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Essays on Volatility and Contagion in Financial Markets

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List of Publications

The list of the author's publications, on the basis of which the thesis has been prepared:

- I Harkmann, Kersti (2014). Stock Market Contagion from Western Europe to Central and Eastern Europe during the Crisis Years 2008-2012. *Eastern European Economics*, vol. 52, no. 3, pp. 55–65. DOI: <https://doi.org/10.2753/EEE0012-8775520303>. (ETIS 1.1.)
- II Harkmann, Kersti (2020). Integration of the Baltic stock markets with developed European markets. *International Journal of Finance and Economics*, forthcoming, DOI: <https://doi.org/10.1002/ijfe.2165>. (ETIS 1.1.)
- III Filipozzi, Fabio; Harkmann, Kersti (2020). Optimal currency hedge and the carry trade. *Review of Accounting and Finance*, vol. 19, no. 3, pp. 411–427. DOI: <http://dx.doi.org/10.1108/RAF-10-2018-0219>. (ETIS 1.1)

Author's Contribution to the Publications

- I The author of the thesis is the sole author of the article.
- II The author of the thesis is the sole author of the article.
- III The author of the thesis was mainly responsible for the literature review and the empirical investigation. The author of the thesis co-wrote the article and acted as the corresponding author in the submission and publishing processes.

Introduction

Ever since the modern portfolio first became popular, one of the guiding principles of financial theory has been that investors who want to be on the safe side should keep their portfolios diversified. The integration of financial markets has been accompanied by an increase in financial openness internationally and a growing number of investors investing abroad in search of the benefits of diversification.

The Global Financial Crisis (GFC) that followed the bankruptcy of Lehman Brothers in September 2008 served as a wake-up call for both academics and practitioners and drew attention to the extreme comovements in financial markets. The crisis spread across borders and caused unexpected comovements in the markets, which challenged efforts at diversification. More generally, recent decades have seen increasing globalisation and financial integration, which in turn may have accelerated the spillover of shocks across markets and countries.

It is evident that capital markets have continued to develop and become much more interconnected, and they move quickly in reaction to news and to changes in the world, but it is still a challenge to predict periods of extreme volatility and comovements. Market crashes can be short-lived, as illustrated by events after the earthquake in Japan in March 2011, but they can also be followed by deep economic recessions like the Great Depression in the 1930s. Figure 1 shows key stock market indices from the USA, Germany and Sweden from 1994 to 2020. The figure provides a first-hand illustration of the substantial volatility and covariation of these stock market indices.

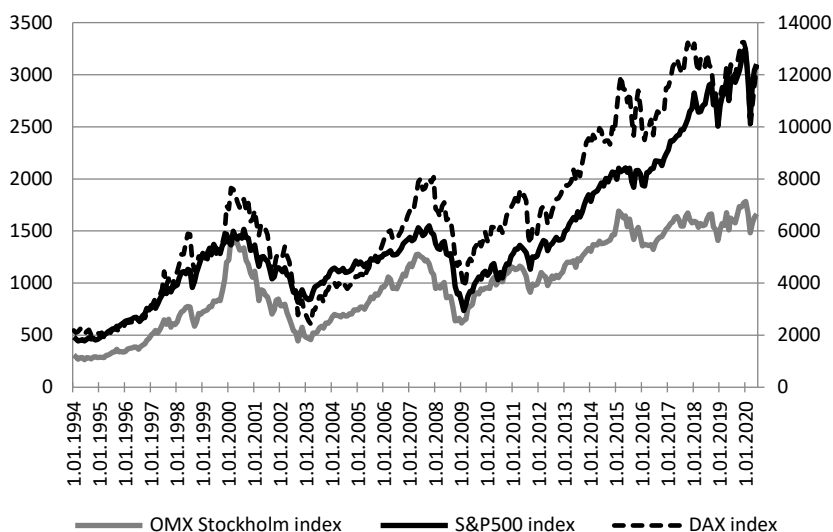


Figure 1. S&P 500 index, DAX index and OMX Stockholm index

Source: World equity indices, Bloomberg

Note. Figure 1 depicts the S&P 500 index from the USA and the Swedish stock market index OMX Stockholm on the left vertical axis and the German stock market index DAX on the right vertical axis.

Laeven & Valencia (2018) report that between 1970 and 2017 there were altogether 151 systemic banking crisis events around the world, meaning there were around three major banking crises each year. On top of these, Laeven & Valencia (2018) also identify 236 currency crises, and 74 sovereign debt crises. Many of these events started from unexpected shocks that affected financial markets seriously and caused extreme volatility and comovements for extended periods of time.

More recently, the Global Financial Crisis and the European Debt Crisis that started in late 2009 have received a lot of attention because of their contagious nature. The outbreak of the Covid-19 pandemic means that there is once again much attention on the topic of the extreme volatility and cross-market contagion in financial markets.

The Global Financial Crisis that evolved after the bankruptcy of the Lehman Brothers and the subsequent European Debt Crisis led to extensive financial market fluctuations, and these developments have been the main sources of motivation for this thesis. The GFC caused extreme volatilities and comovements to occur simultaneously in financial markets and raised the question of whether these comovements were temporary or longer-lasting, perhaps because financial markets were becoming more highly integrated.

The thesis studies the volatility, contagion, and incidental comovements in financial markets from two dimensions: how the comovements can be measured in the short and long-term perspectives, and how an investor should deal with these comovements. Understanding the comovements in financial markets and how to measure them might help both participants in financial markets and decision makers to take suitable steps to tackle financial shocks. As the beginning of the 21st century has shown, unexpected shocks appear repeatedly and create endless research questions.

The existing literature on comovements in financial markets has mainly concentrated on the relationships between financial indices in developed, large and liquid markets (Forbes & Rigobon, 2002; Chiang et al., 2007; Asongu, 2012; Mobarek et al., 2016; Panda & Nanda, 2017). The literature on comovements in financial markets is less extensive for emerging market economies and smaller developed economies, and this also applies to the literature on spillovers and contagion in the CEE region.

The vast part of the literature on correlation and cointegration analysis has been centred on the larger financial markets in the CEE region, principally those in Poland, Hungary and Czechia.¹ The literature on the comovements between the Baltics and developed financial markets is quite limited with a few notable exemptions (Maneschiöld, 2006; Syllignakis & Kouretas, 2011; Olbrys & Majewska, 2014; Bořoc & Anton, 2020). The first two publications in this thesis help address the gap in the literature about short and long-term comovements by putting a special focus on the Baltic financial markets. It should be noted that the past has shown that under certain circumstances even relatively small financial markets can cause volatility and contagion.

Another area connected to the time-varying nature of comovements and cross-correlations between financial markets that has not received enough attention in the literature is the question of how to preserve wealth in portfolio management and how the optimal hedging level is linked to the returns of underlying assets in the form of bond yields. Some aspects of hedging currency exposure have been addressed, but there is no comprehensive assessment of different hedging strategies and their

¹ See for instance Gilmore & McManus (2002), Voronkova (2004), Égert & Kočenda (2007), Syriopoulos (2007), Gilmore et al. (2008), Horváth & Petrovski (2013), Gjika & Horváth (2013), and Hung (2019).

relationship to currency carry trades. The existing literature suggests that the hedging strategy depends on the composition of the portfolio, and the correlations and covariance between different asset classes, and also on changes in the covariance structure (Haefliger et al. 2002; Ackermann et al. 2016; de Boer et al. 2019). However, the link between the hedging strategy and currency carry trades has received little attention. The third publication in this thesis adds to the literature by helping to disentangle the question of how the optimal hedging strategies rely on the comovements of underlying assets and how the optimal hedge levels are linked with carry trades.

Three approaches and methods are used in the thesis. First, it studies the effects of shocks and the comovements in financial markets by taking a close look at the correlations between selected stock markets. The thesis presents evidence that in times of crisis, the dynamic conditional correlations might increase, and this can be attributed to increased financial integration but also captures the moments of contagion. Second, the thesis studies the long-term relationships between stock markets using cointegration analysis. Third, it studies how investors could respond to volatility and covariations in the currency markets to hedge the currency risk of their bond investments by computing and assessing different hedging strategies. The thesis improves the understanding of the challenges that stem from volatility, comovements and contagion in financial markets.

The thesis consists of three articles, of which one has been published and two are forthcoming. The articles focus on financial markets and their intrinsic patterns of volatility and cross-market contagion. The first two articles use stock market data from selected countries, while the third one considers currency and bond markets.

The rest of the thesis is organised as follows. Section 1 discusses the characteristics of volatility, comovements and contagion and how they can be measured. It further discusses how the dynamics of comovements and covariations feed into portfolio theory. This is followed by an overview of the three publications of the thesis. Section 2 contains the final comments summarising the contributions of the articles and presenting possible avenues for future research. Appendices I-III contain the three publications of the thesis.

1 Volatility and contagion

Shocks in financial markets create periods of volatility when prices swing wildly and rapidly between very high and low levels. These periods can often be quite short but they can also translate into financial crises or prolonged periods of instability. It has been observed that if volatility increases in one market, similar comovements may coincide and occur even in countries that are not closely linked to the country where the crisis that caused the volatility originated (Karolyi & Stulz, 1996; Serwa & Bohl, 2005; Corsetti et al., 2005; Lee et al., 2007; Chiang et al., 2007). Such movements and the simultaneous occurrence of instabilities are often manifestations of contagion.

In a broad perspective, contagion is often used as a synonym for spillovers of shocks or disturbances from one financial market to another. However, the term contagion has been used and preferred in the literature since the 2000s because of the need to differentiate between comovements that occur in response to fundamental causes like common shocks and tight links between countries, and comovements that occur in response to changes in investor sentiment. Masson (1998) helps to elucidate the differences between comovements caused by fundamentals and those caused by spillovers. Masson (1998) argues that simultaneous comovements can be explained by monsoonal effects, spillovers and pure contagion. A monsoonal effect, or global shock, occurs when the world is hit by a common shock that causes volatility everywhere and markets react simultaneously in a similar way. Indeed it has been shown that global shocks, such as those from changes in the US economy, are the main drivers of comovements in stock markets (Gomes & Taamouti, 2016; Chen, 2018).

One of the earliest works to show that price changes and volatility in the markets cannot always be explained by changes in the underlying economic fundamentals was a study by Robert Shiller (1981, 2014). He found that a large part of the volatility of stock prices could not be attributed to changes in fundamentals or news about fundamentals but was instead connected to an unobservable fear of uncertainty among investors (Shiller, 1981). Market sentiment has also been the focus of the works of Joseph E. Stiglitz, who advocates the view that financial markets fail to function perfectly because of information asymmetries (Löfgren et al., 2002). This school of thought has been developed further by Benhabib et al. (2016) for example, who show how information frictions can cause sentiment-driven changes in markets that can in turn cause volatility to rise, resulting in a financial crisis. Nițoi & Pochea (2020) show that the beliefs of investors can move the markets in the direction of those beliefs and this may increase the correlations between markets; negative sentiments are especially important in intensifying comovements.

When there are spillovers and interdependence, shocks in one market cause comovements in other markets and spread across borders because the markets are closely connected through financial and trade links. This also means that the more financially integrated markets are, the more likely spillovers and comovements are (Chen, 2018). Where there is less integration, the financial markets are driven by country-specific factors to a larger extent.

In cases of pure contagion as described by Masson (1998), simultaneous comovements and crises are caused by events elsewhere but cannot be explained by global shocks, fundamentals or close links between the countries. The emergence of simultaneous extreme comovements can be explained by changes in market sentiment. These shifts are caused by surprising bad news, which can be called wake-up calls as in

Van Rijckeghem & Weder (2003) and Mobarek et al. (2016), and which may result in herding behaviour. This means that under certain conditions some highly unlikely events can intensify and cause extreme volatility and comovements (Devereux & Yu, 2020).

The very nature of financial markets means that changes in stock market indices and returns are inevitable, as is the occurrence of periods when the markets exhibit covariation. A global factor may provoke strong reactions and temporarily cause high levels of comovement, like after the earthquake in Japan in 2011 as shown in Asongu (2012), while in the absence of a single major surprise, financial markets change, co-vary and diverge from each other for many reasons, including country-specific ones, but still follow similar trends. Some moments of comovements are temporary while others remain persistent, like the Global Financial Crisis that started in 2008 and is notable for the record levels of extreme volatility seen around the globe for a prolonged period (Idier, 2011). The time dimension of these comovements is of the utmost importance, as investigating long-term and short-term comovements in financial markets helps to reveal the specific nature of volatility, comovements and contagion. This thesis describes comovements in financial markets by explicitly distinguishing between long-term interdependence and short-term contagion.

Short-term comovements and extreme cases of comovement are often associated with contagion. These comovements are often studied using some form of correlation analysis (Forbes & Rigobon, 2002; Gjika & Horváth, 2013; Nițoi & Pochea, 2020). It is believed by some that high levels of correlation between financial markets are a sign of integration, as discussed for example by Dellas & Hess (2005) and Donadelli & Paradiso (2014). No less importantly, high levels of correlation could also be indications of short-term comovements and spillovers, and under certain conditions could also be evidence of pure contagion. In fact, correlations between markets increasing significantly and beyond their normal levels during periods of high volatility may be taken as evidence of pure contagion. Such episodes of contagion that are not justified by fundamentals can be short term in nature, as discussed above.

Cointegration analysis helps in studying the comovements of financial markets from another perspective. It helps to determine whether there is some kind of long term equilibrium relationship between financial markets. Cointegration analysis allows financial markets to drift apart in the short term but if there is cointegration between them, it will show that they adjust back to their joint equilibrium path sooner or later and that in the long term a shock in one market will lead to corrections in the other one as well. In other words, cointegration between markets means that the markets are integrated and shocks will always spill over to other markets over time.

Correlation and cointegration analyses investigate the short-term and long-term dynamics of the comovements in financial markets and may therefore be seen to complement each other. The third perspective of the thesis connects the implications of comovements and covariances in financial markets with portfolio theory. Modern portfolio theory is built on the finding that the uncorrelated returns of asset markets can be used in a portfolio to provide protection against risk. Investors can gain from international diversification if the returns from global financial markets are not correlated. Starting from the 1970s, many studies have found gains from cross-country diversification because the risk levels of a portfolio can be minimised considerably if assets with low or negative correlations are incorporated into a portfolio (Solnik, 1974; Meric & Meric, 1989; Cosset & Suret, 1995; Driessen & Laeven, 2007; Flavin & Panopoulou, 2009).

However, the extensive research on the integration of financial markets has shown that financial markets have become more interconnected over time, and long-term relationships have strengthened (Longin & Solnik, 1995; Baumöhl & Lyócsa, 2014; Panda & Nanda, 2017). The resulting increases in correlations and covariances have implications for international portfolio management as they make international diversification less effective. Furthermore, comovements are not only important inside the one asset class of stock markets, as the comovements between various asset classes must also be borne in mind. This becomes especially important when there is foreign currency exposure, as there is in an international portfolio.

Correlation analyses and cointegration techniques are employed in this thesis to study volatility, contagion and comovements in financial markets. Another perspective is added to this as the peculiarities of comovements, covariations and correlations are also studied by using regression analysis to bring together comovements and portfolio theory.

Publication I studies the correlations between selected stock markets. High levels of correlation may first be a sign that financial markets are highly integrated, but they may under certain conditions indicate pure contagion, as discussed earlier. Either way, the correlations between markets illustrate the short-term relationships between them, while cointegration between markets shows long-term and more persistent relationships.

The cointegration method is used in Publication II to study the comovements and the long-term relationships that the Baltic stock markets have with selected stock markets that are more advanced. While the correlation analysis gives a picture of rapid reactions and may be seen as illustrating contagion, the cointegration analysis sheds light on the fundamental links and on interdependence.

Publication III approaches the presence of volatility and comovements from another perspective as it investigates how the peculiarities of volatility and comovements can be addressed in the context of portfolio theory, given that the standard mean-variance portfolio theory of Markowitz (1952) is built on the notion that the optimal portfolio allocation depends on the structure of the correlations of the underlying assets.

Next, subsections 1.1, 1.2 and 1.3 provide overviews of the three publications of the thesis.

1.1 Overview of Publication I

Publication I, *Stock Market Contagion from Western Europe to Central and Eastern Europe during the Crisis Years 2008-2012*, explores the short-term comovements between selected stock markets in Europe. More specifically, the coefficients of dynamic conditional correlation (DCC) between the STOXX 50 Index, which is used as a proxy for the euro area stock markets, and selected stock indices from Central and Eastern Europe are computed for a period when financial markets in Europe were being influenced by the Global Financial Crisis and the European Debt Crisis.

The publication uses daily data from the Euro STOXX 50 Index and daily stock market indices for Bulgaria, Czechia, Estonia, Hungary, Latvia, Lithuania, Poland and Romania. All these stock market indices rose strongly starting from the early 2000s until 2007, when they all dropped sharply. Furthermore, even though the stock markets recovered somewhat after hitting their lowest levels in 2008, the European Debt Crisis and the accompanying uncertainties kept their rises modest.

The methodology is built on Engle's (2002) dynamic conditional correlation (DCC) approach, which adjusts the correlations between variables for changes in volatility by fitting generalised autoregressive conditional heteroscedasticity (GARCH) models individually onto the indices used. This approach helps first to account for the volatility bias and second, in studying how the dynamic correlations change over the time.

Following the approach in Engle (2002), the dynamic conditional correlation coefficients between the returns of the daily stock market indices are computed for the selected CEE indices and the STOXX 50 Index. The results indicate that even though the estimated DCCs increased on average over the period following the Lehman Brothers' bankruptcy, there are no noticeable permanent shifts towards higher and stable levels of correlation. This could be proof of slow but gradual integration between the markets, with contagion effects appearing from Lehman Brothers and the European Debt Crisis. From the portfolio theory perspective, this could mean that most of the benefits of diversification disappear over the long run.

The correlations between the Euro STOXX 50 and Bulgaria and Latvia are particularly low, and are even at some points negative. Czechia, Hungary and Poland show higher levels of correlation with the Euro STOXX 50, which may not be surprising given the characteristics of these CEE countries. While Bulgaria and Romania only entered the European Union in 2007, Czechia, Poland and Hungary have been members since 2004, and the stock markets of these three countries are relatively large and liquid next to smaller markets such as those in the Baltic States.

The highest levels of dynamic correlations are found for all the CEE countries in the period between 2008 and 2012; the peaks in correlations seem to coincide with the episode of the Lehman bankruptcy and around the sovereign debt crisis. The dynamic correlations soared sharply about one month after Lehman Brothers filed for bankruptcy in September 2008. The average of the dynamic correlations increased to the highest level in the sample shortly after Greece sought financial support in April 2010. These increases in correlations are noticeable and add further evidence for the presence of contagion in these stock markets between 2008 and 2012. As these jumps in the dynamic correlations have been brief and volatile it can be concluded that these higher levels represent contagion rather long-term stable integration between the markets.

Publication I helps to shed light on the contagion from stock markets in Western Europe to markets in Central and Eastern Europe over the sample period studied. It does not however provide an answer for the channels or features of such contagion, as both monsoonal effects, spillovers and pure contagion may be present. As discussed earlier, the correlation analysis helps in studying the short-term relationships between the markets but it does not manage to disentangle the integrated markets from the others without further study.

The paper was presented at the 5th international conference *Economic Challenges in Enlarged Europe* in 2013 in Tallinn, Estonia. Earlier versions were presented at the doctoral summer school in 2013 and at various doctoral seminars at Tallinn University of Technology. The paper was accepted for publication in the journal *Eastern European Economics* in 2014.

1.2 Overview of Publication II

Publication II, *Integration of the Baltic stock markets with developed European markets*, explores the degree of integration between the financial markets in the Baltic States and Western European and US markets using cointegration analysis based on Johansen (1988, 1991).

The publication focuses on the stock markets in the Baltic States and examines whether they have long-term relationships with the Euro STOXX 50 index, the Finnish OMX Helsinki index, the Swedish stock market index, and the S&P 500 stock market index in the US. The weekly returns of the stock market indices are used and the sample covers the period from December 2005 to December 2015.

The cointegration approach facilitates the measurement of financial integration between the markets in the longer term, and of which shocks are transmitted across borders to the Baltic region. As discussed earlier, correlations between asset returns do not provide much information on possible longer-term relationships between markets, but if the stock markets are cointegrated, they follow the same path and only deviate temporarily from their long-run relationship.

The results of Publication II are interesting. First, despite the preparatory work that the Baltic States did to join the single currency union and the accession itself, there is no evidence of long-term relationships between the Baltic stock markets and the euro area markets proxied by the Euro STOXX 50 and the Finnish index. This result shows that even though the Baltic States were already members of the European Union and were moving towards accession to the euro area and then became members of it, as Estonia did in January 2011, their stock markets were not really integrated with the Western markets during the period considered. Likewise, the study found no evidence of integration between the Baltic stock markets and the markets captured by the S&P 500 index.

The most striking result of the study is that all of the Baltic indices exhibit a long-term relationship with the Swedish index. The analysis using vector error correction models (VECM) shows firstly that the Baltic States are exposed to changes coming from Sweden, and secondly that shocks in the Swedish market pass through to the Baltic markets and cause adjustments in them. This means for instance that negative shocks that originate from the Swedish financial market and affect the Swedish stock market index may be transmitted to the markets in the Baltic States.

These long-term relationships are also studied from another angle to shine further light on the cointegration between the stock markets under review. Cointegration analyses using rolling windows over consecutive sub-samples also provide evidence of long-run equilibrium relationships between the Baltic and Swedish markets.

The paper was presented at the doctoral summer school in 2015 and in doctoral seminars at Tallinn University of Technology. The paper was accepted for publication in the journal *International Journal of Finance and Economics* in July 2020.

1.3 Overview of Publication III

Publication III, *Optimal currency hedge and the carry trade*, takes as its starting point the volatility and comovements of financial markets and investigates the consequences of these from the perspective of portfolio management. It explores how the risk-minimising investor can tackle with the problem of volatility by using hedging to preserve the value of a portfolio of global government bonds that is exposed to foreign

currency fluctuations and the covariations between all the components of the portfolio. Publication III compares the efficiency of different hedging strategies.

One of the main contributions of Publication III is its use of a portfolio of multiple foreign bonds to mimic the portfolio of an official institution. Other assumptions that are closer to reality mean that a weekly hedging horizon is used instead of a daily approach, a restriction on the short-selling of currencies is explored, and forward contracts are applied instead of futures.

The weekly data are taken for the period from January 2000 to January 2018. Because there are foreign bonds in the portfolio, the foreign currencies used are the US dollar, the Japanese Yen, the UK pound sterling, the Australian dollar, the Canadian dollar, the Norwegian krone and the Swiss franc.

The analysis is conducted using simple regression methods to find the optimal hedge ratios. This somewhat basic approach is complemented by using the dynamic conditional correlation method of Engle (2002) to find the time-varying hedge ratios. This innovation helps first in finding the optimal time-varying hedge ratios that account for the changes in the covariations and volatilities of the returns, and this then also helps to disentangle the relationship between the optimal hedging strategy and the carry trades.

The results are straightforward and show that it is not optimal for a risk-averse investor to leave their foreign exposure unhedged, as hedging reduces the volatility of the bond portfolios considerably. Furthermore, investors can achieve a better risk-adjusted return by fine-tuning their currency exposure using optimal hedge ratios. Comparing different portfolios built either on hedge ratios found by simple regression or on time-varying hedge ratios does not give a final answer as to whether one strategy performs better than the other, but it can be concluded that both strategies achieve the objective of minimising the variance of a foreign portfolio. What the analysis shows is that the optimal portfolio contains carry trades, meaning there is an inverse relationship between the optimal hedge ratios and the levels of interest rates.

The results are robust to various changes. The conclusions are the same for monthly data and in different market conditions, as the sample was split for the periods before and after the Lehman Brothers default.

Before being published in the Review of Accounting and Finance, an earlier version of the paper was issued under the title *Currency Hedge – Walking on the Edge?* in the Working Papers of Eesti Pank (5/2014). It was presented at the 6th International Conference *Economic Challenges in Enlarged Europe* in 2014, Tallinn, Estonia. The paper was accepted for publication in the journal Review of Accounting and Finance in August 2020.

2 Final Comments

This thesis is based on three publications and investigates issues stemming from volatility and contagion in financial markets. Contagion, alternatively known as spillovers or extreme comovements in financial markets, was widely discussed after the crises that hit the world in 1997-1998. It received even more attention after the bankruptcy of Lehman Brothers in 2008 and the eruption of the Global Financial Crisis. The outbreak of Covid-19 in December 2019 has once again led to extreme volatility in financial markets, and it is clear that issues of contagion are as topical as ever, since comovements in financial markets are omnipresent.

This thesis studies the comovements in financial markets from two angles. It first discusses how to measure the extent of comovements, and second it addresses the question of how portfolio management can deal with the consequences of cross-country comovements and covariations.

Publications I and II complement each other by emphasising the differences between the short and long-term dynamics of the comovements. The results from the first publication show that the dynamic conditional correlations (DCCs) are not constant over time and depend on the volatility of the underlying market. The results also show that the DCCs for the markets studied have increased gradually, though this growth is not stable as there are moments of high levels of correlation that do not last for long. The results from Publication II indicate that there is a cointegrating relationship between the stock markets in the Baltic States and Sweden but no long-term relationships between the Baltic States and the euro area or the USA. When these results are compared, it becomes clear that the comovements do not necessarily mean the financial markets are integrated. The shocks to financial markets that cause volatility may escalate the short-term ties as the sentiment of investors changes and the comovements increase and lead to higher correlations. The results indicate that during periods of high stress, there may be temporary extreme comovements, which are often referred to as contagion.

However, even if the correlations increase, this does not necessarily mean that they will then remain at the elevated levels. During stable times, the extreme correlations decrease and become cleaned of the temporary volatility, so in the long term, the comovements of the financial markets should not be based on temporary market sentiments but should arise as markets align with those that they are cointegrated with.

The results from Publications I and II show that shocks may, in the short term, tighten the short-term temporary ties and increase comovements between financial markets even in the absence of deep financial integration. Where there is strong financial integration however, measured in the form of cointegration in Publication II, the exogenous shocks are expected to be magnified as the financial integration works as a channel through which shocks are propagated. Furthermore, these long-term relationships do not appear suddenly, but rather evolve slowly and should be seen as long-term phenomena that may amplify the shocks.

Closely connected to this, though coming from another perspective, is the question of how investors should respond to volatility and comovements, and this is studied in the third publication. The optimal composition of a portfolio is governed by the correlations between underlying assets, but, as discussed in the first two publications, it is in the nature of comovements to be dynamic. Shocks that hit financial markets daily cause investors to shift their preferences and change their positions, and so cause

volatility. These peculiarities are brought together in Publication III, which analyses how a risk-minimising investor could use hedging to preserve the value of their portfolio of bonds denominated in foreign currency. The results show that the overall risk level of a portfolio can be lowered considerably by hedging some part of the currency exposure.

Though each of the publications in this thesis covers different aspects that emerge from the volatility and comovements of financial markets, some limitations of the work may be noted. The DCC method of Engle (2002) describes well the short-term comovements between the developed and the CEE stock markets, and the cointegration methods of Johansen (1988, 1991) help to identify the long-term equilibrium ties between the markets. Both of these show that under certain circumstances, the shocks to financial markets may propagate and create considerable comovements. However, it was beyond the scope of the publications in this work to explore the fundamental underlying reasons, and so the studies do not consider which shocks cause these dynamics. Thus one major stream of work that can be explored further would be to study the comovements jointly in terms of the dynamic conditional correlation of financial markets and the potential drivers of the comovements, which may be macroeconomic fundamentals or the risk perception of investors. It would also be interesting to compare the drivers of short-term comovements of the integrated financial markets and markets that are not integrated in terms of cointegration.

Further to this, the size of the sample studied in Publication II was limited to the Baltic stock markets, and so expanding the cointegration analysis to, for instance, the other CEE stock markets would help in drawing wider conclusions about the short and long-term ties between the CEE markets and developed stock markets.

Closely connected to the result that the comovements and cross-correlations tend to increase during periods of high stress in financial markets, as discussed in Publication I, is the question of whether the ties also increase between different asset markets during periods of high volatility. Given that bond markets are usually perceived as safe-haven assets and there is a tendency to move investments from stock markets to bond markets when risk aversion increases among investors, further analysis could concentrate on comovements between foreign stock markets and foreign government bond markets. This line of research would support further work on the issues covered in Publication III.

A key implication that emerges from the studies in this thesis is the understanding that even though international financial integration may give better access to capital, it comes with the side effect that it acts as a channel that allows the free movement of capital and helps propagate and potentially amplify both positive and negative shocks. Given the interconnectedness of financial markets and the transmission of volatility, Publication III underlines the opportunities that hedging foreign currency exposure offers for risk-averse market participants.

Financial markets never rest, volatility is ever-present, and there are always comovements and occasionally extreme jumps and sharp declines in asset prices. The continuously changing nature of the financial markets means there will always be new issues to investigate.

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Abstract

Essays on volatility and contagion in financial markets

This thesis consists of three publications investigating volatility and comovements in financial markets.

Stock Market Contagion from Western Europe to Central and Eastern Europe during the Crisis Years 2008-2012 focuses on the short-term comovements in financial markets shown in stock market returns. The dynamic conditional correlation (DCC) method of Engle (2002) is used. The publication inspects the dynamic time-varying conditional correlations between the stock market benchmark for the euro area and stock markets in Central and Eastern Europe. The correlations between the Euro STOXX 50 Index and stock market indices for Bulgaria, Czechia, Estonia, Hungary, Latvia, Lithuania, Poland and Romania are studied. The dynamic conditional correlation coefficients increase gradually between 2002 and 2012. The analyses also demonstrate that the DCCs increase extensively when there is high stress in the financial markets. The dynamic correlations between the indices increased noticeably during the Global Financial Crisis, and the peaks in the DCCs coincide with the major shock events of the sovereign debt crisis.

Integration of the Baltic stock markets with developed European markets examines long-term comovements using the cointegration methodology of Johansen (1988, 1991). The study assesses the extent of long-term integration of the Baltic stock markets of Estonia, Latvia and Lithuania with financial markets in Western Europe and the USA. The advanced stock markets are proxied by the Euro STOXX 50 index, the Finnish OMX Helsinki, the Swedish stock market index, and the S&P 500 index in the US. The empirical analysis over the period 2005-2015 reveals that the Baltic stock markets are integrated with the Swedish stock market, and that the transmission of shocks goes from Sweden to the Baltic States. There is no evidence of any long-term relationships between the Baltic markets and the euro area or the USA, which suggests the Baltic markets offer diversification benefits for some stock markets.

Optimal currency hedge and the carry trade investigates how the side effects of comovements and volatility in financial markets can be mitigated in portfolio management. The publication studies how a risk-minimising investor holding a portfolio of foreign currency bonds could respond to covariations of the underlying assets to preserve the value of the portfolio by hedging some of the currency exposure. The portfolio studied consists of foreign bonds and the US dollar, the Japanese Yen, the UK pound sterling, the Australian dollar, the Canadian dollar, the Norwegian krone and the Swiss franc. The performance of different hedging strategies is compared and the results show that for a risk-minimising investor, the hedging is always more beneficial than leaving the currency exposure open. The optimal hedging is superior to full hedging of the currency exposure. Moreover, it can be observed that portfolios with optimal hedges imply carry trades.

Lühikokkuvõte

Esseed volatiilsusest ja nakkuslikkusest finantsturgudel

Käesolev doktoritöö „Esseed volatiilsusest ja nakkuslikkusest finantsturgudel” põhineb kolmel publitseeritud artiklil. Finantsturgude volatiilsust ja koosliikumisi uuritakse kahest vaatenurgast: mil viisil saab finantsturgude koosliikumisi mõõta ja kuidas saab finantsturgude koosliikumiste tagajärgedega tegeleda. Kahes publikatsioonis keskendutakse valitud aktsiaturgude koosliikumiste uurimisele. Kolmas artikkel käsitleb viise, kuidas riskikartlikud investorid saavad enda võlakirjaportfelli valuutaturgude volatiilsuse eest kaitsta. Finantsturgude koosliikumisi uuritakse nii lühi- kui ka pikaajalises perspektiivis, mis aitab illustreerida aktsiaturgude integratsiooni ja nakkuslikku olemust.

Doktoritöö esimene publikatsioon „Kriisiaegne Lääne aktsiaturgude nakkuslikkus Kesk- ja Ida-Euroopa aktsiaturgudele aastatel 2008 kuni 2012” uurib Euroopa finantsturgude lühiajalisi koosliikumisi globaalse finantskriisi ajal. Artiklis kasutatakse päevaseid aktsiaturgude andmeid ja dünaamilise konditsionaalse korrelatsiooni meetodit. Euroopa aktsiaturgude võrdlusindeksina kasutatakse publikatsioonis Euro STOXX 50 indeksi ning selle korrelatsiooni hinnatakse Balti riikide, Ungari, Poola, Tšehhi, Bulgaaria ja Rumeenia aktsiaindeksitega.

Leitud korrelatsioonikordajad tõendavad valitud aktsiaturgude koosliikumisi ja finantskriisi nakkuslikkust. Tulemused näitavad, et ajal, mil finantsturud olid finantskriisist tingituna väga volatiilsed, suurenesid ka korrelatsioonikordajad valitud indeksi vahel hüppeliselt. Suurimad keskmised korrelatsioonitasemed saavutati Lehman Brothers'i pankroti ja Euroopa võlakriisi ajal, kui Kreeka taotles finantsabi. Need järsud tõusud on ajutised ja iseloomustavadki finantsturgude lühiajalisi koosliikumisi. Teisisõnu, isegi kui finantsturgude koosliikumine lühiajaliselt suureneb, ei pruugi finantsturud olla omavahel püsivalt integreeritud. Ajutised tõusud on pigem tõendus finantskriiside nakkuslikkusest, mitte pikaajalisest stabiilsest seosest finantsturgude vahel. Vaadeldes korrelatsioone kogu uuritud perioodi vältel, on näha, et vaatamata ajutistele hüpetele suurenesid korrelatsioonid nende aastate jooksul üksnes marginaalselt.

Doktoritöö teine publikatsioon „Balti aktsiaturgude integratsioon arenenud aktsiaturgudega” käsitleb finantsturgude pikaajalisi koosliikumisi. Artiklis kontrollitakse, kas Balti riikide aktsiaturgude ja valitud riikide aktsiaturgude vahel esineb ajavahemikus 2005-2015 kointegratsioon ehk pikaajaline stabiilne tasakaaluseos. Artiklis kasutatakse nädalase sagedusega andmeid. Arenenud aktsiaturgude võrdlusindeksitena kasutatakse Euro Stoxx 50 indeksi, OMX Helsingi aktsiaindeksi, Rootsi aktsiaindeksi ja USA S&P 500 indeksi.

Esiteks tõestab analüüs, et Rootsi ja Balti aktsiaturgude vahel esineb kointegratsioon. See oluline tulemus näitab, et isegi kui aktsiaturud liiguvad ajutiselt erisuunaliselt, taastub varem või hiljem tasakaaluline liikumine. Teiseks annab analüüs kinnitust sellest, et igasugune šokk Rootsi aktsiaturgudel kandub üle ka Balti aktsiaturgudele. Šokke ja finantskriise, mis kanduvad üle kointegratsiooni tõttu, ei saa pidada nakkuslikeks. Pigem on tegemist loomuliku levikuga, mis on tingitud turgude integratsioonist ja lähedastest seostest. Tulemused näitavad ka seda, et Balti aktsiaturgudel puudub pikaajaline tasakaalu seos teiste arenenud aktsiaturgudega. Seega pakuvad Balti riikide aktsiaturud arenenud aktsiaturgudele portfelli hajutamise võimalusi.

Doktoritöö kolmas publikatsioon „Optimaalne valuutariski maandamine ja „carry“ tehingud“ otsib vastust küsimusele, kuidas saaksid institutsionaalsed ja riskikartlikud investorid vähendada finantsturgude koosliikumiste mõju välisriikide võlakirjadesse investeerimisel. Moodne portfelli juhtimisteooria eeldab, et optimaalses portfellis kasutatakse omavahel instrumente, millede omavaheline korrelatsioon on negatiivne või puudub. Arvestades asjaolu, et teatud juhtudel – eriti finantskriiside ajal – finantsturgude koosliikumised suurenevad, vajavad riskikartlikud investorid meetodeid portfelli riski vähendamiseks. Artiklis kontrollitakse, kas ja millises ulatuses saab vähendada välisriikide võlakirjadest koosneva portfelli volatiilsust valuutariskide maandamise abil.

Küsimust uuritakse euroala investori perspektiivist, kasutades seitsme riigi võlakirjadest koosnevat portfelli ja nädalase sagedusega andmeid. Kasutades klassikalist regressioonanalüüsi ja DCC-GARCH-mudelit, leitakse võlakirjaportfellidele optimaalsed valuutariski maandamise tasemed. Omavahel võrreldakse maandamata, täielikult maandatud ja optimaalselt maandatud valuutariskidega portfelle. Artiklis näidatakse, et valuutariski maandamisel väheneb välisriikide võlakirjade portfelli volatiilsus märkimisväärselt. Parim riski ja tulususe suhe saavutatakse valuutariski optimaalse maandamise korral. Lisaks näitavad tulemused, et optimaalselt maandatud portfelli puhul on optimaalsed valuutariski maandamise tasemed ja võlakirjade intressitasemed omavahel negatiivselt seotud - mida kõrgem on tulusus, seda madalam on optimaalne valuutariski maandamise tase.

Doktoritöö artiklid kajastavad kolme uurimisvaldkonda finantsturgude volatiilsuse ja koosliikumiste nakkuslikkuse olemusest ning saadud tulemused annavad väärtusliku panuse teaduskirjandusse. Kuna finantsturgude olemuseks on pidevalt muutuda ja reageerida nii oodatud kui ka ootamatutele uudistele, tekitavad need pidevalt uusi uurimisküsimusi. Artiklites esitatud uurimistulemused võimaldavad finantsturgude dünaamikaga seotud teematikat veelgi põhjalikumalt uurida.

Appendix

Publication I

Harkmann, Kersti (2014). Stock Market Contagion from Western Europe to Central and Eastern Europe during the Crisis Years 2008-2012. *Eastern European Economics*, vol. 52, no. 3, pp. 55–65. DOI: <https://doi.org/10.2753/EEE0012-8775520303>. (ETIS 1.1.)

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Filipozzi, Fabio; Harkmann, Kersti (2020). Optimal currency hedge and the carry trade. *Review of Accounting and Finance*, vol. 19, no. 3, pp. 411–427. DOI: <http://dx.doi.org/10.1108/RAF-10-2018-0219>. (ETIS 1.1)

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