Financial contagion of the 2008 crisis: is there any evidence of financial contagion from the US to the Baltic states

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Abstract

The paper aims to investigate the research question whether the US 2008 crisis spilled over contagiously to the Baltic States as small open economies. In order to examine the evidence of financial contagion as a systematic component of financial risks in the case of the Baltic States, we employ several testing methodologies like correlation coefficients based methods adjusting also with possible heteroskedasticity and ARCH-GARCH framework. The results are somewhat mixed. On the one hand, stock returns' correlations between US and Baltic States increased during crisis times, confirming the financial contagion hypothesis. On the other hand, volatility has not spilled over from US to Estonia, Latvia and Lithuania, neither have volatility spillovers become stronger after the crisis hit.

Keywords: financial crisis, financial contagion, crisis management, Baltic states

JEL Classification: F36, P34

1. Introduction

The events associated with the US 2008 crisis, which saw many countries falling into serious problems one after another like domino stones, reminded us

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Acknowledgements: The authors of the paper are grateful to the Estonian Ministry of Education and Science (grant No SF0180037s08) and the Estonian Science Foundation (research grant No 7756) for their financial support. The views expressed in the paper are solely those of the authors and, as such, should not be attributed to other parties.

once again of the phenomenon of financial contagion as a systematic component of financial risks. Financial contagion in the broadest view means the transmission of a crisis from one economy to others which has often been quite unrelated to the fundamental problems of the countries and markets under observation. Contagious nature of financial crises undermines the risk-reducing potential of international portfolio diversification of international investors and makes countries vulnerable to the crises originating elsewhere. In the conditions of a highly global world the events that occur in one part of the world can have enormous impact on all markets and countries around the globe.

Small open economies like the Baltic States are particularly vulnerable to global economic development. Therefore financial contagion analysis is exceptionally important for these countries – EU new member countries with post-socialist path-dependence.

Since regaining their independence in 1991, the Baltic States have undergone similar processes of economic, political and social transformation. Under the Washington Consensus policy framework these countries aimed to create stability and international trust as well as attractiveness for foreign direct investments through a fixed exchange rate, balanced state budget and comparatively low tax and administrative burdens. In the late 1990s, the transition and restructuring paradigms were replaced by the concepts of catching up and economic convergence to the level of the developed economies of the enlarged EU. Unfortunately, large amounts of foreign investment and private lending went into financing consumption and the real estate boom, and as a consequence the export competitiveness of the Baltic economies started to weaken in the 2000s (see also Estonian Development Report 2008. Also, the deepening downturn in the main trading partners of the Baltic States during the recent global crisis has remarkably weakened the economic outlook for these countries. Estonia is the only country among the three Baltic States that joined the euro zone in 2011. Adopting the euro in itself is unlikely to trigger any major change in the pace of recovery, but it was expected during the joining that may remove liquidity risks, add stability to the economy and help attract new investments. These small countries are facing a double challenge to simultaneously overcome recent economic downturn as consequences of global economic crises as well as national economic policies.

The paper aims to investigate the research question of whether the US 2008 crisis spilled over contagiously to the Baltic States as small open economies. The essential aim of this study is to provide additional information for elaborating proposals mitigating or even avoiding some negative consequences of possible future crises' spreading.

In order to explore the evidence of financial contagion in the case of the Baltic States, we employ alternative testing methodologies like the correlation coefficients based methods and ARCH-GARCH framework. We focus on

examining the evidence of financial contagion from the US to the Estonian, Latvian and Lithuanian stock markets. The data set employed for the analysis includes daily closing prices of the US (Standard & Poor's 500), Estonian (OMX Tallinn), Latvian (OMX Riga) and Lithuanian (OMX Vilnius) stock markets' indices over the time period from February 29th 2008 to March 9th 2009.
This paper is structured as follows. In the following part of the paper we give a short overview of several considerations and discussions regarding the concept of financial contagion. The next parts of the paper present information about data and research methodology and the main research results. The paper ends with conclusions and discussion.

2. Financial contagion

The concept "contagion" is borrowed from epidemiology. In economic literature it is ordinarily considered as the transmission of crisis from on economy to others and usually some further restrictions have been made (see alternative definitions below). Financial contagion has become increasingly popular research task in the recent decades when several crises transmitted rapidly to other countries in 1980's, 1990's and in the current century. Many of the countries that have got hit by the crisis' snowball are rather different in terms of size and economic structure as compared to the country of origin of a crisis.

The most comprehensive information about several approaches to the concept of "financial contagion", the transmission channels of financial crisis, and the results of empirical studies focused on financial contagion is provided by the Word Bank Group (2009) on their special website. According to the World Bank approach there are three main alternative definitions of financial contagion:

- Contagion is the cross-country transmission of shocks or the general cross-country spillover effects which have been emphasized during the crisis times. Contagion can be observed through co-movements of different financial indices in different countries or rising probabilities of default if crisis occurs elsewhere. So, unlike other definitions this one includes fundamental linkage as a channel of contagion.
- Contagion is the transmission of shocks to other countries or the cross-country correlation, beyond any fundamental link among the countries and beyond common shocks. For example Masson (2004) defines contagion as only those transmissions of crises that cannot be identified with observed changes in macroeconomic fundamentals. Going for somewhat other testing methodology Eichengreen *et al* (1996) argue that there is contagion if the probability of a crisis in a given country increases conditional on the occurrence of a crisis elsewhere, if the standard set of macroeconomic fundamentals is taken into account. This definition is sometimes referred as

excess co-movement – a correlation that remains even after controlling for fundamentals and common shocks. Herding behaviour is usually argued to be responsible for that more-than-expected co-movement. Fundamental linkages are distinguished from contagion by most of the literature.

- Contagion occurs when cross-country correlations increase during "crisis times" relative to correlations during "tranquil times." Or as Forbes and Rigobon (2001) put it: contagion is a significant increase in cross-market linkages after a shock. This definition is sometimes referred as shift-contagion. Forbes and Rigobon (2001 and 2002) stress that this notion of contagion excludes a constant high degree of co-movement in a crisis period. In this case, markets are just interdependent.

As argued by Didier, Mauro and Schmukler (2008), the factors underlying the channels that generated contagion during the crises of the 1990s seem to be potentially at least as strong today as they were a decade ago. One of the main interests of contagion studies is associated to the merits of international diversification. Although the rationale is that theoretically international diversification should significantly reduce the portfolio risk, when cross country correlations increase during crises much of the rationale is undermined. Besides, questions about appropriate financial architecture and investment opportunities and risks to local markets can be answered by studies of financial contagion.

The results of previous empirical studies about empirical evidence of financial contagion (see also overview of Kuusk and Paas 2011) are heterogeneous. They differ depending on several circumstances, like chosen conceptual definition of contagion and even in the most widely used approach of focusing on co-movements in asset prices. There are also substantial differences in study results depending on whether correlations are adjusted for the presence of heteroskedasticity or not. Chosen crisis, time periods, destination countries and even the financial market under investigation may affect the results of empirical studies. In addition, the problems of omitted variables, feedback dependencies between stock markets, different time zones, and arbitrary choices of the crisis window can all affect tests of contagion (see also Billio and Pellizon (2003) and Dungey and Zhumabekova (2001)).

The variability of empirical results of studies on financial contagion can also be explained by several measuring problems. For instance, Rigobon (2002) points out that contagion have been associated with high frequency events; it has been measured on stock market returns, interest rates, exchange rates, or linear combinations of them. Rigobon argues that the data is plagued with simultaneous equations, omitted variables, conditional and unconditional heteroskedasticity, serial correlation, non-linearity and non-normality problems.
Naively counting numbers examining several aspects of contagion we can conclude that evidence for contagion during financial crises has been found more often than not. On the other hand, this result is mostly being obtained when

the presence of heteroskedasticity is not taken into account. The studies that account for heteroskedasticity find evidence for financial contagion far less often. This diversity of results is well illustrated by the research by Daniel Serwa (2005) who used four different testing methodologies and different samples to achieve mixed results. According to his findings contagion is a rather rare phenomenon, but patterns of capital and information flow to stock markets still change during turbulent periods.

In addition, the previous literature relating to issues of financial contagion does not always have consensus on the issue whether the recent crises have been more contagious than those before 1990's. While some authors (Haile and Pozo 2008) argue that currency crises prior to 1990s did not appear to spread across countries with the virulence and speed observed recently, the others (Bordo and Murshid 1999 and 2000) have found no evidence to confirm that.

We agree with the problems stressed in the literature considering financial contagion and rely on the viewpoints presented in the analysed studies discussing some of them in the next part of our paper. We rely on the definition given by Forbes and Rigobon (2002) who distinguish between contagion and interdependence and define contagion as an excessive transmission of shocks from crisis stock market to other stock markets, beyond any idiosyncratic disturbances and fundamental links among them. According to the definition used in this paper, financial contagion, unlike interdependence, means that there are breaks in the international transmission mechanism owing to financial panics, herding or switches of investors' expectations. Accordingly, contagion requires a change in the structure of stock market linkages and in the case of contagion the increase in these linkages during crises has to be statistically significant.

3. Data and methodology

3.1. The correlation coefficients based method

In the empirical part of our paper we employ two main approaches for testing hypotheses regarding possible financial contagion from the US to the Baltic States Estonia, Latvia and Lithuania during the crisis that started in US in 2008. First, we implement the correlation coefficients based methods, and second, the ARCH-GARCH framework.

Employing the correlation based analysis we investigate stock indices from March 3-rd 2008 until March 9-th 2009 and choose the bankruptcy of Lehman Brothers in September 15, 2008 as the starting point of the crisis. According to this approach, the period from March 3-rd 2008 to September 15-th 2008 will be considered as a tranquil period and the period from September 16-th 2008 to March 9-th 2009 as crisis period. The use of stock indices is mainly based on pragmatic reasons. Stock market indices are relatively easily

accessible data compared to other variables such as comparable interest rates, bonds or exchange rates. Also, the stock market data is available on a daily basis, which makes it easier to have reasonable number of observations for the analysis.

As our choice of the starting point of a crisis is clear, the chosen starting point of a tranquil period and the ending point of a crisis period need some further explanation. We have chosen March 9-th 2009 as the ending date of a crisis period, because it was the local minimum for S&P500 during crisis. This kind of logic is previously used by Mishkin and White (2003) and Serwa (2005). The tranquil period cannot be considered to stretch for too long because we do not want any structural breaks during that time. There was quite a sharp fall in the S&P500 index at the end of February, 2008, which stopped at the beginning of March. So, we took March 3rd as the first trading day in March (March 1st and 2nd were at weekend) for our starting date of a tranquil period. This approach also allowed us to have tranquil and crisis period with relatively similar length.

As noted by Billio and Pellizon (2003) and Forbes and Rigobon (2002) correlation based analysis is more suitable than other approaches to shed light on the issues of international diversification, the role of international institutions and bail-out funds, as well as propagation mechanisms.

We test the hypothesis whether the 2008 financial crisis has spilled over contagiously from US to Estonia, Latvia and Lithuania. The logic of the following tests is based on the assumption that contagion occurs when, if a crisis in the US, correlation is stronger because of some structural change in the international economy affecting the links across markets. Relying on this hypothesis and data sample, we consider contagion as significant increase in the correlation coefficient in stock returns between the country of origin of the crisis (the US) and the country of destination (Estonia, Latvia or Lithuania) during the crisis compared to the non-crisis period.

Similarly to many earlier papers (for example Forbes and Rigobon 2002) we consider a model, where stock returns on the country of origin of the crisis are independent variable and influence returns on the country of destination. More specifically, we use the following linear model (see Forbes and Rigobon 2002 and Serwa and Bohl 2005)

$$y_t = \alpha + \beta * x_t + u_t^y \quad (1)$$

$$x_t = u_t^x \quad (2),$$

where x_t are stock returns in the crisis market (US) that are exogenous and influence returns on the calm market y_t (Estonia, Latvia or Lithuania);

u_t^x and u_t^y are idiosyncratic shocks to the respective stock markets.

It is assumed that volatility of stock returns on the crisis market changes during crisis times, but the model parameters and the volatility of idiosyncratic shocks in the destination market remain constant.

We estimate the correlation coefficient in both tranquil and crisis times and then control for the significant increase in the correlation coefficient after crisis hits.

The correlation coefficient for the calm period is given by the equation

$$\rho^{\text{non-crisis}} = \text{Corr}(x,y) = \frac{\text{Cov}(x,y)}{\sqrt{\text{Var}(x)\text{Var}(y)^{\text{non-crisis}}}} = \left[1 + \frac{\text{Var}(u^y)}{\beta^2 \text{Var}(x)^{\text{non-crisis}}}\right]^{-\frac{1}{2}} \quad (3)$$

and for the crisis period

$$\rho^{\text{crisis}} = \text{Corr}(x,y) = \frac{\text{Cov}(x,y)}{\sqrt{\text{Var}(x)\text{Var}(y)^{\text{crisis}}}} = \left[1 + \frac{\text{Var}(u^y)}{\beta^2 \text{Var}(x)^{\text{crisis}}}\right]^{-\frac{1}{2}} \quad (4)$$

We agree with Forbes and Rigobon (2002) who show that correlation is conditional on the volatility of stock returns in the crisis market and therefore, the correlation between stock returns in crisis and non-crisis country may rise even when contagion does not occur. Thus, it is not fully correct to test for contagion using simple correlations that to not take into account increased volatility during crises. Therefore we consider that the testing approach with heteroskedasticity adjustment in post-crisis correlations seems to be more reliable.

Thus, estimating correlation coefficients we also adjust for heteroskedasticity by using the Forbes and Rigobon (2002) approach who propose an adjustment so that the correlation coefficient does not depend on the volatility of returns in the crisis market:

$$\rho * \frac{\rho^{\text{crisis}}}{\sqrt{1 + \delta[1 - (\rho^{\text{crisis}})^2]}} \quad (5)$$

ρ^{crisis} is the correlation coefficient between the crisis and the non-crisis market observed during the crisis period.

The parameter δ represents the relationship between the variances of stock returns from the crisis country during the turmoil period, $\text{Var}^{\text{crisis}}(y_t)$ and during the calm period, $\text{Var}^{\text{non-crisis}}(y_t)$:

$$\delta = \frac{\text{Var}^{\text{crisis}}(y_t)}{\text{Var}^{\text{non-crisis}}} - 1 \quad (6)$$

We start with estimating simple correlations and later use the adjustments proposed by Forbes and Rigobon (2002). The correlation coefficients (both not adjusted and adjusted) are transformed through a Fisher transformation, so that they are approximately normally distributed. This transformation is necessary in order to have relevant results from the hypotheses controlling (Dungey and Zhumabekova 2001, Jokipii and Lucey 2006, Lee *et al.* 2007).

3.2. The ARCH-GARCH framework

Although easy to use and providing some other advantages, the correlation coefficients based methods also have several drawbacks. For example, as it is demonstrated by Baur contagion tests that base on correlation coefficient, it can be misleading when correlations are time-varying and volatility is contagious *per se* (Baur 2003).

In order to check for the robustness of the empirical results we also implement the autoregressive conditionally heteroskedastic (ARCH) and generalised ARCH (GARCH) framework of statistical models to explore the possible contagion from the US stock market (S&P 500) to the Baltic States stock markets. The same framework to investigate contagion in emerging markets is used for example by Edwards and Susmel (2001 and 2003).

According to French *et al* (1987) a member of ARCH family, GARCH-M, is a good representation of the daily stock-return behaviour in the US because of its successful capturing of effects of time-varying volatility on a expected return of a stock.

We investigate two main hypotheses. Firstly, we test whether price changes in the US stock market influence prices in the Baltic States stock markets, and secondly, we explore whether changes in price volatility in the US stock market are related to changes in price volatility in the Baltic States stock markets. In order to test these hypotheses we examine daily stock returns in US and Baltic stock markets over the period, March 3, 2008, to March 9, 2009. For the US stock market we use Standard & Poor's Composite Index, for Estonia we use OMXT, for Latvia OMXR and for Lithuania OMXV indices. We focus on average two-day returns to control for the fact that markets in different countries are not open during the same hours (for how to avoid the problem of nonsynchronous trading periods for different markets, see Lin, Engle and Ito 1994). Our sample period includes September 2008 when one of the most severe stock market crashes in history took place. To investigate the contagion effect we have estimated our models over two sub-periods, before and after the Lehman Brothers bankruptcy in September 15, 2008.

We use many extensions of the basic ARCH model that was developed by Engle (1982) and generalized to GARCH model by Bollerslev (1986). Firstly, we allow the conditional mean to be a function of the conditional variance, which was first proposed by Engle, Lilien and Robins (1987). This extension gives us the GARCH(1,1)-M model.

Secondly, we use the extension first given by French, Schwert and Stambaugh (1987), who adjusted the conditional mean return for a first-order moving average. This is done mainly because of nonsynchronous trading in the US and Baltic States which is problematic in the ARCH family of models (see for example Cohen *et al* 1980).

Third, we include a dummy variable into the model, which helps to capture the fact that there are no price movements at weekends. This weekends' influence that gives Mondays somewhat special status is well known in literature (see French 1980, Gibbons and Hess 1981 and others) and is called Monday effects.

And finally, we include stock returns in crisis market as explanatory variable into the non-crisis market's stock returns' equation.

Thus, we implement the MA(1)-GARCH(1, 1)-M model given by the formula:

$$X_t = \alpha + \beta b_t + \gamma D_t + \delta Y_t + \varepsilon u_{t-1} + u_t \quad (7)$$

$$b_t = a + \mathrm{bb}_{t-1} + \mathrm{cu}_{t-1^2} + \mathrm{dD}_t + \mathrm{fZ}_t \quad (8)$$

where

X_t – stock index return in non-crisis market at time *t*;

b_t – conditional variance of the *R* at time *t*;

D – dummy variable for Monday effect (*D* takes value of 1 on days following weekends and holidays and is 0 otherwise);

Y_t – stock index return in crisis market at time *t*, u_t and u_{t-1} are error terms at time *t* and *t-1* respectively;

Z_t – squared residual derived from an MA(1)-GARCH(1,1)-M model applied to the returns of US stock market.

This kind of model is first proposed by Hamao, Masulis and Ng (1990).

As we do not have Z_t we first have to estimate the equation

$$Y_t = \alpha + \beta b_t + \delta D_t + \varphi u_{t-1} + u_t \quad (9)$$

$$b_t = a + \mathrm{bb}_{t-1} + \mathrm{cu}_{t-1^2} + \mathrm{dD}_t \quad (10)$$

from where we derive needed squared residual.

The empirical results of our study are presented in the next part of the paper.

3.3. Empirical results

In the empirical section of the paper, we first compare the correlation coefficients between stock returns of the US (a crisis country) and Baltic States (Estonia, Latvia and Lithuania) during the non-crisis and crisis period. Secondly, we measure changes in volatility to examine whether conditional means and conditional variances of financial variables are related to each other among countries during the crisis period. Investigation is based on the methodology outlined in the previous section and uses the data and time periods that are also explained in the previous section 3. We use two-day average rolling log stock returns to control for non-synchronous trading hours in the US and Baltic States. The number of observations used is 266. All stock indices used are denominated in US dollars.

Unadjusted correlation coefficients are calculated using formulas 3 and 4 in the previous section. The results are given in the second (pre-crisis correlations)

and third row (post-crisis correlations) in the following table 1. The final row in table 1 is obtained by adjusting the unadjusted post-crisis correlations given in the previous row by the adjustment procedure given by the formula 5 (see section 3).

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Table1. Correlation coefficients between US and Baltic stock markets

	US and Estonia	US and Latvia	US and Lithuania
Pre-crisis	0.169	0.112	0.186
Post-crisis, unadjusted	0.435	0.294	0.477
Post-crisis, adjusted	0.286	0.191	0.315

Source: authors' calculations. Sample size is 266 observations.

As seen in table 1, the correlation coefficient for the pre-crisis period (after Fischer transformation) between the US and Estonia is 0.169, between the US and Latvia 0.112 and between US and Lithuania 0.186. The corresponding simple correlations for the crisis period are 0.435, 0.294 and 0.477, and they are statistically significant. It is seen that post-crisis correlations are significantly higher which is confirmed only by the t-test. This finding supports the contagion hypothesis according to which linkages between crisis and non-crisis countries have become stronger after the starting point of a crisis. Thus, there has to have been some changes in the structure of stock market linkages which can be explained by herding behaviour or switches in investors' expectations and attitude.

However, as pointed out in the previous section 3, the higher correlation coefficients in this simple model may be caused by the higher volatility that is present during the crisis times. Because of this bias we adjust crisis times

correlations to the higher volatility bias. After doing this (adjusting post-crisis correlations for the presence of heteroskedasticity) the correlations are much lower, 0.286 for Estonia, 0.191 for Latvia and 0.315 for Lithuania but still statistically significant. So it is clearly seen that not adjusting for heteroskedasticity increases the probability to find supporting evidence for the existence of financial contagion. Still, in all three cases the post-crisis correlations are more than 1.5 times higher than pre-crisis correlations and we can deduce that there has been some kind of structural break in the financial shocks' transmission mechanism, although not quite as strong as suggested by the simple unadjusted correlations.

It is expected that the countries´ level of volatility will increase in more turbulent times. It means that conditional and unconditional variances may be changing over time. In order to capture better picture of the contagion it is assumed that there are two regimes in the volatility where one regime associates to lower volatility, tranquil times, and the other to high volatility, so the called turbulent times. So to test for contagion we used as second approach an ARCH or GARCH framework for estimating the variance-covariance transmission mechanism across viewed countries. The used methodology is given by the formulas 7-10 in the previous section 3. Following Table 2 shows the results of the model estimation.

Starting with the pre-crisis period it is seen that statistically significant mean spillover effects (see values of sigma in the Table 2) are observed in Estonian and Lithuanian but not in the Latvian stock market. It means that the conditional mean return in Estonian and Lithuanian stock market exhibits a positive spillover effect from the US stock market – high (low) return in the S&P 500 index is followed by a high (low) return in the OMXT and OMXV, but such relation is not found between S&P 500 and OMXR. It is an interesting finding for which we do not have good theoretical explanation.

Table 2. The results of estimating the MA(1)-GARCH(1, 1)-M model for the spillover effects between US and Baltic States stock markets.

	From US to Estonia		From US to Latvia		From US to Lithuania	
	non-crisis	crisis	non-crisis	crisis	non-crisis	crisis
α	-0.002*	-0.01*	0.002	-0.01*	-0.002	-0.001
β	11.53	16.24*	-32.34	9.27	15.72	-0.99
γ	-0.004	-0.001	-0.002	-0.002	-0.003	-0.002
δ	0.15*	0.20*	0.07	0.14	0.14*	0.20*
ε	0.13	0.06	-0.25*	-0.13	0.09	0.03
a	-0.000	0.000	0.000	0.000	0.000	0.000
b	1.05*	-0.17	0.68*	0.07	0.50*	0.67*
c	-0.004	0.49*	0.08	0.32*	0.38*	0.27*
d	0.000	0.000	0.000	0.000	0.000	0.000*
f	-0.02*	0.02	0.09	0.09	-0.08	-0.001

The coefficients are estimated from the MA(1)-GARCH(1, 1)-M model

$$X_t = \alpha + \beta b_t + \gamma D_t + \delta Y_t + \varepsilon u_{t-1} + u_t$$
$$b_t = a + b b_{t-1} + c u_{t-1}^2 + d D_t + f Z_t$$, where

X_t – stock index return in non-crisis market at time *t*;
b_t – conditional variance of the *R* at time *t*;
D – dummy variable for Monday effect (*D* takes value of 1 on days following weekends and holidays and is 0 otherwise);
Y_t – stock index return in crisis market at time *t*, u_t and u_{t-1} are error terms at time *t* and *t-1* respectively;
Z_t – squared residual derived from an MA(1)-GARCH(1,1)-M model applied to the returns of US stock market.
Source: authors' calculations.
* statistically significant at 5% level.

Turning attention to the crisis period it is seen that mean spillover effects are now stronger in all three markets. In the crisis period mean spillover effects are statistically significant even between US and Latvian stock markets if 0.1 confidence level is used. This finding is in line with the contagion hypothesis as post-crisis linkages seem to be stronger than those in pre-crisis period.

We also investigate spillover effects in conditional variance (see values of *f* in Table 3). Unlike conditional mean conditional variance does not exhibit statistically significant positive spillovers in any of the observed markets, nor in the crisis period neither in the non-crisis period. The only statistically significant spillover effect is observed in Estonian stock market in pre-crisis period and it is negative. Thus high volatility in the S&P 500 index does not give any reason to expect that we will see high volatility also in Baltic stock markets. The conditional variance spillover effects are not stronger in the crisis period than in the non-crisis period. This means that no structural breaks in volatility transmission mechanisms are observed and thus no support for contagion hypothesis is found.

Summarizing the findings of the empirical section we can say that the results of the correlation coefficients based and the volatility spillovers based method are somewhat contradictory. Correlations in returns on stock indices between US and Baltic States stock markets are clearly higher during turmoil period compared to tranquil period, which is supporting evidence on the contagion hypothesis. On the other hand the estimation results of the MA(1)-GARCH(1, 1)-M model while showing some increasing spillover effects on conditional mean, did not show any sign neither positive nor increasing during crisis times spillover effects on conditional variance.

4. Conclusions and discussion

The paper examines whether there has been financial contagion from US to the three Baltic States during the 2008 financial crisis by using stock returns data during time period from March 3-rd 2008 until March 9-th 2009. Financial crises and their contagion have been long studied and modelled by economists and several alternative definitions of financial contagion have been used. This paper defines contagion as a structural break in the linear transmission mechanism of financial shocks and applies both correlation coefficients based tests and ARCH-GARCH framework to test for financial contagion.

Correlation coefficients based testing reveals supporting evidence on financial contagion. The unadjusted (for the presence of heteroskedasticity) post-crisis correlation between the US and all three Baltic countries is quite significantly higher than the pre-crisis correlation, which supports the contagion hypothesis and indicates that linkages between the US (crisis country) and Estonia, Latvia and Lithuania (non-crisis countries) have become stronger after September 15-th, 2008 which was agreed upon as the starting date of a crisis. Because of the bias of unadjusted correlation coefficients towards overestimating contagion effects, we adjust crisis times correlations for the presence of heteroskedasticity. Using these adjusted correlations the differences between pre- and post-crisis correlations are much smaller but still more than 1.5 times in favour of post-crisis correlations.

The results of the MA(1)-GARCH(1,1)-M model are mixed. Mean spillover effects from US to Estonia, Latvia and Lithuania are stronger during the crisis period as compared to the tranquil period. During crisis times conditional mean return in all three Baltic stock markets exhibits a positive spillover effect from the US stock market. This is not true for the conditional variance, which does not exhibit statistically significant positive spillovers in any of the observed markets, or in the crisis period either in the non-crisis period. Further, there is no sign for the positive spillovers of conditional variance to strengthen during crisis times. These results also confirm once again that financial contagion is a complex phenomenon and examining it needs further investments into employment and development of study methods.

The contagious transmission of crisis from the US to the Baltic States stock markets (and economy) that the correlation coefficients based testing indicated somewhat undermines the rationale of the merits of international risk diversification and shows the risks that small open economies have to face. However, although in 2009 the Baltic States faced similar problems to Greece's in the recent crisis, they managed to overcome this problem with the help of several retrenches. The rating agency Standard & Poor's has increased all three countries rating outlook bringing out the reason of success in decreasing the budget. Thus, one can judge that the infection was not especially hard for the Baltic countries, as many countries with less open economies are facing even

larger problems. Not so great susceptibility to financial contagion of Baltic countries was also indicated by the testing of spillover effects of conditional variance, which revealed that in spite of being extremely open economies the Baltic countries stock markets do not exhibit a positive variance spillover effect from the US stock market and the presence of the 2000 crisis-in the US did not make these spillovers significantly stronger.

Thus, small open economies like Baltic States do not seem to be more susceptible to financial crises than other countries and should probably continue to be as open as possible for both foreign trade and investment, an aspect which has been one of the main reasons for their success story so far. In order to deal with some unavoidable contagion from elsewhere, government interventions to direct knowledge and innovation based development which could enable better mitigation of the negative consequences of crises are probably necessary.

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