Cross-Border Spillover of Returns and Volatility in the Baltic Stock Markets

Alar Kein
Estonian Business School
e-mail: alar.kein@ebs.ee

Abstract

This paper investigates if, and to what extent returns and volatility in the Baltic stock markets (Estonia, Latvia, Lithuania) are influenced by the returns and volatility in international stock markets. The consolidated impact of world stock markets on the Baltic stock markets is studied by applying a VAR-EGARCH-based framework and using daily as well as weekly data from the period January 3rd, 2000 to December 31st, 2012. Attention is given to possible sign- and size-related asymmetries in the spillover of returns and volatility. The author finds robust evidence in support of the hypothesis of significant spillover of returns from the world stock markets into the Baltic stock markets and revealsthe asymmetric nature as well as the cross-market differences of the cross-border spillover of returns and volatility.

Keywords: *stock returns, spillover, transmission, stock market, asymmetric impact*

1. INTRODUCTION

Along with the liberalization in financial markets, integration of economies and advancements in information technology, the inter-market linkages have attracted ever more attention of researchers and practitionersin recent decades. As a result, a considerable amount of empirical evidence on cross-market spillovers of returns and volatility, has emerged. However, the available empirical evidence is mostly built upon the studies of interrelationship of largerstock markets (SMs), while the impact of exogenous price- and volatility-changes in small SMs of open economies, has found considerable less attention. Among such markets are also the SMs of the three Baltic States – Estonia, Latvia and Lithuania. While the cross-border spillover of returns and volatility in the Estonian SM has been earlier studied by the author (see Kein, 2009), there is only very littleknown on the role of external shocks in the Latvian and Lithuanian SMs. Besides, there is also no evidence on the Estonian SM, which would be based on more recent data. The current paper tries to fulfill the gap in the empirical literature and focuses on the impact of world SMs on three small SMs of open economies – the SMs of Estonia, Latvia and Lithuania, which, in general can be called as the Baltic SMs.By applying the same methodological framework with regard to all the three Baltic SMs, this study also attempts to highlight the cross-market similarities and differencies in the exposure to external shocks. Identification of spillover channels and underlying factors that could explain the differences or similarities in the spillover of exogenous returns and volatility as well as the study of structural breaks, is left for further studies.

The current study addressesfivemain research questions:

- is there a spillover of returns from world SMs into the Baltic SMs?
- does the impact of exogenous negative returns differ from the impact of exogenous positive returns of the same magnitude?
- does the response of the Baltic SMs depend on the absolute size of exogenous returns?
- is there a spillover of volatility from world SMs into the Baltic SMs?
- does the impact of exogenous volatility-increases differ from the impact of exogenous volatility-decreases of the same magnitude?

This paper is structured in the following way. First, a brief review of empirical literature on the cross-market spillover of returns and volatility, is provided. Thereafter, the methodology is described. This is followed by the presentation and discussion of results. The paper ends with the overall conclusions and suggestions for further research.

2. LITERATURE REVIEW

Transmission of returns and volatilities across SMs has been reported in a large number of studies, most of which have emerged just within the last two decades. These studies have focused either on the interrelationship of returns and volatilities of major international SMs (e.g., Hirayama & Tsutsui,1998) or examined the inter-regional (e.g.,Ratanapakorn & Sharma, 2002) or intra-regional (e.g., Alkulaib et al, 2009; Yilmaz, 2010) linkages of returns and volatility.

Thestudies that are available up to date cover geographically wide range of markets. For instance, Billio and Pelizzon (2003) have focused onthe European SMs,Égert and Kočenda (2007) have focused on Central and Eastern EuropeanSMs, Yilmaz (2010) has taken under investigation the East Asian SMs, Alkulaib et al (2009) have studied the MENA SMs, Johnson and Soenen (2003) have examined the American SMs, while,Ratanapakorn and Sharma (2002) have taken a more global approach and examined the inter-market relationships in major international and regional SMs. Thus, the empirical evidence that has emerged, is geographically rather broad-based

In general, the findings of studies are overwhelmingly supportive of the hypothesis of cross-border spillover of returns as well as volatility, regardless of the method applied or frequency of data used. The studies also tend to suggest that the size of the impact and the structural aspects of spillover are rather market-specific and often dependent on the period studied and frequency of data used.

Majority of the studies of inter-market linkages investigate the interrelationships between individual markets. The role of consolidated returns in the world SMs on the national SM, is examined only in relatively few studies. For instance, Jouini (2013) and Billio and Pelizzon (2003) have incorporated the MSCI world index into their studies.Generally, the findings in those studies that use global returns, remain supportive of the hypothesis of the cross-border spillover of returns and volatility.

While most of the studies simply try to establish whether certain markets have significant impact on the others, few of the studies have examinedalso on the structural and dynamic aspects of the spillover of returns and volatility. Among the structural aspects the researchers have focused mostly on two types of asymmetric effects: 1) sign-related-asymmetries and 2) size-related-asymmetries. Sign-related-asymmetries havebeen studied for instance by Hirayama and Tsutsui (1998), Verma and Verma (2005). The empirical evidence that is provided by these studies supports the hypothesis of asymmetric impact of positive and negative news (returns, shocks) and suggests that negative news (returns, shocks) in one market have a greater impact on the other markets than positive news of the same magnitude. Asymmetries have been found also in the process of inter-market transmission of small and large returns (shocks). For instance, Hirayama and Tsutsui (1998)find that small exogenous index-changes do not affect the other country's index, while large exogenous index-changes have a significant effect in most cases. Such threshold effect in international linkage of stock prices is reported also by other studies. Yet, compared to the empirical evidence of the existence of sign-related-asymmetries, there is much less empirical evidence on the existence of magnitude-related-asymmetries.

A number of studies have focused also on the dynamics of inter-market linkage and tested the structural breaks in inter-market linkages (e.g., Billio & Pelizzon, 2003). Overall, the empirical evidence that is provided by these studies strongly suggests that the inter-market linkages strengthen during the crisis periods.

Thus, theaccumulated empirical evidence that is based ondiversity of SMs studied, periods considered, methodologies applied and frequencies of data used, allows to expect significant and asymmetric spillover of returns and volatility from the world SMs into the Baltic SMs.

3. METHODOLOGY

3.1. Models Applied

Studies of short-term causal relationships rely extensively on ARCH-based models, whichallow to take into account some of the most widely accepted stylised facts about the distributional characteristics of stock returns. Namely, that: 1) the volatility of stock returns occurs in clusters, 2) the distribution of stock returns exhibits leptokurtosis. (see for instance,Cont, 2001).

As the preliminary examination of distributional characteristics of data reveals accordance with the stylized facts, the VAR-EGARCH framework, which accounts for these chracteristics and which isbased on the works of Engle (1982), Bollerslev (1986) and Nelson (1991), is chosen as a methodological framework for the present study. In total six models are designed to investigate the cross-market spillover of returns and volatility.Four of these models allow for spillover of returns only, while two of the models allow for simultaneous spillover of returns as well as volatility from world SMs into the Baltic SM studied.All these models rely on simplified assumptions: 1) the return in a Baltic SM is a function of its own lag(s) and contemporaneous and/or lagged returns in world SMs, 2) the variance of returns is time-varying, and possibly a function of exogenous volatility-changes, 3) there is no spillover from the Baltic SMs into world SMs given the smallness of the Baltic SMs.

The simplest model, **Model 1** is specified by the following framework (Eq.1-3):

$$\ln R_{B,t} = c_B + \sum_{k=1}^{h} \beta_{B,k} \ln R_{B,t-k} + \sum_{g=0}^{n} \beta_{W,g} \ln R_{W,t-g} + \varepsilon_{B,t} \quad \text{(Eq.1)}$$

$$\varepsilon_{B,t} \mid \varphi_{B,t-1} \sim N(0, \sigma^2_{B,t}) \quad \text{(Eq.2)}$$

$$\ln \sigma^2_{B,t} = \omega_B + \sum_{j=1}^{p} \lambda_{B,j} \ln \sigma^2_{B,t-j} + \sum_{l=1}^{q} \left(\gamma_{B,l} \frac{\varepsilon_{B,t-l}}{\sigma_{B,t-l}} + \alpha_{B,l} \left| \frac{\varepsilon_{B,t-l}}{\sigma_{B,t-l}} - \sqrt{\frac{2}{\pi}} \right| \right) \quad \text{(Eq.3)}$$

where the subscript *B* refers to the Baltic SM studied and *W* stands for world SM. B={EST; LAT; LIT}, where *EST, LAT* and *LIT* denote respectively the Estonian, Latvian andLithuanian SMs. The log return in the Baltic SM is denoted by$\ln R_{B,t}$,*h* is the autoregressive order applicable to the returns in the appropriate Baltic SM, $\ln R_{W,t-g}$is the return in the worldSM at time *t-g*; *n* represents the number of lags.In case of daily data both, the contemporaneousand one-trading-day-lagged returns in the world SM enter into the model as explanatory variables due to the partly-overlapping trading hours.In case of weekly data the exogenous returns are the weekly returns calculated with a one-trading-day-lag compared to the endogenous market. $\varepsilon_{B,t}$ is the error term at time t, $\varphi_{B,t-1}$ is the information set available on the Baltic SM at time $t-1$, $\sigma^2_{B,t}$is the conditional variance of stock returns in the given Baltic SM at time t.q is the order of ARCH terms and p is the order of GARCH terms in the conditional volatility equation. $\beta_{B,k}$, $\beta_{W,g}$, $\alpha_{B,l}$, $\lambda_{B,j}$, $\gamma_{B,l}$ are the parameters, ω_B is a constant. The impact of time $t-g$ returns in the world SM on the time t returns in the Baltic SM is measured by coefficient $\beta_{W,g}$. The coefficient $\beta_{B,k}$ captures the impact of time $t-k$ endogenous returns on the time t returns in the Baltic SM. Parameters $\lambda_{B,j}$ and $\alpha_{B,l}$ indicate whether the conditional variance of returns in the Baltic SM depends on its own past realizations and past innovations, respectively. The parameter $\gamma_{B,l}$reveals whether the impact of past endogenous negative shocks differs from the impact of past endogenous positive shocks on the conditional variance of returns in the Baltic SM.

Model 1 excludes the direct impact of exogenous shocks on the conditional variance of the Baltic SM. The cross-border spillover of returns is allowed only in the mean equation(captured by $\beta_{W,g}$), while the possible sign- or size-related asymmetric impact of exogenous price movements is neglected in the mean equation.

Model 2, which is described by Eq.2, Eq.3 and Eq.4 extends the mean equation of Model 1 andallows positive and negative exogenous and endogenous returns to have different impact on the returnsin the Baltic SM studied. In this model, the mean equation is specified as follows:

$$\ln R_{B,t} = c_B + \sum_{k=1}^{h} \beta_{B,k} \ln R_{B,t-k} + \sum_{k=1}^{h} \beta_{B,k}^{-} \ln R_{B,t-k} D_{B,t-k}^{-} + \sum_{g=0}^{n} \beta_{W,g} \ln R_{W,t-g} + \\ + \sum_{g=0}^{n} \beta_{W,g}^{-} \ln R_{W,t-g} D_{W,t-g}^{-} + \varepsilon_{B,t}$$

(Eq.4)

Where $D^-_{B,t-k}$ is a dummy variable that takes a value of 1 if $lnR_{B,t-k}$< 0, and 0 if $lnR_{B,t-k}$≥ 0. Similarly, $D^-_{W,t-g}$ is a dummy variable that takes a value of 1 if $lnR_{W,t-g}$< 0, and 0 if $lnR_{W,t-g}$≥ 0.Within this setting, the sign-based asymmetric effect of exogenous returns iscaptured by the coefficient $\beta^-_{W,g}$, while the sign-based asymmetric effect of endogenous lagged returns on the mean return in the Baltic SM is captured by the coefficient$\beta^-_{B,k}$.

Size-related asymmetric effects are introduced by **Model 3**, which is described by Eq.2, Eq.3 and Eq.5. In this model, the mean equation takes the following form:

$$\ln R_{B,t} = c_B + \sum_{k=1}^{h} \beta_{B,k} \ln R_{B,t-k} + \sum_{k=1}^{h} \beta_{B,k}^{\%} \ln R_{B,t-k} D_{B,t-k}^{\%} + \sum_{g=0}^{n} \beta_{W,g} \ln R_{W,t-g} + \sum_{g=0}^{n} \beta_{W,g}^{\%} \ln R_{W,t-g} D_{W,t-g}^{\%} + \varepsilon_{B,t} \qquad \text{(Eq.5)}$$

$D^{\%}_{B,t-k}$and $D^{\%}_{W,t-g}$in Eq.5 are dummy variables.$D^{\%}_{B,t-k}$=1 if$|\ln R_{B,t-k}|\geq$s, and 0 otherwise; $D^{\%}_{W,t-g}$=1 if $|\ln R_{W,t-g}|\geq$s, and 0 otherwise, whereas s=0.03. The asymmetric impact of returns of different absolute sizes is revealed by the coefficients $\beta^{\%}_{B,k}$and $\beta^{\%}_{W,g}$.

Model 4, which is described by Eq.2, Eq.3 and Eq.6, allows simultaneously sign- as well as size-related asymmetries. In Model 4, the mean return is specified as follows:

$$\ln R_{B,t} = c_B + \sum_{k=1}^{h} \beta_{EST,k} \ln R_{B,t-k} + \sum_{k=1}^{h} \beta_{B,k}^{\%} \ln R_{B,t-k} D_{B,t-k}^{\%} + \sum_{k=1}^{h} \beta_{B,k}^{-} \ln R_{B,t-k} D_{B,t-k}^{-} + \sum_{k=1}^{h} \beta_{B,k}^{\%-} \ln R_{B,t-k} D_{B,t-k}^{\%} D_{B,t-k}^{-} + \sum_{g=0}^{n} \beta_{W,g} \ln R_{W,t-g} + \sum_{g=0}^{n} \beta_{W,g}^{\%} \ln R_{W,t-g} D_{W,t-g}^{\%} + \sum_{g=0}^{n} \beta_{W,g}^{-} \ln R_{W,t-g} D_{W,t-g}^{-} + \sum_{g=0}^{n} \beta_{W,g}^{\%-} \ln R_{W,t-g} D_{W,t-g}^{\%} D_{W,t-g}^{-} + \varepsilon_{B,t} \qquad \text{(Eq.6)}$$

$B^{\%-}_{B,k}$ and $\beta^{\%-}_{W,g}$ are the coefficients that detect the possible asymmetric impact of negative returns that exceed 3% (in absolute terms).The dummy variables $D^{\%}_{B,t-k}$, $D^{\%}_{W,t-g}$, $D^{-}_{W,t-k}$, $D^{-}_{W,t-g}$ are described as in Eq.4 and Eq.5.

Exogenous volatility spillovers are considered by Model 5 and Model 6. These models introduce the exogenous variables - the variances of returns in the world SM, into the theconditional variance equation. **Model 5**, which is specified by Eq.1, Eq.2 and Eq.7 neglects possible asymmetries in the spillover of returns as well as volatility. **Model 6**, which is described by Eq.2, Eq.4 and Eq.8 allows sign-based asymmetries both, in the spillover of returns as well as in the spillover of volatilities.

In Model 5 the conditional variance is specified as follows:

$$\ln\sigma_{B,t}^2=\omega_B+\sum_{j=1}^{p}\lambda_{B,j}\ln\sigma_{B,t-j}^2+\sum_{l=1}^{q}\left(\gamma_{B,l}\frac{\varepsilon_{B,t-l}}{\sigma_{B,t-l}}+\alpha_{B,l}\left|\frac{\varepsilon_{B,t-l}}{\sigma_{B,t-l}}-\sqrt{\frac{2}{\pi}}\right|\right)+ \\ +\sum_{g=0}^{n}\theta_{W,g}\ln\left(\frac{\sigma_{a,W,t-g}^2}{\sigma_{a-1,W,t-g-1}^2}\right) \qquad \text{(Eq.7)}$$

where$\vartheta_{W,g}$ is a parameter that indicates the spillover of volatility from world SM into the Baltic SM studied; $\sigma^2_{a,W,t-g}$ denotes the variance of returns in the worldSM at time*t-g*, which is calculated based on the *a* most recent trading days (weeks) (including the time *t-g* data) in the world SM. For daily-returns-based-models *a*=22; for weekly-returns-based-models *a*=5; $\sigma^2_{a-1,W,t-g-1}$ is the variance of returns in the world SM at time *t-g-1*, which is calculated based on the *a-1* most recent trading days (or weeks) (including the time *t-g-1* data). The choice of *a*tries to emphasize the relevance of moderately recent historical performance only. The changes in these exogenous variances described serve as a proxy for the term „volatility“within the current paper.

The conditional variance equation in Model 6 takes the following form:

$$\ln\sigma_{B,t}^2=\omega_B+\sum_{j=1}^{p}\lambda_{B,j}\ln\sigma_{B,t-j}^2+\sum_{l=1}^{q}\left(\gamma_{B,l}\frac{\varepsilon_{B,t-l}}{\sigma_{B,t-l}}+\alpha_{B,l}\left|\frac{\varepsilon_{B,t-l}}{\sigma_{B,t-l}}-\sqrt{\frac{2}{\pi}}\right|\right)+ \\ +\sum_{g=0}^{n}\theta_{W,g}\ln\left(\frac{\sigma_{a,W,t-g}^2}{\sigma_{a-1,W,t-g-1}^2}\right)+\sum_{g=0}^{n}\theta_{W,g}^{+}D_{W,t-g}^{+}\ln\left(\frac{\sigma_{a,W,t-g}^2}{\sigma_{a-1,W,t-g-1}^2}\right) \qquad \text{(Eq.8)}$$

where $D^+_{W,t-g}$is a dummy variable that takes a value of 1 if $ln(\sigma^2_{a,W,t-g}/\ \sigma^2_{a-1,W,t-g-1})>0$ and 0 otherwise, and $\vartheta^+_{W,g}$ is a coefficient that captures the asymmetric effect of exogenous volatility-changes.

No *ex ante* restrictions are imposed on the expected sign of the coefficients characterizing the impact of exogenous returns. Similarly, no*ex ante* restrictions are imposed on the sign of the overall impact of market's returns in any of the models applied. The impact coefficient of market's returns as well as the overall expected impact of market's return can be either positive, zero or negative. *Ex ante* restrictions, however are imposed on the coefficients characterizing the spillover of volatility. Considering that there is no reasonable explanation for opposite-directional response to exogenous volatility-changes, it is assumed that the overall expected impact of a volatility-change in an exogenous SM must be positive in order to conclude that there is a spillover of volatility from an exogenous SM into the Baltic SM studied.This restriction imposed is an empirical and not a technical one.

3.2. Data used

The present study employs dailyas well as weekly nominal log returns in the Estonian, Latvian, Lithuanianand the world SM from the period January 3rd, 2000 to December 31st, 2012. The returns in these SMs are calculated as follows:

$$ln\ R_{i,t} = ln\ (I_{i,t} / I_{i,t-1}) \quad \text{(Eq.9)}$$

where $I_{i,t}$ and $I_{i,t-1}$ denote respectively the closing value of benchmark index in market *i* at time *t* and at time *t-1*. Weekly returns in the Baltic SMs are Wednesday-to-Wednesday returns. Weekly returns in the world SM are Tuesday-to-Tuesday returns in order to avoid using any information that arrives after the closing of Baltic SMs. The returns in the Estonian SM are calculated based on the OMX Tallinn Index. The returns in the Latvian SM are based on the OMX Riga Index. Thereturns in the Lithuanian SM are derived from the OMX Vilnius Index. For the exogenous market – the world SM, the Euro-based FTSE-All-World-Index, serves as the proxy.The data on closing values of these indexes were obtained from Thomson Reuters Datastream.

All the return series appear to be characterized bynon-normal distribution.None of the time series usedexhibits unit root, as implied by the Augmented Dickey-Fuller test results.The returns in the Baltic SMs follow an autoregressive process. The optimal autoregressive order (*h*) is selected based onthe Bayesian Information Criterion .

Few, but important issues related to data, should be pointed out before the results are discussed. As the closing value of the FTSE-All-World-Index is calculated after the closing of the trading in the Baltic SMs, the time *t* exogenous returns that are calculated based on the closing values of FTSE-All-World-Index contain both, the information that was available during the opening hours of the Baltic SMs at time *t* as well as the information that arrived at time *t* after the closing of trading in the Baltic SMs.This implies that when using time *t* exogenous returns as explanatory variables, also the future information is regarded as explanatory variable. At the same time it also implies that when using only time *t-1* exogenous returnsas explanatory variables, the newest information that has arrived during the opening hours of the Baltic SMs at time *t*, is ignored.The ideal solution to avoid these issues would be to use synchronized intraday data. As the intraday data on FTSE All-World Index were not available for the author, itwas considered appropriate to treat both, the one-trading-day-lagged and the contemporaneous daily exogenous returns as the concurrent explanatory variables for the daily returns inthe Baltic SMs. This approach ensures that all the new information that arrives in the world SMs since the closing of the Baltic SMs at time *t-1* until the closing of the Baltic SMs at time *t*, will be contained in the explanatory variables of time *t* returns in the Baltic SMs. To justify the use of time *t* exogenous daily returns as explanatory variables, it can be pointed out that,with certain reservation, the time *t*exogenous daily returns could be treated as the (perfect) expected daily returns in the world SM and, therefore, could be used as the proxies for the daily returns in the world SM at the closing time of the Baltic SMs. In case of weekly returns, a more conservative approach was adopted. In order to avoid using any future information in an explanatory variable, the weekly returns in the world SM, which enter into the models as explanatory variables, were calculated with a lag of one day. Although this approach means that some of the newest information is ignored, the relative loss of the newest information is relatively low compared to the daily returns. At the same time, this more conservative approach ensures that only the information, which was available by the closing time of the Baltic SM, is used in modelling the returns and volatility in the Baltic SMs.

In any case, it is evident that the use of closing value-based returns in the conditions of partly overlapping trading hours and non-overlapping closing times may create noise in the regression results. Thehigher is the frequency of data used, the larger is likely to be the degree of such noise. Aside the exogenous returns, the noise may also arise from the endogenous returns. As the Baltic SMs are relatively thin markets,the large spread between the bid andask prices can lead to overestimation of the volatility as well as returns in these markets. This concern is mostly relevant in case of daily returns. Given these potential biases that may affect the results, the results obtained from using lower frequency (weekly) returnsare likely to produce more accurate estimatesthan the results that are based on higher frequency (daily) returns, *ceteris paribus*.

4. RESULTS

4.1. Results obtained from daily data

The regression results obtained from the daily data are presented in Tables 1-3. Given the focus of this paper, the discussion that follows will be limited to the role of exogenous returns and volatility only. The discussion is structured in the following way: first, the results of daily data are discussed market by market. Thereafter, the main findings from weekly data, are outlined for each of the market. Generalized findings and cross-market differences are presented in the conclusions. In the discussion that follows, the estimated coefficients significant at 5% levelare referred to as (statistically)

„significant". Thecoefficients significant at 5% level are marked as bold and figures in brackets are the standard errors in the Tables of regression results. Given the size restrictions imposed by the conference organizers, only the coefficients that reveal the exogenous spillover, are reported. Full results are readily available upon request.

Table 1. Results: daily, Estonia

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
$\beta_{W,0}$	**0.183** (0.015)	**0.102** (0.028)	**0.175** (0.016)	**0.096** (0.035)	**0.174** (0.015)	**0.093** (0.028)
$\beta^{-}_{W,0}$		**0.147** (0.040)		**0.140** (0.052)		**0.146** (0.042)
$\beta^{\%}_{W,0}$			0.051 (0.033)	0.057 (0.059)		
$\beta^{\%-}_{W,0}$				**0.049** (0.076)		
$\beta_{W,1}$	**0.180** (0.015)	**0.125** (0.029)	**0.160** (0.017)	**0.116** (0.033)	**0.181** (0.016)	**0.133** (0.029)
$\beta^{-}_{W,1}$		**0.100** (0.044)		0.086 (0.052)		**0.089** (0.044)
$\beta^{\%}_{W,1}$			**0.123** (0.035)	0.096 (0.057)		
$\beta^{\%-}_{W,1}$				0.071 (0.077)		
$\Theta_{W,1}$					**-0.637** (0.094)	**3.671** (0.392)
$\Theta^{+}_{W,1}$						**-5.058** (0.460)

As revealed by the results, the evidence on the significant impact of daily returns in the world SM on the daily returns in the Estonian SM is highly robust. Statistically significant and economically meaningful impact of contemporaneous as well as one-trading-day-lagged (hereafter referred to as lagged) daily exogenous returnsis implied by the results of all the six models considered. The estimated impact of lagged returns is practically of the same magnitude as the impact of contemporaneous returns. Given the share of US stocks in the FTSE All World Index and considering that the trading in the US starts after the closing of Baltic SMs, this finding is not surprising and is likely to reflect indirectly the lagged impact of the US markets. The results also reveal the existence of sign-related asymmetries in the spillover of returns and strongly suggest that the impact of negative exogenous returns exceeds substantially the impact of positive exogenous returns.Sign-related asymmetries appear to be more significant in the spillover of contemporaneous returns than in the spillover of lagged returns. Evidence on size-relatedasymmetries is somewhat weaker. General sign-related asymmetries are revealed by the results of Model 3 only, which implystronger impact oflarge lagged exogenous returns. In case of contemporaneous exogenous returns the size-related asymmetry is observable only in case of negative returns.Evidence on the spillover of volatility remains somewhat mixed. Considering *ex ante* restrictions, the estimated coefficients imply that the volatility spillover is rather limited to exogenous volatility-decreases only.

Table 2. Results: daily, Lithuania

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
$\beta_{W,0}$	**0.141** (0.012)	**-0.003** (0.031)	**0.140** (0.012)	0.011 (0.036)	**0.132** (0.012)	0.008 (0.031)
$\beta^{-}_{W,0}$		**0.247** (0.047)		**0.226** (0.058)		**0.221** (0.046)
$\beta^{\%}_{W,0}$			0.009 (0.034)	0.006 (0.071)		
$\beta^{\%-}_{W,0}$				0.033 (0.086)		
$\beta_{W,1}$	**0.081** (0.011)	**0.091** (0.033)	**0.079** (0.012)	0.041 (0.038)	**0.149** (0.017)	**0.090** (0.032)
$\beta^{-}_{W,1}$		0.093 (0.051)		**0.192** (0.058)		**0.111** (0.051)
$\beta^{\%}_{W,1}$			0.031 (0.042)	0.051 (0.079)		
$\beta^{\%-}_{W,1}$				-0.136 (0.093)		
$\Theta_{W,1}$					**-1.346** (0.120)	**1.459** (0.495)
$\Theta^{+}_{W,1}$						**-3.131** (0.531)

Robust evidence on the spillover of daily returns from world SMs is also revealed in the Lithuanian SM, whereas the evidence on the spillover is robust both, in case of contemporaneous as well as one-trading-day-lagged exogenous returns.According to theregression results, the spillover of one-trading-day-lagged exogenous returns is rather general, unconditional on the sign of the return. The spillover of contemporaneous exogenous returns, however, is rather limited to negative returns only, as implied by the significant coefficients $\beta^{-}_{W,0}$ and non-significant or negative coefficients $\beta_{W,0}$ in those models that allow sign-related asymmetries. The results also reveal thatthe spillover of one-trading-day-lagged exogenous returns is characterized by the size-related asymmetries. The hypothesis of the existence of size-related asymmetries in the spillover of daily returns does not find any support by the results. Evidence on the volatility spillover is rather weak, whereas the volatility spillover seems to be limited to volatility-decreases only.

Table 3. Results: daily, Latvia

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
$\beta_{W,0}$	**0.077** (0.017)	0.023 (0.028)	**0.074** (0.020)	0.018 (0.030)	**0.076** (0.018)	0.024 (0.028)
$\beta^{-}_{W,0}$		**0.106** (0.039)		**0.107** (0.046)		**0.102** (0.041)
$\beta^{\%}_{W,0}$			0.027 (0.040)	0.002 (0.080)		
$\beta^{\%-}_{W,0}$				0.020 (0.092)		
$\beta_{W,1}$	**0.092** (0.016)	-0.041 (0.032)	**0.097** (0.018)	-0.066 (0.037)	**0.095** (0.016)	-0.041 (0.033)
$\beta^{-}_{W,1}$		**0.218** (0.050)		**0.264** (0.067)		**0.219** (0.050)
$\beta^{\%}_{W,1}$			-0.031 (0.039)	0.033 (0.073)		
$\beta^{\%-}_{W,1}$				-0.097 (0.092)		
$\Theta_{W,1}$					-0.028 (0.094)	-0.809 (0.572)
$\Theta^{+}_{W,1}$						0.939 (0.675)

The hypothesis of the spillover of daily returns from the world SMs finds robust support also in the Latvian SM. However, the results suggest that the spillover of contemporaneous as well as one-trading-day-lagged returns is limited to negative exogenous returns only. While the evidence on sign-related asymmetries is robust, the results do not reveal any size-related asymmetries in the spillover of daily exogenous returns in the Latvian SM. Similarly, the results do support the hypothesis of the spillover of volatility from the world SMs into the Latvian SM.

4.2. Results obtained from weekly data

The regression results obtained from the weekly data are presented in Tables 4-6. Similarly to the daily data, the hypothesis of spillover of returns from world SMs into the Estonian SM finds robust support also when the weekly returns are applied. The estimated influence of exogenous returns is much stronger than implied by the results of daily data. The results also reveal the existence of sign-related asymmetries in the spillover of weekly returns and suggest that negative exogenous weekly returns have substantially larger impact in the Estonian SM than positive exogenous weekly returns. This finding coincides with the evidence provided by the results of daily data. The results of weekly data, however, do not provide any support for the hypothesis of size-related asymmetries in the spillover of returns.The hypothesis of spillover of exogenous volatility finds stronger support in theresults of weekly data than in the results of daily data, whereas, similarly to the results of daily data, the results of weekly data tend to suggest that the spillover of exogenous volatility is limited to volatility-decreases only.

Table 4. Results: weekly, Estonia

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
$\beta_{W,0}$	**0.501** (0.030)	**0.267** (0.070)	**0.450** (0.062)	0.171 (0.131)	**0.496** (0.032)	**0.290** (0.067)
$\beta^{-}_{W,0}$		**0.534** (0.104)		**0.555** (0.247)		**0.396** (0.106)
$\beta^{\%}_{W,0}$			0.085 (0.070)	0.089 (0.130)		
$\beta^{\%-}_{W,0}$				-0.053 (0.214)		
$\Theta_{W,1}$					**0.120** (0.048)	**0.594** (0.256)
$\Theta^{+}_{W,1}$						**-0.650** (0.294)

Table 5. Results: weekly, Lithuania

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
$\beta_{W,0}$	**0.258** (0.033)	0.109 (0.062)	**0.221** (0.061)	**0.322** (0.130)	**0.278** (0.038)	**0.139** (0.071)
$\beta^{-}_{W,0}$		**0.299** (0.096)		-0.193 (0.230)		**0.259** (0.113)
$\beta^{\%}_{W,0}$			0.039 (0.074)	-0.237 (0.126)		
$\beta^{\%-}_{W,0}$				**0.488** (0.203)		
$\Theta_{W,1}$					**0.349** (0.048)	-0.123 (0.312)
$\Theta^{+}_{W,1}$						0.503 (0.347)

Robust evidence on the spillover of exogenous weekly returns can be found also in the Lithuanian SM.Similarly to the findings in the Estonian SM, the estimated impact of exogenous returns in the Lithuanian SM is substantially stronger than implied by the results of daily data. Sign-related asymmetries in the spillover of returns that were revealed in the results of daily data, appear also from the results of weekly data. Similarly to the daily results, the predicted impactof negative exogenous returns in the Lithuanian SM is substantially larger than the predicted impact of positive exogenous returns. However, the results seem to attribute such stronger impact to the large negative exogenous returns only.According to the weekly results the size-relatedasymmetries are sign-specific andpresent in the spillover of negative weekly returns only. Evidence on the spillover of volatility remains relatively week in weekly data.

Table 6. Results: weekly, Latvia

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
$\beta_{W,0}$	0.030 (0.026)	**0.148** (0.063)	0.132 (0.068)	0.096 (0.114)	**0.155** (0.027)	0.006 (0.064)
$\beta^{-}_{W,0}$		0.029 (0.095)		-0.156 (0.200)		**0.356** (0.105)
$\beta^{\%}_{W,0}$			0.064 (0.075)	0.103 (0.108)		
$\beta^{\%-}_{W,0}$				0.280 (0.163)		
$\Theta_{W,1}$					-0.029 (0.670)	**2.275** (0.180)
$\Theta^{+}_{W,1}$						**-2.674** (0.194)

In contrast to the evidence from daily data, and differently from the SMs of Estonia and Lithuania, evidence on the spillover of exogenous weekly returns in the Latvian SM is rather weak. Spillover of weekly returns, regardless of the sign of return, is suggested by the results of two models only. Spillover of negative weekly returns finds support in three models. Evidence of sign-related asymmetries is weak as different impact of negative and positive exogenous weekly returns is suggested by the results of Model 5 only, which predict larger impact of negative weekly returns. Size-related asymmetries, however, do not find any support by the results of weekly data. Differently from the results of daily data, the results of weekly data provide some evidence on the spillover of volatility, by suggesting that only the exogenous volatility-decreases spill over into the Latvian SM.

5. CONCLUSIONS

As it appears from the results, the hypothesis of spillover of returns from world SMs into the Baltic SMs finds robust support in each of the Baltic SMs considered.The results reveal the cross-border spillover of contemporaneous and one-trading-day-lagged daily returns as well as weekly returns. In general(in Estonia and Lithuania) the role attributed to exogenous returns is much greater when the weekly returns instead of daily returns are used. Considering the universality of spillover as well as the size and the significance of estimated coefficients, the Estonian SM seems to be the most responsive to exogenous returns, while the Latvian SM seems to be the least responsive toexogenous returns amongst these markets.

The regression results also revealthe existence of sign-related asymmetries and strongly suggest that the impact of negative exogenous returns differs significantly from the impact of positive exogenous returns. In case of daily returns, this observation holds for all the three Baltic SMs considered. In case of weekly returns, evidence on the sign-related asymmetries is robust in case of the Estonian and Lithuanian SM.The hypothesis of the existence of size-related asymmetries, however,finds only little support. Size-related asymmetries, if these occur, are associated withthe spillover of negative exogenousreturns only.

The results offer also evidence on the spillover of volatility from world SMs into the Baltic SM and reveal the asymmetric nature of the spillover of exogenous volatility, suggesting thatthe spillover of volatility is rather limited to the exogenous volatility-decreases only.

Thus, the results of this study allow firmly to suggest that returns in the world SMs have an influential role in the formation of stock prices in the Baltic SMs. Since theestimated impact of exogenous returns in the Baltic SMsis generally the larger,the lower is the frequency of data used, it can be also suggested thatalthough the returns in these SMs may deviate from the returns in the world SM in short-run, the medium- and long-run performance of these small SMs of open economies, is likely to be determined largely by the external factors.Indeed, this suggestion is still preliminary since the spillover channels, structural breaks in the spillover as well as the long-run integration of these SMs with the world SMs, are still largely unexplored in these markets. Hopefully the current study provides motivation to undertake further studies that would enrich our knowledge on the role of external factors in these markets.

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REFERENCES

Alkulaib, Y.A., Najand, M., Mashayekh, A. (2009), “Dynamic linkages among equity markets in the MiddleEast and North African countries“, *Journal of Multinational Financial Management*, 19, pp. 43-53.

Cont, R. (2001), “Empirical properties of asset returns: stylized facts and statistical issues“, *Quantitative Finance*, Volume 1, pp. 223–236.

Billio, M., Pelizzon, L. (2003), “Volatility and Shocks Spillover before and after EMU in European Stock Markets“,*Journal of Multinational Financial Management*, 13, pp. 323-340.

Bollerslev, T. (1986), “Generalized Autoregressive Conditional Heteroscedasticity“,*Journal of Econometrics*, Vol.31, pp. 307-327.

Égert, B., Kočenda, E. (2007),“Interdependence between Eastern and Western European stock markets: Evidence from intraday data“, *Economic Systems*, 31, pp. 184-203.

Engle, R. (1982),“Autoregressive Conditional Heteroscedasticity with Estimates of the Variance of United Kingdom Inflations“,*Econometrica*, 50, pp. 987-1008.

Hirayama, K., Tsutsui, Y. (1998),“Threshold Effect in International Linkage of Stock Prices“,*Japan and the World Economy*, 10, pp. 441-453.

Johnson, R., Soenen, L. (2003), “Economic integration and stock market comovement in the Americas“,*Journal of Multinational Financial Management*, 13, pp.85-100.

Jouini, J. (2013), “Stock markets in GCC countries and global factors: A further investigation”, *Economic Modelling,*31, pp. 80-86.

Kein, A. (2009), “A Study of Spillovers of Returns and Volatilities and Associated Asymmetries in the Estonian Stock Market“, Dissertation, Clark University.

Nelson, D.B. (1991),“Conditional Heteroscedasticity in Asset Returns: A New Approach“,*Econometrica*, 59, pp. 347-370.

Ratanapakorn, O., Sharma, S.C. (2002),“Interrelationships among regional stock indices“,*Review of Financial Economics*, 11, pp.91-108.

Verma, R., Verma, P. (2005),“Do emerging markets respond symmetrically to US market upturns and downturns? Evidence from Latin America“,*International Journal of Business and Economics*, Vol.4, No.3, pp. 193-208.

Yilmaz, K. (2010), “Return and volatility spillovers among the East Asian equity markets“, *Journal of Asian Economics*, 21, pp. 304-313.