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RETURN AND VOLATILITY LINKAGES BETWEEN THE S&P 500 AND EMERGING STOCK MARKETS IN EASTERN EUROPE

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ABSTRACT

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The aim of this thesis is to research mean return spillovers as well as volatility spillovers from the S&P 500 stock index in the USA to selected stock markets in the emerging economies in Eastern Europe between 2002 and 2014. The sample period has been divided into smaller subsamples, which enables taking different market conditions as well as the unification of the World's capital markets during the financial crisis into account. Bivariate VAR(1) models are used to analyze the mean return spillovers while the volatility linkages are analyzed through the use of bivariate BEKK-GARCH(1,1) models. The results show both constant volatility pooling within the S&P 500 as well as some statistically significant spillovers of both return and volatility from the S&P 500 to the Eastern European emerging stock markets. Moreover, some of the results indicate that the volatility spillovers have increased as time has passed, indicating unification of global stock markets.

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Tämän tutkielman tarkoituksena on tutkia tuoton ja volatiliteetin siirtymistä Yhdysvaltain S&P 500 – osakeindeksistä valikoituihin Itä-Euroopan kehittyviin pörssi-indekseihin vuosien 2002 ja 2014 välillä. Aineisto on lisäksi jaettu mainitun aikajakson sisällä pienempiin tarkasteluperiodeihin, jolla tavalla pyritään huomioimaan erilaiset markkinaolosuhteet sekä finanssikriisin aiheuttama kansainvälisten pääomamarkkinoiden yhdentyminen. Tuottojen siirtymistä on mallinnettu kahden muuttujan VAR(1) mallilla, kun taas volatiliteetin siirtymistä on mallinnettu kaksimuuttujaisilla BEKK-GARCH(1,1) –malleilla. Tutkimustulokset osoittavat paitsi volatiliteetin klusteroitumista S&P 500 -indeksin sisällä, myös joidenkin maiden osalta tilastollisesti merkitsevää tuoton ja volatiliteetin siirtymistä S&P 500 –indeksistä Itä-Euroopan indekseihin. Tulokset osoittavat lisäksi volatiliteetin siirtymisen lisääntyneen ajan myötä, mikä käytännössä merkitsee kansainvälisten osakemarkkinoiden yhdentymistä.

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In Vantaa, the 16th of May 2016

Oskar Loisamo

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1 INTRODUCTION

1.1 Background

As the world economy has unified, stock markets have also become increasingly interdependent (see e. g. Ng, Chang and Chow (1991), Lin, Engle and Ito (1994), Karolyi (1995), Kim and Rogers (1995) and Booth, Martikainen and Tse (1997)), even in times where macroeconomic variables might suggest otherwise. Increased linkages in stock market volatility have also been noticed immediately after the stock market crash of 1987 as well as after the financial crises in Russia and Asia (see e. g. Eun & Shim (1989), von Furstenberg and Jeon (1989), King and Wadhwani (1990), Schwert (1990), Hamao, Masulis and Ng (1990), King, Sentana and Wadhwani (1994), Arshanapalli and Doukas (1993) and Longin & Solnik (1995)): these have demonstrated the fact that such increases in volatility are rarely contained within a single region in today's world economy. Other notable takeaways from these studies include elevated correlation in times of high overall volatility, linkages between high volatility and large decreases in market values, time-varying correlations across markets and finally the fact that while some correlations in return and volatility can be explained by fluctuation in the US stock market, no other market can in turn explain the fluctuation in the US stock market.

In spite of China's vast economic growth and the rise to the United States' side as the World's largest economy, the capital markets outside the US have grown nowhere as fast and remain quite insignificant against the US capital markets. The US stock market, consisting of companies listed in either NASDAQ or the New York Stock Exchange (NYSE), is still regarded as the largest driving force behind all other stock markets in the world, not least due to its monstrous combined market value. The S&P 500 index, whose market capitalization has been measured in tens of trillions of dollars in the 2010s, is an index consisting of the 500 largest companies of NYSE and NASDAQ based on their market capitalization, and perhaps globally the most carefully followed stock index.

As research has established the fact that the US stock market seems to be a driving force behind the performance of other stock markets in the world, modelling the return and volatility linkages between it and the stock markets in the rest of the world has become an extensive, and versatile, field of research. More specifically, and related to the increased interdependence of the world's capital markets mentioned previously, it is of value to further investigate the effect of the US stock market on the stock markets in emerging economies. This thesis studies the return and volatility spillovers from the S&P 500 in the US to six selected stock markets in emerging countries in Eastern Europe between the years 2002 through 2014. The selected time period provides information on how the markets interact with each other during times of financial stability and instability: to further enable this, the selected time period will be divided in three subsets to review changes between them. The stock markets selected are those of the Czech Republic, Estonia, Hungary, Latvia, Lithuania and Poland. The motivation for selecting these markets is twofold. Firstly, choosing to study emerging stock markets in Eastern Europe as an entire geographical territory dictated the selection of stock markets to be used. Secondly, suitable stock markets from the emerging countries in Eastern Europe were selected by using criteria such as stock market capitalization and political stability in each country. As a side note, countries such as Russia and Ukraine, which otherwise could have made for valuable data in the research, had to be dismissed from the study due to their recent political instabilities.

In this thesis, the individual Eastern European stock markets are pitted against the S&P 500 to test for return and volatility spillovers from the S&P 500 to the stock markets of the emerging economies. Furthermore, the ARCH effects of each individual stock market are under investigation for evidence of volatility clustering. The findings of this paper are in line with the established consensus in empirical research so far in that statistically significant volatility spillovers from the S&P 500 to the Eastern European stock markets are found.

All of the developing stock markets are located in countries which, according to the most notable rankings (such as those of the IMF and the World Bank), are regarded as emerging markets, not as frontier markets. Thus, this thesis is strictly a study on the volatility linkages between the S&P 500 and selected emerging markets.

The table below shows the market capitalization (the aggregate market value of all the constituents in that stock market) and the number of constituents per each stock index used for the study. It is noteworthy that the number of constituents does not necessarily equal the number of all listed companies in a country: the numbers of constituents here refer to the number of constituents in the index used as data in this study. To name one example, the Czech PX index used in this study consists of the 50 largest listed companies in the Czech Republic measured by market capitalization. Another notable thing is the vast market capitalization of the S&P 500 compared to the other markets: from this point of view, it is no wonder that empirical research has found significant return and volatility spillovers from the S&P 500 to other markets, as it is over 70 times larger than all the other markets used in this study put together.

Table 1. Market capitalizations and the amount of constituents in each stock index used in the study (Quandl 2016)

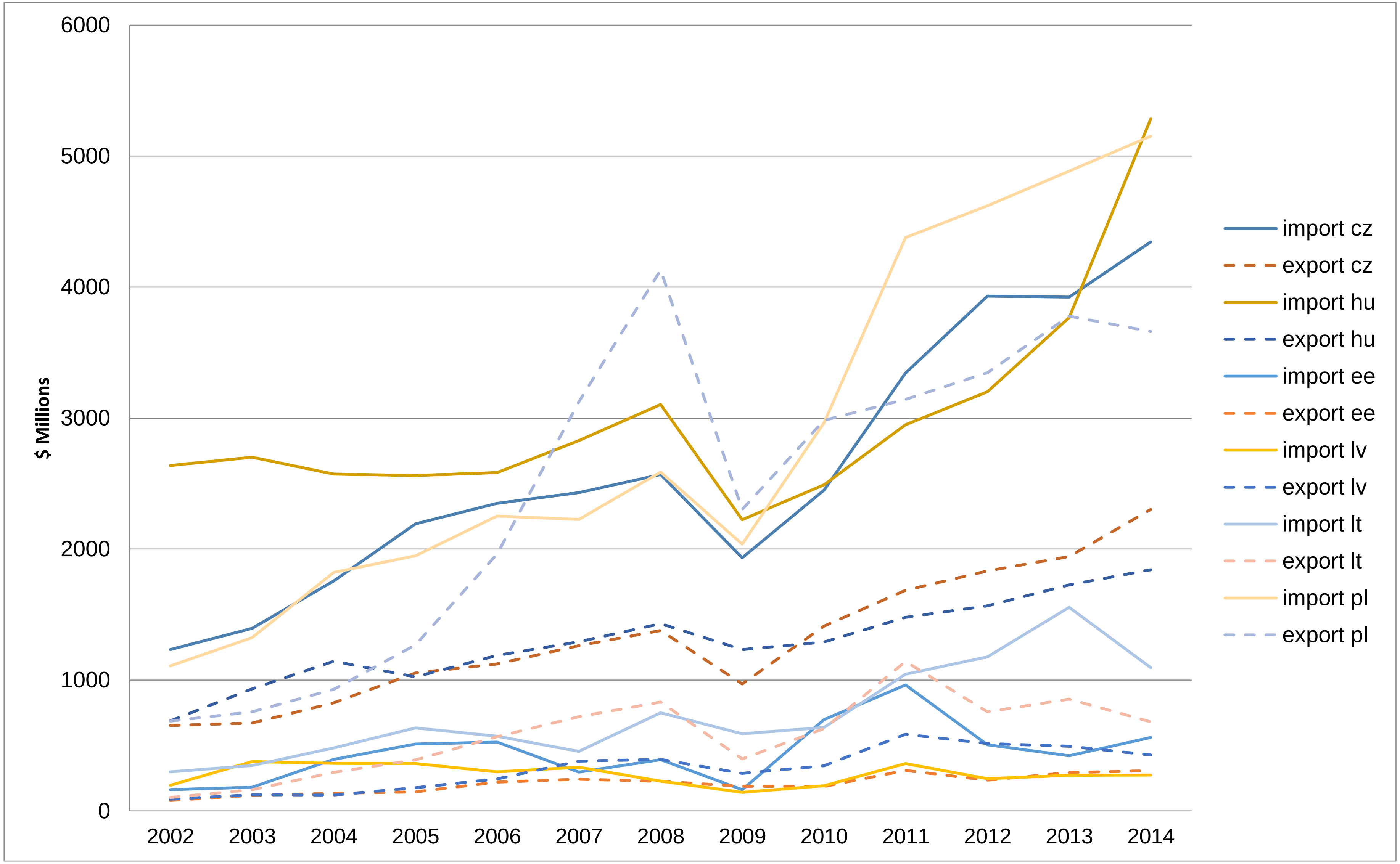
Country	Market cap	Approximate number of constituents	Index name
Poland	$178bn	480	WIG
Czech Republic	$37bn	50	PX Index
Hungary	$21bn	25	BUX
Lithuania	$4bn	35	OMX Vilnius
Estonia	$2bn	14	OMX Tallinn
Latvia	$1bn	25	OMX Riga
USA	$17,853bn	500	S&P 500

Besides the liquidity and market capitalization of the stock markets, an important indicator of the trade linkages of an economy is its direct international imports and exports with the US. However, it is noteworthy that even without a direct impact in international trade, the volatility phenomena in the US may be felt by another economy through other stock markets as well, so the import and export statistics of one country alone are not an entirely sufficient proxy. They do, however, give an idea of the scale in which an economy is indirectly involved in the development of the US economy.

Graph 1 on page 13 shows the development of both the import and the export between all individual markets under study against the US. The data obtained from the US Census Bureau is available in numerical form in Appendix I. The data is in millions of US dollars.

As of the end of 2014, the most significant trade partners of the US from largest to smallest are Poland, Hungary, the Czech Republic, Lithuania, Estonia and Latvia. This order is somewhat in line with the World Bank's 2014 GDP estimates, which basically means that among these markets, the importance of international trade with the US is mainly dictated by the size of the domestic economy. Furthermore, the US has a trade deficit against each of these countries, meaning that the US imports more from the countries than it exports to them. The health of the US economy is important to the markets in Eastern Europe as their exports rely on it.

A more significant interpretation of the international trade statistics is that every emerging market used in this study aggregates a significant share from its GDP through trade with the US. Therefore, besides pressure from merely the US capital markets, the emerging economies are directly affected by changes in such macroeconomic variables in the US as employment and inflation rates as well as the resulting purchasing power of US consumers and companies, since they create the demand for products from these emerging markets.



Graph 1. International trade between the US and the Eastern European economies selected for the study

1.2 Objectives of the thesis

The objective of the thesis is to determine whether there are statistically significant return and volatility spillovers from the S&P 500 stock index in the USA to six different emerging stock markets in Eastern Europe. The reason for this objective being of interest is that prior research has shown the phenomenon of the S&P 500 (and the US capital markets in general) affecting other stock markets in the World in many different cases. Another objective is to determine how the linkages are affected by differences in market conditions: hence, the entire dataset has been divided into three different subsamples. The first subsample spans from 2002 through 2007 and depicts a period of tranquility and ease in most mature capital markets, whereas the period of the financial crisis, where capital markets are expected to be unified and inter-market correlations increased based on previous research, spans from 2008 through 2010. The final, post-financial-crisis period spans from 2011 through the end of 2014.

The research questions to be answered are listed below.

1. Are there spillovers of returns and volatility from the S&P 500 to emerging stock markets in Eastern Europe?
2. Is there evidence of increased correlations in returns and volatility between the different stock markets during times of financial instability?
3. Have global stock markets become more unified after the global financial crisis?

The remainder of the thesis has been structured so that the theoretical background and framework for the thesis are introduced in their entirety in chapter 2. A brief literature review spanning previous studies in the area is presented in chapter 3. The data and the methodology are introduced in chapter 4, and all the empirical results from the models are presented in chapter 5. Finally, chapter 6 concludes the results and their empirical implications.

2 THEORETICAL BACKGROUND

2.1 Asset pricing theory & CAPM

In classical asset pricing, the price of an asset is determined by risk level and future expected profits. For academic purposes, some of the original, stiff and even partially obsolete pricing approaches are still being used. One of the early pioneering theories in asset pricing is the Capital Asset Pricing Model (CAPM), introduced initially by Sharpe (1964) followed by separate introductions by Lintner (1965) and Mossin (1966). A vital assumption of CAPM is that the data is completely homoscedastic: this, however, is hardly ever true for financial return data. Thus, the ordinary least squares estimator is no longer the best linear unbiased estimator, and an improved model is required, which can better take into account the effects of leptokurtosis (i.e. fat tails and excess peakedness at the mean of a return distribution) and different volatility-related attributes.

Furthermore, the CAPM is based on the assumption that the return of an asset can be related to prevailing risk and that markets are both perfect and fully segmented. In this regard, it has been deemed unable to explain real-world pricing by further empirical research. One reason to this is that CAPM can only assume a domestic risk, whereas stock markets in the real world are at least partially interdependent and thus country-specific risk can in some cases be diversified. One attempt to work around this issue is through the use of the international CAPM or ICAPM suggested by Adler and Dumas (1983).

2.2 Autoregressive processes and phenomena related to volatility

To understand the basics of how ARCH class models work, one must first understand how autoregressive processes function. An autoregressive model is one where the dependent variable depends only on the past values of that variable and a stochastic term. An autoregressive model of order p, or AR(p) is expressed as follows:

(1) $$y_t = c + \varphi_1 y_{t-1} + \varphi_2 y_{t-2} + \ldots + \varphi_p y_{t-p} + u_t.$$

Here u_t is a stochastic white noise process with zero mean and constant variance, c is constant and $\varphi_1 \ldots \varphi_p$ are the parameters of the model.

(Brooks 2014)

There are a number of features besides leptokurtosis that linear models are unable to properly capture. These are related to the volatility of the financial (time series) data, that is, how much variation there is in the data over time. The most relevant related phenomena are volatility pooling and leverage effects.

Volatility pooling describes the nature of similar-degree volatility to appear in subsequent lags (or bunches): for example, large returns, both positive and negative, are expected to follow large returns, while small returns of either direction are expected to follow small returns. An explanation to this attribute is that the delivery of financial information also appears in bunches, rather than in an even flow. (Brooks 2014, 380)

Leverage effects, first introduced by Black (1976), refer to the tendency of volatility rising more as a result of a decrease in a stock price than it would as a result of an increase of the same magnitude. This asymmetry is believed to stem from the fact that as investors bear the residual risk of a firm, they will perceive their future cash flows to be riskier in the case of a decrease in price, thus discounting them and thereby causing a reduction in the market price (Brooks 2014, 404).

For instance, Veronesi (1999) stated that markets tend to underreact to good news during bad times and overreact to bad news during otherwise good times, with no regime shifts present. Furthermore, Veronesi concluded that the model created for the purpose of his research better describes features related to stock returns, such as volatility pooling, leverage effects and excess volatility, than the conventional models presented hitherto.

2.2.1 Vector autoregressive models

Vector autoregressive models (VAR), popularized by Sims (1980), are systems regression models comprising of more than one dependent variable. They can be regarded as a generalization of normal univariate autoregressive models. In a VAR model, all variables are endogenous. (Brooks 2014, 290)

The most basic case of a VAR model is a bivariate VAR(1) model, where the current values of the two variables are dependent solely on the immediately previous values of both variables and an error term. The simple bivariate VAR(1) model can be written as:

(2)

$$y_{1t} = \beta_{10} + \beta_{11} y_{1t-1} + \alpha_{11} y_{2t-1} + u_{1t} \ ;$$

$$y_{2t} = \beta_{20} + \beta_{21} y_{1t-1} + \alpha_{21} y_{2t-1} + u_{2t} \ .$$

Here u_{1t} and u_{2t} are error terms where $E(u_{1t})$ = 0 and $E(u_{1t}u_{2t})$ = 0. As a result, y_{1t} is dependent on both the previous values of y_{1t-1} and y_{2t-1} as well as on an error term.

2.2.2 ARCH and GARCH models

When volatility is being modelled, linear econometric models are invalid due to the presence of a conditional variance in the mean equation. Thus, a model needs to be used that can capture time-sensitive variance.

The Autoregressive conditional heteroskedasticity (ARCH) model, suggested by Engle (1982), takes into account the nonlinearity of financial time series data. In an ARCH model, the variance of the error term is dependent upon the previous values of squared errors: hence the notion of conditional variance.

The conditional variance can be defined for a random variable as follows:

(3) $$\sigma^2 = var(Ut|u_{t-1}, u_{t-2}, \ldots) = E[(u_t - E(u_t))^2|u_{t-1}, u_{t-2}, \ldots].$$

Here σ^2 stands for the conditional variance and u_t the random variable.

If $E(u_t)$ is assumed to be zero, the conditional mean of the variance of a zero mean normally distributed random variable, will be equal to the expected value of the square of u_t:

(4) $$\sigma^2 = var(Ut|u_{t-1}, u_{t-2}, \ldots) = E[u_t^2|u_{t-1}, u_{t-2}, \ldots].$$

The ARCH(q) model can be written as follows:

(5)

$$\varepsilon_t = z_t \sigma_t \qquad z_t \sim N(0,1),$$

$$\sigma_t^2 = \alpha_0 + \sum_{i=1}^{q} \alpha_i \, \varepsilon_{t-i}^2$$

Here ε_t is the error term, z_t is a sequence of random variables with normal distribution, zero mean and unit variance, σ_t^2 is the estimate of the conditional variance, α_0 is the constant term, and α_i is the ARCH term.

Here the conditional variance can only depend on one lagged square error, that is, the error from exactly one earlier period: hence the notation ARCH(1).

A step further from the simple ARCH model is the process known as Generalized autoregressive conditional heteroskedasticity (GARCH), introduced independently by Bollerslev (1986) and Taylor (1986). The benefit compared to regular ARCH models, in addition to being less parsimonious, is that GARCH models aren’t quite as likely to breach non-negativity constraints.

$$\varepsilon_t = z_t \sigma_t \qquad z_t \sim N(0,1),$$

(6)

$$\sigma_t^2 = \alpha_0 + \textstyle\sum_{i=1}^{q} \alpha_i \, \varepsilon_{t-i}^2 + \sum_{j=1}^{p} \beta_j \, \sigma_{t-j}^2$$

This is a GARCH(p,q) model, where ε_t is the error term, z_t is a sequence random variables with normal distribution, zero mean and unit variance, σ_t^2 is the estimate of the conditional variance, α_0 is the constant term, α_i is the ARCH term and β_j is the GARCH term. The non-negativity constraints here are $\alpha_0 > 0$, $\alpha_i \geq 0$ and $\beta_j \geq 0$.

2.2.3 Multivariate GARCH models

The original forms of both ARCH and GARCH presented above are univariate models, where the objective was to capture spillovers of both returns and volatility from a market to another. Since then, the models have been extended into multivariate GARCH models, enabling interpretation of stock market return attributes such as leverage effects, volatility pooling and leptokurtosis. (Higgins and Bera 1992; Brooks 2014)

The technical difference between univariate and multivariate GARCH models is that while an univariate GARCH model only specifies the variance to move over time, multivariate GARCH models also enable the covariances of the variables to vary over time. While providing the ability to study volatility relationships between two different assets in empirical finance research, this makes them much harder to specify and estimate than their univariate counterparts. As a direct result of this, the number of parameters required to estimate a multivariate GARCH model rises rapidly as a model becomes more complex. Another issue limiting the benefits of multivariate GARCH models is that the variance-covariance matrix is positive definite at all times. Provided that the variance-covariance matrix is positive definite, the diagonal of the matrix is will always have positive values and it will be symmetrical, that is, the covariance of between two series will be the same regardless of the order of operations. (Brooks 2014, 434)

The first major addition to the univariate GARCH models was the VECH model introduced by Bollerslev, Engle and Wooldridge (1988). In a VECH model, all the elements in the variance-covariance matrix H_t are linear functions of the lagged squared innovations, cross-products of the innovations and lagged values of H_t itself.

The VECH-GARCH model was specified by Bollerslev et al. as follows:

$$(7)\quad VECH(H_t) = C + \sum_{i=1}^{q} A_i\, VECH(\varepsilon_{t-i}\varepsilon'_{t-i}) + \sum_{j=1}^{p} B_j\, VECH\big(H_{t-j}\big),$$

$$\varepsilon_t|\Omega_{t-1} \sim N(0, H_t),$$

where A_i and B_j are the parameter matrices, p and q indicate the order (i.e. the number of lags of squared error and variance, respectively) of the model and Ω_{t-1} captures all available information at t-1.

The main drawback in the VECH model is that it does not ensure a forcibly positive definite variance-covariance matrix. It also suffers from the other problem mentioned earlier, namely that estimation of the model quickly becomes quite infeasible upon the addition of new series. Even a bivariate case of a VECH model requires the estimation of 21 parameters.

To come around the issue of multiple parameters to be estimated, Bollerslev et al. proposed a simplified version of the full VECH model, called the diagonal VECH model.

The diagonal VECH model can be specified as follows:

$$(8)\qquad h_{ijt} = c_{ij} + A_{ij}\varepsilon_{it-1}\varepsilon_{jt-1} + \beta_{ij}h_{ijt-1},$$

where c_{ij}, A_{ij} and β_{ij} are the parameters.

Even with the diagonal VECH model, one of the initial problems with multivariate GARCH models remains, that is, the diagonal VECH cannot produce a forcibly positive variance-covariance matrix. To address this issue, the BEKK model was constructed by Baba, Engle, Kraft and Kroner (presented by Engle and Kroner (1995)).

$$(9) \qquad H_t = CC' + \sum_{i=1}^{q} A_i(\varepsilon_{t-i}\varepsilon'_{t-i})A'_i + \sum_{j=1}^{p} B_j H_{t-j}B'_j.$$

Here C is the lower triangular share of the variance-covariance matrix and A_i and B_j are square (n by n) matrices. Based on the quadratic nature of this model, H_t will always be positive definite provided that CC' is positive definite.

A third variation of the multivariate GARCH model besides the VECH and BEKK models is the Constant Conditional Correlations (CCC) model proposed by Bollerslev (1990). In it all conditional correlation is constant and the conditional variances are modelled by univariate GARCH models.

The CCC(1,1) model can be presented as follows:

$$(10) \qquad H_t = D_t R_t D_t, \qquad D_t = diag\{\sqrt{h_{it}}\},$$

where D_t is a diagonal matrix of conditional volatility and R_t is a quadratic correlation matrix. (Engle 2002)

An upside to the CCC model is its unrestricted applicability for large systems of time series. On the other hand, the assumption of constant correlation is likely to be restrictive. For example, in analyses related to empirical finance research elevated correlation in times of crisis or in crash situations is typical. (Bollerslev 1990)

3 LITERATURE REVIEW

This chapter presents some of the earlier research regarding the field of this study and elaborates on the importance of studying linkages in return and volatility.

3.1 Foundation of diversification benefits and the effect of increased linkages

The empirical need for research when it comes to mean return and volatility spillovers stems from the fact that significant spillovers indicate that there are diversification benefits to be gained when investing in different markets that are not completely interdependent with one another. While low correlations among international markets do benefit international diversification, the ongoing financial integration in the world seems to have led to increased correlations among the world's capital markets, with the addition that volatility and return linkages have increased during financially unstable periods, which as a result of the increased interdependence has diminished international diversification benefits. (See Goetzmann, Li & Rouwenhorst 2005; Brooks & Del Negro 2004; Kizys & Pierdzioch 2009; Errunza, Hogan & Hung 1999; Driessen & Laeven 2007, for example)

3.2 Volatility linkages and spillovers among international markets

Spillovers in return and volatility are something that financial research has paid close attention to for the last few decades. The increase of interdependence has been an area of interest especially in areas of noticeable capital market and economic growth, such as in Southeast Asia. According to Soenen and Johnson

(1998), similar economic expectations, trading conditions, financial regulations and technological innovations are likely to lead to positive correlation between markets in the long run.

In their study, Koutmos and Booth (1995) analyzed the volatility spillovers among the markets in the US, the UK and Japan using a model based on exponential GARCH (EGARCH) with a dataset from 1986 to 1993. The authors found significant volatility spillovers among all three markets and that there was considerable asymmetry in the spillovers, meaning that negative shocks in one market affect the volatility in the other markets more than a positive shock would have: the authors were able to point out through the use of the EGARCH. The asymmetry in volatility shocks is a rather common phenomenon and subject to a plethora of research (see e.g. Engle & Ng 1993; Zakoian 1994; Wu & Xiao 1999).

Another study to find evidence of volatility spillover asymmetry between the US and the UK, Germany, France, Italy and Spain is one by Savva (2009). The asymmetry in volatility linkages is one of the regularities established in previous research, as mentioned previously. The other two major regularities are the tendency of stock market interdependence to increase in the form of financial contagion in crisis periods where volatility is high and the fact that volatility spillovers have been proven to occur at least among the largest and most unified stock markets of the world. Examples of such stock markets, besides the US, are the UK and the Japanese stock markets.

As an example of previous research regarding volatility transmission from developed markets to developing markets, Ng (2000) measured the volatility spillovers from both Japan and the US to six different developing stock markets in the Pacific Basin. It was found that besides market liberalization including reforms in capital markets and reducing different restrictions in the markets, the local shocks from Japan and the global shocks from the USA also played a major role in the fluctuation of the markets in the Pacific Basin.

Continuing with the subject of volatility linkages between developed and developing markets, in their paper, Beirne, Caporale, Schulze-Ghattas and Spagnolo (2009) used VIX as the source index for volatility when measuring volatility spillovers from the US stock market to 41 different emerging economies. What the authors found was clear evidence of mature market (in this case, the S&P 500 via the VIX index) affecting conditional variance in many emerging markets. Furthermore, the authors found that during financially unstable periods, spillover parameters would change: for most emerging economies, conditional correlations between the emerging and mature market would increase during financial instability. A noteworthy notion in the results is that while conditional variances in emerging markets do increase during financial instability, they seem to rise more in the mature market, providing the greater contribution to conditional correlations.

In addition to using VIX, many studies have used other measures of the US stock market’s volatility as a benchmark for modeling spillovers into other markets. As an example of this, Canarella, Sapra and Pollard (2007) studied asymmetry and spillover effects from the US stock market to those in Mexico and Canada: what they found was that volatility spillover effects, unlike mean spillover effects, were asymmetric in nature, with negative shocks from the US stock market affecting the stock markets in Mexico and Canada more than the positive ones. Another study by Theodossiou and Lee (1993), albeit slightly outdated, concluded that shocks in both return and volatility induce significant and large shocks across many other developed markets. Conditional mean returns and volatility were found to be causal from the US to the UK, Canada, Japan and Germany.

Li and Majerowska (2008) used stock market data from two developed and two developing markets, the US, Germany, Poland and Hungary respectively, to test for linkages in volatility between developed and developing markets. As opposed to this paper, where all models are bivariate and simply representations of the linkages between the USA and one emerging market, Li and Majerowska used a GARCH-BEKK model of four variables for the paper. The findings indicate only weak linkages between developed and developing markets, indicating that there are at least some diversification benefits to be found by complementing a portfolio with instruments from both the developed and the developing markets.

Karunanayake, Valadkhani, and O'Brien (2009) used multivariate GARCH to test for return linkages in the stock markets of Australia, Singapore, the UK and the US. Their data spanned from 1992 through 2008, so it is noteworthy that while the Asian twin crises of the late 90s are represented here, the later financial crisis in its entirety is not. What the authors found here was that there were significant positive mean return spillovers from the US to every other stock market, but not vice versa. This supports what seems to be the general result in that the dominant effect of the US stock market is only unidirectional and no other stock market can directly affect the US in a significant manner in the long run. Karunanayake et al. concluded that international diversification benefits from these four countries alone would be impossible because of the high degree of interdependence between them.

A paper by Kabigting and Hapitan (2011) tested for mean and volatility transmission (that is, the spillover of both mean returns and volatility) cross-country in the ASEAN 5 countries, which are Singapore, Malaysia, Thailand, Indonesia and Philippines. What the authors found was that, in addition to volatility clustering, there was evidence of volatility spillovers, as well as spillovers from stock returns to exchange rate changes for all the ASEAN 5 countries. Furthermore and unsurprisingly, volatility was higher for the subperiod of 6/2007 through 12/2010 than the whole period of 2000-2010. The authors concluded here that since ASEAN 5 countries have grown increasingly interdependent of each other, any news affecting either the stock market or the foreign exchange market of those countries would have a volatility spillover effect in said country and subsequently spread across other ASEAN 5 countries.

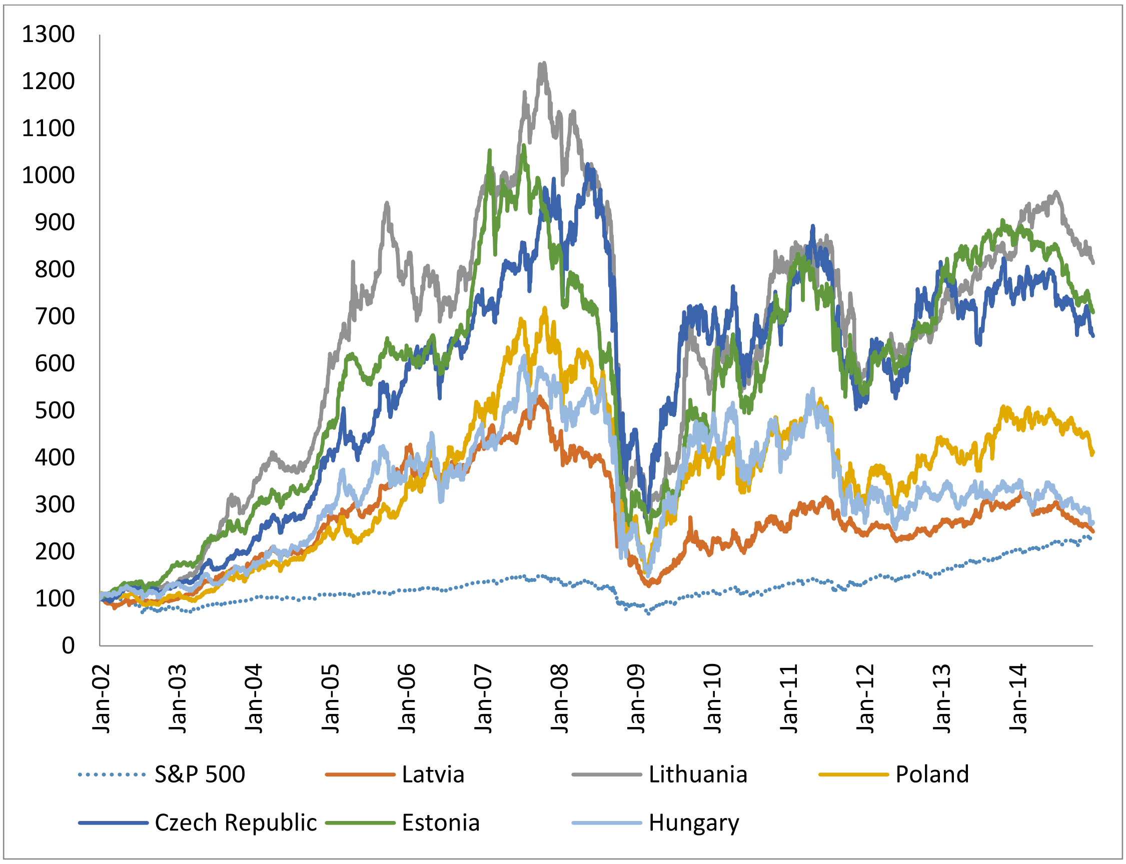
4 DATA AND METHODOLOGY

4.1 Data

The data consists firstly of index data for the S&P 500 index. Using the S&P 500 volatility as a measure of risk is not uncommon, spanning also to the use of the CBOE Volatility Index. Known also as the fear gauge, the index (ticker VIX) is a common measure for the implied volatility of S&P 500 index options. It is therefore an indication of the public's expectation of upcoming volatility in the S&P 500 during the course of the following 30 days. As it is annualized, it shows the expected fluctuation of the S&P 500 during the next year at a 68 % confidence level.

The rest of the data consists of total return indexed data for six different emerging markets in Eastern Europe: Estonia, Latvia, Lithuania, Hungary, Poland and the Czech Republic. Time-wise, the data is weekly from Monday to Friday and spans from the beginning of the year 2002 until the end of 2014. The reason for the selection of weekly data over daily data is that the opening hours of the stock markets in the USA and in Europe are non-synchronized: most European stock markets used in this study have already closed before trading in the New York Stock Exchange begins during the same day. This problem is diluted through the use of weekly returns.

All the data is in US dollars and has been obtained from Thomson Reuters DataStream. In the analyses, logarithmic returns are applied.



Graph 2. Development of the indices from the beginning of 2002 through the end of 2014.

The graph above is a visualization of the fluctuation of the seven different indices during the course of this study, that is, from 2002 through 2014. The data is indexed so that the value for January 1st 2002 is equal to 100 for all indices. Notable takeaways from this graph include the very apparent stock market crash in 2008, and the fact that overall fluctuation has been much larger in all of the emerging markets than that in the S&P 500. This is very well in line with the established fact that as a mature market, the S&P 500 should experience less overall volatility over a long period. Finally, while the year 2014 was a year of negative growth of all European indices, the S&P 500 grew by about 450 index points (roughly 28 index points in the graph above). This is a result of the prolonged economic difficulties within the EU, while the rest of the world economy showed more significant growth in 2014.

Table 2. Descriptive statistics for the entire dataset 2002-2014. Asterisks have been added to describe the significance of the parameter estimates at 10 % (*), 5 % (**) and 1 % (***) risk levels.

MARKET	S&P 500	LATVIA.	LITHUANIA	POLAND	CZECH REPUBLIC	ESTONIA	HUNGARY
Mean 12 m %	6.644	7.211	17.587	10.669	15.625	16.008	7.111
Median	0.002	0.003	0.005	0.005	0.005	0.003	0.000
Maximum	0.114	0.124	0.253	0.196	0.191	0.165	0.207
Minimum	-0.200	-0.166	-0.230	-0.253	-0.328	-0.199	-0.349
Stdev 12 m %	17.8	21.8	23.5	29.5	28.6	23.9	34.5
Skewness	-0.852	-0.757	-0.578	-1.049	-1.193	-0.544	-0.945
Kurtosis	8.305	4.910	11.465	5.571	9.718	5.762	6.417
Jarque-Bera	2027.56***	744.84***	3745.30***	999.50***	2824.73***	969.96***	1262.55**
ARCH-LM	24.09***	10.25***	20.25***	30.28***	23.54***	26.51***	17.77***
Observations	677	677	677	677	677	677	677

Table 3. Descriptive statistics for 2002-2007. Asterisks have been added to describe the significance of the parameter estimates at 10 % (*), 5 % (**) and 1 % (***) risk levels.

MARKET	S&P 500	LATVIA.	LITHUANIA	POLAND	CZECH REPUBLIC	ESTONIA	HUNGARY
Mean 12 m %	5.818	27.595	49.621	34.534	45.305	41.974	31.901
Median	0.002	0.005	0.008	0.008	0.009	0.007	0.007
Maximum	0.072	0.092	0.102	0.107	0.101	0.084	0.118
Minimum	-0.083	-0.139	-0.097	-0.095	-0.125	-0.097	-0.128
Stdev 12 m %	13.8	18.3	18.5	23.7	21.0	18.5	26.9
Skewness	-0.390	-0.388	-0.166	-0.307	-0.497	-0.318	-0.620
Kurtosis	2.024	3.402	1.267	0.485	1.572	1.486	1.197
Jarque-Bera	61.18***	158.33***	22.33***	7.94***	44.96***	33.98***	38.62***
ARCH-LM	7.39***	2.00*	0.520	7.36***	2.35*	0.210	7.84***
Observations	312	312	312	312	312	312	312

Table 4. Descriptive statistics for 2008-2010. Asterisks have been added to describe the significance of the parameter estimates at 10 % (*), 5 % (**) and 1 % (***) risk levels.

MARKET	S&P 500	LATVIA.	LITHUANIA	POLAND	CZECH REPUBLIC	ESTONIA	HUNGARY
Mean 12 m %	-3.059	-15.444	-10.040	-10.826	-8.330	-4.942	-9.853
Median	0.002	-0.001	0.003	0.007	0.004	-0.001	0.000
Maximum	0.114	0.124	0.253	0.196	0.191	0.165	0.207
Minimum	-0.200	-0.166	-0.230	-0.253	-0.328	-0.199	-0.349
Stdev 12 m %	26.9	32.5	35.4	42.5	43.9	37.1	50.8
Skewness	-0.824	-0.620	-0.292	-1.113	-1.070	-0.354	-0.898
Kurtosis	5.289	2.287	7.761	3.989	5.932	2.615	4.426
Jarque-Bera	200.76***	44.25***	396.21***	136.47***	260.16***	48.00***	149.23***
ARCH-LM	4.19***	2.07*	4.07***	6.42***	4.08***	4.34***	2.64**
Observations	157	157	157	157	157	157	157

Table 5. Descriptive statistics for 2011-2014. Asterisks have been added to describe the significance of the parameter estimates at 10 % (*), 5 % (**) and 1 % (***) risk levels.

MARKET	S&P 500	LATVIA.	LITHUANIA	POLAND	CZECH REPUBLIC	ESTONIA	HUNGARY
Mean 12 m %	15.936	-1.311	0.117	-2.916	-2.346	-0.524	-10.826
Median	0.004	0.001	0.003	0.003	0.000	0.001	0.000
Maximum %	0.072	0.067	0.094	0.089	0.093	0.083	0.105
Minimum %	-0.074	-0.067	-0.129	-0.137	-0.124	-0.091	-0.147
Stdev 12 m %	14.4	15.6	17.6	24.9	23.2	17.0	28.8
Skewness	-0.265	-0.348	-1.061	-0.615	-0.448	-0.318	-0.410
Kurtosis	2.095	0.783	5.982	2.013	1.250	2.603	1.176
Jarque-Bera	40.49***	9.50***	349.19***	48.24***	20.50***	62.21***	17.80***
ARCH-LM	7.10***	1.22	5.52***	1.28	5.61***	7.24***	2.96**
Observations	208	208	208	208	208	208	208

The descriptive statistics depicted above for the entire dataset and all subperiods show the statistic attributes of the weekly logarithmic return data used in the models. Mean and standard deviation have been annualized to describe the 12 month values. The Maximum and Minimum percentages depict the largest positive and negative weekly returns in each series, respectively. The null hypothesis of normal distribution has been rejected at a 1 % level on all series using the Jarque-Bera test. To test for stationarity, an augmented Dickey-Fuller (ADF) test as well as a Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test were performed on all series. The results of both tests indicate that the series have no unit roots and are therefore completely stationary. Ultimately, Engle tests were applied to test for ARCH effects in the squared residuals. The ARCH-LM statistics of the tests are visible on the ARCH-LM row in all descriptive statistics. Most ARCH-LM statistics are significant at 1 %, which indicates that the GARCH type parameterization is appropriate for modeling the conditional variances and covariances in this dataset, as all squared residuals exhibit autocorrelation.

The data will first be analyzed as a whole and subsequently divided into three separate samples, with one spanning from 2002 to 2007 another from 2008 to 2010 and the last one from 2011 to 2014. The division is motivated by the difference in market behavior in those timespans: 2002-2007 was globally much more stable as stock market conditions are concerned, with the global financial crisis emerging from 2008 onwards. Ultimately, in 2010 global stock markets started showing clear signs of relief, even though Europe was still under heavy financial distress. As prevailing financial research has shown international capital markets to have become more harmonized and dependent on each other after the start of the banking crisis in 2008, the periods from 2008 to 2010 and 2011 to 2014 should act as a time of increased dependence between capital markets.

4.2 Methodology

To look for linkages in the returns (i.e. return spillovers) and thus determine whether there are signs of interdependence, bivariate VAR(1) models are used for the S&P 500 against every single market. Put simply, this indicates possible spillover in return from the S&P 500 to the other markets.

As mentioned in the theoretical background chapter, the simple VAR(1) model can be written as follows:

(11)

$$y_{1t} = \beta_{10} + \beta_{11} y_{1t-1} + \alpha_{11} y_{2t-1} + u_{1t} \;;$$

$$y_{2t} = \beta_{20} + \beta_{21} y_{1t-1} + \alpha_{21} y_{2t-1} + u_{2t} \;.$$

Here u_{1t} is an error term where $E(u_{1t}) = 0$ and $E(u_{1t}u_{2t}) = 0$. As a result, y_{1t} is dependent on both the previous values of y_{1t-1} and y_{2t-1} as well as on an error term.

The relevant lag to be used has been chosen for the VAR models as the Schwartz Information Criterion (SIC) suggests it to be statistically the most significant. The SIC has been opted for instead of the Akaike Information Criterion as it tends to lead to lower-order models for forecasting and more accurate forecasting when dealing with time series data (Koehler & Murphree 1988, 193). Moreover, VAR models for all pairs have been estimated separately for each time period as well as for the entire period, which enables reflection as to how the return spillovers have changed over time. The parameter estimates derived from the VAR(1) models depict the return spillovers, and keeping in line with the unidirectional nature of this study (ie. only the effect of the USA on the other markets is being studied, not the other way around), only the return spillovers from the US to the other stock markets are presented in this thesis.

To estimate volatility spillovers from the S&P 500 to the other markets, the author has used a BEKK-GARCH (1,1) model. The BEKK model captures both the effects of shocks (ARCH effects) as well as effects of volatility (GARCH effects). In the off-diagonal elements of the forcibly positive covariance matrix created by the model, shock transmissions and volatility spillovers from one market to the other are captured.

The BEKK-GARCH(1,1) can be written as:

(12) $$H_t = C_0 C_0' + A_{11} \varepsilon_{t-1} \varepsilon'_{t-1} A'_{11} + G_{11} H_{t-1} G'_{11}.$$

Here C_0 is the lower triangular portion of the matrix and A_{11} and G_{11} are 2 by 2 matrices. The elements in the A_{11} matrix capture the effects of shocks (ARCH effects), while the elements in the G_{11} matrix capture the past volatility effects (GARCH effects). To elaborate, the diagonal elements in matrices A_{11} and G_{11} capture their own ARCH and GARCH effects, while the off-diagonal elements of A_{11} capture the shock transmissions between the markets, whereas the off-diagonal elements of G_{11} capture the volatility spillovers between the markets.

For clarification of the matrices and how their diagonal and off-diagonal elements are defined, the BEKK-GARCH formula above can be expanded as showed below so that each individual matrix element is visible:

(13) $$H_t = C_0 C_0' + \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} \begin{bmatrix} \varepsilon_{1t-1}^2 & \varepsilon_{1t-1}\varepsilon_{2t-1} \\ \varepsilon_{2t-1}\varepsilon_{1t-1} & \varepsilon_{2t-1}^2 \end{bmatrix} \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix}' + \begin{bmatrix} g_{11} & g_{12} \\ g_{21} & g_{22} \end{bmatrix} H_{t-1} \begin{bmatrix} g_{11} & g_{12} \\ g_{21} & g_{22} \end{bmatrix}',$$

5 EMPIRICAL RESULTS

In this chapter, a correlation analysis on all the markets as well as all the results from the VAR(1) and the BEKK-GARCH(1,1) models are presented. Different subchapters divide the results into the four time periods used in the research (along with the entire research period, the remaining periods are 2002 through 2007, 2008 through 2010 and 2011 through 2014). The implications of the differences in the results between the different time periods are discussed in the conclusions chapter.

5.1 Correlation analysis

Table 6 on the following page shows the cross-market correlation coefficients between the different markets.

Table 6. Cross-market correlations between the stock markets 2002-2014.

	SP500	LATVIA	LITHUANIA	POLAND	CZECH REP.	ESTONIA	HUNGARY
SP500	1.000						
LATVIA	0.244	1.000					
LITHUANIA	0.368	0.599	1.000				
POLAND	0.576	0.461	0.521	1.000			
CZECH REP.	0.575	0.493	0.553	0.791	1.000		
ESTONIA	0.374	0.552	0.724	0.533	0.538	1.000	
HUNGARY	0.551	0.443	0.510	0.785	0.778	0.521	1.000

According to the table, the largest of the emerging markets under study, that is, the Czech Republic, Poland and Hungary, exhibit the largest cross-market correlations with the S&P 500 (0.55-0.58). However, the largest cross-market correlations are between the three largest emerging stock markets, at over 0.75 each. There are no negative average correlations present. On average, the cross-market correlations are higher within Europe than those between the US stock market and the European stock markets.

5.2 Full sample period 2002-2014

Mean return spillovers, ARCH effects and GARCH effects for the entire length of the sample are introduced in table 7 on the following page.

Table 7. Mean return spillovers, ARCH effects and GARCH effects from 2002 to 2014. All values represent the effect of the S&P 500 on each individual market presented on the top of the column, with the ARCH and GARCH effects in the S&P 500 reflecting the market's responses to its own past volatility. Asterisks have been added to describe the significance of the parameter estimates at 10 % (*), 5 % (**) and 1 % (***) statistical significance. The mean return spillover parameter estimates are estimated using the VAR(1) model, while the parameter estimates for ARCH and GARCH effects have been estimated through the use of the BEKK-GARCH(1,1) model.

Market	S & P 500	Estonia	Lithuania	Poland	Czech Republic	Latvia	Hungary
Return spillovers		0.26*	0.15*	0.26*	0.11*	0.09**	0.28*
t-statistic		4.81	2.94	3.28	1.44	1.84	3.15
ARCH effects	0.20***	0.65***	0.23***	1.06***	-0.42***	0.01	-0.35**
t-statistic	8.02	9.20	3.84	10.05	3.08	0.27	2.51
GARCH effects	0.75***	-0.26***	-0.13***	-0.09	-0.21***	-0.02	-0.16**
t-statistic	37.96	-4.45	-4.38	-1.21	-3.35	-1.05	-2.15

Using the entire dataset to analyze spillovers, all the mean return spillovers turned out to be statistically significant at some rate, however none very highly so. Measuring in magnitude, the largest spillovers from the S&P 500 were those to the Estonian, Polish and Hungarian stock markets.

All ARCH effects for this sample, except those from the S&P 500 to Latvia, are highly significant: the largest effects in magnitude are the ones to Estonia and Poland while the weakest significant effects of the S&P 500 are to the Lithuanian and Hungarian indices, out of which the spillover to Hungary is negative.

The GARCH effects from the S&P 500 to the other markets in the study are all highly significant except for those to Poland and Latvia. The GARCH effects indicating volatility spillovers from the S&P 500 to the other markets are all negative, with the largest being those to Estonia and the Czech Republic.

Finally, given the univariate GARCH and ARCH coefficients of the S&P 500, it is worth noting that there is sufficiently clear evidence of dependence of the market’s own shocks and variances in the S&P 500 on the entire dataset.

5.3 Pre-crisis period 2002-2007

Mean return spillovers, ARCH effects and GARCH effects for the pre-crisis period are introduced in table 8 on the following page.

Table 8. Mean return spillovers, ARCH effects and GARCH effects from 2002 to 2007. All values represent the effect of the S&P 500 on each individual market presented on the top of the column, with the ARCH and GARCH effects in the S&P 500 reflecting the market's responses to its own past volatility. Asterisks have been added to describe the significance of the parameter estimates at 10 % (*), 5 % (**) and 1 % (***) statistical significance. The mean return spillover parameter estimates are estimated using the VAR(1) model, while the parameter estimates for ARCH and GARCH effects have been estimated through the use of the BEKK-GARCH(1,1) model.

Market	S & P 500	Estonia	Lithuania	Poland	Czech Republic	Latvia	Hungary
Return spillovers		0.17*	0.14*	0.25	0.14*	0.08*	0.25
t-statistic		2.17	1.97	2.33	1.58	0.97	2.17
ARCH effects	-0.06***	0.27***	0.07	0.10	0.13	0.44**	0.02
t-statistic	0.02	2.82	0.59	0.91	0.89	2.22	0.21
GARCH effects	0.92***	0.025	-0.02	0.00	-0.04	-0.13	-0.00
t-statistic	82.93	0.51	-0.63	0.00	-0.69	-0.98	-0.13

In the pre-crisis period data, there is some evidence of weak unidirectional return spillovers from the S&P 500 to all markets except Poland and Hungary. In this dataset, most ARCH and GARCH off-diagonal effects from the S&P 500 to the other markets are neither particularly large in magnitude nor significant, with the only exceptions being the ARCH effects to the Estonian and Latvian markets. The GARCH effect indicating volatility clustering within the S&P 500 is also large in magnitude and highly significant, but the ARCH effect within the S&P 500 is both less significant and smaller in magnitude.

Compared to the entire dataset, the return spillovers from the S&P 500 to the other markets are weaker and less significant on average. The ARCH effects are mostly less significant and smaller than for the entire dataset: interestingly, however, there seems to be a positive unidirectional ARCH effect from the S&P 500 to the Latvian market in this dataset, while in the entire dataset there were no significant ARCH effects between these markets. The GARCH effects are unable to indicate any volatility spillovers from the S&P 500 to the other markets, indicating that diversification benefits may be present due to the apparently low degree of interdependence.

5.4 Crisis period 2008-2010

Mean return spillovers, ARCH effects and GARCH effects for the crisis period are introduced in table 9 on the following page.

Table 9. Mean return spillovers, ARCH effects and GARCH effects from 2008 to 2010. All values represent the effect of the S&P 500 on each individual market presented on the top of the column, with the ARCH and GARCH effects in the S&P 500 reflecting the market's responses to its own past volatility. Asterisks have been added to describe the significance of the parameter estimates at 10 % (*), 5 % (**) and 1 % (***) statistical significance. The mean return spillover parameter estimates are estimated using the VAR(1) model, while the parameter estimates for ARCH and GARCH effects have been estimated through the use of the BEKK-GARCH(1,1) model.

Market	S & P 500	Estonia	Lithuania	Poland	Czech Republic	Latvia	Hungary
Return spillovers		0.41	0.21	0.43	0.27	0.11	0.60
t-statistic		3.46	1.81	2.51	1.32	0.93	2.80
ARCH effects	0.66***	-0.77***	-0.25	-1.08***	-1.10***	-0.66	-1.58***
t-statistic	-7.24	-5.82	-1.91	-5.55	-5.80	-4.54	-6.40
GARCH effects	0.18	-0.12	-0.31***	-1.01***	-0.30*	-0.37***	1.15**
t-statistic	6.82	-0.87	-4.01	-3.79	-1.64	-3.21	2.24

The crisis period, which is arguably the most relevant subsample in this study, shows some evolvement in the ARCH and GARCH effects that quite strongly supports the hypotheses and research questions of this thesis. The volatility clustering within the S&P 500 is smaller in magnitude and also not statistically significant. Moreover, the ARCH effects within the S&P 500 are significant and now much larger in magnitude, indicating that there is a clear dependence on own shocks present in the S&P 500 during the crisis period.

The coefficients for the mean return spillovers from the S&P 500 to the other markets in this dataset are mostly very large, but all are statistically insignificant. Thus, no conclusions can be made as to whether there is increased interdependence during times of financial distress in the form of larger return spillovers as regards the crisis period data.

The GARCH effects from the S&P 500 to the emerging markets are both more significant and larger across the board. It is noteworthy that both the ARCH and GARCH effects from the S&P 500 to both Poland and Hungary are both highly significant and over one: this is an undesirable character for the coefficients and may stem from too few observations in the dataset, rendering the coefficients unreliable. The largest unidirectional volatility spillovers under the critical value of 1 are those to Latvia, Lithuania and the Czech Republic.

5.5 Post-crisis period 2011-2014

Mean return spillovers, ARCH effects and GARCH effects for the post-crisis period are introduced in table 10 on the following page.

Table 10. Mean return spillovers, ARCH effects and GARCH effects from 2011 to 2014. All values represent the effect of the S&P 500 on each individual market presented on the top of the column, with the ARCH and GARCH effects in the S&P 500 reflecting the market's responses to its own past volatility. Asterisks have been added to describe the significance of the parameter estimates at 10 % (*), 5 % (**) and 1 % (***) statistical significance. The mean return spillover parameter estimates are estimated using the VAR(1) model, while the parameter estimates for ARCH and GARCH effects have been estimated through the use of the BEKK-GARCH(1,1) model.

Market	S & P 500	Estonia	Lithuania	Poland	Czech Republic	Latvia	Hungary
Return spillovers		0.09*	-0.01*	-0.03	-0.21	0.05*	-0.03
t-statistic		0.98	-0.08	-0.24	-1.54	0.70	-0.22
ARCH effects	0.20**	-0.60***	-0.21	-0.25	-0.49***	-0.23**	-0.80***
t-statistic	-5.07	-6.81	-1.60	-0.60	-3.80	-2.54	-4.02
GARCH effects	0.68***	-0.57***	0.20*	0.95***	-0.79***	0.22	-0.48***
t-statistic	7.60	-7.81	1.65	3.69	-7.45	0.93	-6.36

In the last, post-crisis subset, there are weak signs of mean return spillovers again. The only significant mean return spillovers are those to Estonia, Lithuania and Latvia, but they are all relatively small in magnitude.

A notable takeaway from the post-crisis parameter estimates table is that the ARCH effects within the S&P 500 have now become smaller, while the GARCH effects indicating volatility clustering have grown larger. Both remain, however, statistically very significant.

Judging from the ever-increasing GARCH effects from the S&P 500 to the other markets, it can be concluded that as time has passed, some volatility spillovers have been constantly increasing, while others seem to have settled after the financial crisis. The fact that some of the GARCH effects have still grown after the financial crisis does not side completely with existing research in that the volatility transmission should have stalled and become weaker after the financial crisis: however, the status of the subperiod from 2011 to 2014 as a port-crisis period can be questioned. While the definition as a post-crisis period will probably stand for the S&P 500, the volatility remained high in the emerging markets through that time.

However, as an empirical application this study will conclude that in times of financial distress, international diversification benefits from the S&P 500 to these six emerging markets will diminish due to the increased positive correlations in both return and volatility. The positive correlations indicating linkages in volatility are also present during times of more peaceful volatility, but at a weaker level. This confirms, at least on the account of volatility linkages, the hypothesis that there is evidence of increased interdependence between the stock markets during times of financial instability. Also, global stock markets do seem to have become more unified after the financial crisis, based on the GARCH effects which increased even after the crisis.

While the increasing ARCH effects within the S&P 500 indicate larger dependence of the S&P 500 on its own shocks, the change in the ARCH effects of the emerging markets is the opposite. Based on this, the emerging markets seem to have become less and less dependent on their own shocks and more and more dependent on the volatility transferred to them from the S&P 500. In general, the ARCH and GARCH coefficients across the markets are in line with their respective correlations with the S&P 500 presented in the correlation analysis.

Across the three subsets, the largest difference seems to be that most of the return and volatility spillover coefficients from the S&P 500 to the other markets seem to be exaggerated in the crisis period compared to the other periods. However, as none of the return spillover coefficients for the period are statistically significant, a reliable conclusion about their empirical significance should not be made.

Some of the ARCH and GARCH coefficients for Poland, Czech Republic and Hungary are over one in value, which makes effective interpretation problematic. All the values over one are within the crisis period dataset (with the only exception being the ARCH effect from the S&P 500 to the returns of Poland for the entire dataset), which also has the least observations: a reason for the infeasible coefficients might be the fact that the period only spans for three years and with weekly data, the amount of observations is only roughly 150.

6 CONCLUSIONS

This thesis analyzed the spillovers of returns and spillovers from the S&P 500 to selected Eastern European stock markets as well as volatility clustering in the S&P 500 between 2002 and 2014. Spillovers in volatility were modeled using bivariate BEKK-GARCH(1,1) models while return spillovers were examined using bivariate VAR(1) models. The dataset was split into three shorter subsamples in order to capture the effects of financial instability and times of increased volatility in the analyses. The main hypotheses of the thesis were that there would be spillovers of both returns and volatility present in the data and that there would be some volatility clustering. A further hypothesis was that in times of increased volatility, spillovers would increase, indicating increased interdependence between the markets.

The results showed that on average, especially with the GARCH effects but also with mean return spillovers and the ARCH effects, the emerging Eastern Europe stock markets became more unified with the S&P 500 over time. However, the return spillover coefficients, which rose in magnitude during the crisis period, are not statistically significant, and thus a reliable conclusion should not be made as regards the increase in return spillovers during times of financial turmoil. The most notable increase in volatility linkages seemed to happen as the financial crisis took shape, and continued even after the financial crisis. Also, the magnitude of the coefficients was largely in line with the average cross-market correlations between the markets. This trend of global stock markets becoming more unified during times of financial instability is very much in line with existing econometric research regarding the subject.

The notion that the integration between the US and the emerging stock markets has increased over time is important knowledge not only to international investors, but domestic investors especially within the emerging markets used in this study. Even though they have no direct exposure to the fluctuation and volatility of the S&P 500, they will experience it indirectly through the effects that the S&P 500 has on the emerging markets. As a result, the changes in volatility caused by the S&P 500 within the emerging markets is a variable which must be acknowledged and quantified even when investing within the emerging markets exposed to spillovers from the US. It is also noteworthy that not all of the emerging markets were always positively driven by the US: the negative spillover effects should be taken into account.

In practice, increased linkages in volatility and return signify an increase in interdependence and thus diminish the international diversification benefits available to a portfolio investment through investing in both of these types of markets. According to the results, the financial crisis initiated a period during which the emerging markets used for this study became less dependent of their own shocks and more dependent on the volatility transferred to them by the S&P 500. Even though there are positive correlations in the volatility and return spillovers diminishing the international diversification benefits present throughout the entire sample of the study, they seem to grow as time passes. The reason to the fact that some of the volatility linkages kept on increasing even after the crisis remains unclear, but it is possible that the post-crisis period was still too turbulent a time in the emerging markets of Eastern Europe that the period is simply unable to represent a financially peaceful time. The economic struggles related to economic stagnation and a the EMU currency crisis were still ongoing in Eastern Europe during the last subsample, while the S&P 500 already showed noticeable signs of recovery at the same time: this may in part explain the increase in GARCH effects even after the financial crisis. This is also supported by the graph showing the development of the indices after 2011: while the S&P 500 grew quite steadily until the end of 2014 with only minor periods of negative returns, there was much more fluctuation in all of the emerging markets, which can at least partially be attributed to the Eurozone crisis and the subsequent economic struggles in Europe. However, the implication that volatility linkages grew significantly upon the start of the financial crisis is clear. This is also supported by previous research: for instance, Theodossiou and Lee (1993) concluded that the US is the major source of the spillovers among the stock markets of the world.

The scientific contribution of this thesis lies in it supporting existing research on volatility and return spillovers from the USA to the emerging countries, as the results were very much in line with most of the prior research results. As further research goes, expanding the investigation of return and volatility spillovers could be incorporating the economic values of the mean return and volatility spillovers to the analysis and analyze the amount of risk integrated in the spillovers from the US to the emerging markets. Furthermore, the amount of economic value created or destroyed within the emerging economies through the change of their respective market capitalizations as a result of the spillovers from the US would be an interesting field to study.

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APPENDICES

Appendix I. Trade statistics in numerical form

year	import cz	export cz	import hu	export hu	import ee	export ee	import lv	export lv	import lt	export lt	import pl	export pl
2002	1233,40	653,70	2637,50	688,00	163,50	81,50	196,90	91,00	299,60	102,80	1108,40	686,20
2003	1393,94	672,15	2700,65	933,26	181,53	120,56	377,40	123,74	346,91	162,32	1323,73	758,13
2004	1755,92	826,62	2572,61	1142,56	393,10	134,27	364,64	121,10	481,97	295,10	1821,48	929,24
2005	2192,86	1053,56	2561,17	1023,26	511,38	145,43	362,16	177,54	633,91	390,03	1948,59	1267,75
2006	2349,15	1122,60	2584,33	1187,64	526,25	221,42	298,88	245,47	570,11	566,64	2252,58	1960,75
2007	2430,57	1262,34	2827,52	1291,87	296,18	242,28	334,02	381,39	455,65	720,30	2226,01	3123,43
2008	2568,68	1378,42	3102,76	1430,95	392,08	225,55	228,34	393,97	750,04	831,26	2586,90	4130,61
2009	1933,36	969,64	2223,44	1232,88	162,21	189,47	141,55	288,59	589,91	398,54	2038,06	2301,52
2010	2450,06	1410,84	2491,19	1290,39	697,51	187,88	193,06	344,95	637,29	628,12	2963,74	2982,93
2011	3344,15	1684,71	2948,68	1479,34	962,25	309,60	362,57	585,96	1044,43	1141,94	4378,52	3143,11
2012	3930,63	1832,28	3201,29	1566,16	506,54	235,99	246,25	514,79	1176,20	756,98	4621,45	3346,36
2013	3922,89	1943,34	3767,86	1726,91	422,70	293,18	272,67	494,56	1554,35	854,30	4885,38	3778,19
2014	4344,82	2302,42	5283,58	1842,81	562,55	308,46	274,50	428,18	1093,92	681,15	5152,15	3660,28

All values are in millions of US dollars.