*	
	(0.072)		(0.067)		(0.088)		(0.075)	
	[-9.174	-8.892]	[0.649	0.908]	[-0.273	0.075]	[0.225	0.517]

Notes: The posterior standard deviations and 95% posterior credibility intervals are presented in the parentheses and brackets, respectively. * denotes statistical significance at the 5% level.

The findings on the coefficient $\hat{\sigma}_\eta$ are interesting for Poland and Lithuania. Actually, it would be expected that there exists a trade-off between the volatility of volatility and volatility persistence and if the volatility of volatility is high, the volatility persistence tends to be relatively low. However, we find out that there is both a high variability of volatility and a high volatility persistence in the stock markets of Poland and Lithuania.

In these stock markets, volatility clustering occurs and in addition to this, future volatility is relatively uncertain by comparison with the other stock markets from the CEE region.

5. Conclusions

The present paper is a first attempt to find out stock market volatility dynamics in the CEE economies using the framework of asymmetric stochastic volatility models. The data set involves daily closing MSCI price indices of nine CEE countries and consists of stock indices of Bulgaria, Croatia, the Czech Republic, Estonia, Hungary, Lithuania, Poland, Romania and Slovenia.

The empirical findings provide weak evidence of asymmetry for only three of the CEE stock markets which are the Czech Republic, Hungary and Poland. The estimation results display that there is a leverage effect in the stock markets of the Czech Republic, Hungary and Poland so a negative shock increases stock market volatility more than a positive shock at the same magnitude in these markets. So it can be concluded that the leverage effect is in existence for the markets which are called emerging markets in the CEE region.

Also it is shown that the CEE stock markets have a significant and high volatility persistence. Especially it can be implied that the volatility clustering occurs in the stock markets of Bulgaria, the Czech Republic, Estonia, Hungary, Lithuania, Poland and Romania. Moreover, the empirical results demonstrate that there exists a high variability of the volatility in stock markets of the CEE region which are Bulgaria, Croatia, Estonia, Lithuania, Poland and Slovenia.

The most interesting and unique results obtained from the present paper are that there is both a high variability of volatility and a high volatility persistence in the stock markets of Poland and Lithuania. Additionally, we can conclude that the stock markets of the Czech Republic and Hungary, which have leverage effect, have lower variability of volatility and in these markets the future volatility is relatively certain as compared to the other stock markets from the CEE region.

The results presented in this paper could be a guide for the investors who are planning to invest in stock markets from the CEE region.

Note

(1) Code used in MCMC estimations of the parameters can be downloaded from Professor Yasuhiro Omori's web site http://www.omori.e.u-tokyo.ac.jp/WinBUGS/index.htm

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