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Essays on the Co-movement Dynamics of Frontier/Emerging and Developed Financial Markets

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Julkaisun nimike
Esseitä kehittyvien reunamaiden ja kehittyneiden maiden rahoitusmarkkinoiden välisistä riippuvuussuhteista

Tiivistelmä
Väitöskirja käsittelee kehittyvien reunamaiden ja kehittyneiden maiden rahoitusmarkkinoiden välisiä dynaamisia riippuvuussuhteita sekä globaalin rahoitusmarkkinakriisin (vuosina 2008–2009) vaikutuksia näihin riippuvuussuhteisiin. Väitöskirja koostuu johdantoluvusta ja neljästä esseestä. Ensimmäisessä esseessä tutkitaan (i) Euroopan kehittyvien reunamarkkinoiden ja kehittyneiden Yhdysvaltain ja Euroopan osakemarkkinoiden välisiä riippuvuussuhteita aallokeanalyysia hyödyntämällä sekä (ii) makrotaloudellisten tekijöiden mahdollisia vaikutuksia riippuvuussuhteiden ajalliseen muutokseen eri aikafrekvensseillä. Tulokset osoittavat, että keskinäisen riippuvuuden voimakkuus vaihtelee eri reunamarkkinoilla ja eri aikafrekvensseillä, vaihdellen myös ajan kuluessa. Markkinoiden keskinäinen riippuvuus on voimakkaampaa matalammalla frekvenssitasolla ja voimistuu rahoitusmarkkinakriisin aikana. Toinen essee keskittyy Baltian ja Euroopan kehittyneiden osakemarkkinoiden yhteyksiin ennen rahoitusmarkkinakriisiä ja kriisin aikana. Tulokset osoittavat, että Baltian osakemarkkinat olivat ilmeisen segmentoituneet ennen kriisiä ja integroituivat voimakkaasti kehittyneiden markkinoiden kanssa kriisin kuluessa.

Väitöskirjan kolmannessa esseessä muodostetaan yhteisintegroitunut vektori-autoregressiivinen malli, jolla tutkitaan rahoitusmarkkinakriisin vaikutusta Euroopan reunamarkkinoiden ulkoisiin ja sisäisiin yhteyksiin. Tulokset osoittavat, että Euroopan reunamarkkinoiden pitkän ja lyhyen aikavälin ulkoiset yhteydet voimistuivat kriisin aikana – heikentäen siten sijoittajien hajautusmahdollisuuksia. Neljännessä esseessä tutkitaan kehittyvien reunamaiden ja Yhdysvaltain velkakirjamarkkinoiden dynaamisia riippuvuussuhteita sekä tekijöitä, jotka selittävät keskinäisten riippuvuuksien ajallisen muutoksen. Tulokset osoittavat, että eri makrotaloudellisilla tekijöillä ja globaalien velkakirjamarkkinoiden epävarmuudella on merkittävä rooli selitettäessä velkakirjamarkkinoiden tuottojen keskinäisiä riippuvuussuhteita.

Asiasanat
reunamarkkinat, rahoitusmarkkinakriisi, dynaaminen keskinäinen riippuvuus, makrotaloudelliset tekijät, kehittyvien markkinoiden velkakirjat

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Abstract

This thesis examines the co-movement dynamics of frontier/emerging and developed financial markets, paying special attention to the impact of the 2008–2009 financial crisis. The thesis consists of an introductory chapter and four essays. The first essay examines: (i) the dynamics of European frontier stock markets co-movement with the USA and developed markets in Europe by utilizing wavelet squared coherency; (ii) global and domestic macroeconomic factors that could explain time variations in co-movement at different frequency levels. The results show that strength of co-movement varies considerably across the frontier markets, at different frequencies, and over time. Co-movement is stronger at lower frequencies and increases during the 2008–2009 financial crisis. The second essay focuses on the linkages of Baltic stock markets with developed European markets in the pre-crisis and 2008–2009 crisis period. The results demonstrate that while the Baltic stock markets were apparently segmented before the crisis, they became highly integrated during the crisis.

The third essay employs a cointegrated vector-autoregressive framework to examine the impact of the 2008–2009 financial crisis on the external and internal linkages of European frontier stock markets. The results show that long- and short-term external linkages of European frontier stock markets were strengthened during the crisis, implying the significant impact of the 2008–2009 financial crisis on their diversification potential. The fourth essay examines the co-movement dynamics of emerging/frontier government bond markets with the US market and the driving forces behind the time-varying co-movement. The results reveal that macroeconomic factors and global bond market uncertainty play important roles in explaining time variations in the bond return co-movement.

Keywords
Frontier Market, Financial Crisis, Co-movement Dynamics, Macroeconomic Factors, Emerging Market Bonds

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Vaasa, June 2013

Vanja Piljak

Contents

This thesis consists of an introductory chapter and the following four essays:

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1 INTRODUCTION

This doctoral dissertation examines co-movement in international financial markets in four different essays. The focus of the dissertation is on the emerging/frontier financial markets. In particular, the first, second, and third essay examine co-movement dynamics of emerging/frontier stock markets with the developed markets, while the fourth essay extends the scope of the dissertation by investigating co-movement dynamics of emerging/frontier bond markets with respect to the US government bond market.

The issue of co-movement among various financial markets is an important aspect of financial market integration, which is a central theme in international finance. While financial market integration represents the broader concept of the complex inter-relationships among various financial markets, the co-movement across financial markets is a more specific concept interpreted in terms of the nature and extent of interdependences across asset returns (Kim, Moshirian & Wu 2006). This dissertation utilizes the aforementioned concept of co-movement, which is in line with earlier studies that focus on co-movement as a special dimension of financial market integration (Bekaert & Harvey 1995; Karolyi & Stulz 1996; Bracker, Docking & Koch 1999).

The dissertation also focuses on the impact of the 2008–2009 financial crisis on the emerging/frontier stock markets. This research topic is timely and relevant, as indicated by growing body of literature offering evidence on the significant impact of the global 2008–2009 financial crisis on various financial markets worldwide. For instance, the impact of the crisis is documented for stock markets (e.g. Bartram & Bodnar 2009; Dooley & Hutchison 2009; Chudik & Fratzscher 2011), fixed-income markets (e.g. Dwyer & Tkac 2009), and foreign exchange markets (e.g. Fratzscher 2009). The emerging/frontier markets provide an interesting environment for further research given that they were a significant source of diversification benefits prior to the 2008–2009 financial crisis. Given that earlier literature has documented that the strength of stock market linkages and consequently the level of diversification benefits tend to change during times of crisis (e.g. Yang et al. 2006), it is of great interest to examine how the diversification potential of emerging/frontier markets is affected by the global financial crisis.

Acknowledging the importance of understanding the driving forces behind the co-movement dynamics among financial markets, the dissertation also examines the role of macroeconomic fundamentals in explaining time variations in those co-movement dynamics. In particular, the co-movement analysis is enriched by investigating the impact of both global and domestic macroeconomic factors (busi-

ness cycle fluctuations, inflation environment, and monetary policy stance) on the co-movement dynamics. In addition to macroeconomic fundamentals, there is evidence in literature that market uncertainty, as measured by implied volatility, has an important impact on the co-movement dynamics of asset returns (Connolly, Stivers & Sun 2005; Kim, Moshirian & Wu 2006; Andersson, Krylova & Vähämaa 2008). This dissertation builds upon the proposed use of implied volatility measures as proxies for market uncertainty and in its fourth essay extends Connolly, Stivers and Sun (2005) by applying an implied volatility measure to examine the impact of global bond market uncertainty on time variations in international bond market co-movement.

The remainder of this introductory chapter is organized as follows. Section 2 describes the contribution of this dissertation. The next section briefly discusses the main theoretical fundamentals of portfolio diversification, financial market integration and crisis transmission mechanisms. Section 4 provides a brief introduction to emerging markets finance and gives an overview of European frontier stock markets and emerging markets bonds. Sections 5, 6, and 7 discuss the literature related to the co-movement between international financial markets, the relationship between financial markets co-movement and macroeconomic factors, and the impact of the financial crisis on the co-movement dynamics. Section 8 summarizes the four essays that comprise this dissertation. Finally, Section 9 offers concluding remarks and briefly discusses the practical implications of the results.

2 CONTRIBUTION OF THE DISSERTATION

The objective of the dissertation is to examine co-movement dynamics of frontier/emerging and developed financial markets. Four separate essays address the topic from different angles. The first essay analyzes co-movement dynamics in the simultaneous time-frequency framework, emphasizing the importance of frequency domain in the co-movement analysis. In addition, the first essay also addresses the topic from the angle of the fundamental forces (macroeconomic factors) that drive co-movement at different time horizons. The second and third essays examine the topic in the light of the 2008–2009 global financial crisis. The common denominator of the three aforementioned essays is reflected in examining co-movement dynamics from the standpoint of frontier stock markets. The fourth essay differs from those three essays in addressing the main topic of the dissertation from the bond markets perspective, covering a comprehensive set of frontier and emerging markets. The aspect of driving forces (macroeconomic factors) behind the co-movement dynamics is also represented in the fourth essay, but with respect to bond markets co-movement.

This dissertation contributes to finance literature through its four inter-related essays within the research area of emerging financial markets. The main contribution of the dissertation is in the field of emerging markets finance, but the dissertation also makes a number of contributions to several specific streams of literature (stock market interdependence, international portfolio diversification, fixed-income markets, financial crisis, and macroeconomic literature). Hence, the overall contribution of the dissertation is in merging these several strands of literature to shed new light on each of them. A more specific description of the contribution of each essay in this dissertation is given below.

The first essay contributes to the literature in three respects. First, the essay adds to the literature on integration and co-movement of emerging markets by investigating those stock markets belonging to the subcategory of European frontier markets, which have received little attention thus far. Second, the essay adopts an advantageous three-dimensional wavelet coherency approach, enabling simultaneous assessment of the co-movement across different investment horizons and over time. In other words and to the best of my knowledge, this essay is the first to use a wavelet analysis to measure the co-movement of the European frontier markets with the US and the developed European markets simultaneously in both time and frequency domains. Third, another novel feature of this essay stems from employing the wavelet squared coherency to analyze whether macroeconomic factors explain variations of the co-movement at different time frequencies.

The second essay contributes to two different strands of literature. First, the essay extends the growing extensive literature on the effects of the financial crisis by providing new evidence on the impact of the recent 2008–2009 global financial crisis on one special subset of emerging markets. Second, the essay enriches the literature on the linkages between developed and emerging stock markets by focusing on the stock markets in the Baltic region, which represents an increasingly attractive investment destination, but is still a thinly investigated subset of emerging markets.

The third essay contributes to the existing literature in two ways. The first aspect of the contribution is the focus on the impact of the 2008–2009 financial crisis on the long-term relationships and short-term dynamic linkages of European frontier stock markets. The results of this essay therefore provide new insights on how the diversification potential of frontier markets changes during a crisis period. In particular, both the external stock market linkages of European frontier markets with the major developed markets (the UK, France, and Germany) and the internal cross-dynamics among the frontier markets before and during the 2008–2009 financial crisis are examined. The second aspect of the contribution is reflected in focusing on an interesting subset of frontier markets (namely Croatia, Estonia, Romania, Slovakia and Slovenia), which are considered as larger frontier markets in terms of market capitalization and diversification potential, but on which very limited research has been conducted.

The fourth and final essay of the dissertation makes a number of contributions to the relevant literature. First, while most of the previous studies on international bond market co-movement have focused on the correlation dynamics between international markets, this essay examines the driving forces behind the time-variation of the bond return correlations. In particular, the essay investigates the role of both global and domestic macroeconomic fundamentals in explaining variations in bond return co-movement. Second, a novel feature of this essay is provided by examining the influence of global bond market uncertainty (based on an implied volatility measure) on time variations in bond market co-movement. Hence, this essay extends the literature by jointly examining the impact of macroeconomic factors and global bond market uncertainty on international bond market correlations. Third, the essay investigates a comprehensive set of emerging and frontier bond markets with substantial diversity, contributing a new dimension to the literature on international bond market co-movement that has traditionally focused on developed markets.

3 THEORETICAL FUNDAMENTALS

3.1 Portfolio diversification

The seminal work by Markowitz (1952, 1959) constitutes the main cornerstone of modern portfolio theory. Markowitz formulated the fundamental theorem of mean variance portfolio theory, which was developed to find the optimum portfolio based on the trade-offs between risk and return. One important finding of Markowitz's work was the fact that investors have to consider how each security co-move with all other securities in the portfolio. Moreover, considering these co-movements when constructing a portfolio leads to an ability to find a portfolio with the same expected return and less risk than a portfolio that ignores the interactions between the securities. The portfolio theory was further developed by Kraus and Litzenberger (1976) and Lee (1977), who provide alternative specifications of portfolio theories that included skewness as an additional moment that might more adequately describe the distribution of the portfolio returns. Additionally, Fama (1965) and Elton and Gruber (1974) offered enhancements to portfolio theory in terms of more realistic descriptions of the distribution of return. An excellent review of the historical development and the current state of the modern portfolio theory is provided by Elton and Gruber (1997).

The main implication of the mean variance theory is that portfolio diversification can lead to reduced risk. Furthermore, international diversification is identified as an important risk reduction tool. Elton and Gruber (1995) developed the following formula for calculating the international diversification portfolio benefits:

(1) $$R_N - r_f > [R_{US} - r_f]\,[\sigma_N \rho_{N,\,US} / \sigma_{US}],$$

where: R_N = the expected return on the non-U.S. securities in dollars
r_f = the risk-free rate of interest
R_{US} = the expected return on U.S. securities
σ_N = the standard deviation of non-U.S. securities in dollars
$\rho_{N,\,US}$ = the correlation between U.S. securities and non-U.S. securities
σ_{US} = the standard deviation of U.S. securities.

Elton and Gruber (1995) argue that as long as the expression in the last bracket of the equation is less than one, the international diversification will be profitable, even if the expected returns are lower than those on the domestic market. The

equation (1) is written from a U.S. investor's perspective, but a similar equation could be used by investors from any country considering foreign investments.

Early empirical studies in this area demonstrated that international diversification is beneficial for investors. For instance, Solnik (1974) investigated international diversification using a sample of seven European stock markets and proved that an internationally well-diversified portfolio is 50% less risky than a well-diversified portfolio of U.S. stocks (with the same number of holdings). Errunza (1977) shows that international diversification is beneficial for investors especially if they diversify into less developed (emerging) countries. However, studies that are more recent indicate that potential benefits from international diversification are diminishing due to globalization of financial markets and increased market integration (e.g. Hanna, McCormac & Perdue 1999; Kearney & Lucey 2004; Chelley-Steeley 2005).

3.2 Financial market integration

In the literature on international financial integration, there are three basic approaches used in determining the definition of the degree of international financial market integration (see Kearney & Lucey 2004). Each approach is classified as either a direct or an indirect measure of financial market integration. The first approach defines financial market integration in terms of the extent to which the rates of return on financial assets with similar risk characteristics and maturity are equalized across different countries. This approach applies the law of one price to financial assets (assets with identical cash flows should command the same return) and is therefore considered a direct measure.

The second approach is based on the concept of international capital market completeness and it falls into the category of indirect measures. This definition is given by Stockman (1988), who states: "*Financial integration is perfect when there exists a complete set of international financial markets that allows economic and financial market participants to insure against the full set of anticipated states of nature.*" The third approach defines financial market integration in terms of the extent to which domestic investment is financed from world sources rather than from domestic ones (Feldstein & Horioka 1980). This approach falls into the category of indirect measures.

Although the literature provides evidence of the increasing integration of global equity markets, there is no consensus in the literature on a well-accepted measure of integration (Pukthuanthong & Roll 2009). The theoretical literature on measur-

ing international stock market integration could be divided into three main streams: testing the segmentation of stock markets through application of the international capital asset pricing model (CAPM); examining changes in the correlation and cointegration structure of stock markets; and applying time-varying measures of integration. The stream of literature using the CAPM is based on the assumption that world capital markets are perfectly integrated. This set includes studies of a world CAPM (Harvey 1991), a world CAPM with exchange risk (Dumas & Solnik 1995), world arbitrage pricing theory (Solnik 1983), world consumption-based model (Wheatley 1988), and world multibeta models (Ferson & Harvey 1993, 1994).

Further development in testing market integration via CAPM is provided by Errunza, Losq and Padmanabhan (1992), who derive an international CAPM in which the polar segmented/integrated cases are not assumed. However, the main disadvantage of this model is that the degree of segmentation is constant over time. The seminal works by Harvey (1989) and Bekaert and Harvey (1995) provide new evidence of time-varying equity risk premium, indicating that modeling of market integration should account for this time variation. In particular, Bekaert and Harvey (1995) develop a new methodology that allows for the degree of market integration to change over time. Further enhancements to modeling time-varying market integration come from De Jong and De Roon (2005) who develop an international asset pricing model with partially segmented markets, allowing for a time-varying beta that is linear in the segmentation variable.

More recent contributions to the literature on measuring market integration include the work of Carrieri, Errunza and Hogan (2007), Chambet and Gibson (2008), Pukthuanthong and Roll (2009), and Bekaert et al. (2011). Carrieri, Errunza and Hogan (2007) propose a measure of integration based on a static asset pricing model that links expected equity returns to local and global risk factors (variances and covariances) and prices of risk. In their model, risk factors and prices of risk are allowed to vary through time. Chambet and Gibson (2008) propose a measure of financial integration based on a model that includes global and local factors plus a systematic emerging market factor. They also add indicators of real activity (trade openness and trade concentration) to their proposed measure of financial integration. Pukthuanthong and Roll (2009) derive a new integration measure based on an adjusted R-square from a multi factor model for country equity returns. More recently, Bekaert et al. (2011) developed a new measure of the degree of equity market segmentation, based on industry-level earnings yield differentials (relative to world levels) aggregated across all industries in a given country.

A significant stream of literature has examined the international stock market integration in terms of changes in correlation and cointegration structure of market returns over time. The rationale behind this methodological approach is that if the correlation structure changes over time with the trend of increasing correlation, then it indicates a higher degree of integration. Some examples of early studies using this approach include Campbell and Hamao (1992), Madura and Soenen (1992), Meric and Meric (1997), and Bracker and Koch (1999). In the vein of cointegration studies, early papers used the Engle-Granger methodology (e.g. Kasa 1992), while recent studies have used more advanced Johansen multivariate approach (e.g. Gilmore & McManus 2002; Yang et al. 2006; Syriopoulos 2007; Kenourgios & Samitas 2011).

3.3 Crisis transmission mechanisms

The theoretical literature on shock transmission mechanisms in the international context is extensive and can be divided into two broad categories: crisis-contingent and non-crisis-contingent theories (Forbes & Rigobon 2001). The main criterion behind such a classification is the assumption of whether the transmission mechanisms change during a crisis or remain the same during a crisis and stable periods. Crisis-contingent theories assume that transmission mechanisms change during a crisis, which consequently leads to increased cross-market linkages after a shock. On the other hand, non-crisis-contingent theories assume that transmission mechanisms before and during the crisis are not significantly different and therefore any large cross-market correlations after a shock are actually spillovers resulting from the normal interdependence (linkages that existed before the crisis) among markets. Dornbusch, Park and Claessens (2000) provide a detailed overview of the theoretical literature on international transmission of shocks.

A set of crisis-contingent theories suggests three main mechanisms for the international transmission of shocks: multiple equilibriums; endogenous liquidity; and political economy. In this framework, the multiple equilibriums mechanism occurs when a crisis in one market causes another market to move to a bad equilibrium (characterized by decreasing asset prices, devaluation, capital outflows, or debt default). The theoretical explanation for this mechanism is based on sudden changes in investors' expectations after the initial crisis in the first market (see e.g. Gerlach & Smets; 1995; Jeanne 1997; Masson 1998). A second mechanism of shock transmission across countries relates to endogenous liquidity shocks. The argument in this framework is that a crisis in one country leads to reduced liquidity among market participants, forcing them to sell their asset holdings in

other markets (e.g. Goldfajn & Valdes 1997; Yuan 2005; Boyer, Kumagai & Yuan 2006). The third transmission mechanism within the framework of the crisis-contingent theories is political contagion. For instance, Drazen (1999) examines the European devaluations of 1992–1993 and provides evidence that political factors played an important role in causing contagion, since the presidents of the central banks were under political pressure to maintain their countries' fixed exchange rates.

The non-crisis-contingent theories suggest that shocks (either global or local) will be transmitted across countries because of their real and financial linkages. This group of theories can be divided into three types of models: trade links and competitive devaluations; financial linkages; and random aggregate shocks. The first type of models explains the transmission of financial and currency shocks through direct trade and competitive devaluations channels (e.g. Glick & Rose 1999; Corsetti et al. 2000). For example, a crisis in one country could cause a reduction in income and consequently in the demand for imports, affecting the trade balance and related economic fundamentals in trading-partner countries. The second transmission mechanism is based on financial linkages between countries (see e.g. Lagunoff & Schreft 2000; Van Rijckeghem & Weder 2001). In a highly integrated region with strong financial linkages, a crisis in one country will directly affect other countries, in such forms as reduction in foreign direct investments and capital flows. The third type of models argues that global or common shocks could simultaneously hit the fundamentals of many countries. Any type of global shock (for example, major changes in interest rates or currency values, or a contraction in the international supply of capital) can simultaneously trigger economic slowdown and a crisis. A consequence of such a global shock would be an increase of the co-movement of asset prices in countries affected by the crisis. The theoretical models of common shocks are explained in Calvo, Leiderman and Reinhart (1996) and Masson (1998).

4 EMERGING MARKETS FINANCE

Emerging markets finance has evolved into a challenging research issue over the past two decades (see e.g. Bekaert & Harvey 2003 for a survey; Cuadro-Saez, Fratzscher & Thimann 2009; Barclay, Fletcher & Marshall 2010). The significance of the emerging markets is reflected in the fact that they have become a relevant driver of global economic growth in recent years, providing high returns for investors at the same time.

Research on emerging stock markets emphasizes the importance of the features of those markets for investment purposes. To start with, emerging markets exhibit higher expected returns, as well as higher levels of volatility compared to the developed markets. However, the inclusion of emerging market assets in the investment portfolio significantly enhances portfolio opportunities as a result of low correlations between emerging and developed equity markets (see Harvey 1995). This finding has generated a growing body of literature that investigates the features of emerging market equity returns including two important research areas: 1) the risk–return tradeoff within emerging markets (e.g. Harvey 1991; Bekaert & Harvey 1997; De Jong & De Roon 2005); and 2) international portfolio diversification through combining investments in emerging stock markets with investments in developed stock markets (Divecha, Drach & Stefek 1992; Bekaert & Urias 1996; Barry, Peavy & Rodriguez 1998; Driessen & Laeven 2007; Li & Majerowska 2008).

The main focus of research on the risk-return relationship within the emerging markets is on the global market risk and currency risk (Bailey & Chung 1995; De Santis & Imrohoroglu 1997; Pajuste, Kepitis & Högfeldt 2000; Mateus 2004), but particular attention is also paid to certain specific risk factors such as political risk (Diamonte, Liew & Stevens 1996; Bilson, Brailsford & Hooper 2002) and country risk (Erb, Harvey & Viskanta 1996a, 1996b). An additional area of research investigates the applicability of asset pricing models to observed emerging market returns (Harvey 1991, 1995; Cheng, Jahan, Parvar & Rothman 2010; Iqbal, Brooks & Galagedera 2010).

4.1 European frontier stock markets

In 1996, the International Finance Corporation (IFC) introduced the frontier market category as a special subset of emerging markets. The frontier market category encompasses markets characterized by thin trading activity, a short history, and higher risk levels than developed markets. The attractiveness of the frontier stock

markets stems from high returns provided in the past. As a reflection of increased interest among global investors in these markets, the first fully investable index for frontier equity markets (S&P/IFCG Extended Frontier 150 Index) was launched by Standard & Poor's in 2007. By the following year, a few other index providers (including MSCI Barra and FTSE) had emerged, to track and maintain index data on the frontier stock markets. Additionally, stocks traded on frontier markets have become more accessible through several exchange-traded funds and mutual funds.

The frontier markets are worth researching because of the diminished potential for international portfolio diversification resulting from increased interdependence among the developed international stock markets.[3] The literature also provides recent evidence of increased integration of the emerging markets into the world markets (e.g. Tai 2007), which suggests that an alternative to future benefits of international diversification could be in the frontier markets sub-category. The promising diversification potential of the frontier markets is documented by Berger, Pukthuanthong and Yang (2011), who examine a set of frontier markets worldwide and find that those markets exhibit low levels of integration with the world market and subsequently offer significant diversification benefits. Additionally, Speidell and Krohne (2007) find low correlations between frontier and developed stock markets, while Jayasuriya and Shambora (2009) examine diversification benefits across market classifications by analyzing optimal portfolios of developed, emerging and frontier markets. Their results suggest that diversification into frontier markets improves portfolio risk and returns.

The frontier stock markets in Europe are of particular research interest, given their potential for accelerated economic growth and the attribute of regulated markets linked to the advantages of EU membership. Additionally, the use of the European frontier markets in this dissertation is motivated by the fact that relatively few studies have examined these stock markets, making that area of research ripe for exploration.

The sample selection of frontier markets in this dissertation was driven by the Standard and Poor's classification of frontier markets. There are nine countries in Europe classified in this category (representing a constituent universe for the S&P/IFCG Extended Frontier 150 Index), but the dissertation focuses on eight

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[3] Several studies show that the international stock markets have become increasingly interdependent since the 1987 U.S. Stock Market Crash, implying decreased benefits of international diversification (Arshanapalli & Doukas 1993; Chelley-Steeley 2000; Bessler & Yang 2003; Wong et al. 2004; Berben & Jansen 2005; Wongswan 2006).

countries, excluding Ukraine because of limited data availability. The following frontier markets are included: (i) Estonia, Latvia, and Lithuania (the Baltic market); (ii) Bulgaria, Croatia, Romania, Slovakia, and Slovenia (Central and Southeastern European markets). The investigated frontier markets are characterized by differences in market size and their degree of economic development; but, however, all of them bear similarities in their rapid and successful transition from communist to capitalist systems. The transition process included privatization of state-owned enterprises, a set of economic reforms to liberalize the financial sector, and the creation of new legislation providing for removal of restrictions on foreign investment and the regulation of stock market trading.

Although the main focus of the dissertation is on the European frontier markets, the first essay also provides a brief analysis of frontier markets worldwide (African, Asian, and South American frontier markets). This additional analysis is offered in order to extend investigation of the diversification potential of frontier markets in general and strengthen results obtained by using the sample of European frontier markets.

4.2 Emerging market bonds

International investors' increased interest in emerging market bonds traces its origins back to the 1990s, a time when emerging market bonds provided very high average rates of return. For instance, the average returns on emerging market bonds exceeded return on the Standard & Poor's 500 index from 1991 to the summer of 1997 (Erb, Harvey & Viskanta 1999). Early research on emerging market bonds emphasized the benefits of investing in this investment vehicle (Dahiya 1997; Froland 1998). In addition, Kelly, Martins and Carlson (1998) demonstrate that investing in emerging market bonds in conjunction with emerging market equities is a good investment strategy. However, a very sharp increase in the popularity of emerging markets bonds in the early 1990s was followed by a downswing caused by the Russian bond default in 1998 and Argentina's debt default in late 2001. Dungey et al. (2006) document that the Russian bond default in 1998 caused significant contagion effects on emerging and developed bond markets. Despite negative contagion effects from the default episodes, the emerging bond markets did not collapse, but instead continued to grow after 2002 following fast economic growth and strengthened sovereign debt ratings.

The previous literature provides evidence of the benefits available from diversification in international bond markets. For instance, Hunter and Simon (2005) find that the benefits of diversification across major developed government bond mar-

kets were alive and well in the period 1992–2002. Similarly, Cifarelli and Paladino (2006) show that international portfolio diversification in emerging sovereign bonds is a powerful strategy for risk reduction. However, as a consequence of the global financial turmoil of 2008–2009 and the recent sovereign bond crisis in Europe, there is renewed interest in reassessing the diversification potential of international bond markets. Hence, this dissertation provides new insights into the field of international diversification in bond markets from the emerging market perspective (this topic is addressed in the fourth essay of this dissertation).

That fourth essay uses a sample set of ten emerging (Brazil, China, Malaysia, Mexico, Peru, Philippines, Poland, Russia, South Africa, and Turkey) and four frontier[4] (Argentina, Bulgaria, Colombia, and Ecuador) government bond markets that are constituents of the J. P. Morgan Emerging Market Bond Index Global (EMBI Global). The J.P. Morgan EMBI indices (EMBI+, EMBI Global, and EMBI Diversified) are the most widely used and comprehensive emerging market sovereign debt benchmarks.

[4] The breakdown of markets as emerging vs. frontier is based on the Standard & Poor's (S&P) classification.

5 CO-MOVEMENT BETWEEN INTERNATIONAL FINANCIAL MARKETS

The co-movement among international financial markets is one of key issues in international finance as it has relevant implications in asset allocation and risk management (see e.g. Karolyi & Stulz 1996; Forbes & Rigobon 2002). According to modern portfolio theory, the evaluation of the co-movement is of striking importance for international investors who are engaged in a continuous search for benefits arising from a well-diversified global portfolio. The stylized fact that the co-movement of stock returns is not constant over time (see e.g. Longin & Solnik 1995) emphasized the importance of examining co-movement dynamics and has recently made research in this area more appealing.

The very extensive body of literature on the co-movement among international financial markets might be divided into three main streams. The first stream focuses on various aspects of the equity market co-movement (Longin & Solnik 2001; Bessler & Yang 2003; Brooks & Del Negro 2004; Kim, Moshirian & Wu 2005; Graham & Nikkinen 2011). The second stream investigates stock-bond co-movement in a single country or multi-country context (Connolly, Stivers & Sun 2005; Cappiello, Engle & Sheppard 2006; Andersson, Krylova & Vähämaa 2008; Baur & Lucey 2009; Panchenko & Wu 2009; Yang, Zhou & Wang 2009), while the third stream addresses the issue of co-movement among international bond markets (Smith 2002; Yang 2005; Lucey & Steeley 2006; Kumar & Okimoto 2011).

Since this dissertation focuses on the co-movement in the category of emerging financial markets, the remainder of this section will primarily discuss a stream of literature related to this research area.

5.1 Co-movement between emerging and developed stock markets

Most of the earlier literature on the co-movement between international stock markets has focused on the developed markets (e.g., Arshanapalli & Doukas 1993; Lin, Engle & Ito 1994; Longin & Solnik, 1995; Meric & Meric 1997; Engsted & Tanggaard 2004; Goetzmann, Li & Rouwenhorst 2005). A number of studies in this area provide evidence that international stock markets have become increasingly interdependent since the mid-1990s (Brooks & Del Negro 2004; Berben & Jansen 2005; Pukthuanthong & Roll 2009). One important implication of stronger international co-movement among financial markets is a reduction in

the level of the diversification benefits from diversifying across countries (Kearney & Lucey 2004).

As an alternative for obtaining diversification benefits, emerging markets have attracted significant attention from international investors over the last decade. Consequently, an extensive stream of literature on the linkages between developed and emerging stock markets has recently emerged. In general, most of those studies focus on short- and long- term stock market linkages for specific regions using various methodologies including for instance, multivariate GARCH modeling (e.g. Li & Majerowska 2008; Yu & Hassan 2008; Beirne et al. 2010; Kenourgios & Samitas 2011; Syllignakis & Kouretas 2011) and vector autoregression (VAR) framework (e.g. Chelley-Steeley 2005; Syriopoulos 2006; Yang et al. 2006). In particular, stock market linkages in Asian emerging markets are examined by Yang, Kolari and Min (2003), Phylaktis and Ravazzolo (2005), Chiang, Jeon and Li (2007); while the evidence from Latin American emerging markets is provided by Pagan and Soydemir (2000), and Chen, Firth and Rui (2002). Recently, several studies have addressed the issues of stock market integration and linkages of the emerging markets in the Middle East and North Africa (MENA) region (e.g. Yu & Hassan 2008; Cheng, Jahan-Parvar & Rothman 2010; Neaime 2012; Graham et al. 2013).

Earlier research on linkages between emerging stock markets in Europe and the developed markets has focused on major emerging Central European markets such as Poland, Hungary, and the Czech Republic. The empirical findings are not consistent in all studies, since several studies provide evidence on existence of long-term equilibrium of those markets with their mature counterparts (e.g. Syriopoulos 2004, 2007; Voronkova 2004); while no long-term relationship is found in Gilmore and McManus (2002) and Gilmore, Lucey and McManus (2008). Lucey and Voronkova (2008) investigate Russian stock market linkages with respect to other emerging markets in Central and Eastern Europe (Hungary, the Czech Republic, and Poland) and developed markets in the period before and after the 1998 crisis. They find that in the long-term there is no strong evidence of the Russian stock market convergence with other emerging markets in Central and Eastern Europe and the developed markets, but in the short-term there was evidence of increased conditional bivariate correlations in the post-crisis period compared to the pre-crisis period.

However, very limited research has been conducted on the subset of frontier markets in Europe. Among the few contributions to the literature on frontier markets, Samitas, Kenourgios and Paltalidis (2006) investigates linkages between Balkan stock markets (Romania, Bulgaria, Serbia, the former Yugoslav Republic of Mac-

edonia, Turkey, Croatia, Albania) and developed stock markets, while Syriopoulos (2011) examines financial integration of the six markets in the Balkan region (Romania, Bulgaria, Croatia, Turkey, Cyprus and Greece). The empirical results on the long-term equilibrium between the Balkan stock markets and the developed markets are in line with Syriopoulos (2004, 2007) and Voronkova (2004) suggesting limited diversification benefits in the long-term, while the short-term benefits might be still feasible.

On the other hand, Li and Majerowska (2008) and Middleton, Fifield and Power (2008) find significant diversification potential in the Central and Eastern European emerging markets. Maneschiöld (2006) demonstrates that Baltic markets can provide diversification benefits for international investors on a long-term investment horizon. Mateus (2004) provides evidence of the partial integration of five European frontier stock markets (Bulgaria, Estonia, Lithuania, Romania, and Slovenia) with respect to the world market. More recently, Wang and Shih (2011) have produced evidence of time-varying integration in emerging European markets (including five frontier markets), suggesting that those markets are partially integrated with international financial markets.

5.2 Co-movement between emerging and developed bond markets

The issue of linkages in international bond markets has important implications for monetary policymaking independence, modeling and forecasting long-term interest rates, and bond portfolio diversification (see e.g. Yang 2005). However, despite the identification of relevant implications, empirical research on co-movement across government bond markets has received less attention than equity market co-movement and most of empirical studies have been carried out for developed markets. One stream of the literature in this area generally focuses on various issues related to bond market integration (Smith 2002; Yang 2005; Davies 2007; Kumar & Okimoto 2011) and the impact of various factors on the degree of bond market integration (Driessen, Melenberg & Nijman 2003; Barr & Priestley 2004; Abad, Chulia & Gomez-Puig 2010). Another stream of the literature addresses volatility spillovers in international bond markets (Skintzi & Refenes 2006; Christiansen 2007). However, surprisingly little has been written on the emerging and frontier bond markets.

Among several recent studies focusing on the co-movement in emerging bond markets are those of Kim, Lucey and Wu (2006), Cifarelli and Paladino (2006), Bunda, Hamann and Lall (2009), and Vo (2009). In particular, Kim, Lucey and

Wu (2006) address the issue of bond market integration of three European emerging markets (the Czech Republic, Hungary and Poland) in the context of dynamic bond market linkages between established and accession European Union countries. Bunda, Hamann and Lall (2009) examine co-movements in emerging market bond returns with special emphasis on contagion effects during periods of heightened market volatility and provide evidence of pure contagion (excess co-movement) in the case of the Hong Kong market crash of October 1997, the Russian crisis and the Long-Term Capital Management (LTCM) crisis in 1998 and the Argentinean crisis of 2001. Vo (2009) investigates the relationships amongst Asian emerging bond markets and the advanced developed counterparts of the USA and Australia paying particular attention to the 1997 Asian financial crisis period. On the other hand, in the realm of volatility spillover studies, Cifarelli and Paladino (2006) investigate volatility co-movement between sovereign bonds issued by ten emerging countries.

6 THE RELATIONSHIP BETWEEN FINANCIAL MARKETS CO-MOVEMENT AND MACROECONOMIC FACTORS

The impact of macroeconomic factors on the direction of the international co-movement of financial markets has been extensively investigated in financial economics literature. Most of the previous studies focus on the relationship between macroeconomic fundamentals and stock market interdependence (Dumas, Harvey & Ruiz 2003; Araujo 2009; Cai, Chou & Li 2009; Syllignakis & Kouretas 2011). Their main findings are that macroeconomic factors help to explain changes in the international co-movement of stock returns. The main factors that have been found to directly or indirectly affect stock market co-movement include business cycle fluctuations, the inflation environment, and monetary policy stance. However, some other studies provide evidence that the links between macroeconomic variables and the international co-movement of stock returns are rather weak (Verma & Ozuna 2005; Kizys & Pierdzioch 2006). In the light of the mixed evidence on the existence of a relationship between macroeconomic fundamentals and stock market co-movement, this dissertation provides fresh insights on this debate from perspective of the emerging/frontier stock markets (this issue is examined in the first essay of this dissertation).

In addition to the research on the links between macroeconomic variables and the international co-movement of stock returns, considerable efforts have been made recently to explore the links between macroeconomic factors and stock-bond co-movement. In particular, several studies document that macroeconomic fundamentals play an important role in stock-bond co-movement dynamics (Li 2004; Andersson, Krylova & Vähämaa 2008; Yang, Zhou & Wang 2009). Li (2004) demonstrate through the use of asset pricing modeling that the correlation between stock and bond returns can be explained by their common exposure to macroeconomic factors. Similarly, Yang, Zhou and Wang (2009) provide convincing evidence of time-varying stock-bond correlations over macroeconomic conditions (the business cycle, the inflation environment, and monetary policy stance) by using data for the US and the UK covering the past 150 years.

In addition, Andersson, Krylova and Vähämaa (2008) find that macroeconomic expectation and perceived stock market uncertainty can help to predict future co-movement between stock and bonds in the largest financial markets worldwide. The important role of stock market uncertainty in explaining stock-bond correlations has also been previously provided by Connolly, Stivers and Sun (2005) and Kim, Moshirian and Wu (2006). Acknowledging the relevance of market uncertainty as one of the important driving forces behind financial asset co-movement,

this dissertation investigates this issue further by examining the role of bond market uncertainty in explaining the international co-movement of bond markets in its fourth constituent essay.

The studies on the linkages between international bond returns co-movement and macroeconomic factors are relatively limited. Hunter and Simon (2005), Ludvigson and Ng (2009), and Baele, Bekaert and Inghelbrecht (2010) are among the few authors to have addressed the issue of the links between macroeconomic fundamentals and international bond return correlations and volatility. Specifically, Hunter and Simon (2005) provide evidence that differences in business cycle conditions may explain the time-varying correlations of international bond returns, and also that international bond returns are sensitive to similarities in monetary policy. In a similar vein, Baele, Bekaert and Inghelbrecht (2010) find that macroeconomic factors do play a relatively large role in bond market volatility dynamics; while Ludvigson and Ng (2009) show that macroeconomic fundamentals carry an important predictive power for excess returns on US government bonds.

In line with previous studies on the relationship between asset returns and macroeconomic fundamentals (Ilmanen 2003; Li 2004; Yang, Zhou & Wang 2009), the macroeconomic factors used in the empirical framework of this dissertation include the business cycle fluctuations, the inflation environment, and monetary policy stance.

7 IMPACT OF THE 2008–2009 FINANCIAL CRISIS ON STOCK MARKET CO-MOVEMENTS

The 1987 international stock market crash, the 1997 Asian financial crisis, the 1998 Russian crisis, and the 1999 Brazilian crisis have provoked much debate on the impact of financial crises on the international stock markets. Early research in this area provides evidence that interdependence among international stock markets tend to increase during the turbulent periods of financial crisis (Lin, Engle & Ito 1994; Longin & Solnik 2001; Tuluca & Zwick 2001). Specifically, Chakrabarti and Roll (2002) demonstrate that volatility contagion in European and East Asian countries significantly increased during the 1997 Asian financial crisis compared to the pre-crisis period. Similarly, Yang et al. (2006) show that both the long-term and short-term relationships between ten Asian emerging stock markets and the USA and Japan were strengthened during the 1997–1998 Asian financial crisis, suggesting that the crisis altered market integration among Asian countries over time.

Unlike past crises, the recent 2008–2009 financial crisis was characterized by rapidity and apparent synchronicity with which it spread around the world. Furthermore, the effects of the crisis went far beyond the financial markets, having a large negative impact on the real economy, which lead to the largest global recession since the great depression (see e.g. Chudik & Fratzscher 2011). Given this unique remarkable feature of being truly global, the 2008–2009 financial crisis provides an interesting scenario for investigating the co-movement dynamics among the global financial markets. In particular, the global nature of this crisis emphasized the importance of examining the dynamic interrelationships among global financial markets during crisis periods in order to better understand crisis transmission mechanisms, the extent of global market integration and the differences in equity performance across countries. For instance, Bartram and Bodnar (2009) provide convincing evidence of high correlations and transmission of price-relevant information among stock markets worldwide due to the truly global character of the 2008–2009 financial crisis. Similarly, Dwyer and Tkac (2009) analyze the effects of 2008–2009 financial crisis on the fixed-income markets.

The impact of the 2008–2009 global financial crisis on the emerging and frontier stock markets has been addressed in several studies (Dooley & Hutchison 2009; Cheung, Fung & Tsai 2010; Aloui, Alissa & Nguyen 2011; Kenourgios & Samitas 2011; Samarakoon 2011; Syllignakis & Kouretas 2011; Neaime 2012). Specifically, Dooley and Hutchison (2009) offer a broad analysis of how and why emerging markets responded to a crisis originating from the US market. They outlined three phases of the financial crisis transmission to emerging markets. In

the first and the second phase, the emerging markets seemed to be relatively insulated from shocks in US financial markets from 2007 until summer 2008. However, the Lehman Brothers bankruptcy in September 2008 marked the start of a very intense crisis in emerging markets. Cheung, Fung and Tsai (2010) examine the changing interrelationships among the global financial markets in the periods before and during the 2008–2009 financial crisis using the sample of several developed markets (the US, Japan, Hong Kong, and Australia) and two large emerging markets (China and Russia). Aloui, Alissa and Nguyen (2011) provide evidence of time-varying dependence between the BRIC countries (Brazil, Russia, India, and China) and the US stock market during the global 2008–2009 financial crisis.

Kenourgios and Samitas (2011) examine the impact of the 2008–2009 financial crisis on the time-varying correlation dynamics among five emerging Balkan stock markets, the USA and three developed European markets (the UK, Germany, and Greece). They report that stock market dependence was heightened during the 2008 stock market crash period. Similarly, Samarakoon (2011) investigates stock market interdependence and contagion during the 2008–2009 financial crisis for a large sample of 62 emerging and frontier markets. The findings of the study suggest the presence of bi-directional (although asymmetric) interdependence and contagion between the USA and emerging markets (with some regional variations). In addition, there is also evidence of interdependence and contagion for frontier markets with respect to US shocks, but it is of a smaller magnitude compared to the emerging markets.

Syllignakis and Kouretas (2011) demonstrate that there is a significant increase in conditional correlations between the stock returns of the Central and Eastern European emerging markets and the developed markets of the US and the UK during the 2008–2009 financial crisis. Their results imply the existence of contagion effects in the Central and Eastern European emerging markets due to herding behavior during the 2008 stock market crash. Finally, Neaime (2012) investigates how the 2008–2009 financial crisis affected emerging stock markets in the Middle East and North Africa (MENA) region. The main finding of the study is that the markets most affected by the global financial crisis were those with strong linkages with developed markets (Egypt, Jordan, Kuwait, Morocco, and the United Arab Emirates). In contrast, the crisis had an insignificant impact on the stock markets of Saudi Arabia and Tunisia, owing to a very low level of financial integration and those two markets' weak linkages with the global financial markets.

8 SUMMARY OF THE ESSAYS

This dissertation consists of the four essays that are described briefly below. The individual contribution of each co-author of the constituent essays in this dissertation is as follows:

Essay 1: The main author of the essay is Vanja Piljak, who is responsible for the research idea, research design, data collection, analysis and interpretation of results, and writing the essay. The role of J. Kiviaho is related to software support (program coding) in methodological part, while Professor Nikkinen and Professor Rothovius contributed with giving advices and comments in the revision process.

Essay 2: Professor Nikkinen and Professor Äijö are responsible for initial research idea and methodological design, while Vanja Piljak is responsible for data analysis and further development of initial research setup. All three authors shared responsibilities in writing the essay. Individual contribution of each author of this essay is approximately equal, while author Vanja Piljak was especially responsible for the revision of the paper according to the Editor's and Reviewer's comments in the publication process.

Essay 3: The main author of the essay is Vanja Piljak, who is responsible for the research idea, research design, data collection, analysis and interpretation of results, and writing the essay. The role of Professor Nikkinen and Professor Rothovius is related to giving advices and comments for improvements in the paper.

Essay 4: Single-authored by Vanja Piljak.

8.1 The co-movement dynamics of European frontier stock markets

The first essay of this dissertation examines the dynamics of European frontier stock market co-movement with the USA and the three largest developed markets in Europe (UK, Germany, and France), by applying a three-dimensional analysis of wavelet squared coherency. This advantageous methodology enables simultaneous consideration of both the time and frequency domains in international co-movements of stock returns, making the co-movement analysis more comprehensive and useful for investors. In addition, the essay investigates various macroeconomic factors to explain variations in co-movement at different frequency levels.

Interaction among international stock markets is an important issue in the international portfolio diversification literature (Forbes & Rigobon 2002; Bessler & Yang 2003), since it has important implications for asset allocation management. Earlier literature largely focused on examining the co-movement among developed markets (see, e.g., Lin, Engle & Ito 1994; Longin & Solnik 1995; Engsted & Tanggaard 2004; Graham & Nikkinen 2011) and, more recently, between developed and emerging markets (Bekaert & Harvey 1995; Chambet & Gibson 2008; Graham, Kiviaho & Nikkinen 2012). In contrast, empirical evidence on the dynamics of equity co-movements and integration of the frontier markets is limited. Therefore, the main aim of this study is to expand the empirical research on the dynamics of stock return co-movement between frontier and developed markets and to assess potential portfolio diversification benefits.

The sample examined in this essay covers eight frontier stock markets in Europe (Bulgaria, Croatia, Estonia, Latvia, Lithuania, Romania, Slovakia, and Slovenia) in the period from 2000 to 2010. The motivation for focusing on the frontier markets located in Europe is based on the growing economic performance of these markets over the last decade and their improved legal, liquidity, and corporate governance profiles resulting from EU legislation. Although the main focus of the essay is on the European frontier markets, a brief analysis of frontier markets worldwide (African, Asian, and South American frontier markets) is also included as a robustness check. This additional analysis is performed in order to extend investigation of the diversification potential of frontier markets in general and strengthen results obtained by using the sample of European frontier markets.

Taken together, the findings of this study suggest that European frontier stock markets may offer significant diversification benefits, especially for short-term investment horizons. There is also evidence that the degree of co-movement varies over time on all time horizons. Further, a clear pattern of intensified co-movement at higher frequencies in all markets during the turbulent period of the 2008–2009 financial crisis is identified. Despite increased co-movement during this global financial crisis, the diversification benefits are still apparent. In particular, a relatively higher potential for diversification gains is observable for frontier markets in Central and Southeastern Europe (Bulgaria, Croatia, Romania, Slovakia, and Slovenia) than in Baltic markets (Estonia, Latvia, and Lithuania). Of the markets analyzed, Slovakia presents the lowest degree of co-movement across all frequencies, while Lithuania appears to be the most dependent market.

Finally, the reported results reveal that macroeconomic fundamentals can explain variations in co-movement on both short- and long-term horizons. In general, macroeconomic factors have greater explanatory power in explaining co-

movement on long-term horizons compared to short-term horizons. Specifically, the influence of domestic macroeconomic factors on stock return co-movement on short-term horizons seems to be greater than the influence of global factors. Domestic monetary policy is identified as the most prominent factor for short-term horizons, while in the long term, the most influential factors are global monetary policy and domestic exchange rate movements. The results demonstrate that macroeconomic factors differ in their importance with respect to co-movement on both the short-term and long-term horizon.

This study has both important practical and academic implications. First, a unique focus on frontier markets provides new and important insights into the field of international portfolio diversification, given the evidence of the significant diversification potential of European frontier markets. The outcomes of the co-movement analysis conducted in this study may provide investors with a roadmap for investment decisions. More specifically, the results of this study shed light on the extent to which investors can benefit from investing in frontier markets by accounting for the time and frequency-varying co-movement of stock returns in designing international portfolios.

Second, in light of the debate in the literature as to whether the phenomenon of increased co-movement between international stock markets is permanent or temporary in nature, this study contributes by offering new insights from the frontier-markets perspective. The findings suggest that increased stock co-movement of European frontier markets with the developed markets in recent years has both a permanent and a transitory component. The permanent component is attributed to the overall increasing trend toward global capital markets integration, in addition to the financial market liberalization associated with EU accession.[5] However, an overall increase in co-movement might also involve a transitory component resulting from the contagious nature of the global financial crisis.

8.2 Baltic stock markets and the financial crisis of 2008–2009

The second essay of this dissertation examines the linkages between the stock markets in the Baltic region (a special subset of European emerging markets) and the developed European stock markets. Specifically, the study focuses on Estoni-

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[5] Dvorak & Podpiera (2006) provide evidence that the announcement of the EU enlargement contributed to increased stock market integration of the EU accession countries.

an, Latvian, and Lithuanian stock markets with particular emphasis on the recent financial crisis of 2008–2009. The particular empirical question addressed in this study is how the Baltic stock markets were integrated with respect to the EUROSTOXX50 stock index (a proxy for developed European stock markets) in the pre-crisis and crisis period.

The motivation for conducting this study was based on the indication from previous literature that while developed stock markets are highly integrated (e.g. Bekaert & Harvey 1995; Bessler & Yang 2003; Kim, Moshirian & Wu 2005), emerging markets may still be segmented and therefore capable of offering significant diversification benefits (e.g. Mateus 2004; Chambet & Gibson 2008; Yu & Hassan 2008; Cheng, Jahan-Parvar & Rothman 2010). However, an observation that the stock markets behaved very similarly across different countries during the global financial crisis of 2008–2009 casts serious doubts on the usefulness of the traditional portfolio theory during crisis periods. This is particularly the case if the less integrated frontier and emerging markets become fully integrated during global crises.

The literature also provides evidence that the degree of integration among stock markets tends to change over time, particularly in time of crisis (Yang, Kolari & Min 2003; Yang et al. 2006). Therefore, a relevant and timely question is whether there are still some markets that are less integrated, and which as such could provide better diversification benefits, even during a global crisis. Given that the earlier literature on the Baltic stock markets has documented that these markets were segmented (Mateus 2004; Maneschiöld 2006), it is particularly interesting to investigate how these markets behaved during the financial crisis of 2008–2009 and how the crisis affected their diversification potential.

The data used in the empirical analysis consist of total return (dividend adjusted) stock indices of three Baltic markets (the Estonian, Lithuanian, and Latvian stock markets) and the EUROSTOXX50 index. Two different sample periods are used in order to examine the effect of the crisis on stock market linkages, namely: i) pre-crisis (1/2004–12/2007); ii) crisis period (1/2008–6/2009). The econometric framework of this study comprises two parts: i) vector autoregression analysis (VAR) including Granger causality test and variance decomposition analysis; ii) a quantile regression approach.

The results of this study[6] demonstrate that while the Baltic stock markets were segmented with respect to the developed European stock markets before the crisis, they became highly cross-correlated during the crisis. The variance decomposition analysis revealed that a large proportion of the forecast variance of the Baltic stock markets can be explained by the EUROSTOXX50 index during the crisis, indicating the significant impact of the financial crisis on the linkages between the Baltic and developed European markets. Finally, the results from the quantile regression analysis provide further evidence that during the crisis the returns of the lowest quantile were most sensitive to the EUROSTOXX50 index. Taken together, the findings of this study imply less diversification benefits are available during crises when investors would need them the most.

8.3 The impact of the 2008–2009 financial crisis on the external and internal linkages of European frontier stock markets

The third essay continues with the financial crisis theme and investigates the impact of the 2008–2009 financial crisis on the external linkages of European frontier stock markets (Croatia, Estonia, Romania, Slovakia, and Slovenia) with the world market portfolio and three largest developed equity markets in Europe (the UK, France, and Germany). In addition, the internal linkages within the frontier markets group are examined as well.

The global nature of the recent financial crisis of 2008–2009 has indicated that there is a renewed interest in investigating how a financial crisis may affect stock market linkages among international markets (Bartram & Bodnar 2009; Chudik & Fratzscher 2011; Kenourgios & Samitas 2011). Given the evidence in the literature that financial crises affect the strength of the stock market linkages and consequently the level of potential diversification opportunities (e.g. Syllignakis & Kouretas 2011), it is of great importance to investigate how the frontier markets, considered a significant source of diversification benefits, are affected by the global financial crisis.

The sample examined in this essay covers the five major European frontier stock markets included in the S&P/IFCG Extended Frontier 150 Index. The dataset

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[6] The results support findings by Yang, Kolari & Min (2003) and Yang et.al (2006) that the degree and nature of stock market integration tend to change over time, especially around the periods of financial crisis.

consists of daily stock price indices of the selected frontier markets. In addition, the stock market indices of the United Kingdom (FTSE100), France (SBF250) and Germany (CDAX) are employed to serve as proxies for the developed stock markets in Europe. The world market portfolio is proxied by the Morgan Stanley Capital International (MSCI) World equity market index. The sample period extends from 1997–2009 and it is divided into two sub-samples (the period before the financial crisis and during the crisis), where the Lehman Brothers collapse on September 15, 2008 marks the starting point of a very intense financial crisis in emerging markets. This essay employs a cointegrated vector autoregression (VAR) framework, including cointegration analysis, the Granger causality test, impulse response analysis, and forecast error variance decomposition. This advantageous methodology enables analysis of both long-term and short-term relationships between the investigated stock markets.

In general, the reported results reveal that both long- and short-term external linkages of European frontier stock markets were strengthened during the crisis, implying that the 2008–2009 financial crisis significantly affected their diversification potential. In particular, the Croatian, Estonian, and Slovenian markets show a considerable degree of dependence on the world market portfolio and the three largest developed stock markets in Europe. In contrast, the stock market of Slovakia appears to be segmented relative to both. The results on internal linkages within the frontier markets group show a very low level of mutual interdependence among the group members in both periods. This finding implies that investing in frontier markets as a group might be considered an important alternative for obtaining diversification benefits during the crises periods.

8.4 Bond markets co-movement dynamics and macroeconomic factors: Evidence from emerging and frontier markets

The forth essay extends the scope of the dissertation in two main respects. First, the co-movement analysis among international financial markets is expanded to cover the fixed-income markets. Second, the coverage of the analyzed markets is more comprehensive and the sample covers a large group of emerging markets in addition to the subset of frontier markets. The essay focuses on the co-movement dynamics of ten emerging and four frontier government bond markets with the US market and the driving forces behind the time-varying co-movement. In particular, the essay examines whether domestic and global macroeconomic factors and global bond market uncertainty play an important role in explaining the dynamics of bond return co-movement in emerging/frontier markets. The extent of

international bond market co-movement is an important research issue, as it has relevant implications for the monetary policymaking independence, modeling and forecasting of long term interest rates, and bond portfolio diversification (see e.g. Abad, Chulia & Gomez-Puig 2010).

Previous literature on the impact of macroeconomic factors on the co-movement of asset returns has been extensively investigated for stock market returns (Dumas, Harvey & Ruiz 2003; Syllignakis & Kouretas 2011) and for the co-movement between stock and bond returns (Andersson, Krylova & Vähämaa 2008; Yang, Zhou & Wang 2009), while the studies on the linkages between international bond returns co-movement and macroeconomic factors are limited. Hence, this essay aims to provide new evidence on linkages between macroeconomic factors and bond returns co-movement from the emerging/frontier bond markets perspective. In addition to macroeconomic fundamentals, the literature also provides evidence that perceived market risk or uncertainty has an important impact on the co-movement dynamics of asset returns (Connolly, Stivers & Sun 2005; Kim, Moshirian & Wu 2006). This essay builds upon the proposed use of implied volatility measures as proxies for market uncertainty and extends the work of Connolly, Stivers and Sun (2005) by applying an implied volatility measure to examine the impact of bond market uncertainty on time variations in international bond market co-movement.

The sample set includes monthly data on the USA 10-year government bond total return index and total return bond indices of ten emerging markets (Brazil, China, Malaysia, Mexico, Peru, Philippines, Poland, Russia, South Africa, and Turkey) and four frontier markets (Argentina, Bulgaria, Colombia, and Ecuador) that are constituents of the J.P. Morgan Emerging Market Bond Index Global (EMBI Global). The sample period extends from 2000 to 2011. The macro factors in the empirical framework include the business cycle fluctuations, the inflation environment, and monetary policy stance. Global bond market uncertainty is proxied by the Merrill Lynch Option Volatility Estimate MOVE Index (a widely-followed measure of government bond volatility derived from option prices on US Treasury bonds). The econometric framework comprises two parts: (i) the Dynamic Conditional Correlation (DCC) bivariate GARCH framework, and (ii) ordinary least squares (OLS) regressions.

In summary, the results of this essay reveal several important findings. First, considerable variation in the patterns of the correlation dynamic paths across the countries suggests that emerging/frontier bond markets taken as a single group constitute a good alternative source of diversification benefits for US investors. More specifically, frontier markets appear to have higher diversification potential

than emerging markets. Second, domestic and global macroeconomic factors play important roles in explaining time variations in the bond return co-movement between emerging/frontier markets and the US government bond market. In particular, domestic macroeconomic factors are of higher relative importance than global factors, with domestic monetary policy and domestic inflationary environment identified as the most influential factors. Third, the global bond market uncertainty, based on an implied volatility measure, significantly affects the bond return co-movement dynamics between emerging/frontier markets and the US market.

9 CONCLUDING REMARKS AND IMPLICATIONS

The overall objective of the thesis is to investigate the issue of co-movement dynamics of frontier/emerging and developed financial markets. Four different essays examine the topic from different perspectives. The first perspective emphasizes the role of macroeconomic factors in the co-movement dynamics; the second perspective is related to the impact of the 2008–2009 financial crisis on the co-movement dynamics; and the third perspective reflects frontier and emerging financial markets standpoint in the context of international portfolio diversification. The essays are integrated to the general topic of the dissertation by merging these specific perspectives in one unified general framework. The focus of the first three essays is on the stock markets, while the fourth essay extends the scope of the thesis by covering bond markets in the co-movement analysis.

The main findings of the thesis might be summarized with respect to the three aforementioned perspectives. In relation to the first perspective, the results indicate that macroeconomic fundamentals can explain variations in co-movement of European frontier stock markets and developed markets at both short- and long-term horizons. In particular, macroeconomic factors have greater explanatory power in explaining co-movement at long-term horizons compared to short-term horizons. Specifically, the influence of domestic macroeconomic factors on stock return co-movement at short-term horizons seems to be greater than the influence of global factors. Domestic monetary policy is identified as the most prominent factor for short-term horizons, while in the long run, the most influential factors are global monetary policy and domestic exchange rate movements.

In addition, macroeconomic factors play an important role in explaining time variations in the bond return co-movement between emerging/frontier markets and the US government bond market. In particular, domestic macroeconomic factors are of higher relative importance compared to global factors, with domestic monetary policy and domestic inflationary environment identified as the most influential factors.

The results related to the second and the third perspectives show that both long- and short-term external linkages of European frontier stock markets with the developed markets were strengthened during the 2008–2009 financial crisis, implying the significant impact of the crisis on the diversification potential of those markets. On the other hand, the results on internal linkages within the frontier stock markets group reveal a very low level of mutual interdependence among the group members in both pre-crisis and crisis periods, implying that investing in frontier markets as a group might be considered an important alternative for ob-

taining diversification benefits during the crises periods. The main results concerning the bond markets co-movement dynamics demonstrate that there is considerable variation across emerging/frontier markets in the patterns of dynamic correlation with the US bond market, implying that emerging/frontier bond markets, taken as a single group, constitute a good alternative source of diversification benefits for US investors. In particular, frontier bond markets appear to have higher diversification potential than their counterparts in emerging markets.

The findings of this thesis have some important implications for international investors and national policymakers. From investors' point of view, the thesis offers new insights into international portfolio diversification from frontier/ emerging markets perspective. The outcomes of the co-movement analysis, conducted in this thesis, have direct implications for investors in formulating and implementing asset allocation decisions and investment strategies. The low level of dynamic interaction of certain frontier/emerging financial markets with the developed markets, identified in this thesis, might help international investors select target countries with the greatest diversification potential. Furthermore, the results of this thesis shed light on the extent to which investors can benefit from investing in frontier markets by accounting for the time and frequency-varying co-movement of stock returns. For policymakers, the results of the thesis might be useful in macroeconomic policy formulation. For instance, understanding the extent of international bond market linkages is important for modeling and forecasting long-term interest rates.

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The Co-movement Dynamics of European Frontier Stock Markets

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Abstract

We examine, through application of wavelet coherency, the co-movement of European frontier stock markets with the USA and developed markets in Europe. We find that the strength of co-movement varies considerably across the frontier markets, at different frequencies (time horizons), and over time. Co-movement is relatively weaker for the frontier markets of Central and Southeastern Europe than in the Baltic region. Of the markets examined, Slovakia in particular shows low dependence, whereas Lithuania seems to be the most dependent market. Co-movement is stronger at lower frequencies (longer horizons) and increases during the turbulent period of the global financial crisis of 2008/2009. We identify several macroeconomic factors related to variations in co-movement at different time frequencies.

Keywords: *frontier market*, *co-movement of stock returns*, *wavelets*

JEL classification: *C*40, *F*30, *F*36, *G*15

1. Introduction

This paper focuses on the co-movement of stock returns between the European frontier markets and major developed markets. Interaction among international stock markets is an important issue in the international portfolio diversification literature (see, e.g.,

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Forbes and Rigobon, 2002; Bessler and Yang, 2003).[1] A growing body of literature has documented that international stock markets have become increasingly interdependent since the mid-1990s (Brooks and Del Negro, 2004; Pukthuanthong and Roll, 2009). It is unclear, however, whether this phenomenon is permanent or temporary in nature. Arguing for its permanence, some authors attribute this interdependence to an increase in equity market integration (Ayuso and Blanco, 2001) or to the decline in importance of country-specific effects relative to global industry factors (Ferreira and Ferreira, 2006; Hargis and Mei, 2006). By contrast, Brooks and Del Negro (2004) argue that this phenomenon is temporary in nature, linking it to the stock market bubble of the late 1990s.

Most of the literature focuses on the co-movement among developed markets (see, e.g., Lin *et al*., 1994; Longin and Solnik, 1995; Engsted and Tanggaard, 2004) and, more recently, between developed and emerging markets (Bekaert and Harvey, 1995; Chambet and Gibson, 2008). In contrast, empirical evidence concerning the dynamics of equity co-movements and integration of the European frontier markets is limited.[2] One recent study, Berger *et al*. (2011), provides evidence of significant diversification potential for frontier markets worldwide due to very low integration of these markets with the world market.

Interest in investing in frontier stock markets has grown over the last decade. As a result, the first fully investable index for frontier equity markets (S&P/IFCG Extended Frontier 150 Index) was launched by Standard & Poor's in 2007. By the following year, several more index providers emerged (including MSCI Barra and FTSE) to track and maintain index data on frontier stock markets. Establishment of frontier market exchange-traded funds and mutual funds facilitated investing in these markets and contributed to the further promotion of frontier markets as an attractive investment target.

This study investigates the stock return co-movement of European frontier markets with the US market and the three largest developed markets in Europe (UK, Germany, and France) by applying three-dimensional analysis of wavelet coherency. This advantageous approach enables simultaneous consideration of two important domains (time and frequency) in international co-movements of stock returns, making the co-movement analysis more comprehensive and useful for investors.[3] Assessment of co-movement in terms of frequency is very important for international investors when choosing a short-term or long-term profile in investment strategies (see Smith, 2001). Short-term investors consider information on co-movement at higher frequencies more valuable than that of co-movement at lower frequencies, and vice versa for long-term investors. Hence, analysis of co-movement relationships and the potential economic factors driving

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[1] The importance of this topic stems from the relevant implications for managing asset allocation and creating global investment strategies.

[2] Some of the European frontier stock markets are included in studies investigating Central and Eastern European markets. For example, Wang and Shih (2011) investigate time-varying world and regional integration in emerging European markets (including five frontier markets).

[3] Several studies apply a wavelet approach in financial time-series analysis. For example, Fernandez (2005) focuses on return spillovers in stock markets at different time scales. Kim and In (2005) use wavelet correlations to study the relationship between stock returns and inflation. Nikkinen *et al.* (2011) apply wavelet cross-correlation techniques to analyse the cross-dynamics of exchange rate expectations.

co-movements at different time frequencies among various markets provides investors with a powerful tool for portfolio rebalancing decisions.

Motivated with the importance of understanding the fundamental forces that drive variations in co-movement at different time horizons, we investigate whether macroeconomic factors can explain these variations. Macroeconomic factors that have been found to affect international stock correlations include business cycle fluctuations, the inflation environment, and monetary policy stance (*e.g.*, Longin and Solnik, 1995; Dumas *et al*., 2003; Cai *et al*., 2009; Yang *et al*., 2009; Syllignakis and Kouretas, 2011). On the contrary, several studies find that the relationship between international stock correlations and macroeconomic variables is not significant (Ammer and Mei, 1996; Kizys and Pierdzioch, 2006). A unique feature of our study relates to incorporating domestic and global macroeconomic factors into co-movement analysis, performed simultaneously in both time and frequency domains, by using the wavelet squared coherency as a measure of co-movement over time across frequencies; this is motivated by the mixed results reported in the previous literature.

Most studies using the wavelet approach in international co-movement analysis focus on developed and emerging market asset classes, while evidence from frontier markets remains absent. Rua and Nunes (2009) apply wavelet analysis to examine the co-movement of stock returns between four developed markets (Germany, Japan, UK, and USA), while Graham and Nikkinen (2011) examine co-movement of the Finnish stock markets with stock markets in both developed and emerging economies. Graham *et al*. (2011) use the wavelet coherency to investigate integration of 22 emerging stock markets.

Our study contributes to the literature in three ways. First, we add to the literature on integration and co-movement of emerging markets by investigating those stock markets belonging to the subcategory of European frontier markets, which have received little attention thus far. Frontier markets are of increased interest given the diminished potential for international portfolio diversification resulting from increased interdependence among the developed international stock markets.[4] There is also recent evidence of increased integration of emerging markets into the broader world markets (see Tai, 2007), which suggests that benefits from international diversification may lie in the subcategory of frontier markets in the future. We focus on the frontier markets located in Europe because of their growing economic prospects and their improved legal, liquidity, and corporate governance profiles resulting from EU legislation. These markets recorded significant increases in stock prices following announcement of EU enlargement in 2001 (Dvorak and Podpiera, 2006). Actual EU membership additionally boosted these markets' investment profiles by lifting all restrictions on the movement of capital, making these markets more accessible to foreign investors.

Second, our study adopts an advantageous three-dimensional wavelet coherency approach, enabling us to simultaneously assess co-movement across different investment horizons and over time. To the best of our knowledge, this study is the first to use a wavelet analysis to measure the co-movement of the European frontier markets with the USA and the developed European markets simultaneously in both time and frequency

[4] In general, frontier markets, as a special subset of emerging markets, are characterised by relatively thin trading activity, short history, and higher risk levels than developed markets, but they have provided very high returns in recent years. They also have less exposure to shocks in the global economy and lower correlation with other stock markets.

domains. By applying the wavelet squared coherency, we capture the time-varying nature of equity market linkages and make a distinction between short-term and long-term investors. Third, another novel feature of our study stems from employing the wavelet squared coherency to analyse whether macroeconomic factors explain variations of the co-movement at different time frequencies. Our results demonstrate that the co-movement of the European frontier stock markets with the USA and the developed European markets is stronger at lower frequencies (longer horizons), implying greater benefits from diversification into frontier markets in the short run relative to the long run. We also identify a clear pattern of increased co-movement at higher frequencies in all markets during the turbulent period of the 2008–2009 financial crisis. Although the co-movement in general was strengthened and extended to higher frequencies during the crisis, considerable variation across markets is found. Additionally, we detect several macroeconomic factors that are related to variations in the co-movement at different frequency levels.

The remainder of this paper is organised as follows. Section 2 provides an overview of European frontier markets. Section 3 presents data and the descriptive statistics. In Section 4, we set forth a brief description of the wavelet analysis approach. The empirical results are presented in Section 5, while Section 6 provides conclusions.

2. European Frontier Markets

Europe's frontier markets can be divided into two groups according to their geographical location and similarities in market environment. One grouping consists of three countries in North Europe: Estonia, Latvia, and Lithuania, the Baltic market. Another group comprises markets in Central and Southeastern Europe, including Bulgaria, Croatia, Romania, Slovakia and Slovenia.

In Table 1 (Panel A) we provide a summary of stock market information, including years since stock exchange establishment. The Baltic stock markets have a rather short history compared to developed European equity markets. The initial establishment of the Tallinn Stock Exchange in Estonia, the Riga Stock Exchange in Latvia, and the Vilnius Stock Exchange in Lithuania took place, respectively, in 1920, 1926, and 1937, but these exchanges were closed at the beginning of the Second World War. The Baltic stock exchanges resumed trading in the middle of the 1990s following the collapse of the Soviet Union. During the 2002–2004 period, the Baltic stock exchanges became part of the OMX group, which owns and operates exchanges in the Nordic countries. In 2007, NASDAQ acquired the OMX group, creating the world's largest exchange company, the NASDAQ OMX Group. This acquisition led to the harmonisation of trading rules and practices, resulting in increased interest in investment in the Baltic stock exchanges.

Unlike the Baltic markets, which are unified under a joint Baltic exchange and securities list, as well as similar market regulations and environment, the Central and Southeastern European stock markets are characterised by substantial variation in market size, attractiveness to foreign investors, and degree of economic development. Despite showing differences in level of economic development, all European frontier markets are characterised by similarities in the path taken in the transition process from communist to capitalist systems. This transition included privatisation of state-owned enterprises, a set of economic reforms to liberalise the financial sector, and creation of new legislation providing for removal of restrictions on foreign investment and the regulation of stock market trading. The most important events in the stock market liberalisation process are given in Table 1 (Panel B).

Table 1

Stock markets highlights

This table presents an overview of European frontier stock markets and a summary of important events in the stock market liberalisation process. Information sources include national stock exchanges (Panel A) and Bekaert and Harvey's chronology of important financial, economic and political events in emerging markets (http:// www.duke.edu/_charvey/chronology.htm) for Panel B. ADR stands for the American Depositary Receipts.

Panel A: European frontier stock markets

Country	Index	Stock exchange	Stock market established	First ADR
Bulgaria	BSE Sofix	Sofia	1997	1998
Croatia	CROBEX	Zagreb	1991	1996
Estonia	OMX Tallinn	Tallinn	1995	1997
Latvia	OMX Riga	Riga	1995	1997
Lithuania	OMX Vilnius	Vilnius	1993	1996
Romania	BET	Bucharest	1995	NA
Slovakia	SAX	Bratislava	1991	1996
Slovenia	LJSE Composite	Ljubljana	1989	1997

Panel B: Summary of important events in the stock market liberalisation process

Country	Year	Important events in the market liberalisation process
Bulgaria	1997	Certain restrictions regarding controls on capital, money market instruments and direct investments lifted.
	2003	Parliament passed the first draft of a law to encourage more foreign investment, which would equalise investment conditions for domestic and foreign investors.
Croatia	1998	FDI, inward portfolio investments and profit transfers abroad are not restricted.
	2002	New laws passed in 2002 to boost investments in tourism, research, and manufacturing.
Estonia	1999	No restrictions for foreign investors in acquiring a company or equity except in certain industries.
Latvia	1996	Amendments to the Investment Law passed in 1996 removed virtually all restrictions on foreign investment.
Lithuania	1999	Under the 1999 Investment Law, foreign investment is permitted in almost all sectors, with the exception of certain industries.
Romania		Not available
Slovakia	1998	Controls on capital, money market instruments and real estate transactions were lifted.
	2000	Removal of controls on credit operations in 2000.
Slovenia	1999	Certain restrictions on the participation of foreign portfolio investors in the Slovenian capital market are eliminated.
	2000	A government scheme promoting FDI has been in place since 2000.

Table 2
Main characteristics of European frontier stock markets

This table presents an overview of the important characteristics of European frontier stock markets in the period from 2000 to 2009. Data are obtained from the World Bank's Data Catalog (World Development Indicators, WDI). Market capitalisation refers to the market value of the companies listed on the country's stock exchanges at the end of year, excluding investment companies, mutual funds, or other collective investment vehicles. Foreign direct investments (net inflows) are defined as the sum of equity capital, reinvested earnings, other long-term capital, and short-term capital, as shown in the balance of payments.

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Market capitalisation (*billions of US dollars*)										
Bulgaria	0.61	0.50	0.73	1.75	2.80	5.08	10.3	21.79	8.85	7.10
Croatia	2.74	3.31	3.97	6.12	10.95	12.91	29.00	65.97	26.79	25.63
Estonia	1.84	1.48	2.42	3.79	6.20	3.49	5.96	6.03	1.95	2.65
Latvia	0.56	0.69	0.71	1.14	1.65	2.52	2.70	3.11	1.60	1.82
Lithuania	1.58	1.19	1.46	3.51	6.46	8.18	10.19	10.13	3.62	4.47
Romania	1.06	2.12	4.56	5.58	11.78	20.58	32.78	44.92	19.92	30.32
Slovakia	1.21	1.55	1.90	2.77	4.41	4.39	5.57	6.97	5.07	4.67
Slovenia	2.54	2.83	4.60	7.13	9.67	7.89	15.18	28.96	11.77	11.76
Foreign direct investment, net inflows (*billions of US dollars*)										
Bulgaria	1.00	0.81	0.90	2.09	2.66	4.31	7.75	13.2	9.92	4.59
Croatia	1.10	1.58	1.09	2.04	1.07	1.78	3.45	4.99	6.01	2.95
Estonia	0.38	0.54	0.28	0.91	0.96	2.94	1.78	2.72	1.74	1.75
Latvia	0.41	0.13	0.25	0.30	0.63	0.71	1.66	2.31	1.35	0.09
Lithuania	0.37	0.44	0.71	0.17	0.77	1.03	1.84	2.01	1.83	0.23
Romania	1.03	1.15	1.14	1.84	6.44	6.48	11.39	9.92	13.88	6.31
Slovakia	2.05	NA	4.10	0.55	3.03	2.41	4.16	3.36	3.23	−0.03
Slovenia	0.13	0.50	1.65	0.30	0.83	0.54	0.64	1.53	1.93	−0.57
GDP growth (*annual %*)										
Bulgaria	5.72	4.15	4.65	5.50	6.74	6.35	6.51	6.44	6.21	−5.51
Croatia	3.75	3.65	4.87	5.31	4.12	4.27	4.93	5.05	2.16	−5.99
Estonia	9.55	8.51	7.94	7.56	7.22	9.43	10.56	6.91	−5.06	−13.89
Latvia	6.91	8.04	6.47	7.19	8.67	10.60	12.23	9.97	−4.24	−17.95
Lithuania	3.25	6.73	6.86	10.24	7.35	7.80	7.84	9.83	2.92	−14.74
Romania	2.10	5.70	5.10	5.19	8.40	4.17	7.90	6.00	9.42	−8.50
Slovakia	1.37	3.48	4.58	4.77	5.03	6.66	8.50	10.58	6.17	−6.20
Slovenia	4.38	2.85	3.97	2.83	4.28	4.49	5.80	6.79	3.49	−7.80

Table 2 presents an overview of the main characteristics of the examined European frontier stock markets, including market capitalisation, foreign direct investment (FDI), net inflows, and annual GDP growth rates. The market capitalisation of the Baltic stock exchanges amounts to 8.94 billion US dollars (USD), as of the end of December 2009. The biggest stock market is Vilnius, accounting for 50% of the region's market capitalisation (4.47 billion USD), followed by Tallinn with 29% (2.65 billion USD), and Riga with 21% (1.82 billion USD). Among the markets in Central and Southeastern Europe, there is considerable variation in market size; market capitalisation ranges from 4.67 billion USD in Slovakia to 30.32 billion USD in Romania.

The European frontier markets have become an attractive destination for foreign direct investment (FDI) following announcement of EU enlargement in 2001.[5] Statistics on major FDI indicators show that some countries in the region experienced a significant increase in inward FDI in the 2000–2008 period. The greatest change is observed for Romania and Slovenia, where, for instance, the level of FDI rose more than 13 times, from 1.03 billion USD in 2000 to 13.88 billion USD in 2008 in Romania, and from 0.13 billion USD in 2000 to 1.93 billion USD in 2008 in Slovenia. However, due to the financial crisis, the inflow of FDI decreased in 2009.

The observed pattern of economic growth differs across the examined frontier markets. For instance, the highest growth rates throughout the period before the financial crisis were recorded for the Baltic markets, especially for Latvia and Estonia, where the annual growth rates in 2006 were 12.23% and 10.56%, respectively. In the Central and Southeastern Europe countries, Slovakia had the fastest economic growth, with the GDP growth rates ranging from 1.37% in 2000 to 10.58% in 2007. The other economies in this group had more even growth on average, between 3% and 6%. In general, all examined European frontier markets grew substantially faster than the EU average; EU average GDP growth rates in the same time period were between 2% and 3%. The rapid economic growth in the frontier European markets, however, ceased in 2009, when all the examined countries recorded negative GDP growth as a result of a global economic slowdown.

3. Data

Our data set consists of weekly stock returns from eight frontier markets in Europe. The markets are selected according to the Standard and Poor's classification of frontier markets. There are nine countries in Europe classified in this category (representing a constituent universe for the S&P/IFCG Extended Frontier 150 Index), but we focus our analysis on eight countries, excluding Ukraine because of limited data availability. The following markets (and indices) are included: Bulgaria (BSE Sofix), Croatia (CROBEX), Estonia (OMX Tallinn), Latvia (OMX Riga), Lithuania (OMX Vilnius), Romania (BET), Slovakia (SAX 16), and Slovenia (LJSE Composite[6]). In addition, we use the stock indices of the United States (S&P 500), the United Kingdom (FTSE100), France (SBF250), and Germany (CDAX), as representative of the developed markets. All data are extracted from the Thomson DataStream database.

The sample period extends from 25 October 2000 to 30 June 2010, representing the longest common time period of data availability and comprising 505 weekly observations. In order to alleviate the problem of non-synchronous trading, we use weekly returns. The returns are defined as logarithmic first difference of weekly stock price indices. Following Rua and Nunes (2009), we use returns denominated in the local currency of each country examined in order to avoid potential distortion caused by currency devaluations.

Table 3 reports descriptive statistics for the return series. During the period under study, all frontier markets have higher average returns than the USA and the developed

[5] Estonia, Latvia, Lithuania, Slovenia, and Slovakia joined the EU in 2004, while Bulgaria and Romania joined in 2007. Croatia signed an EU accession treaty in December 2011, and it is anticipated that accession will take place in July 2013.

[6] The SBI20 Index was renamed the LJSE Composite in March 2010.

Table 3

Descriptive statistics for stock market returns

This table reports descriptive statistics for stock market returns in the frontier (Panel A) and developed markets (Panel B) from 25 October 2000 to 30 June 2010, for a total of 505 weekly observations. Panel C provides correlation coefficients for all pairs of markets.

Panel A: Frontier markets

	Bulgaria	Croatia	Estonia	Latvia	Lithuania	Romania	Slovakia	Slovenia
Mean	0.0025	0.0015	0.0025	0.0016	0.0024	0.0043	0.0015	0.0012
Median	0.0020	0.0019	0.0015	0.0032	0.0031	0.0060	0.0015	0.0027
Maximum	0.1800	0.1159	0.1452	0.2565	0.1962	0.1402	0.1431	0.1100
Minimum	−0.2820	−0.1317	−0.2021	−0.4080	−0.2949	−0.1838	−0.1388	−0.1806
Std. Dev.	0.043	0.032	0.032	0.043	0.032	0.041	0.028	0.026
Skewness	−0.886	−0.418	−0.456	−2.505	−1.086	−0.459	0.062	−1.253
Kurtosis	11.922	5.278	8.508	34.404	19.639	5.308	8.052	11.341

Panel B: Developed markets

	USA	Germany	France	UK
Mean	−0.0005	−0.0006	−0.0009	−0.0005
Median	0.0008	0.0040	0.0027	0.0023
Maximum	0.1018	0.1562	0.1507	0.1358
Minimum	−0.1645	−0.1543	−0.1510	−0.1273
Std. Dev.	0.026	0.033	0.031	0.026
Skewness	−0.536	−0.663	−0.454	−0.330
Kurtosis	7.444	6.403	6.554	6.754

Table 3
Continued.

Panel C: Correlation coefficients of weekly returns for all markets

	USA	Germany	France	UK	Bulgaria	Croatia	Estonia	Latvia	Lith.	Rom.	Slovakia
Germany	0.78										
France	0.79	0.93									
UK	0.78	0.84	0.90								
Bulgaria	0.21	0.20	0.19	0.18							
Croatia	0.31	0.37	0.39	0.35	0.29						
Estonia	0.33	0.39	0.40	0.33	0.29	0.39					
Latvia	0.12	0.16	0.18	0.15	0.19	0.08	0.28				
Lithuania	0.26	0.32	0.33	0.27	0.36	0.34	0.60	0.32			
Romania	0.26	0.28	0.30	0.28	0.32	0.34	0.31	0.17	0.35		
Slovakia	0.09	0.03	0.04	0.04	0.13	0.08	0.10	0.02	0.01	0.07	
Slovenia	0.31	0.32	0.34	0.31	0.32	0.42	0.33	0.18	0.32	0.37	0.03

European markets. Further, the average returns for all eight frontier markets are positive, while the returns for the developed markets are negative. The highest return within the group is recorded for Romania (0.0043), but the Romanian market is also one of the most volatile as measured by standard deviation (0.041). The volatility levels of the frontier markets are generally higher than those of the developed markets. The least volatile market is Slovenia, with a standard deviation of 0.026, which equals the volatility levels of the US and UK markets. The distribution of the returns series is non-normal, with kurtosis exceeding 3 in all cases (leptokurtic series) and showing negative skewness (except Slovakia). The correlations between the frontier markets and the developed markets do not exceed 0.40. The highest correlation with the US market is shown for Estonia (0.33), which is also the market most correlated with Germany (0.39) and France (0.40). The lowest correlation with the developed markets (as well as with the other frontier markets) is recorded for Slovakia, where the correlation coefficients are below 0.10 (below 0.13 with the other frontier markets).

4. Wavelet Analysis Approach

In this section, we give a brief overview of the wavelet analysis approach. The term *wavelets* literally means short waves with finite length and oscillatory behavior (see Crowley, 2007). These waves are certain types of basic functions used to decompose a time series into more elementary functions containing information about a series. Wavelets are derived from a single function (called a mother wavelet) ψ, defined as a function of the time position τnd the scale s, which is related to frequency. The mother wavelet should satisfy the condition of zero mean ($\int_{-\infty}^{\infty} \psi(t)dt = 0$) and the condition that its square integrates to unity ($\int_{-\infty}^{\infty} |\psi(t)|^2 dt = 1$). The following expression gives a precise definition of wavelets:

$$\psi_{\tau,s}(t) = \frac{1}{\sqrt{s}}\psi\left(\frac{t-\tau}{s}\right), \tag{1}$$

where $\frac{1}{\sqrt{s}}$ denotes a normalisation factor which should provide comparability of wavelet transforms across scales and time series (Percival and Walden, 2000; Gencay *et al*., 2002).

In our analysis, we follow Grinsted *et al*. (2004) and Torrence and Compo (1998). Our wavelet analysis represents a combination of feature extraction and multi-resolution analysis with the continuous wavelet transform.[7] For a discrete time series $x(t)$, $t = 1, \ldots, N$ the continuous wavelet transform is defined as the convolution

$$W_x(s,\tau) = \frac{1}{\sqrt{s}}\sum_{t=1}^{N} x(t)\,\psi^*\left(\frac{t-\tau}{s}\right) \tag{2}$$

where s denotes the scale, τ is the time position, and * denotes a complex conjugate.

Our choice for appropriate mother wavelet is the most commonly used wavelet: the Morlet wavelet. A definition of the Morlet wavelet is given by the following expression:

$$\psi(\eta) = \pi^{-\frac{1}{4}} e^{i\omega\eta} e^{-\frac{1}{2}\eta^2} \tag{3}$$

[7] Wavelet analysis can be conducted in continuous or discrete time, depending on the application selection (see Grinsted *et al*., 2004 for more details).

where ω (the dimensionless frequency) is equal to 6, since it gives a good balance between time and frequency localisation (see Grinsted *et al*., 2004 for details), and η denotes a dimensionless time parameter. For two given time series $x(t)$ and $y(t)$, we can use the wavelet transforms W_x and W_y to define a cross wavelet transform $W_{xy} = W_x W_y^*$. The use of the cross wavelet transform enables us to calculate the cross wavelet power $| W_{xy} |^2$, which shows areas of high common power of the two time series. By dividing the smoothed cross wavelet power with the individual smoothed wavelet power spectra, we obtain the wavelet squared coherency (denoted as R_t^2 (s))

$$R_t^2(s) = \frac{\left| S\left(s^{-1} W_t^{XY}(s)\right) \right|^2}{S\left(s^{-1} \left| W_t^X(s) \right|^2\right) \cdot S\left(s^{-1} \left| W_t^Y(s) \right|^2\right)}, \tag{4}$$

where S denotes a smoothing operator (see Rua and Nunes, 2009). The value of the wavelet squared coherency is between 0 and 1, and it can be used to measure the co-movement of two time series over time across frequencies. An interpretation of the wavelet squared coherency value is similar to the interpretation of the coefficient of correlation, where higher values of the wavelet squared coherency correspond to stronger co-movement. Thus, graphical representation of the wavelet squared coherency enables us to identify areas of co-movement between two time series in the time-frequency space considering, simultaneously, both time and frequency variations.

5. Empirical Results

5.1 *European frontier markets*

In this section, we report the results of the dynamics of stock return co-movement obtained by applying the wavelet analysis approach. The results are presented in three-dimensional graphs in which the wavelet squared coherency is portrayed through a contour plot. The frequency is depicted on the vertical axis and is expressed in time units (years). Time is presented on the horizontal axis. The third dimension (height) is pictured via different shades of grey, indicated on the grey scale, where an increasing value of the wavelet squared coherency is symbolised by increasing darkness of the grey colour. The three-dimensional setting enables us to detect areas of varying co-movement among return series over time across frequencies. Areas of stronger co-movement in the time-frequency space imply lower benefits from international portfolio diversification. The wavelet squared coherency is statistically significant at the 5% level in the time-frequency areas separated by the black bold line.[8]

Figure 1 shows the wavelet squared coherency between the frontier stock markets and the US market. We note several findings from analysing the co-movement patterns presented in Figure 1. First, the co-movement of the Baltic markets with the US seems to be much stronger than that of the frontier markets in Central and Southeastern Europe. In particular, the highest degree of co-movement over the whole sample period is associated with Lithuania, with the strength of co-movement particularly intense over the 2008 to 2010 time period. The stronger co-movement is detected not only at low, but also

[8] Similar to Rua and Nunes (2009), the Monte Carlo simulation was applied to calculate the level of significance.

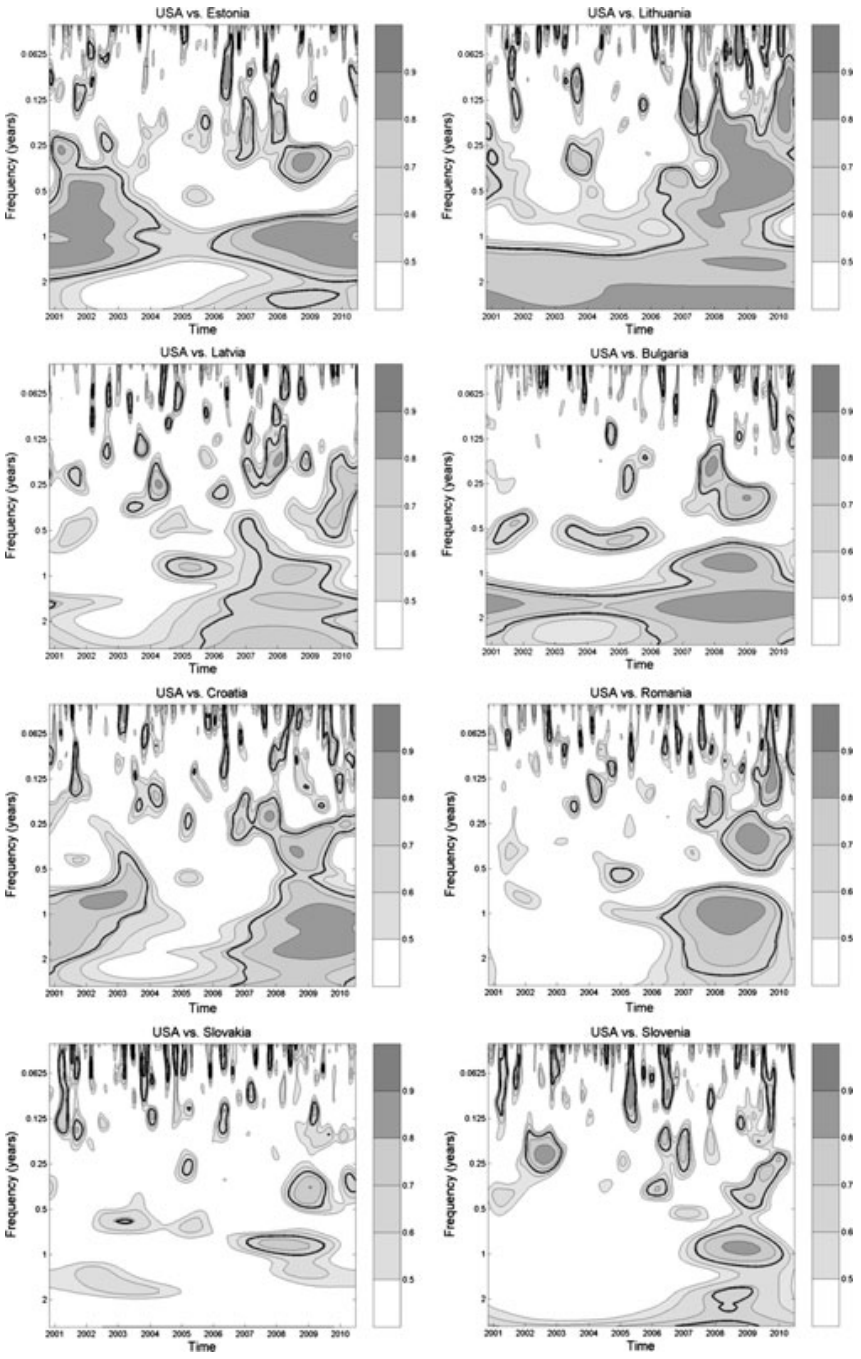

Fig. 1. Wavelet squared coherency for frontier stock markets versus US market (weekly data)

This figure presents the wavelet squared coherency between frontier stock markets and the US market. Time and frequency are represented on the horizontal and vertical axes, respectively. The third dimension (height) is pictured by different variations of gray color, indicated on the gray scale. Frequency is converted into years. The black bold line delimits the statistically significant area at the significance level of 5%.

at intermediate and high frequencies (short horizons). This is to be expected, given that Lithuania alone accounts for 50% of the Baltic region's market capitalisation. Estonia also shows some episodes of stronger co-movement at intermediate and high frequencies during the 2001 to 2004 and 2008 to 2010 time periods. The pattern of co-movement observed for Latvia is slightly different; the strength of co-movement is on a lower level than those of Lithuania and Estonia. This moderate level of co-movement may be due to the small size of the Latvian market; the market capitalisation of the Latvian market is lowest among all European frontier markets. However, the strength of co-movement is especially intense between 2008 and 2010. The time interval 2001–2004 coincides with the period following the announcement of EU enlargement with ten accession countries (including Estonia, Latvia, and Lithuania). A positive market reaction to the accession news may have led to stronger co-movement, marking the Baltic markets as an attractive investment spot to foreign investors. The second time interval of stronger co-movement coincides with the 2008/2009 global financial crisis.

With regard to the co-movement of frontier markets in Central and Southeastern Europe with the US market, we find considerable variation in the co-movement pattern across countries. Bulgaria shows strong co-movement with the US market at low frequencies throughout the sample period. Starting in 2007, strengthened co-movement is observed for intermediate frequencies as well. This strengthening effect may be due to greater market interdependence during the global financial crisis, but it is also likely that this effect is partly a consequence of EU membership. The case of Romania, where strong co-movement is observed only after 2007, provides additional support for the possible impact of EU accession on increased market co-movement. Croatia presents a pattern similar to that of Estonia, with two periods (prior to 2004 and from 2008 to 2010) of stronger co-movement at low and intermediate frequencies. In 2004, Croatia obtained EU candidate status. Factors associated with preparation for EU membership candidacy, such as stock market liberalisation and economic reforms, most likely contributed to strengthening linkages with other markets. Slovenia shows stronger co-movement only after 2007. The Slovakian market is unique in the sense that its co-movement is very weak throughout the sample period.

The strongest co-movement with the US market during the crisis period is found for Romania. This is not surprising, considering that Romania's is the largest market (in terms of market capitalisation), has the highest average returns and nearly the highest volatility, and recorded the greatest increase in FDI in recent years among all European frontier markets. Given these characteristics, it is most likely that such a market could have higher exposure and response to global market shocks relative to the other, smaller markets with lower volatility level.

In general, the co-movement of the European frontier stock markets with the US market is stronger at lower frequencies (longer horizons), as indicated by the darker areas at the bottom of the graph. Interestingly, all frontier stock markets show a change in the pattern of the co-movement from 2008 to 2010, when the co-movement intensifies and extends to higher frequencies as well. This finding provides evidence of increased co-movement among international stock markets during volatile periods such as global financial crises, which is consistent with the findings of Longin and Solnik (1995) and Cheung *et al.* (2010).

The patterns of co-movement between frontier stock markets and developed European markets (UK, Germany, and France) are relatively similar to those observed for the

USA.[9] The common features are stronger co-movement at low frequencies compared to high frequencies and an observed trend of increasing co-movement starting from 2008. The differences between the co-movement of frontier markets with the USA and the UK are reflected in weaker co-movement of the Baltic markets with the UK relative to the USA. In particular, the Lithuanian stock market exhibits strong co-movement with the UK only at low frequencies, which contrasts with the case of co-movement with the USA at almost all frequencies. In addition, the Baltic markets present slightly stronger co-movement at intermediate frequencies with Germany in comparison with the UK. The frontier markets of Central and Southeastern Europe show a fairly similar pattern in co-movement with the USA and all three developed European markets.

The next stage in our analysis is to identify potential macroeconomic factors that could explain time variations in co-movement at different time frequencies. These factors include domestic macroeconomic variables used to proxy business cycle fluctuations, the inflation environment, and monetary policy stance, denoted as Industrial Production Index (IP), Harmonised Consumer Price Index (HICP), and three-month interbank interest rates (IIR), respectively.[10] In addition, we use the Exchange Rate Index (ERI) as an explanatory variable to account for the potential impact of exchange rate fluctuations. Global macroeconomic factors are represented by the same type of the macroeconomic variables as for the USA. All macroeconomic and stock return data are at a monthly level and the sample period corresponds to the sample period used in the co-movement analysis.

We regress the wavelet squared coherencies (measure of the degree of co-movement between two stock markets) at different time frequencies with the aforementioned explanatory variables using ordinary least squares (OLS) regressions. Specifically, we estimate the following equation:

$$WSC_{ij,f} = a + \beta_1 IP_i + \beta_2 IP_j + \beta_3 HICP_i + \beta_4 HICP_j + \beta_5 IIR_i + \beta_6 IIR_j + \beta_7 ERI_i + \beta_8 ERI_j + \varepsilon_{ij,f} \quad (5)$$

where $WSC_{ij,f}$ is the wavelet squared coherency between the stock returns of the US market and the European frontier markets, such that i = USA and j = Bulgaria, Croatia, Estonia, Latvia, Lithuania, Romania, Slovakia, and Slovenia; f is the frequency domain given at two different levels, expressed in time units of 0.25 years (high-frequency) and 2 years (low-frequency).

In Table 4 we present the results obtained by running regressions described in Equation (5). The results reveal several important findings. First, domestic macroeconomic factors are more prominent than the corresponding global factors in explaining co-movements between European frontier markets and the US market at high frequencies (short-term horizons). In particular, the most influential factor is domestic monetary policy (significant in four out of eight countries), while the domestic inflationary environment and domestic exchange rate movements are observed to be significant for three countries. It is interesting that the global exchange rate factor is significant in none of the countries. Second, the most important factors in explaining co-movement between European frontier markets and the US market at low frequencies (long-term

[9] The figures of the frontier markets vs. developed European markets (UK, Germany, and France) are not shown here due to lack of space; they are available from the authors upon request.

[10] The data source for the macroeconomic variables is the Global Financial Database.

Table 4

Relationship of stock market co-movement and macroeconomic factors

This table presents estimation results from a regression model linking wavelet coherency at different time horizons with a number of domestic and global macroeconomic factors (Equation 5). The explanatory variables include IP (the Industrial Production Index as a proxy for business cycle fluctuations), HICP (the Harmonised Consumer Price Index as a proxy for inflation environment), IIR (the three-month interbank interest rate as a proxy for monetary policy stance), and ERI (the Exchange Rate Index as a proxy for exchange rate movements). Figures in parentheses are the Newey-West robust standard errors. * and ** denote statistical significance at the 5% and 1% levels, respectively.

	Bulgaria	Croatia	Estonia	Latvia	Lithuania	Romania	Slovakia	Slovenia
Short-term horizon ($f = 0.25$ *year*)								
α	−7.141*	−2.816	0.716	1.770	−3.079	−0.838	−1.438	−0.918
	(2.772)	(3.086)	(3.943)	(1.891)	(4.283)	(2.408)	(3.385)	(4.220)
IP_{USA}	0.000	0.001	−0.020	−0.013	0.005	−0.025*	0.056**	−0.019
	(0.011)	(0.014)	(0.019)	(0.012)	(0.018)	(0.012)	(0.017)	(0.015)
$IP_{DOMESTIC}$	0.004	0.001	−0.002	−0.000	0.000	−0.004*	−0.000	0.000
	(0.002)	(0.002)	(0.002)	(0.003)	(0.002)	(0.002)	(0.002)	(0.001)
$HICP_{USA}$	0.050	−0.067*	0.015	0.004	0.006	0.046*	0.013	0.045
	(0.026)	(0.027)	(0.041)	(0.012)	(0.028)	(0.018)	(0.023)	(0.025)
$HICP_{DOMESTIC}$	−0.043**	0.035	−0.024	−1.608	−0.008	0.004	−0.079**	−0.065*
	(0.015)	(0.026)	(0.024)	(1.907)	(0.015)	(0.006)	(0.013)	(0.028)
IIR_{USA}	−0.020	0.043	0.059	0.043	−0.024	0.086*	−0.058*	0.046
	(0.020)	(0.032)	(0.045)	(0.031)	(0.052)	(0.033)	(0.028)	(0.034)
$IIR_{DOMESTIC}$	−0.010	−0.045*	0.034	−0.003	0.021	0.011*	−0.125**	−0.073*
	(0.029)	(0.020)	(0.035)	(0.007)	(0.024)	(0.005)	(0.041)	(0.030)
ERI_{USA}	0.017	−0.000	0.000	−0.001	0.007	0.000	0.013	0.005
	(0.009)	(0.008)	(0.013)	(0.007)	(0.013)	(0.008)	(0.011)	(0.006)
$ERI_{DOMESTIC}$	0.046**	0.063**	0.024	−0.005	0.022	−0.014	0.025**	0.047
	(0.012)	(0.021)	(0.021)	(0.008)	(0.015)	(0.008)	(0.007)	(0.036)
R-squared	0.353	0.420	0.291	0.134	0.249	0.662	0.319	0.483
Long-term horizon ($f = 2$ *years*)								
α	1.351**	−4.486*	2.439**	0.239	1.270**	−3.281*	1.316**	−8.023**
	(0.463)	(1.752)	(0.542)	(0.181)	(0.257)	(1.276)	(0.294)	(1.654)
IP_{USA}	−0.012**	−0.003	−0.014**	0.001	−0.006**	−0.010	0.003	−0.005
	(0.002)	(0.010)	(0.002)	(0.000)	(0.001)	(0.007)	(0.002)	(0.006)
$IP_{DOMESTIC}$	−0.001*	−0.004**	−0.003**	−0.000	−0.000*	0.001	0.000*	−0.001
	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)
$HICP_{USA}$	0.000	0.029*	0.004	0.001	−0.004*	0.024*	−0.012**	0.036**
	(0.003)	(0.014)	(0.004)	(0.000)	(0.001)	(0.010)	(0.001)	(0.010)
$HICP_{DOMESTIC}$	0.011**	0.013	0.020**	−0.085	0.014**	0.004	0.003	0.001
	(0.001)	(0.012)	(0.003)	(0.156)	(0.001)	(0.003)	(0.001)	(0.010)
IIR_{USA}	0.072**	0.066**	0.052**	−0.003	0.037**	0.037*	−0.046**	0.057**
	(0.004)	(0.020)	(0.006)	(0.002)	(0.002)	(0.014)	(0.004)	(0.013)
$IIR_{DOMESTIC}$	0.017**	0.027*	0.019**	0.000	0.005**	0.010**	0.006	0.026*
	(0.006)	(0.011)	(0.005)	(0.000)	(0.001)	(0.003)	(0.003)	(0.011)
ERI_{USA}	−0.003**	0.011**	−0.008**	−0.000	−0.005**	0.002	−0.000	0.010**
	(0.001)	(0.003)	(0.001)	0.000	(0.001)	(0.004)	(0.001)	(0.003)
$ERI_{DOMESTIC}$	−0.004*	−0.001	−0.021**	0.003**	−0.005**	0.010**	−0.002**	0.037**
	(0.001)	(0.010)	(0.003)	(0.000)	(0.001)	(0.003)	(0.000)	(0.010)
R-squared	0.972	0.927	0.962	0.925	0.985	0.953	0.968	0.937

horizons) are global monetary policy and domestic exchange rate movements, as these factors are statistically significant for seven out of eight frontier markets. In addition, domestic monetary policy plays an important role in six countries. In contrast to the co-movement at high frequencies, global exchange rates and both global and domestic industry production factors are found to be of higher importance for co-movement at low frequencies.

Third, a number of significant explanatory factors for each country is much higher at low frequencies (long-term horizons) compared to high frequencies (short-term horizons). The explanatory power of the model (R-squared) differs substantially between short-term and long-term horizons, ranging from 13% to 66% for the short-term horizon and from 92% to 98% for the long-term horizon. Finally, in a fourth finding, the country-specific results indicate that in the short-run frontier stock markets in Central and Southeastern Europe are more affected by macroeconomic fundamentals than are Baltic markets, while in the long run macroeconomic factors are quite important for all frontier markets (except Latvia) in explaining stock return co-movement with the US market. Taken together, the results support the notion that there is a difference in importance among macroeconomic factors with respect to co-movement on both the short-term and long-term horizon.

5.2 *Robustness checks*

We conduct several robustness checks on the results reported in the preceding subsection. First, we repeat the wavelet co-movement analysis based on daily and monthly data. Our main findings obtained with weekly data are robust to whether we perform the co-movement analysis based on daily or monthly data.[11] Second, we extend our co-movement analysis within a multivariate framework by applying the Dynamic Conditional Correlation (DCC) multivariate GARCH model of Engle (2002) to examine time-varying conditional correlations among the analysed markets. Table 5 presents the results of the multivariate DCC-GARCH model applied on the weekly stock returns of all analysed markets. The estimates of the DCC (1,1) parameters a and b in the DCC equation are statistically highly significant, indicating the presence of a time-varying co-movement. Coefficients α and β in the variance equation of the DCC model capture the effects of the lagged shock-squared terms and the lagged conditional volatility on dynamic conditional correlations. Consistent with the results of the wavelet analysis, the statistically significant estimates of α and β coefficients reveal a substantial time-varying co-movement for all markets (except Slovakia and Slovenia, where the estimated β parameter of the lagged conditional volatility is statistically insignificant).

Figure 2 displays pairwise conditional correlations between US stock returns and those of European frontier markets during the study period. As in the case of the wavelet results described above, almost all frontier markets (except Slovakia) show a pattern of rapidly increased conditional correlations with the US market during 2008, reaching their peaks in the last quarter of 2008. The observed pattern of increased conditional correlations during the financial crisis confirms our previous results of increased co-movement among the analysed markets starting in 2008, obtained using the wavelet

[11] To avoid the problem of non-synchronous trading periods for different markets, we use two-day rolling average returns (see Lin *et al*., 1994) when performing co-movement analysis with daily data. Detailed results and graphs are available upon request.

Table 5
Estimation results from the DCC-GARCH model

This table reports estimates of the following variance equations and the DCC equation:Variance equations: $h_{ii,t} = \omega_i + \alpha_i \varepsilon^2_{i,t-1} + \beta_i h_{ii,t-1}$ for $i = 1, 2, \ldots 12$.
DCC equation:

$$q_{ij,t} = \bar{\rho}_{ij}(1 - a - b) + bq_{ij,t-1} + a\eta_{i,t-1}\eta_{j,t-1}$$

$$\rho_{ij,t} = \frac{q_{ij,t}}{\sqrt{q_{ii,t}}\sqrt{q_{jj,t}}} \quad \text{where } i, j = 1, 2, \ldots 12 \text{ and } i \neq j.$$

Figures in parentheses are standard errors. * and ** denote statistical significance at the 5% and 1% levels, respectively.

Panel A: Variance equations

	ω	α	β
Bulgaria	0.0000*	0.4433**	0.6794**
	(0.0000)	(0.0000)	(0.0000)
Croatia	0.0001	0.2410**	0.7382**
	(0.0492)	(0.0299)	(0.0613)
Estonia	0.0001*	0.4464**	0.5913**
	(0.0000)	(0.0000)	(0.0000)
France	0.000	0.2203**	0.8206**
	(0.1017)	(0.0548)	(0.0996)
Germany	0.0001	0.4061**	0.5544**
	(0.0983)	(0.0514)	(0.1559)
Latvia	0.0002	0.6694**	0.3653**
	(0.1024)	(0.1871)	(0.1159)
Lithuania	0.0001	0.4370*	0.5413**
	(0.0789)	(0.2070)	(0.0606)
Romania	0.0002**	0.3072**	0.5897**
	(0.0000)	(0.0000)	(0.0001)
Slovakia	0.0002	0.6141**	0.2827
	(0.0634)	(0.0645)	(0.2634)
Slovenia	0.0001	1.2293**	0.2913
	(0.0781)	(0.0698)	(0.1642)
UK	0.0000	0.2511**	0.7686**
	(0.0745)	(0.0422)	(0.0782)
USA	0.0001	0.5947**	0.5052**
	(0.0000)	(0.0001)	(0.0000)

Panel B: Multivariate DCC equation

a	0.0191**
	(0.0044)
b	0.8402**
	(0.0475)

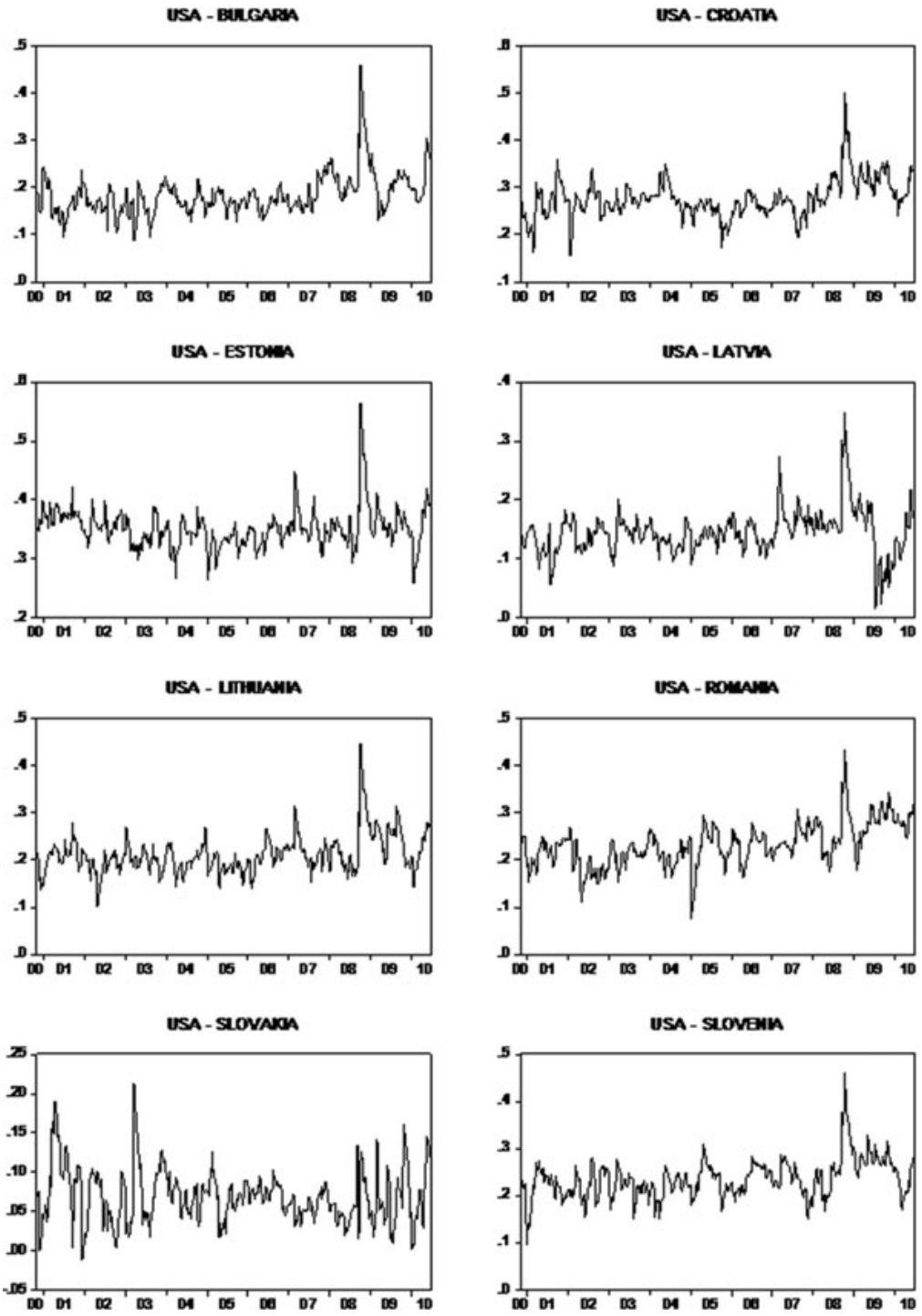

Fig. 2. Dynamic conditional correlations

This figure presents dynamic conditional correlations between European frontier stock markets and the US market in the period October 2000 to June 2010.

analysis approach. In the case of Slovakia, the peak of conditional correlations is not observed during the crisis period, but instead during 2003, coinciding with preparations for EU entry. This observation is consistent with our previous finding that Slovakian market exhibits very low co-movement with the US market and, taken together with the result of statistical insignificance for the conditional volatility parameter for Slovakia in the DCC model, suggests that the Slovakian market has higher diversification potential relative to the other European frontier markets. The results for the conditional correlations between European frontier markets and the developed European markets (UK, Germany, and France) are fairly similar to those obtained for the US market and are in accordance with our wavelet results.

5.3 *Other frontier markets worldwide*

In order to investigate the diversification potential of frontier stock markets as a special subset of emerging markets and further assess the robustness of our previous results, we extend our analysis to frontier markets outside Europe. In this additional analysis, we use eight countries included in the S&P Select Frontier Index, representing frontier markets from three different continents: 1. Africa (Jordan, Kuwait, Nigeria, and Oman); 2. Asia (Pakistan and Vietnam) and 3. South America (Argentina and Colombia). By using weekly returns of the main stock indices of selected countries, we carry out a wavelet analysis of stock market co-movements with the US market during the same period as for the European frontier markets.[12]

In general, all eight frontier markets exhibit relatively similar behaviour: strengthened co-movement with the US market during the 2008–2009 financial crisis, consistent with the European frontier markets. The differences across these markets relate to the strength of co-movement on different frequency levels. For example, the strongest co-movement with the US market throughout the sample period is recorded for South American markets, especially Argentina, where the strong co-movement is present at all frequency levels, while the Columbian market is characterised by strong co-movement only at intermediate frequencies. African frontier markets show patterns of weak co-movement with the US market, mainly at low frequencies. In particular, Kuwait and Oman (members of the Gulf Cooperation Council) present stronger co-movement than Nigeria and Jordan. Relatively weak co-movement with the US market is also observed for Asian frontier markets. Taken together, the results from co-movement analysis of frontier stock markets worldwide with developed markets confirm our finding about the significant diversification potential of the frontier markets.

6. Conclusions

This study examines the dynamics of European frontier stock market co-movement with the USA and the three largest developed markets in Europe, by utilising the powerful tool of wavelet squared coherency. This technique enables us to simultaneously consider

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[12] We use the following stock price indexes: Amman SE Financial market (Jordan), Kuwait KIC General (Kuwait), S&P Nigeria BMI (Nigeria), Oman Muscat Securities Market (Oman), Karachi SE 100 (Pakistan), Ho Chi Min VSE (Vietnam), Argentina Merval (Argentina), and Colombia – DS Market (Colombia). We also conduct the same analysis for the UK, France, and Germany and obtain similar results. To save space, these results are not reported, but are available upon request.

both the time and frequency domains in the co-movement analysis. In addition, we investigate various macroeconomic factors to explain variations in co-movement at different frequency levels.

We find that co-movement of the Baltic frontier markets with the USA and the three largest developed markets in Europe seems to be stronger than that of frontier markets in Central and Southeastern Europe. However, the strength of co-movement varies considerably across countries and across time horizons. The lowest degree of co-movement across all frequencies is observed for Slovakia, indicating the higher diversification potential of this market relative to the other frontier markets. Overall, we find stronger co-movement of the European frontier markets with the USA and the three largest developed markets in Europe at low frequencies (long horizons) compared to high frequencies (short horizons). We also find that in the period from 2008 to 2010, which coincides with the global financial crisis, the co-movement is strengthened and extends to higher frequencies. Our findings therefore suggest that the benefits of international portfolio diversification in the European frontier markets may be more significant in the short-term than in the long-term. Finally, our results reveal that macroeconomic fundamentals can explain variations in co-movement at both short- and long-term horizons. In general, macroeconomic factors have greater explanatory power in explaining co-movement at long-term horizons compared to short-term horizons. Specifically, the influence of domestic macroeconomic factors on stock return co-movement at short-term horizons seems to be greater than the influence of global factors. Domestic monetary policy is identified as the most prominent factor for short-term horizons, while in the long run, the most influential factors are global monetary policy and domestic exchange rate movements. The results of this study offer interesting insights into how international investors can benefit from investing in frontier markets by taking into account time-and-frequency varying co-movement of stock returns in designing international portfolios. Our findings are also helpful in understanding which economic factors drive stock return co-movements in European frontier markets at short and long horizons.

In light of the debate in the literature as to whether the phenomenon of increased co-movement between international stock markets is permanent or temporary in nature, our findings suggest that the increase in stock co-movement of European frontier markets with the developed markets in recent years contains both a permanent and a transitory component. The permanent component is attributed to the overall increasing trend toward global capital market integration documented in many studies (e.g., Ayuso and Blanco, 2001; Pukthuanthong and Roll, 2009). Further, EU membership contributes to the accelerated stock market integration of European frontier markets through financial reforms and openness to foreign investors. However, an overall increase in co-movement might also involve a transitory component, resulting from the contagious nature of the global financial crisis. Disentangling the permanent and transitory components of increased co-movement is a challenge left for future research.

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Baltic stock markets and the financial crisis of 2008–2009

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ABSTRACT

This study presents new evidence on stock market integration by investigating the linkages between developed European stock markets and emerging stock markets. We focus on three countries in the Baltic region, namely Estonia, Latvia and Lithuania with particular attention to the recent financial crisis of 2008–2009. The study is motivated by traditional stock market studies of integration, which show that developed stock markets are highly integrated, while emerging markets may be segmented. How integrated these emerging stock markets are in a crisis period with respect to the EUROSTOXX50 stock index is an empirical question investigated in this study. While the results of this study demonstrate that the Baltic stock markets were apparently segmented before the crisis, they were highly integrated during the crisis. The results of the variance decomposition analysis show that a large proportion of the forecast variance of the Baltic stock markets can be explained by the EUROSTOXX50 during the crisis. The results from the quantile regressions demonstrate that during the crisis the returns of the lowest quantile were most sensitive to the EUROSTOXX50 stock index. All these results imply less diversification benefits during crises when investors would need them the most.

1. Introduction

An observation according to which the stock markets behaved very similarly across different continents and countries during the global financial crisis of 2008–2009 casts serious doubts on the

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usefulness of the traditional portfolio theory during crisis periods.[3] This is the case in particular if the less integrated frontier emerging markets become fully integrated during global crises. From the perspective of portfolio theory, a relevant question is therefore whether there are still some markets that are less integrated and as such could provide better diversification benefits, also during global crises.

In this study, we examine the integration of a subset of European emerging markets, namely the Baltic stock markets (of Estonia, Latvia and Lithuania), with the developed European stock markets, paying particular attention to the financial crisis period. Our study is motivated by the traditional stock market studies of integration (e.g., Bekaert and Harvey, 1995; Bessler and Yang, 2003; Kim et al., 2005; Carrieri et al., 2007), which generally show that while developed stock markets are highly integrated, emerging markets may still be segmented (e.g., Mateus, 2004; Chambet and Gibson, 2008; Yu and Hassan, 2008; Cheng et al., 2010; Claus and Lucey, 2012). The specific goal of our study is to examine how integrated the emerging Baltic stock markets were during the 2008–2009 crisis with respect to the European stock markets.

Our research problem is timely and relevant as indicated by the large number of related studies on financial crises on various other markets. These include, for example, foreign exchange markets (see e.g., Baba and Packer, 2009; Fratzscher, 2009; Melvin and Taylor, 2009), fixed income markets (see e.g., Acharya et al., 2009; Dwyer and Tkac, 2009; Hartmann, 2010) and stock markets (see e.g., Bartman and Bodnar, 2009; Dooley and Hutchison, 2009; Billio and Caporin, 2010; Chudik and Fratzscher, 2011; Schwert, 2011; Syllignakis and Kouretas, 2011). The studies show that several asset classes and markets were significantly affected by the financial crisis of 2008–2009.

Our study contributes to both the financial crisis literature and studies on the Baltic markets by examining the effects of the financial crisis, specifically on the integration of the Baltic countries during the recent global crisis. The work most closely related to ours is that by Syllignakis and Kouretas (2011), who examine the correlation dynamics for seven Eastern European countries during the financial crisis, whereas studies focusing on the Baltic stock markets are scarce.[4] Of the few existing studies focusing on the integration of the Baltic equity markets, Maneschiöld (2006) examines long-run and short-run integration of the Baltic stock markets with several international markets (US, Japan, Germany, UK, and France) during the period 1996–2005, while Mateus (2004) investigates the Baltic markets within the sample of the 13 EU accession countries during the period 1997–2002. Maneschiöld (2006) shows that the Baltic markets exhibit a low degree of integration with developed international markets and therefore can provide diversification benefits for international investors, especially on a long-term investment horizon. Furthermore, Mateus (2004) presents evidence about the partial integration of the Baltic stock markets with respect to the world market. In sum, the literature on the integration of the Baltic stock markets suggests that these emerging markets are indeed segmented. In this study, we contribute to the existing literature by examining the cross-dependence of the Baltic countries with particular attention to the financial crisis, which has not been previously investigated.

Several studies have documented that the degree of integration among stock markets tends to change over time, particularly in time of crisis. For instance, Yang et al. (2003) find that ten Asian emerging stock markets have generally been more integrated during and after the 1997–1998 Asian financial crisis than before the crisis. Similarly, Yang et al. (2006) present evidence of the significant impact of the 1998 Russian financial crisis on the integration of four major Eastern European emerging stock markets (Czech Republic, Hungary, Poland, and Russia). Given that the literature has documented that the Baltic stock markets are segmented (Mateus, 2004; Maneschiöld, 2006), it is particularly interesting to investigate how these markets behave during a financial crisis.

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[3] This is not surprising given the evidence of globally integrated stock markets (see e.g. Lin et al., 1994; Longin and Solnik, 2001).

[4] Generally, the stock markets in the Baltic region provide an interesting environment for further research given their fast economic growth in the years prior to the global financial crisis of 2008–2009, as well as the status of regulated markets associated with the benefits of EU membership. Earlier studies on the stock market integration of the European emerging markets have focused on larger markets in Central and Eastern Europe such as those of Poland, Hungary and the Czech Republic (Gilmore and McManus, 2002; Voronkova, 2004; Chelley-Steeley, 2005; Gilmore et al., 2008; Li and Majerowska, 2008; Middleton et al., 2008), and more recently on the Balkan markets (Samitas et al., 2006; Kenourgios and Samitas, 2011; Syriopoulos, 2011), while the evidence from the Baltic region is limited.

Our results demonstrate that while the Baltic stock markets were segmented before the crisis, they became highly cross-correlated during the crisis. This indicates that they are closely linked to the developed European stock markets, proxied by the EUROSTOXX50 index. This is also evident from the results of the variance decomposition analysis, which show that a large proportion of the forecast variance of the Baltic stock markets can be explained by the EUROSTOXX50 index during the crisis. Finally, the results from the quantile regression analysis provide further evidence that during the crisis the returns of the lowest quantile were most sensitive to the EUROSTOXX50 index. Taken together, these results imply that during stock market turbulence, the segmented Baltic markets also become integrated with the developed European stock markets.

The remainder of this paper is organized as follows. Section 2 presents an overview of the market environment and economies of the Baltic countries, while Section 3 describes the data. Section 4 presents the econometric methodology used to analyze stock market integration. It also presents the empirical results. Section 5 concludes.

2. Baltic market environment

2.1. Baltic market environment in pre-crisis period (2004–2007)

The Baltic stock markets (Estonia, Latvia and Lithuania) have a rather brief history compared to developed equity markets in Europe. The Tallinn Stock Exchange in Estonia, the Riga Stock Exchange in Latvia and the Vilnius Stock Exchange in Lithuania were established, respectively, in 1920, 1926 and 1937, but these exchanges were closed at the beginning of the Second World War. After the collapse of the Soviet Union the Baltic stock exchanges resumed trading in the middle of the 1990s. The first stock exchange to reopen in the Baltic region was the Vilnius Stock Exchange in 1993, followed by the Riga Stock Exchange and Tallinn Stock Exchange in 1995.

The Baltic stock exchanges became part of the OMX Group during 2000–2004. The OMX group, which owns and operates exchanges in the Nordic countries, was acquired by NASDAQ in 2007. This acquisition resulted in forming the world's largest exchange company, the NASDAQ OMX Group, and consequently it led to the harmonization of trading rules and practices, increasing at the same time interest in investments in the Baltic region. The Baltic stock exchanges have a common list which includes all listed Baltic companies divided into four different segments: Baltic Main List, Baltic Secondary List, Baltic Funds List and Baltic Bond List. The main purpose of a common list and sharing the same trading system is to make securities more attractive to foreign investors.

The Baltic countries are classified as high income (Estonia) and upper-middle income (Latvia and Lithuania) economies according to the World Bank. However, despite the relatively high developmental level, all three Baltic stock markets are categorized as frontier stock markets (i.e. the special subset of emerging markets in the S&P classification of the stock markets) due to their small size.

Table 1 provides an overview of the stock market characteristics of the Baltic markets, including the number of listed companies, market capitalization, total value of stocks traded, and turnover ratio.[5] The market capitalization of the Baltic stock exchanges amounted to 19.28 billion US dollars, as of the end of December 2007. The biggest stock market is Lithuania, accounting for 53% of the region's market capitalization (10.13 billion US dollars), followed by Estonia with 31% (6.04 billion US dollars) and Latvia with 16% (3.11 billion US dollars). The most active market in terms of trading activity (as measured by the turnover ratio) is the Estonian market, with the turnover ratio peaked at 51.1% in 2005 (the lowest level was 16.2% in 2009). On the other hand, the Latvian market shows rather thin trading activity, with the turnover ratio ranging from the highest level of 8.1% in 2004 to the lowest of 1.1% in 2009.

Prior to their EU accession all three Baltic countries liberalized their financial markets,[6] which in conjunction with the privatization of state-owned enterprises and lifting of all restrictions on

[5] The turnover ratio is defined as the total value of shares traded during the period divided by the average market capitalization for the period.

[6] The legal restrictions on foreign participation in the Baltic markets were removed gradually during the period 1996–1999. The first American Depositary Receipts (ADR) was issued in Lithuania in 1996, followed by Estonia and Latvia in 1997.

Table 1
Financial indicators.

Subject descriptor	Units	Scale	2004	2005	2006	2007	2008	2009
Panel A: Estonia								
Listed domestic companies. Total	Companies	Unit	13	15	16	18	18	16
Market capitalization of listed companies	Percent of GDP		51.6	25.1	35.9	28.2	8.3	13.9
Market capitalization of listed companies	U.S. dollars	Billions	6.203	3.495	5.963	6.037	1.951	2.654
Stock traded. Total value	Percent of GDP		6.9	17.8	5.9	9.8	3.3	2.0
Stock traded. Turnover ratio	Percent change		17.5	51.1	20.5	34.9	25.4	16.2
Foreign direct investments, net inflows	U.S. dollars	Millions	965	2941	1787	2728	1745	1751
Panel B: Latvia								
Listed domestic companies. Total	Companies	Unit	39	45	40	41	35	34
Market capitalization of listed companies	Percent of GDP		12.0	15.8	13.6	10.8	4.8	7.0
Market capitalization of listed companies	U.S. dollars	Billions	1.655	2.527	2.705	3.111	1.609	1.824
Stock traded. Total value	Percent of GDP		0.8	0.6	0.6	0.5	0.1	0.1
Stock traded. Turnover ratio	Percent change		8.1	4.6	4.3	4.8	1.8	1.1
Foreign direct investments, net inflows	U.S. dollars	Millions	636	713	1664	2315	1357	93
Panel C: Lithuania								
Listed domestic companies. Total	Companies	Unit	43	43	44	40	41	40
Market capitalization of listed companies	Percent of GDP		28.7	31.5	33.9	25.9	7.7	12.0
Market capitalization of listed companies	U.S. dollars	Billions	6.463	8.183	10.191	10.134	3.625	4.477
Stock traded. Total value	Percent of GDP		2.1	2.9	7.0	2.6	1.0	0.8
Stock traded. Turnover ratio	Percent change		9.8	10.1	22.8	10.1	59.9	7.5
Foreign direct investments, net inflows	U.S. dollars	Millions	773	1031	1840	2017	1839	230

Source: World Bank.

movement of capital enhanced their investment profiles. The actual status of the EU Member State, obtained in May 2004, additionally promoted the Baltic markets as an attractive destination for foreign direct investments (FDI). In particular, all three Baltic markets recorded significant increases of inward FDI during the period 2004–2007. For instance, the level of inward FDI for Estonia rose from 965 million US dollars in 2004 to 2728 million US dollars in 2007. One significant source of FDI entry into Baltic region (especially in Estonia) was in the mode of brownfield investments, which contributed to the overall increase in FDI and consequently to the accelerated economic growth.[7] The reasons why Baltic countries successfully attracted remarkable amount of FDI are attributable to macroeconomic stabilization, structural reforms, privatization and FDI-friendly environment (Hunya, 2004). Additionally, the FDI promotion agencies played an important role in FDI promotion policy in all three Baltic countries. Increase in FDI inflows was followed with very fast economic growth (among the highest within the EU) in all three Baltic countries in the years prior to the financial crisis of 2008/2009. The region as a whole was growing more rapidly than the EU average in terms of GDP annual growth in the period 2004–2007. For instance, the GDP annual growth rates of Latvia ranged from 8.67% to 12.23%, those of Estonia between 6.91% and 10.56%, and those of Lithuania between 7.35% and 9.83%; while the EU average GDP growth rates in the corresponding time period were between 2% and 3%. A more detailed description of the main macroeconomic indicators is provided in Table 2.

2.2. Baltic market environment during the 2008–2009 financial crisis

The fast economic growth in the period from 2004 to 2007 ceased in 2008 and 2009 due to the global economic slowdown caused by the financial crisis. The Baltic countries were the most heavily affected economies by the 2008–2009 financial crisis among the EU member states. The GDP growth rate in the EU for the year 2009 was negative and amounted to −4.25% on average, while the corresponding rates for the same year in Estonia, Lithuania, and Latvia amounted to −13.89%, −14.74% and

[7] The brownfield investments represent a special mode of FDI regarded as a hybrid mode between acquisition and greenfield investments. A brownfield entry in foreign market entails the purchase of an existing firm by an acquirer outside the country, involving a restructuring of the firm primarily with the resources provided by acquirer during a short transformation period (Meyer and Estrin, 2001; Cheng, 2006).

Table 2
Macroeconomic indicators.

Indicator	Units	Scale	2004	2005	2006	2007	2008	2009
Panel A: Estonia								
Gross domestic product, current prices	U.S. dollars	Billions	12.03	13.90	16.80	21.69	23.70	19.30
Gross domestic product per capita, current prices	U.S. dollars	Units	8905.05	10317.77	12499.60	16160.24	17651.19	14402.46
Inflation, average consumer prices	Percent change		3.04	4.09	4.43	6.59	10.36	−0.08
Unemployment rate	Percent of total labor force		9.65	7.91	5.90	4.65	5.51	13.76
Population	Persons	Millions	1.35	1.34	1.34	1.34	1.34	1.34
GDP growth	Annual %		7.22	9.43	10.56	6.91	−5.06	−13.89
Panel B: Latvia								
Gross domestic product, current prices	U.S. dollars	Billions	13.76	16.04	19.94	28.79	33.86	25.92
Gross domestic product per capita, current prices	U.S. dollars	Units	5933.74	6955.25	8689.97	12622.46	14912.92	11465.61
Inflation, average consumer prices	Percent change		6.18	6.89	6.57	10.08	15.25	3.26
Unemployment rate	Percent of total labor force		10.61	8.82	6.99	6.20	7.82	17.31
Population	Persons	Millions	2.31	2.30	2.29	2.28	2.27	2.26
GDP growth	Annual %		8.67	10.60	12.23	9.97	−4.24	−17.95
Panel C: Lithuania								
Gross domestic product, current prices	U.S. dollars	Billions	22.54	25.97	30.08	39.09	47.17	37.11
Gross domestic product per capita, current prices	U.S. dollars	Units	6562.96	7608.24	8863.06	11582.12	14047.46	11115.06
Inflation, average consumer prices	Percent change		1.16	2.65	3.78	5.77	11.13	4.16
Unemployment rate	Percent of total labor force		11.37	8.27	5.62	4.29	5.84	13.70
Population	Persons	Millions	3.43	3.41	3.39	3.37	3.35	3.33
GDP growth	Annual %		7.35	7.80	7.84	9.83	2.92	−14.74

Source: International Monetary Fund, World Economic Outlook Database.

even −17.95% respectively. A very sharp decline of the economic growth was partly attributable to a dramatic decrease in the FDI inflows (especially in Latvia), since the FDI inflows were considered as an important driver of the accelerated growth in the years prior to the financial crisis. Overall macroeconomic environment was unfavorable, being additionally worsened by increase in the unemployment rate in all three countries (for instance, the unemployment rate reached 17.31% in Latvia during 2009).

The financial crisis also had a profound impact on public finances and banking sector, especially in Latvia (Purfield and Rosenberg, 2010). Faced with a serious budget deficit problems and very high inflation rates (one of the highest in EU), Latvian government sought financial aid from the IMF, the European Commission and the Swedish government in 2008. The banking sector of Latvia (for instance Parex Bank) also had to rely on financial support from the state and external creditors. The global financial turmoil in 2008 and 2009 strongly affected the equity markets as well in all three Baltic countries. The total market capitalization of the Baltic stock exchanges declined dramatically, being reduced for more than double at the end of 2009 compared to the end of 2007 (from 19.28 to 8.95 billion

Table 3
Summary statistics and correlations between stock markets.

	Pre-crisis				Crisis			
	Europe	Estonia	Latvia	Lithuania	Europe	Estonia	Latvia	Lithuania
Panel A: summary statistics								
Mean	0.001	0.001	0.001	0.001	−0.001	−0.002	−0.002	−0.003
Median	0.001	0.001	0.000	0.001	−0.001	−0.002	−0.002	−0.001
Maximum	0.029	0.072	0.049	0.037	0.104	0.057	0.092	0.110
Minimum	−0.034	−0.059	−0.068	−0.038	−0.082	−0.070	−0.079	−0.091
Std. dev.	0.009	0.009	0.009	0.009	0.024	0.016	0.019	0.018
Skewness	−0.350	−0.191	−0.025	−0.201	0.181	−0.457	0.029	−0.272
Kurtosis	4.015	14.908	7.857	5.983	6.062	5.547	6.010	11.605
Jarque–Bera	65.152	6080.432	1010.455	387.942	151.734	116.816	144.597	1186.320
Probability	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Observations	1028	1028	1028	1028	383	383	383	383
Panel B: correlations								
Europe								
Estonia	0.196				0.350			
t-Statistic	(6.397)				(7.289)			
(*z*): Pre-crisis = crisis					[−2.777]			
Latvia	0.042	0.179			0.244	0.347		
t-Statistic	(1.352)	(5.825)			(4.906)	(7.219)		
(*z*): Pre-crisis = crisis					[−3.440]	[−3.014]		
Lithuania	0.091	0.275	0.187		0.371	0.619	0.532	
t-Statistic	(2.918)	(9.161)	(6.090)		(7.798)	(15.379)	(12.272)	
(*z*): Pre-crisis = crisis					[−4.972]	[−7.341]	[−6.731]	

Table reports the summary statistics and correlations between the markets. (*z*) Statistics are Fisher transformations testing for the equality of pre-crisis correlations with crisis period correlations and they are presented in the square brackets.

US dollars). The market capitalization expressed in percents of GDP remarkably dropped compared to the years prior to the crisis. In addition, the number of listed domestic companies slightly decreased in all three Baltic countries.

3. Data

The data used in our empirical analysis consist of the EUROSTOXX50 index (hereafter EUROPE) and three Baltic stock markets, namely the Estonian, Lithuanian, and Latvian stock markets. We use total return (dividend adjusted) stock indices available from the web pages of the respective stock exchanges.[8] The sample period is from January 3, 2004 to June 30, 2009. The starting period is selected based on the fact that the Baltic countries joined the EU in spring 2004, while the endpoint corresponds to the end of the crisis. In our analysis, we use two different sample periods to examine the effect of crisis on stock market linkages, namely: (i) pre crisis (1/2004–12/2007); (ii) crisis period (1/2008–6/2009).[9] As can be seen from Panel A of Table 3, all pre-crisis mean returns are positive and seem to be somewhat higher for the Baltic indices than for EUROPE. However, in the crisis period the mean returns are all negative and, interestingly, they are significantly more negative for the Baltic markets. Volatilities measured by standard deviations of returns increase for all stock markets during the crisis. Typically all return series exhibit excess kurtosis relative to the normal distribution.

Panel B of Table 3 reports Pearson's correlation coefficients for pre-crisis and crisis periods. The results from this preliminary analysis of the cross-dynamics of the stock markets imply that the correlations are low before the crisis (2004–2007). The highest contemporaneous, although very low,

[8] Baltic markets (http://www.nasdaqomxbaltic.com/market/?pg=charts) and Eurostoxx50 (http://www.stoxx.com/indices/index_information.html?symbol=SX5E).

[9] The results are not sensitive to differently chosen periods. For example, the results remain virtually the same if we use (1/2003–12/2006) and (1/2007–6/2009) as pre-crisis and crisis periods respectively.

correlation between EUROPE and the Baltic stock markets is between EUROPE and Estonia (0.196) and the lowest correlation is between EUROPE and Latvia (0.042). However, the results are remarkably different in the crisis period, as, for example, the correlation between EUROPE and Lithuania is 0.371. All the correlations increase statistically significantly, which is verified by the *Z*-statistic. The test is performed with Fisher's transformed correlations as in Hon et al. (2004). Therefore, the results indicate that the stock markets become more closely correlated during the crisis period.

4. Results and methodology

To investigate the integration of the Baltic stock markets with European developed stock markets in pre-crisis and crisis periods, the Granger (1969) causality test and vector autoregressive analysis (VAR) are applied. These methods provide broad information for the analysis of the linkages of the markets. They are suitable given that the time series are stationary. To investigate the stationarity of the return series, the augmented Dickey–Fuller and Phillips–Perron tests of a unit root are applied to the return series of each stock index. The results show (not tabulated) that all the return series are stationary at the 1% significance level, implying that the VAR analysis can be investigated. Therefore, the following VAR(p) system is used separately in both periods investigated:

$$\Delta x_t = \alpha + \sum_{i=1}^{p} \beta_i \Delta x_{t-i} + \varepsilon_t \tag{1}$$

where $\Delta x_t = (\Delta X_{EUROPE,t}, \Delta X_{ESTONIA,t}, \Delta X_{LATVIA,t}, \Delta X_{LITHUANIA,t})'$ is a covariance stationary 4×1 vector of stock returns, X_t, α is a 4×1 vector of intercepts, $\{\beta_i, i = 1, 2, 3, 4\}$ is a 4×4 matrix of autoregressive coefficients, ε_t is a 4×1 vector of random disturbances with zero mean and positive definitive covariance matrix, and p defines the lag order of the system. The model is estimated with the OLS. As White's (1980) test indicates the presence of volatility persistence, the standard errors based on the Monte Carlo simulation are used.

To verify the appropriate number of lags for the VAR(p) system, Akaike's (AIC) and Schwartz's (SIC) information criteria, final prediction error (FPE) and Lutkepohl's modified likelihood ratio (LR) test statistics are used. Furthermore, if the number of lags is suitable, there should be no autocorrelation left in the residuals. Therefore, the adequacy of the number of lags is confirmed with the Breusch–Godfrey LM test. The results from these analyses (not tabulated) suggest that a lag length of six (three) is appropriate for the VAR(p) model in the crisis (pre-crisis) period.

Table 4 presents the results of the Granger causality analysis for the stock markets investigated. The statistics reported are for a lag order of three for the pre-crisis period and lag order of six in the crisis period. The results indicate that at a 1% level of significance Europe is leading all Baltic stock markets during the crisis. While Europe is not affected by the Baltic markets before the crisis, the results show that during the crisis period there is two-way causality at 1% level of significance, which implies some kind of feedback effect between the markets. The results also imply that the Estonian market leads the Latvian and Lithuanian stock markets in both periods.

Panel A of Table 5 reports the summary statistics of the VAR(3) and VAR(6) models examining the pre-crisis and crisis periods respectively. The *F*-statistics show that the VAR models are significant for all Baltic stock markets. In the pre-crisis period, the adjusted R^2 ranges from 0.000 to 0.047, while in the crisis period they range from 0.086 to 0.154. The Ljung-Box statistic for 10 lags shows that no autocorrelation remains, indicating that the chosen VAR models are adequate. Panel B of Table 5 reports the contemporaneous residual correlations between the markets. The results show that before the crisis the correlations between EUROPE and the Baltic stock markets are low. However, consistent with the previous results, they increase during the crisis period. The highest instantaneous correlation is between EUROPE and the ESTONIA (coefficient of 0.339) and lowest, though highly significant, between EUROPE and the LATVIA (coefficient of 0.235). These are consistent with earlier findings. Table 5 also reports the correlations between the Baltic markets, which are high and increase in the crisis period.

Variance decomposition analysis is used to ascertain how important the innovations of the other variables in the system are in explaining the fraction of variable *i*'s at different steps ahead forecast

Table 4
Granger causalities of the stock markets.

	Pre-crisis		Crisis	
	t-Stat	*p*-Value	*t*-Stat	*p*-Value
Estonia → Europe	0.420	0.738	**4.206**	0.000
Europe → Estonia	**3.238**	0.022	**7.481**	0.000
Latvia → Europe	0.186	0.906	**2.637**	0.016
Europe → Latvia	1.630	0.181	**4.927**	0.000
Lithuania → Europe	1.050	0.370	0.878	0.511
Europe → Lithuania	2.441	0.063	**7.777**	0.000
Latvia → Estonia	2.338	0.072	0.948	0.461
Estonia → Latvia	**4.169**	0.006	**2.311**	0.033
Lithuania → Estonia	1.411	0.238	**2.386**	0.028
Estonia → Lithuania	**3.640**	0.013	**3.296**	0.004
Lithuania → Latvia	**4.188**	0.006	**2.454**	0.024
Latvia → Lithuania	**2.915**	0.033	0.470	0.831

Pre-crisis is defined as (1/2004–12/2007) and crisis is (1/2008–6/2009). Values of *t*-statistics that are statistically significant at the 5% level are presented in bold face.

Table 5
Summary statistics of the VAR models.

Pre-crisis					Crisis				
	Europe	Estonia	Latvia	Lithuania		Europe	Estonia	Latvia	Lithuania
Panel A									
Adj. *R*	0.000	0.047	0.014	0.041	Adj. *R*	0.109	0.142	0.086	0.154
F-Statistic	1.030	5.224	2.234	4.667	*F*-Statistic	3.920	4.955	3.258	5.334
Q(10)	2.781	7.963	15.586	8.847	*Q*(10)	1.874	10.386	8.978	8.297
p-Value	0.986	0.632	0.112	0.547	*p*-Value	0.997	0.407	0.534	0.600
Panel B									
Europe	–				Europe	–			
Estonia	0.212	–			Estonia	0.339	–		
Latvia	0.054	0.160	–		Latvia	0.235	0.291	–	
Lithuania	0.108	0.242	0.170	–	Lithuania	0.338	0.577	0.484	–

Panel A of the table presents the summary statistics of VAR(3) model estimation of the pre-crisis period (VAR(6) in the crisis period). The analysis is based on the following equation:

$$\Delta x_t = \alpha + \sum_{i=1}^{p} \beta_i \Delta x_{t-i} + \varepsilon_t$$

where $\Delta x_t = (\Delta X_{EUROPE,t}, \Delta X_{ESTONIA,t}, \Delta X_{LATVIA,t}, \Delta X_{LITHUANIA,t})'$ is a covariance stationary 4×1 vector of term structures ΔX_t, α is a 4×1 vector of intercepts, $\{\beta_i, i = 1, 2, 3, 4\}$ is a 4×4 matrix of autoregressive coefficients, ε_t is a 4×1 vector of random disturbances with zero mean and positive definitive covariance matrix, and p defines the lag order of the system. The model is estimated with the OLS. As the White's (1980) test indicates the presence of volatility persistence, the standard errors based on the Monte Carlo simulation are used to define the 95% confidence intervals to the impulse responses. Panel B reports the contemporaneous residual correlations between the markets.

variances. The variance decompositions are presented separately in Tables 6 and 7 for pre-crisis and crisis periods respectively. The results in Table 6 (pre-crisis period) further provide clear evidence of the independence of EUROPE among the markets investigated, as its forecast variance is only caused by its own innovations. Although Granger causality tests show bi-directional causality between Baltic and European market during the crisis period, the quantification of the impact shown in the variance decomposition analysis indicate quite limited impact of the Baltic markets on EUROPE (see Table 7). In the period before the crisis EUROPE seems to explain only a fraction (ranging approximately from 1% to 6%) of the different step-ahead forecast variances of the Baltic stock markets.

Table 6
Variance decomposition in pre-crisis period (1/2004–12/2007).

Period	S.E.	Europe	Estonia	Latvia	Lithuania
Pre-crisis					
Variance decomposition of Europe					
1.000	0.008	100.000	0.000	0.000	0.000
2.000	0.009	99.650	0.006	0.005	0.339
3.000	0.009	99.480	0.119	0.063	0.339
4.000	0.009	99.429	0.119	0.084	0.368
5.000	0.009	99.423	0.119	0.089	0.369
Variance decomposition of Estonia					
1.000	0.009	4.501	95.499	0.000	0.000
2.000	0.009	5.831	93.773	0.265	0.131
3.000	0.009	6.081	93.322	0.434	0.162
4.000	0.009	6.093	92.970	0.734	0.203
5.000	0.009	6.105	92.918	0.754	0.224
Variance decomposition of Latvia					
1.000	0.009	0.294	2.323	97.383	0.000
2.000	0.009	0.867	2.742	96.145	0.246
3.000	0.009	0.871	2.983	95.571	0.575
4.000	0.009	0.873	3.253	95.124	0.750
5.000	0.009	0.884	3.277	95.086	0.753
Variance decomposition of Lithuania					
1.000	0.009	1.168	5.022	1.738	92.072
2.000	0.009	2.160	5.019	2.040	90.780
3.000	0.009	2.157	5.026	2.169	90.648
4.000	0.009	2.129	6.044	2.532	89.295
5.000	0.009	2.154	6.172	2.545	89.128

Table 7
Variance decomposition in the crisis period (1/2008–6/2009).

Period	S.E.	Europe	Estonia	Latvia	Lithuania
Crisis					
Variance decomposition of Europe					
1.000	0.022	100.000	0.000	0.000	0.000
2.000	0.022	99.168	0.258	0.445	0.129
3.000	0.023	96.083	1.225	2.441	0.251
4.000	0.023	94.201	1.194	3.267	1.338
5.000	0.024	89.802	5.635	3.046	1.517
Variance decomposition of Estonia					
1.000	0.015	11.465	88.535	0.000	0.000
2.000	0.016	18.146	80.707	1.082	0.064
3.000	0.016	17.425	79.858	1.059	1.659
4.000	0.016	17.155	79.208	1.419	2.218
5.000	0.016	17.766	77.150	1.374	3.710
Variance decomposition of Latvia					
1.000	0.018	5.537	5.046	89.417	0.000
2.000	0.019	9.178	5.365	84.873	0.584
3.000	0.019	9.979	6.193	83.251	0.577
4.000	0.019	10.076	7.730	81.244	0.950
5.000	0.019	9.885	9.016	79.870	1.229
Variance decomposition of Lithuania					
1.000	0.017	11.401	24.163	9.685	54.751
2.000	0.017	15.217	23.498	9.232	52.053
3.000	0.017	14.653	26.523	8.962	49.862
4.000	0.018	16.461	27.711	8.569	47.259
5.000	0.018	17.248	28.342	8.446	45.964

Table 8
Quantile regression approach: Sensitivity of Baltic stock markets to Europe stock returns.

Pre-crisis				Crisis			
Quantile	Coefficient	*t*-Statistic	Prob.	Quantile	Coefficient	*t*-Statistic	Prob.
Estonia							
0.100	**0.268**	6.020	0.000	0.100	**0.200**	4.312	0.000
0.300	**0.099**	3.326	0.001	0.300	**0.227**	5.784	0.000
0.500	**0.075**	2.775	0.006	0.500	**0.220**	4.744	0.000
0.700	**0.089**	3.266	0.001	0.700	**0.236**	5.604	0.000
0.900	**0.189**	2.450	0.015	0.900	**0.263**	2.927	0.004
Latvia							
0.100	**0.116**	2.781	0.006	0.100	**0.262**	4.086	0.000
0.300	**0.080**	2.603	0.009	0.300	**0.227**	3.890	0.000
0.500	0.040	1.262	0.207	0.500	**0.184**	2.913	0.004
0.700	−0.007	−0.175	0.861	0.700	**0.152**	2.631	0.009
0.900	−0.118	−1.531	0.126	0.900	**0.228**	5.278	0.000
Lithuania							
0.100	**0.219**	4.430	0.000	0.100	**0.417**	7.658	0.000
0.300	**0.114**	3.048	0.002	0.300	**0.234**	6.860	0.000
0.500	**0.072**	2.404	0.016	0.500	**0.169**	4.380	0.000
0.700	**0.071**	2.442	0.015	0.700	**0.150**	3.981	0.000
0.900	0.049	0.831	0.406	0.900	**0.241**	2.821	0.005

$$r_i = \alpha_q + \beta_{q,i} r_{europe} + \varepsilon_i \quad Q_r(q|r_{europe,t}) = \alpha_i(q) + \beta_i(q) r_{europe,t}$$

where r_i is the return on Baltic stock markets (i = Estonia, Latvia, Lithuania) and r_{europe} is the return on EUROSTOXX50 index. $Q_r(q|r_{europe,t})$ defines the qth quantile of $r_{i,t}$. Table reports the beta coefficients for each country with quantiles (0.1, 0.3, 0.5, 0.7 and 0.9). Coefficients that are statistically significant at the 5% level are in bold face.

Consistent with the previous results, EUROPE has a significantly higher impact on the Baltic stock markets during the crisis period (see Table 7). For example, the index explains about 17% of the 5 days ahead forecast error variance of the Estonian stock markets. Furthermore, the index explains about 10% (17%) of the 5 days ahead forecast error variance of the Latvian (Lithuanian) stock markets. These findings further demonstrate that a larger proportion of the forecast variance of the Baltic stock markets can be explained by EUROPE during the crisis. Additionally, it is found that the Estonian markets can explain about 9% (28%) of the forecast variance of Latvian (Lithuanian) stock markets during the crisis.

Finally, in addition to analyzing the conditional mean of a dependent variable, we are also interested in examining other aspects of the conditional distribution. For this purpose we use a quantile regression approach (see e.g., Koenker and Bassett, 1978). This approach is especially suitable for our purpose, as we are interested in examining the dynamic dependencies between EUROPE and the Baltic stock markets under different market conditions. Thus, we use the quantile regression approach separately for pre-crisis and crisis periods. In our case, the method provides the estimates of the linear relationship between the returns of the EUROSTOXX50 index (independent variable) and a specified quantile of Baltic stock returns (dependent variable) as follows:

$$r_{i,t} = \alpha_i + \beta_i r_{europe,t} + \varepsilon_{i,t} \quad Q_r(q|r_{europe,t}) = \alpha_i(q) + \beta_i(q) r_{europe,t} \tag{2}$$

where r_i is the return on the Baltic stock markets (i = Estonia, Latvia, Lithuania) and r_{europe} is the return on the EUROSTOXX50 index. $Q_r(q|r_{europe,t})$ defines the qth quantile of $r_{i,t}$.

The results from the quantile regressions are reported in Table 8. The results demonstrate that the impact of EUROPE on the Baltic stock markets is stronger in the crisis period than before the crisis. The coefficients are much lower and in many cases they are not even statistically significant in the pre-crisis period (see Latvia 0.5–0.9 quantiles and Lithuania 0.9 quantile). However, in the crisis period all the coefficients are statistically significant and in the lowest quantiles (0.1–0.3) the coefficients are higher than in the highest quantiles (0.7–0.9). These results imply that the Baltic stock markets are much more sensitive to EUROPE during the crisis, when the returns are highly negative. These results provide further evidence of the high stock market integration of the Baltic stock markets with

developed European markets during the crisis, which casts doubts on the usefulness of the traditional portfolio theory when it should be most useful for investors.

5. Conclusions

The purpose of this study is to provide new evidence on stock market integration by investigating the linkages between developed European stock markets and emerging stock markets from the Baltic region, namely the Estonian, Latvian, and Lithuanian stock markets with particular attention to the financial crisis period 2008–2009. The study is motivated by traditional stock market studies of integration, which show that developed stock markets are highly integrated, while emerging markets may be segmented. How integrated these emerging stock markets are in a crisis period with respect to developed European stock markets proxied by the EUROSTOXX50 stock index is an empirical question investigated in this study.

The results of this study demonstrate that while the Baltic stock markets seem to be segmented before the crisis, the correlations increase significantly during the crisis. These findings indicate that the Baltic stock markets are closely linked to the major European stock markets. The results of the variance decomposition analysis show that a large proportion of the forecast variance of the Baltic stock markets can be explained by the EUROSTOXX50 index during the crisis. Finally, the results from the quantile regressions demonstrate that during the crisis the returns of the lowest quantile are most sensitive to the EUROSTOXX50 index. These results provide further evidence of the high stock market integration of the developed Baltic stock markets especially during the crisis period, which casts doubts on the usefulness of portfolio diversification when it should be most useful for investors.

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THE IMPACT OF THE 2008–2009 FINANCIAL CRISIS ON THE EXTERNAL AND INTERNAL LINKAGES OF EUROPEAN FRONTIER STOCK MARKETS *

ABSTRACT

This study investigates the impact of the 2008–2009 financial crisis on both (i) the external linkages of European frontier stock markets (Croatia, Estonia, Romania, Slovakia and Slovenia) with the world market portfolio and three largest developed equity markets in Europe (the UK, France and Germany) and (ii) internal linkages within the frontier markets. The empirical findings demonstrate that both long- and short-term external linkages of European frontier stock markets were strengthened during the crisis, implying that the 2008–2009 financial crisis significantly affected their diversification potential. Of the markets analyzed, Croatia, Estonia and Slovenia show a considerable degree of dependence on the world market portfolio and the three largest developed stock markets in Europe, whereas the stock market of Slovakia appears to be segmented relative to both. Romania seems to be moderately dependent. An important implication of our study is that despite evident external long-term relationship among investigated markets, the diversification benefits from investing in European frontier markets are still apparent on short-term horizons. The country-specific analysis of internal linkages reveals strong causal relationship only between the Croatian and Slovenian markets before and during the crisis, while the other frontier markets in the group are very weakly linked in both periods. This finding implies that European frontier stock markets taken as a single group constitute a good alternative source of diversification benefits during crises periods.

JEL classification: F36; G11; G15

Keywords: Frontier market, Diversification benefits, Financial crisis

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1 Introduction

The financial crises over the past two decades have emphasized an importance of investigating how the different stock markets are linked both in long and short term and whether they are able to provide diversification benefits also during the turbulent times of financial crises. Traditionally investors have seek shelter by diversifying to emerging markets and consequently emerging markets finance has evolved into a challenging research topic in the recent years (see e.g., Bekaert & Harvey 2003 for a survey; Cuadro-Saez, Fratzscher & Thimann 2009; Barclay, Fletcher & Marshall 2010; Graham, Kiviaho & Nikkinen 2012). Interdependence among emerging stock markets and developed markets has become an important issue in the international portfolio diversification literature.[1] However, even though many studies on international stock market linkages have focused on emerging markets in different regions, very limited research is conducted on the frontier markets, as a special subset of emerging markets.[2]

The promising diversification potential of the frontier markets is documented by Berger, Pukthuanthong & Yang (2011), who examine a set of frontier markets worldwide and find that those markets exhibit low levels of integration with the world market and subsequently offer significant diversification benefits and Kiviaho et al. (2012) who provide evidence on diversification potential of European frontier markets, especially in the short-term. In our study we focus on frontier stock markets and the effects of the 2008–2009 financial crisis on those markets.

As a consequence of the 2008–2009 financial crisis, there is a renewed interest in investigating how a financial crisis may affect stock market linkages among international markets[3] (see, e.g., Bartram & Bodnar 2009; Chudik & Fratzscher

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1 International stock market linkages have been extensively investigated for developed markets (e.g., Meric & Meric 1997; Longin & Solnik 2001; Bessler & Yang 2003) and more recently for major emerging markets in South America, Asia and Central and Eastern Europe (Chen, Firth & Rui 2002; Yang, Kolari & Min 2003; Phylaktis & Ravazzolo 2005; Syllignakis & Kouretas 2011; Graham & Nikkinen 2011).

2 The frontier markets represent a special sub-category of the emerging markets and are characterized by thin trading activity, short history and higher risk levels compared to developed markets. The attractiveness of the frontier stock markets stems from high returns provided in the past. Standard & Poor's launched the first fully investable index for frontier stock markets (S&P/IFCG Extended Frontier 150 Index) in 2007. MSCI Barra and FTSE also started to track the representative indexes on frontier stock markets in the following year, reflecting increased interest of global investors towards those markets. Furthermore, the frontier markets have become more accessible through exchange-traded funds and mutual funds that have emerged in recent years, promoting frontier markets as an attractive alternative investment.

3 Earlier studies in this area documented that the strength of stock market linkages has a tendency to change during the periods of financial crises. For example, Yang et al. (2006) exam-

2011; Kenourgios & Samitas 2011; Syllignakis & Kouretas 2011; and Nikkinen, Piljak & Äijö 2012). The study by Bartram and Bodnar (2009) provides evidence of high correlations and transmission of price-relevant information among the markets around the globe during the 2008–2009 financial crisis due to the global nature of the crisis. Chudik & Fratzscher (2011) examine, through application of a global VAR approach, the effects of the recent 2008–2009 financial crisis on the developed stock markets and bigger emerging markets in different regions, while Kenourgios & Samitas (2011) investigate impact of the financial crisis on the time-varying correlation dynamics among the developed and the Balkan stock markets. Syllignakis & Kouretas (2011) document a significant impact of the 2008–2009 financial crisis on stock market linkages between seven emerging markets in Central and Eastern Europe and the US and German stock markets. Nikkinen, Piljak & Äijö (2012) in turn address the integration of the Baltic stock markets before and during the global financial crisis by examining the short term linkages with the developed European markets.

In this study, we examine how the 2008–2009 financial crisis impacted on the external and internal linkages of European frontier stock markets.[4] We first investigate the long-term relationships and short-term dynamic linkages between European frontier stock markets (Croatia, Estonia, Romania, Slovakia and Slovenia) and the world market portfolio. Second, we examine linkages of European frontier stock markets with the three largest developed stock markets in Europe (the UK, France and Germany), as well as the interdependences within the group of the frontier markets. Third, we analyze how the 2008–2009 financial crisis affected both external and internal linkages. Given the evidence in the literature that financial crises affect the strength of the stock market linkages and consequently the level of potential diversification opportunities (e.g. Syllignakis & Kouretas 2011), it is of great importance to investigate how the frontier markets, considered a significant source of diversification benefits, are affected by the global financial crisis.

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ine impact of the 1998 Russian financial crisis on four Eastern European emerging markets (the Czech Republic, Hungary, Poland, and Russia), concluding that Eastern European stock markets have been more integrated regionally and globally after the crisis than before the crisis. Similarly, Yang, Kolari & Min (2003) show that both long-term and short-term relationship of ten Asian emerging stock markets with the US and Japan were strengthened during the 1997–1998 Asian financial crisis, suggesting that the crisis altered market integration among Asian countries over time.

[4] The external linkages are referred to the linkages of European frontier stock markets with the world market portfolio and the developed European markets, while the internal linkages are referred to the linkages within the group of the frontier markets.

Consequently, our study contributes to the existing literature in two ways. First, we investigate the impact of the 2008–2009 financial crisis on the long-term relationships and short-term dynamic linkages of European frontier stock markets, providing insights how diversification potential of frontier markets changes during the crisis period. In our paper, we examine both the external stock market linkages of European frontier markets with the major developed markets and the internal cross-dynamics among the frontier markets before and during the 2008–2009 financial crisis. Our study differs from the study of Nikkinen, Piljak & Äijö (2012) by focusing on both the long-term co-integration relationships and short-term dynamic linkages of the major European frontier stock markets. From international investor's point of view differentiating between the long-term co-integration relationships and short-term dynamic linkages play important role in determining timing of potential diversification benefits. Therefore, our approach is advantageous. We focus also on an interesting subset of frontier markets, namely Croatia, Estonia, Romania, Slovakia and Slovenia, which are considered as larger frontier markets in terms of market capitalization and unlike other small frontier markets (for example, Latvia) can provide significant diversification potential also to larger investors.[5]

Second, by focusing on European frontier markets, as a special subset of emerging markets on which very limited research has been conducted, we contribute to the body of emerging market literature (see, e.g., Berger, Pukthuanthong & Yang 2011; Samarakoon 2011; Graham, Kiviaho & Nikkinen 2012). Our study includes comprehensive analysis of major European frontier stock markets, based on the co-integrated VAR methodology and innovation accounting techniques. Frontier markets are becoming increasingly important for international investors, since they represent a significant source of diversification benefits considering their lower correlations with developed markets. In particular, European frontier markets are of special research interest given their accelerated economic growth over the last decade. In our study, we particularly examine also the internal linkages of the largest European frontier markets, while Kiviaho et al. (2012) examine the co-movement of European frontier stock markets with major developed markets, but they do not address the internal dynamics within the group of frontier markets. Investigation of the internal linkages is important from international investor's

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[5] The largest European frontier market is Romania with the market capitalization of 30.32 billion USD at the end of 2009, followed by Croatia (25.63 billion US dollars) and Slovenia (11.76 billion US dollars). In contrast, the market capitalization of Latvia amounted to only 1.82 billion US dollars at the corresponding time.

point of view as it answers to a question whether investors should also diversify within the area.

The remainder of the paper is organized as follows. Section 2 presents a brief overview of related literature. Section 3 describes the market environment and introduces data. The econometric framework of analysis is given in Section 4. Section 5 reports the empirical results and discusses their implications. Finally, Section 6 provides conclusions.

2 Related literature on European frontier markets

Previous research on equity linkages between emerging stock markets in Europe and developed markets has focused on major emerging Central European markets such as Poland, Hungary, and Czech Republic. The empirical findings are not consistent in all studies, since several studies provide evidence on existence of long-run equilibrium of those markets with the mature counterparts (e.g. Syriopoulos 2004, 2007; Voronkova 2004); while no long-term relationship is found in Gilmore & McManus (2002) and Gilmore, Lucey & McManus (2008). However, very limited research is conducted on a subset of the frontier markets in Europe. Of the few contributions to the literature on frontier markets, Samitas, Kenourgios & Paltalidis (2006) investigates linkages among Balkan stock markets (Romania, Bulgaria, Serbia, the former Yugoslav Republic of Macedonia, Turkey, Croatia, Albania) and developed stock markets, while Syriopoulos (2011) examines financial integration of the six markets in Balkan region (Romania, Bulgaria, Croatia, Turkey, Cyprus and Greece). The empirical results on the long-run equilibrium between Balkan stock markets and the developed markets are in line with Syriopoulos (2004, 2007) and Voronkova (2004) suggesting limited diversification benefits in the long-term, while the short-term benefits might be still feasible.

On the other hand, Middleton, Fifield & Power (2008) find significant diversification potential of Central and Eastern European emerging markets demonstrating that the optimal portfolio consisting of stocks from eight markets[6] significantly outperformed its developed market counterparts in the UK and the US over the period 1998–2003. Maneschiöld (2006) finds that Baltic markets can provide diversification benefits for international investors on a long-term investment hori-

[6] Four of them are classified as frontier markets (Croatia, Estonia, Latvia and Romania), while the remaining four are emerging markets (Czech Republic, Hungary, Poland and Russia).

zon. Mateus (2004) provides evidence about the partial integration of five European frontier stock markets[7] (Bulgaria, Estonia, Lithuania, Romania and Slovenia) with respect to the world market. Dvorak & Podpiera (2006) suggest that a dramatic rise in stock prices observed in the eight EU accession countries[8] following announcement of EU enlargement towards those countries was due to the integration of accession countries into the world market.

3 Market environment and data description

The sample of European frontier markets is selected according to Standard and Poor's classification of frontier markets. The selected stock markets (Croatia, Estonia, Romania, Slovakia and Slovenia) represent major European frontier markets included in the S&P/IFCG Extended Frontier 150 Index[9]. This index is designed to meet the increasingly sophisticated needs of global investors seeking to expand into markets less known but with a potential for return similar or greater than other better known emerging markets counterparts. The time period under study extends from September 22, 1997 to December 31, 2009. The starting date of our sample is determined by the earliest data available for the Romanian stock market. The sample is divided into two sub-samples (the period before the financial crisis and during the crisis), where the Lehman Brothers collapse on September 15, 2008 marks the starting point of a very intense financial crisis in emerging markets as outlined in Dooley & Hutchison (2009). All the index data used in the study are extracted from the Thomson Datastream database.

The dataset consists of daily stock price indices of Croatia (CROBEX), Romania (BET), Estonia (OMX Tallinn), Slovakia (SAX), Slovenia (SBI20), and the Morgan Stanley Capital International (MSCI) World equity market index, which is the widely accepted benchmark index used to proxy the world market portfolio. In addition, the stock market indices of the United Kingdom (FTSE100), France (SBF250) and Germany (CDAX) are used to serve as proxies for the developed stock markets in Europe since these countries are considered to be the three largest European stock markets. Following Voronkova (2004) and Syriopoulos

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7 The full sample covers 13 European Union accession countries.

8 Five of them are classified as frontier markets (Estonia, Latvia, Lithuania, Slovakia and Slovenia), while the remaining three represent the emerging markets (Czech Republic, Hungary and Poland).

9 The remaining countries included in the Index (Bulgaria, Latvia, Lithuania and Ukraine) are left out from the sample due to either short period of data availability or very small size of the market.

(2011), we use stock price indices denominated in the home currency of each respective country, in order to avoid potential distortion caused by the currency devaluations. The stock indices are transformed into daily rates of returns taking the natural logarithmic first difference of each stock price index. Most of the investigated markets are in the same time zone, so the problem of non-synchronous trading does not arise.

Table 1 provides an overview of the main characteristics of the investigated European frontier markets, including market capitalization, net inflows of the foreign direct investments and annual GDP growth rates of each economy. The investigated frontier markets are characterized by a substantial variation in terms of market size, attractiveness to foreign investors and speed of economic development. The largest stock market at the end of 2009 was Romania, with market capitalization of 30.32 billion US dollars (USD), while the equity market of Estonia was the smallest with only 2.65 billion USD. Following the announcements of European Union (EU) enlargement towards Central and Eastern European countries a confidence of foreign investors with respect to investing in those markets has grown substantially. In particular, some of the frontier markets experienced a significant increase in inward FDI in the 2000–2008 period. Romania and Slovakia recorded the greatest change in the level of FDI, which rose more than 13 times (for example, from 1.03 billion USD in 2000 to 13.88 billion USD in 2008 in Romania). The observed pattern of the economic growth differs across the examined markets. For instance, the fastest economic growth before the financial crisis (measured by the annual GDP growth rate) was recorded for Slovakia, ranging from 1.37 % in 2000 to 10.58% in 2007, while the highest growth rates throughout the whole period are the ones of Estonia (for example, 11.18% in 2006). Slovenia and Croatia had more even growth on average, between 4% and 5%. However, due to the financial crisis all of the examined countries recorded negative GDP growth in 2009.

Table 1. Market indicators for European frontier stock markets

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Market capitalization (billions of US dollars)										
Croatia	2.74	3.31	3.97	6.12	10.95	12.91	29.00	65.97	26.79	25.63
Estonia	1.84	1.48	2.42	3.79	6.20	3.49	5.96	6.03	1.95	2.65
Romania	1.06	2.12	4.56	5.58	11.78	20.58	32.78	44.92	19.92	30.32
Slovakia	1.21	1.55	1.90	2.77	4.41	4.39	5.57	6.97	5.07	4.67
Slovenia	2.54	2.83	4.60	7.13	9.67	7.89	15.18	28.96	11.77	11.76
Market capitalization (percent of GDP)										
Croatia	12.75	14.39	14.98	17.94	26.72	28.82	58.17	111.22	38.32	40.41
Estonia	32.52	23.75	33.17	38.49	51.55	25.13	35.91	28.23	8.29	13.90
Romania	2.88	5.28	9.95	9.38	15.61	20.81	26.73	26.53	9.95	18.82
Slovakia	4.24	5.14	5.50	6.06	7.87	7.16	8.07	8.27	5.15	5.33
Slovenia	12.80	13.92	19.96	24.55	28.69	22.09	38.97	61.21	21.54	23.93
Foreign direct investment, net inflows (billions of US dollars)										
Croatia	1.10	1.58	1.09	2.04	1.07	1.78	3.45	4.99	6.01	2.95
Estonia	0.38	0.54	0.28	0.91	0.96	2.94	1.78	2.72	1.74	1.75
Romania	1.03	1.15	1.14	1.84	6.44	6.48	11.39	9.92	13.88	6.31
Slovakia	2.05	NA	4.10	0.55	3.03	2.41	4.16	3.36	3.23	-0.03
Slovenia	0.13	0.50	1.65	0.30	0.83	0.54	0.64	1.53	1.93	-0.57
GDP growth (annual %)										
Croatia	3.75	3.65	4.87	5.31	4.12	4.27	4.93	5.05	2.40	-5.80
Estonia	9.55	7.66	8.01	7.23	8.25	10.15	11.18	7.11	-5.12	-14.08
Romania	2.10	5.70	5.10	5.19	8.40	4.17	7.90	6.00	9.42	-8.50
Slovakia	1.37	3.48	4.58	4.77	5.03	6.66	8.50	10.58	6.17	-6.20
Slovenia	4.38	2.85	3.97	2.83	4.28	4.49	5.80	6.79	3.49	-7.80

Source: World Bank

Although there are evident differences in the market environment of the investigated European frontier markets, there are also similarities in rapid and successful transition of these markets from communist to market economies. The transition process included a broad set of economic reforms to liberalize the financial sector and eliminate restrictions on foreign investments in order to facilitate equity market integration. The important dates related to the stock market liberalization process in those markets (years of the removal of legal restrictions on foreign investments) are shown in Table 2 (Panel A). The legal restrictions on foreign participation in those markets were lifted mostly before 2000, which in conjunction with privatization of state-owned enterprises and accession to the EU significantly enhanced investment profiles of the markets in question.[10]

Figure 1 displays the time plots of the index series during the period September 22, 1997 – December 31, 2009. In the period before the crisis the indices of the frontier markets follow a relatively similar movement, while MSCI World index

[10] Estonia, Slovenia and Slovakia joined the EU in 2004, while Romania joined in 2007. Croatia signed the EU accession treaty in December 2011 and accession will take place in July 2013.

and indices of the developed European markets exhibit different pattern. The main difference is that the frontier markets started to have an upward trend in the middle of 2001, while the world market and the developed European markets were moving downwards, bottoming out at the end of 2002. The upward trend in the stock indices of the frontier markets could be result of increased interest of foreign investors after the announcements of EU enlargement towards those markets. During the 2008–2009 crisis there is a change in the pattern of the frontier markets indices, where all of them (except Slovakia) follow the same trend as the MSCI World index and the developed markets' indices.

The descriptive statistics for the returns series in the period before and during the crisis, as well as unconditional correlations for all stock market pairs are presented in Table 2 (Panel B, C, and D). In the period before the crisis the frontier markets (except Estonia) have higher average daily returns than the world market, but also higher volatility (except Slovenia) measured by the standard deviation. Relative to the developed European markets all frontier markets have higher average daily returns than the UK and Germany (except Estonia which has the same level of the return. The volatility levels of the frontier markets are in general higher than those of the developed markets (with the exception of Slovenia). During the crisis period the performance of the frontier markets (except Romania) measured by the average return is worse compared to the world and the developed markets. In terms of volatility, only Romania and Croatia exhibit higher levels relative to the world and the developed markets. The correlations of the frontier markets with the world and developed European indices are very low in the period before the crisis, while by contrast the returns of the developed European markets are extremely highly correlated with the world returns, and also with each other. During the crisis there is a substantial increase in the correlations of the frontier markets with both the world and the developed markets. For instance, before the crisis the highest correlation coefficient with the world is 0.15 (Croatia), while in the crisis period the corresponding coefficient is 0.65. The correlations within the group of the frontier markets are also drastically increased.

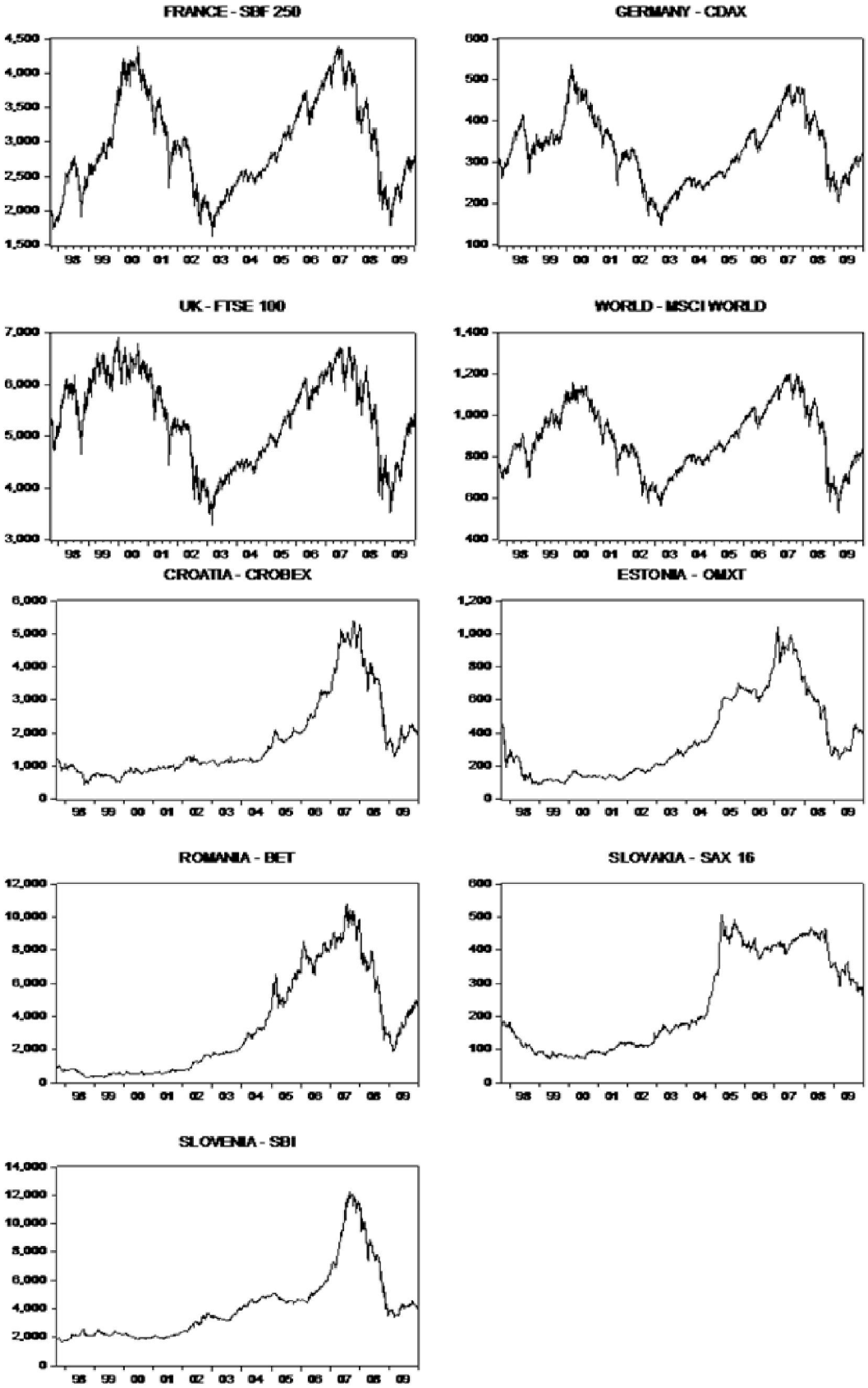

Figure 1. Stock indices in the period September 22, 1997 - December 31, 2009

Table 2. Stock markets highlights and descriptive statistics for stock market returns

Panel A: Stock markets highlights and relevant dates in financial liberalization process

Country	Index	Stock exchange	Stock market established	Removal of restrictions
Croatia	CROBEX	Zagreb	1991	1998
Estonia	OMX Tallinn	Tallinn	1995	1996
Romania	BET	Bucharest	1995	1998
Slovakia	SAX	Bratislava	1991	1998
Slovenia	SBI 20	Ljubljana	1989	1999

Sources: National stock exchanges, Bekaert and Harvey (2002)

Panel B: Descriptive statistics: world and developed markets

	World	Germany	France	UK
Period before crisis				
Mean	0.0000	0.0000	0.0001	0.0000
Median	0.0005	0.0005	0.0002	0.0000
Maximum	0.0460	0.0685	0.0626	0.0590
Minimum	-0.0477	-0.0748	-0.0744	-0.0588
Standard Deviation	0.0091	0.0139	0.0128	0.0117
Skewness	-0.1692	-0.2448	-0.2029	-0.1695
Kurtosis	5.40	5.87	5.69	5.46
Number of observations	2863	2863	2863	2863
Crisis period				
Mean	-0.0003	-0.0003	-0.0002	-0.0000
Median	0.0012	-0.0000	0.0000	0.0005
Maximum	0.0872	0.1064	0.1022	0.0938
Minimum	-0.0715	-0.0755	-0.0926	-0.0926
Standard Deviation	0.0192	0.0224	0.0227	0.0214
Skewness	-0.2667	0.2456	0.1559	-0.0532
Kurtosis	6.29	6.33	6.83	7.19
Number of observations	339	339	339	339

Table 2 continued. Stock markets highlights and descriptive statistics for stock market returns

Panel C: Descriptive statistics: frontier markets

	Croatia	Estonia	Romania	Slovakia	Slovenia
Period before crisis					
Mean	0.0003	0.0000	0.0005	0.0003	0.0004
Median	0.0000	0.0003	0.0000	0.0000	0.0000
Maximum	0.1747	0.1287	0.1154	0.0957	0.1102
Minimum	-0.1338	-0.2157	-0.1190	-0.1148	-0.1134
Standard Deviation	0.0169	0.0166	0.0171	0.0126	0.0090
Skewness	0.0283	-1.4420	-0.0725	-0.4662	-0.0858
Kurtosis	17.63	30.02	8.92	11.16	26.73
Number of observations	2863	2863	2863	2863	2863
Crisis period					
Mean	-0.0015	-0.0008	-0.0002	-0.0014	-0.0015
Median	0.0000	0.0000	0.0000	0.0000	-0.0001
Maximum	0.1477	0.1209	0.1009	0.1188	0.0768
Minimum	-0.1076	-0.0705	-0.1311	-0.0957	-0.0830
Standard Deviation	0.0258	0.0189	0.0288	0.0154	0.0170
Skewness	0.1153	0.4037	-0.4951	-0.1594	-0.7000
Kurtosis	7.51	8.57	5.46	22.31	8.53
Number of observations	339	339	339	339	339

Table 2 continued. Stock markets highlights and descriptive statistics for stock market returns

Panel D: Correlation coefficients of stock market returns for all markets

	World	Germany	France	UK	Croatia	Estonia	Romania	Slovakia
Period before crisis (2863 observations)								
Germany	0.76							
France	0.76	0.86						
UK	0.73	0.76	0.84					
Croatia	0.15	0.19	0.19	0.20				
Estonia	0.13	0.15	0.16	0.13	0.07			
Romania	0.06	0.08	0.08	0.06	0.08	0.04		
Slovakia	0.03	0.01	0.01	0.03	0.02	0.00	-0.02	
Slovenia	0.08	0.09	0.07	0.06	0.13	0.09	0.15	0.00
Crisis period (339 observations)								
Germany	0.86							
France	0.84	0.93						
UK	0.81	0.89	0.95					
Croatia	0.65	0.65	0.65	0.62				
Estonia	0.32	0.33	0.36	0.34	0.39			
Romania	0.52	0.55	0.55	0.55	0.61	0.43		
Slovakia	0.00	-0.05	-0.04	-0.03	0.04	0.13	0.08	
Slovenia	0.39	0.39	0.44	0.43	0.43	0.51	0.46	0.05

4 Econometric framework of analysis

In order to analyze both long- and short-term relationships between the investigated stock markets, we employ a cointegrated vector autoregression (VAR) framework (Engle & Granger 1987), including cointegration analysis, Granger causality test (Granger 1969), impulse response analysis and forecast error variance decomposition. Long-term relationships among European frontier stock markets and developed markets are examined by using Johansen (1991), and Johansen & Juselius (1990) procedure to test for the presence and number of cointegrating vectors. Before testing whether the stock price series are cointegrated, it should be verified that each series is non-stationary. The stationarity of time-series is examined by conducting the augmented Dickey-Fuller (Dickey & Fuller 1979, 1981) and Phillips-Perron unit root tests (Phillips & Perron 1988) in logarithms and first differences. The lag length for the unit root tests is determined by

the Schwarz information criterion. The unit root test results[11] show that there is a unit root in each of stock price indices in both pre-crisis and crisis period, but no unit root in their first differences (i.e., the equity index returns are stationary) at the 5% significance level.

The existence of cointegrating vectors implies the use of a vector error-correction model (VECM), proposed by Engle and Granger (1987), to examine long- and short-term linkages among investigated stock markets. We apply a VECM for two different cases: 1) relationships between the five European frontier stock markets and world market index (referred to as Model 1 in the following text), and 2) relationships between the five European frontier stock markets and the UK, France and Germany (referred to as Model 2). Let *Xt* denote a vector that includes *p* non-stationary variables (stock price indices). In case that *p* time series are cointegrated, a VECM with $k - 1$ lags is of the following form:

(1) $$\Delta X_t = \Pi X_{t-1} + \sum_{i=1}^{k-1} \Gamma i \, \Delta X_{t-i} + \mu + \varepsilon_t$$

where Δ is the difference operator ($\Delta X_t = X_t - X_{t-1}$), X_t is a (p x 1) vector of prices, Π is a coefficient matrix ($\Pi = \alpha\beta'$), the matrix α contains short-run adjustment parameters towards long-run relationship and the matrix β contains long-run coefficients, while Γi is a matrix defining the short-run adjustments to changes in the variables.[12] The number of cointegrating vectors *r* (linearly independent columns in Π) is determined by the rank of Π. We also estimate VECM for two time periods: before the financial crisis and during the crisis. The impact of the crisis on the long-term stock price relationship is examined by comparing the number of cointegrating vectors in the periods before and during the crisis (see, Chen, Firth & Rui 2002; Yang, Kolari & Min 2003). In this study, *p* (number of markets) is equal to 6 for the Model 1, and *p* is equal to 8 in Model 2. The appropriate lag length of the VAR system is determined by applying Akaike's, Schwartz's, Hannan-Quinn's information criteria, and modified likelihood ratio test. Lag length of three is chosen for the period before crisis, while two lags are selected for the time period of crisis. The adequacy of the lag length is confirmed by residual test, which reveals that the residuals are free from autocorrelation.

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[11] Both unit root tests are performed with and without a time trend and results regarding stationarity remain unchanged. The table of results of unit root tests is not shown here in order to save space; it is available upon request.

[12] An alternative approach would be to estimate moving average form of the equation 1 to establish the relative importance of each market to the common trend, or alternatively, the relative importance of the trend to each market.

The short-term causal linkages between different pairs of markets are investigated by Granger causality test, which should provide insights into lead-lag relationships between stock markets examined. Further analysis of short-run dynamic structure of stock market linkages is conducted by applying innovation accounting, which includes generalized impulse response analysis and forecast error variance decomposition. In the impulse response analysis, we use the generalized impulses developed by Pesaran & Shin (1998) since these impulse responses do not depend on the order of the variables. The forecast error variance decomposition is used to detect the fraction of the variation in one stock market explained by a variation in other stock markets in the system.

5 Empirical results

The results of cointegration analysis for Model 1 and Model 2 in the periods before crisis and during the crisis are reported in Table 3. In the cointegration specification, linear trend was allowed in the data, and a constant term and linear trend allowed in the cointegration equation. We report results from the trace test for cointegration, with the critical values tabulated in Osterwald-Lenum (1992). With respect to the linkages between European frontier markets and world market (Model 1), the empirical findings support the presence of one cointegrating vector in the period before the crisis. The null hypothesis that investigated markets are not cointegrated ($r = 0$) is rejected, since the λtrace statistic exceeds the critical value at the 5% significance level, suggesting no more than one cointegrating vector. During the crisis period the number of cointegrating vectors is equal to three. These results indicate that the long-term linkages between European frontier markets and the world market were strengthened during the crisis period. However, when linkages between European frontier markets and the UK, Germany and France (Model 2) are considered, the number of cointegrating vectors is equal to two in both time periods, before and during the crisis. The evidence of cointegration implies existence of a long-run equilibrium among markets under study.

Table 3. Trace tests for the number of cointegrating vectors

Panel A: The world and the frontier markets (Model 1)

Number of cointegrating vectors		λ_{trace} test		Critical value (5%)
		Prior to the crisis	Crisis period	
H_o	H_1			
$r = 0$	$r > 0$	149.34	133.20	114.90
$r \leq 1$	$r > 1$	84.24	91.21	87.31
$r \leq 2$	$r > 2$	45.23	63.27	62.99
$r \leq 3$	$r > 3$	18.46	37.00	42.44
$r \leq 4$	$r > 4$	10.16	16.71	25.32
$r \leq 5$	$r = 6$	2.98	3.33	12.25

Panel B: Developed markets and the frontier markets (Model 2)

Number of cointegrating vectors		λ_{trace} test		Critical value (5%)
		Prior to the crisis	Crisis period	
H_o	H_1			
$r = 0$	$r > 0$	229.75	194.38	182.82
$r \leq 1$	$r > 1$	156.79	149.54	146.76
$r \leq 2$	$r > 2$	108.63	108.21	114.90
$r \leq 3$	$r > 3$	69.22	74.26	87.31
$r \leq 4$	$r > 4$	36.52	50.67	62.99
$r \leq 5$	$r > 5$	19.51	30.65	42.44
$r \leq 6$	$r > 6$	10.44	13.91	25.32
$r \leq 7$	$r = 8$	3.46	3.27	12.25

Notes: The number of cointegrating vectors (r) is tested using the trace test with a constant and a linear trend in the cointegrating vector. *Ho* (*H1*) refers to null (alternative) hypothesis of the number of cointegrating vectors. Critical values are tabulated in Osterwald-Lenum (1992).

The results from the Granger causality tests are presented in Table 4. The returns of Croatia, Estonia, Slovenia and Romania are Granger caused by the returns of the world market at 1 % level of significance. Furthermore, the returns of Croatia, Estonia and Slovenia are highly significantly Granger caused by returns of all three developed markets (France, Germany and the UK), indicating strong influence of the three developed markets. By contrast, the returns of Romania are Granger caused by returns of France (only at 10% level), but not with the returns

of the UK and Germany. An interesting finding is that the returns of Slovakia are not Granger caused by either world or any of the developed markets, suggesting that the Slovakian market is segmented relative to both the world market and the developed European markets. The significance of the causalities between the world and the frontier markets remained unchanged in both time periods, before and during the crisis. The results with respect to the developed markets are also in general the same with the exception of Croatia, which showed no signs of significant causality relations during the crisis time period.

The results on internal linkages within the frontier markets group show that the Estonian market Granger causes the returns of Croatia, Slovenia and Romania at the 1% significance level. Bidirectional causality at 1% level of significance is observed only in the case of Croatia and Slovenia. Slovakia is not Granger caused by either of the frontier markets and moreover Slovakia does not Granger cause any of the markets, providing strong evidence that the Slovakian market is segmented with respect to the other frontier markets in Europe. In addition, Slovakian returns started to be affected (at the 5% level) by the returns of Slovenia and Romania during the crisis, indicating the initial signs of strengthening the linkages with the other frontier markets in the group.

Table 4. Granger causality tests

Markets Time period	F-statistics before crisis (crisis)		p-value before crisis (crisis)	
Panel A: The world and the frontier markets (Model 1)				
World → Croatia	23.360	(6.990)	0.000	(0.001)
World → Estonia	33.844	(22.759)	0.000	(0.000)
World → Romania	4.980	(11.564)	0.001	(0.000)
World → Slovakia	0.982	(0.082)	0.399	(0.920)
World → Slovenia	28.201	(67.231)	0.000	(0.000)
Panel B: Developed markets and the frontier markets (Model 2)				
France → Croatia	6.830	(0.774)	0.000	(0.461)
France → Estonia	13.558	(7.264)	0.000	(0.000)
France → Romania	2.384	(2.783)	0.067	(0.063)
France → Slovakia	0.773	(0.243)	0.508	(0.783)
France → Slovenia	15.722	(16.761)	0.000	(0.000)
Germany → Croatia	5.806	(1.703)	0.000	(0.183)
Germany → Estonia	10.409	(10.820)	0.000	(0.000)
Germany → Romania	1.586	(5.443)	0.190	(0.004)
Germany → Slovakia	1.143	(0.035)	0.329	(0.965)
Germany → Slovenia	14.365	(25.502)	0.000	(0.000)
UK → Croatia	5.910	(1.156)	0.000	(0.315)
UK → Estonia	10.132	(6.858)	0.000	(0.001)
UK → Romania	1.823	(1.413)	0.140	(0.244)
UK → Slovakia	0.829	(0.376)	0.477	(0.686)
UK → Slovenia	16.124	(16.210)	0.000	(0.000)

Table 4 continued. Granger causality tests

Markets Time period	F-statistics before crisis (crisis)	p-value before crisis (crisis)
Panel C: The frontier markets (Model 2)		
Croatia → Romania	3.495 (4.452)	0.014 (0.012)
Croatia → Slovenia	11.268 (29.680)	0.000 (0.000)
Croatia → Estonia	(11.361)	(0.000)
Estonia → Croatia	9.101 (5.373)	0.000 (0.005)
Estonia → Romania	4.508	0.003
Estonia → Slovakia	(2.454)	(0.087)
Estonia → Slovenia	4.022	0.007
Romania → Estonia	(2.687)	(0.069)
Romania→ Slovakia	(3.468)	(0.032)
Romania→ Slovenia	3.242	0.021
Slovakia → Estonia	(2.924)	(0.055)
Slovenia→ Croatia	9.233 (5.481)	0.000 (0.004)
Slovenia→ Estonia	2.246	0.080
Slovenia→ Romania	2.313	0.074
Slovenia→ Slovakia	(3.352)	(0.036)

Note: Panel C reports only those combinations that reveal significant causality relations among the frontier markets (total number of tests is 20 in each period, while the number of significant tests is 9 in the period before the crisis and 10 during the crisis).

In order to quantify the interdependences among the stock markets investigated, variance decomposition analysis is used. Table 5 provides information about return linkages between the frontier markets and the world market (Model 1) in the period before and during the crisis, showing results of 1-day, 2-day, 5-day and 10-day ahead forecast error variances of each frontier market's stock index return series. The results in the period before the crisis demonstrate that returns of the world market have no substantial impact on the returns of the frontier markets. For instance, the greatest impact of the world market returns on the frontier markets returns appeared to be in the case of Croatia, where the world market returns explain 10.7% of the forecast variance of returns five days ahead. In the case of Estonia, the fraction of variance explained by the world market returns is 7.2%. The fraction of variance that is attributable to the world market returns is less than 1% during the whole 10-day period for Slovakia, Slovenia and Romania, demonstrating that the forecast variance is caused solely by innovations in itself. Within the group of the frontier markets the strongest bidirectional relationship is ob-

served between Croatia and Slovenia, where the proportion of Croatian stock return variance (at five-days window) explained by Slovenian returns is 5.9%, while Croatian returns explain 5% of variations in Slovenian returns.

Entries in the brackets in Table 5 show the corresponding figures for the period during the crisis. The main difference compared to the period before the crisis is that the percent of the frontier markets' returns explained by the world market returns has increased drastically, indicating that the financial crisis played a significant role in the strengthening of the linkages between the frontier markets and the world market. For instance, the impact of the world market returns on the frontier markets returns at five-day horizon increased from 0.4% before the crisis to 34.6% during the crisis for Romania, from 0.9% to 31.8% for Slovenia, from 7.2% to 30.2% for Estonia, and from 10.7% to 32.2% for Croatia. Slovakian market showed more moderate change, increasing from 0.4% before the crisis to 9.4% during the crisis.

Table 5. Variance decomposition (Model 1)

Country	Percentage of forecast error variance in					
Days	World	Croatia	Estonia	Romania	Slovakia	Slovenia
Croatia						
1	3.1 (37.8)	94.0 (55.0)	0.3 (1.8)	0.2 (4.8)	0.0 (0.0)	2.4 (0.6)
2	7.2 (40.9)	89.6 (50.5)	0.4 (2.5)	0.2 (4.8)	0.3 (0.1)	2.3 (1.2)
5	10.7 (32.2)	80.0 (47.7)	1.4 (9.6)	0.3 (4.6)	1.7 (3.1)	5.9 (2.8)
10	15.1 (26.9)	72.9 (46.6)	1.8 (15.7)	0.3 (3.7)	2.4 (3.9)	7.5 (3.2)
Estonia						
1	1.9 (12.9)	0.0 (0.0)	97.4 (80.1)	0.0 (0.0)	0.0 (0.0)	0.7 (7.0)
2	6.8 (28.4)	0.6 (1.1)	91.8 (64.7)	0.1 (0.0)	0.1 (0.1)	0.6 (5.7)
5	7.2 (30.2)	1.7 (2.3)	89.2 (52.3)	0.1 (0.2)	0.5 (7.5)	1.3 (7.5)
10	8.7 (32.7)	2.3 (3.0)	86.6 (45.0)	0.1 (0.2)	0.7 (10.7)	1.6 (8.4)
Romania						
1	0.3 (29.2)	0.0 (0.0)	0.0 (3.0)	98.7 (65.9)	0.0 (0.0)	1.0 (1.9)
2	0.6 (36.7)	0.1 (0.7)	0.0 (2.9)	98.3 (58.0)	0.1 (0.0)	0.9 (1.7)
5	0.4 (34.6)	0.3 (5.0)	0.1 (4.8)	98.0 (44.0)	0.4 (8.6)	0.8 (3.0)
10	0.4 (35.7)	0.3 (7.3)	0.1 (6.8)	98.1 (33.7)	0.5 (12.7)	0.6 (3.8)
Slovakia						
1	0.0 (0.7)	0.4 (0.4)	0.1 (3.6)	0.2 (1.3)	99.1 (94.0)	0.2 (0.0)
2	0.0 (1.4)	1.1 (0.6)	0.1 (4.9)	0.2 (1.4)	98.2 (90.6)	0.4 (1.1)
5	0.4 (9.4)	3.8 (0.7)	0.9 (13.4)	0.3 (5.6)	92.8 (68.5)	1.8 (2.4)
10	0.5 (14.1)	5.5 (0.7)	1.3 (17.8)	0.4 (6.2)	89.5 (58.0)	2.8 (3.2)
Slovenia						
1	0.0 (17.8)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	100.0 (82.2)
2	0.9 (40.3)	0.5 (0.5)	0.0 (0.4)	0.0 (0.5)	0.3 (0.8)	98.3 (57.5)
5	0.9 (31.8)	5.0 (1.3)	0.8 (1.1)	0.1 (1.9)	2.1 (0.7)	91.1 (63.2)
10	0.6 (28.9)	7.5 (1.0)	1.2 (1.0)	0.1 (2.0)	3.2 (0.4)	87.4 (66.7)

Notes: This table reports results from variance decomposition for the frontier markets and the world market in the period before and during the crisis. Entries in brackets correspond to the values during the crisis period.

Table 6 presents the results from the variance decomposition for Model 2 in the period before and during the crisis. In the pre-crisis period, only 6.3% of variance forecasts (at five-day horizon) of the Croatian returns are collectively attributable to innovations in the returns of the three developed markets. For Slovenia, Romania and Estonia the fraction of variance explained by the developed markets collectively is 6.2%, 4.6%, and 3.6% respectively. The case of Slovakia reveals that neither of markets examined has an impact on Slovakian returns, with the individual contribution of each market to the variance of returns being lower than even 1 %. This finding suggests that the returns of the other markets (either the developed or the frontier) do not have any significant impact on the Slovakian returns. In general, from the results regarding variance decomposition in the period before the crisis it can be concluded that the extent of influence of the developed markets on the returns of the frontier markets, as well as the extent of mutual influence among the group of the frontier markets is very low. Entries in the brackets in Table 6 show the corresponding figures for the crisis period.

Similarly to Model 1 there is also a substantial increase in the percentage of the fraction of variance explained by the developed market returns. The greatest change of percentage is observed for Romania (from 4.6% before the crisis to 48.3% during the crisis), followed by Croatia (from 6.3% to 46.6%), Slovenia (from 6.2% to 29.6%) and Estonia (from 3.6% to 20.4%). The Slovakian market shows very minor change in the behavior during the crisis (corresponding percentage is changed from 1.2% to 3.2%). The analysis of the dynamics within the frontier markets group during the crisis reveals that very low percentage (ranging from 0% to 6%) of the forecast variance of the European frontier stock markets can be explained by the returns of other frontier markets in the group.

Generalized impulse response functions provide information about responsiveness of each market to shocks coming from the other markets in the VAR system. The responsiveness is determined by the speed with which shocks in a particular market are transmitted to the other markets. We analyze the responses of each European frontier market to a one standard error shock in the world market and the three developed European market for both periods, before and during the crisis.[13] The findings from the generalized impulse response analysis indicate relatively slow response of European frontier markets to a shock coming either from the world market or from the UK, France and German markets in the period before the crisis. The pattern of responsiveness of the frontier markets observed

[13] The graphs of the impulse response analysis are not shown here; they are available upon request.

during the crisis period is slightly different, with the shocks from the world and developed markets being transmitted relatively faster compared to the period before the crisis. The size of the responses has also increased, indicating that the crisis affected responsiveness of European frontier stock markets.

Table 6. Variance decomposition (Model 2)

Country	Percentage of forecast error variance in							
Days	UK	France	Germany	Croatia	Estonia	Romania	Slovakia	Slovenia
Croatia								
1	4.5 (35.5)	0.0 (4.9)	0.3 (2.1)	94.2 (52.0)	0.0 (0.6)	0.2 (4.4)	0.0 (0.0)	0.8 (0.5)
2	4.9 (32.6)	0.0 (4.7)	0.4 (10.1)	93.4 (46.7)	0.1 (0.9)	0.3 (3.8)	0.0 (0.5)	0.9 (0.7)
5	4.6 (26.2)	0.2 (4.7)	1.5 (15.7)	91.8 (44.8)	0.3 (3.2)	0.4 (3.5)	0.0 (0.3)	1.2 (1.6)
10	4.7 (21.7)	0.2 (4.8)	2.0 (19.9)	91.4 (43.9)	0.2 (4.2)	0.5 (3.6)	0.0 (0.3)	1.0 (1.6)
Estonia								
1	1.7 (13.9)	0.5 (0.4)	0.1 (0.2)	0.0 (0.0)	97.4 (78.8)	0.0 (0.0)	0.0 (0.0)	0.3 (6.7)
2	2.8 (20.2)	0.9 (0.3)	0.1 (1.2)	0.2 (0.4)	95.7 (70.8)	0.1 (0.3)	0.0 (1.5)	0.3 (5.3)
5	2.2 (19.1)	0.8 (0.3)	0.6 (1.0)	0.3 (0.4)	95.7 (72.0)	0.1 (1.0)	0.0 (1.1)	0.3 (5.1)
10	2.1 (19.1)	0.7 (0.2)	0.9 (0.7)	0.4 (0.2)	95.6 (72.9)	0.1 (1.3)	0.0 (0.9)	0.2 (4.7)
Romania								
1	0.3 (31.2)	0.5 (2.2)	0.0 (2.6)	0.0 (0.0)	0.0 (2.9)	97.8 (59.6)	0.0 (0.0)	1.4 (1.5)
2	0.4 (28.8)	1.2 (5.0)	0.3 (9.2)	0.1 (0.1)	0.0 (3.5)	96.5 (50.3)	0.0 (1.7)	1.5 (1.4)
5	0.3 (22.6)	3.4 (9.5)	0.9 (16.2)	0.1 (2.0)	0.1 (6.6)	93.3 (39.5)	0.1 (2.0)	1.8 (1.6)
10	0.2 (19.8)	4.5 (11.8)	1.0 (19.3)	0.1 (2.4)	0.1 (7.8)	92.1 (35.3)	0.0 (2.1)	2.0 (1.5)
Slovakia								
1	0.3 (0.0)	0.1 (0.0)	0.0 (0.7)	0.0 (0.0)	0.0 (0.6)	0.1 (0.0)	99.5 (98.6)	0.0 (0.1)
2	0.6 (0.0)	0.1 (0.5)	0.0 (0.7)	0.0 (0.3)	0.1 (0.6)	0.1 (1.0)	99.1 (96.0)	0.0 (0.9)
5	0.9 (0.8)	0.1 (1.3)	0.2 (1.1)	0.0 (0.2)	0.1 (0.5)	0.2 (1.0)	98.5 (94.4)	0.0 (0.7)
10	1.1 (0.9)	0.2 (1.7)	0.2 (1.3)	0.0 (0.2)	0.1 (0.4)	0.2 (1.0)	98.2 (94.0)	0.0 (0.5)
Slovenia								
1	1.1 (17.0)	0.0 (3.1)	0.0 (0.3)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	98.9 (79.6)
2	3.8 (25.5)	0.0 (2.9)	0.3 (4.1)	0.0 (1.6)	0.1 (0.5)	0.1 (0.1)	0.0 (0.8)	95.7 (64.5)
5	5.6 (20.4)	0.1 (3.6)	0.5 (5.6)	0.1 (1.8)	0.2 (0.7)	0.1 (0.2)	0.0 (0.8)	93.4 (66.9)
10	7.1 (18.9)	0.1 (3.8)	0.5 (6.0)	0.1 (1.1)	0.1 (0.5)	0.1 (0.1)	0.0 (0.8)	92.0 (68.8)

Notes: This table reports results from variance decomposition for the frontier markets and the developed markets in the period before and during the crisis. Entries in brackets correspond to the values during the crisis period.

6 Conclusions

In this study, we use a cointegrated vector-autoregressive (VAR) framework to examine the impact of the 2008–2009 financial crisis on the external linkages of European frontier stock markets (Croatia, Estonia, Romania, Slovakia and Slovenia) with the world market portfolio and three largest developed equity markets in Europe (the UK, France and Germany). In addition, we investigate internal linkages within the frontier markets as well. The empirical findings support the presence of cointegration relationships both with the world market and three largest developed European stock markets, indicating that examined markets share a

long-term equilibrium. During the 2008–2009 financial crisis the cointegration relationships became more evident (increase in the number of cointegrating vectors) with respect to the world market portfolio, implying a significant impact of the global financial crisis on strengthening the long-term external linkages of European frontier markets. Further empirical evidence from the variance decomposition indicates that also short-term external dynamic linkages of the examined frontier markets were strengthened during the crisis, implying that the diversification potential of European frontier markets changes during the financial crisis. Responsiveness of European frontier markets to shocks coming from the developed markets is also more apparent during the crisis.

Among European frontier markets investigated, the Croatian, Estonian and Slovenian markets appear to be more dependent on the world market portfolio and the three largest developed stock markets in Europe, while by contrast, the stock market of Slovakia appears to be segmented relative to both. The Romanian market seems to be moderately dependent. In general, although there is evident long-term relationship among investigated markets, the extents of the external short-term linkages between European frontier markets and developed markets are still sufficiently low to provide potential diversification benefits on short-term horizons, even during a crisis period. In particular, the highest potential for diversification gains is observed for the Slovakian stock market.

The results on internal linkages within the frontier markets group reveal a very low level of mutual interdependence among the group members in both periods, implying that investing in frontier markets as a group might be considered an important alternative for obtaining diversification benefits during the crises periods. In particular, strong causal linkages are observed only between the Croatian and Slovenian markets, while the other frontier markets in the group are very weakly linked in both periods, before and during the crisis. The interdependence between the Croatian and Slovenian markets may be explained by their historical links and geographic proximity, as they are adjacent countries which were parts of the same country (the former Yugoslavia) for more than 40 years and have strong industrial and economic relations.

Overall, our study has both important academic and practical implications. Our unique focus on frontier markets, as an increasingly attractive investment destination but still thinly investigated subset of emerging markets, sheds new and important light on the field of international diversification. Furthermore, the outcomes of our analysis may provide an investment roadmap for the global investors who are continuously seeking to expand into new attractive markets charac-

terized by lower correlations with the developed markets, and still able to provide diversification benefits even during turbulent times of financial crises.

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BOND MARKETS CO-MOVEMENT DYNAMICS AND MACROECONOMIC FACTORS: EVIDENCE FROM EMERGING AND FRONTIER MARKETS*

ABSTRACT

This paper examines the co-movement dynamics of ten emerging and four frontier government bond markets with the US market and the driving forces behind the time-varying co-movement. Using the Dynamic Conditional Correlation (DCC) bivariate GARCH framework, we first analyze dynamic correlation patterns and then investigate whether domestic and global macroeconomic factors and global bond market uncertainty can explain time variations in the correlation patterns. The results indicate considerable variation in the correlation dynamic paths across the countries, implying that emerging/frontier bond markets, taken as a single group, constitute a good alternative source of diversification benefits for US investors. In particular, frontier markets appear to have higher diversification potential than emerging markets. We also find that macroeconomic factors and global bond market uncertainty play important roles in explaining time variations in the bond return co-movement. Specifically, domestic macroeconomic factors are of higher relative importance than global factors, with domestic monetary policy and domestic inflationary environment identified as the most influential factors.

JEL classification: F30, G15

Keywords: Emerging market bonds; Macroeconomic factors; Bond market co-movement; Bond market uncertainty

1 Introduction

This paper focuses on the international co-movement of government bond returns between emerging/frontier markets and the US market. The issue of co-movement dynamics among international bond markets is of great importance in asset allo-

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cation management and investors' diversification strategies. Most of the literature on the co-movement between international markets has concentrated on the equity market co-movement (Bessler & Yang 2003; Brooks & Del Negro 2004; Pukthuanthong & Roll 2009; Graham, Kiviaho & Nikkinen 2012) and stock-bond co-movement in a single country or multi-country context (Connolly, Stivers & Sun 2005; Cappiello, Engle & Sheppard 2006; Kim, Moshirian & Wu 2006).

On the other hand, research on the international co-movement across government bond markets has received less attention and the major part of existing literature pertains to the developed bond markets. One group of studies within this strand of literature generally focus on various aspects of bond market integration (Smith 2002; Yang 2005; Kumar & Okimoto 2011), and volatility spillover effects in European bond markets (Skintzi & Refenes 2006; Christiansen 2007), while another group examines the impact of different factors on the degree of bond market integration. In particular, Barr & Priestley (2004) investigate the impact of world and domestic risk factors on international bond market integration of five developed markets (US, UK, Japan, Germany and Canada). Most recently, Abad, Chulia & Gomez-Puig (2010) analyze the impact of Monetary Union on government bond returns in the EU-15 group of countries.[1]

Among the literature on international co-movement across government bond markets, studies focusing on the emerging and frontier markets are scarce. One of the few studies that focuses on emerging bond markets is Bunda, Hamann & Lall (2009), who examine co-movements in emerging market bond returns with special emphasis on contagion effects during periods of heightened market volatility. In the realm of integration studies, Kim, Lucey & Wu (2006) address the issue of bond market integration of three European emerging markets (the Czech Republic, Hungary and Poland) in the context of dynamic bond market linkages between established and accession European Union countries, while Vo (2009) investigates the relationships amongst Asian emerging bond markets and the advanced developed counterparts of the USA and Australia. Volatility co-movement between emerging sovereign bonds is addressed by Cifarelli & Paladino (2006).

The purpose of this study is two-fold. First, we investigate the dynamics of the government bond return co-movement of ten emerging and four frontier markets

[1] More detailed overview of the literature on international bond market integration and co-movement can be found in the review article by Lucey & Steeley (2006).

with the US market over the period 2000–2011 by applying the Dynamic Condition Correlation (DCC) GARCH framework.[2]

The bivariate (individual emerging/frontier bond market versus the US bond market) DCC-GARCH modeling enables assessment of time-varying co-movement among investigated markets and consequently facilitates evaluation of the potential diversification benefits available from investing in emerging/frontier bond markets. Second, acknowledging the importance of understanding the driving forces behind the time-varying co-movement between international bond markets, we investigate whether global and domestic macroeconomic factors play an important role in explaining these time variations. In order to further examine potential determinants of international bond market co-movement, we use global bond market uncertainty (measured by implied volatility of US Treasury options) as an explanatory variable in addition to macroeconomic fundamentals.

The impact of macroeconomic factors on the co-movement of asset returns has been extensively investigated for stock market returns (Dumas, Harvey & Ruiz 2003; Cai, Chou & Li 2009; Syllignakis & Kouretas 2011; Kiviaho et al. 2012) and for the co-movement between stock and bond returns (Li 2004; Andersson, Krylova & Vähämaa 2008; Yang, Zhou & Wang 2009), while the studies on the linkages between international bond returns co-movement and macroeconomic factors are limited. Hunter & Simon (2005), Ludvigson & Ng (2009), and Baele, Bekaert & Inghelbrecht (2010) are examples of the few studies to have addressed the issue of the links between macroeconomic fundamentals and international bond return correlations and volatility.

Hunter & Simon (2005) provide evidence that differences in business cycle conditions may explain the time-varying correlations of international bond returns, as well as that international bond returns are sensitive to similarities in monetary policy. In a similar vein, Baele, Bekaert & Inghelbrecht (2010) find that macroeconomic factors do play a relatively large role in bond market volatility dynamics; while Ludvigson & Ng (2009) show that macroeconomic fundamentals carry important predictive power for excess returns on US government bonds. In line with previous studies on the relationship between asset returns and macroeconomic fundamentals (Ilmanen 2003; Li 2004; Yang, Zhou & Wang 2009), the macro factors in our empirical framework include the business cycle fluctuations, the inflation environment, and monetary policy stance.

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[2] The breakdown of markets as emerging vs. frontier is based on the Standard & Poor's (S&P) classification.

In addition to macroeconomic fundamentals, the literature also provides evidence that perceived market risk or uncertainty has an important impact on the co-movement dynamics of asset returns. For instance, in the literature on the co-movement between stocks and bonds, implied volatility from stock index options is used as a measure of stock market uncertainty (Connolly, Stivers & Sun 2005; Kim, Moshirian & Wu 2006; Andersson, Krylova & Vähämaa 2008). The aforementioned studies provide evidence that stock market uncertainty, as measured by implied volatility, affects time variations in the co-movement of stock and government bond returns.

Our study builds upon the proposed use of implied volatility measures as proxies for market uncertainty. Extending the work of Connolly, Stivers & Sun (2005), we apply a bond market uncertainty measure to examine the impact of bond market uncertainty on time variations in international bond market co-movement. Specifically, we use the Merrill Lynch Option Volatility Estimate MOVE Index (a widely-followed measure of government bond volatility derived from option prices on US Treasury bonds) as a proxy for global bond market uncertainty.

Our study contributes to the literature in three ways. First, while most of the previous studies on international bond market co-movement have focused on the correlation dynamics between international markets, we examine the driving forces behind the time-variation of the bond return correlations. In particular, we investigate the role of both global and domestic macroeconomic fundamentals in explaining variations in bond return co-movement. Second, a novel feature of our study is provided by examining the influence of global bond market uncertainty on time variations in bond market co-movement. Hence, our paper extends the literature by jointly examining the impact of macroeconomic factors and global bond market uncertainty on international bond market correlations.

Third, our study investigates a comprehensive set of emerging and frontier bond markets, contributing a new dimension to the literature on international bond market co-movement that has traditionally focused on developed markets. There is very little research on emerging market bonds relative to emerging market equities, and there is much left to learn about emerging market bonds as pointed out by Erb, Harvey & Viskanta (1999). Emerging market bonds have attracted considerable attention among international investors for their very high average rates

of return during the 1990s, and a number of authors have emphasized their benefits (Dahiya 1997; Froland 1998).[3]

The diversification in international bond markets was examined by Hunter & Simon (2005), who found that the benefits of diversification across major government bond markets were alive and well in the period 1992–2002. However, as a consequence of the global financial turmoil of 2008–2009 and the recent sovereign bond crisis in Europe, there is a renewed interest in reassessing the diversification potential of international bond markets. Hence, our study provides new insights into the field of international diversification in bond markets from the emerging market perspective.

The major findings of this study are: (i) there is considerable variation across emerging/frontier markets in the patterns of dynamic correlation with the US bond market, implying that emerging/frontier bond markets, taken as a single group, constitute a good alternative source of diversification benefits for US investors; (ii) frontier bond markets appear to have higher diversification potential than their counterparts in emerging markets; (iii) macroeconomic factors play an important role in explaining time variations in the bond return co-movement between emerging/frontier markets and the US government bond market; (iv) domestic macroeconomic factors are of higher relative importance compared to global factors, with domestic monetary policy and domestic inflationary environment identified as the most influential factors and (v) global bond market uncertainty, as measured by implied volatility, might have explanatory power in driving co-movement dynamics in emerging/frontier bond markets.

The remainder of this paper is organized as follows. Section 2 presents data and the descriptive statistics. In Section 3, we set out a brief description of the econometric approach. The empirical results are presented in Section 4, while Section 5 provides conclusions.

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[3] The average returns on emerging markets bonds exceeded the return on the Standard & Poor's 500 index from 1991 to the summer of 1997 (Erb, Harvey & Viskanta 1999). However, a very sharp increase in the popularity of emerging markets bonds in early 1990s was followed by a downswing caused by the Russian bond default in 1998 and Argentina's debt default in late 2001. Despite negative contagion effects from those defaults, the emerging bond markets did not collapse, but instead continued to grow after 2002 following fast economic growth and strengthened sovereign debt ratings.

2 Data

2.1 Bond market returns

Our empirical analysis is conducted for a sample set of ten emerging markets (Brazil, China, Malaysia, Mexico, Peru, Philippines, Poland, Russia, South Africa, and Turkey) and four frontier markets (Argentina, Bulgaria, Colombia, and Ecuador) that are constituents of the J.P. Morgan Emerging Market Bond Index Global (EMBI Global).[4] We employ monthly total return bond indices of the selected emerging, frontier markets (obtained from Thomson Datastream), and the USA 10-year government bond total return index (obtained from Global Financial Data). Total return on bonds implies that the coupon payments are reinvested into the bonds forming the index. All indices are denominated in US dollars. The returns are defined as the logarithmic first difference of monthly bond indices times 100.[5] Monthly frequency is chosen because the data on macroeconomic factors used in the further analysis are available only on a monthly level. The sample period extends from October 2000 to December 2011 leading to a sample size of 135 observations. The starting point of the sample period and the coverage across countries were dictated by data availability.

Table 1 reports statistical properties of the monthly bond market returns for each country in the sample. During the period under scrutiny, almost all emerging and frontier markets (except Argentina and China) have higher average bond returns than the USA. The highest returns are recorded for Russia and Brazil. The volatility levels of the emerging and frontier bond markets are generally higher than the volatility of the US market. The least volatile market is China, with the standard deviation of 1.891, which is lower than the volatility level of the US market (2.396). To visualize the returns for each emerging and frontier bond market, we depict the series in Figures 1 and 2, respectively. The plots show that frontier markets exhibit higher volatility relative to emerging markets, while for all markets there are notable bouts of increased volatility around the 2008–2009 global

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[4] The EMBI Global tracks total returns for US dollar-denominated debt instruments issued by emerging markets sovereign and quasi-sovereign entities, including Brady bonds, loans and Eurobonds. To be included in the index, bonds must meet eligibility requirements of a current face amount outstanding of $500 million or more and a remaining lifespan greater than 2.5 years. The J.P. Morgan EMBI indices (EMBI+, EMBI Global, and EMBI Diversified) are the most widely used and comprehensive emerging market sovereign debt benchmarks.

[5] We follow the previous literature in applying log-changes of total return government bond indices (e.g., Kim, Lucey & Wu 2006; Christiansen 2007).

financial crisis. The distributions of bond market returns are statistically non-normal, leptokurtic and show negative skewness (except China).

Table 1. Descriptive statistics for bond index returns

This table reports descriptive statistics for bond index returns from October 2000 to December 2011, for a total of 135 monthly observations.

	Mean	Median	Std. Dev.	Skewness	Kurtosis
US	0.572	0.641	2.396	-0.095	4.217
Frontier markets					
Argentina	-0.209	1.150	10.288	-1.795	11.219
Bulgaria	0.694	0.886	2.519	-2.529	21.489
Colombia	1.084	1.401	3.205	-0.828	7.853
Ecuador	0.952	2.002	9.855	-4.735	38.689
Emerging markets					
Brazil	1.104	1.615	5.221	-0.532	11.330
China	0.570	0.630	1.891	0.307	19.313
Malaysia	0.700	0.789	2.184	-2.057	17.933
Mexico	0.799	0.909	2.193	-0.451	7.760
Peru	1.092	1.278	3.673	-1.118	7.230
Philippines	1.095	1.003	2.395	-0.651	5.730
Poland	0.598	0.717	2.004	-1.690	12.494
Russia	1.176	1.088	3.253	-0.838	6.865
South Africa	0.790	0.908	2.457	-1.955	16.398
Turkey	0.952	1.222	4.303	-1.027	6.391

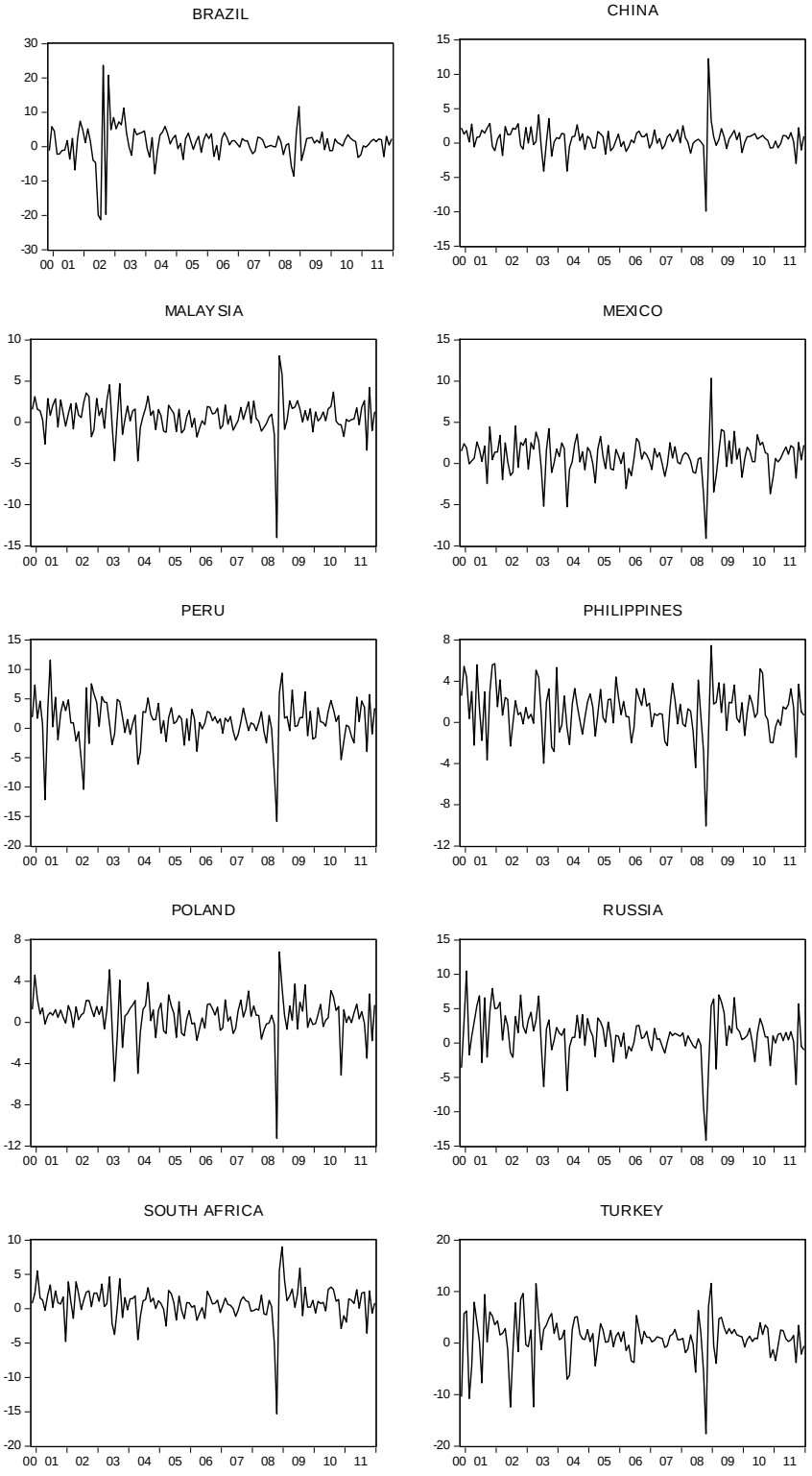

Figure 1. Monthly government bond index returns of emerging markets in the period October 2000 to December 2011. All returns are calculated as logarithmic first differences of the bond indices times 100.

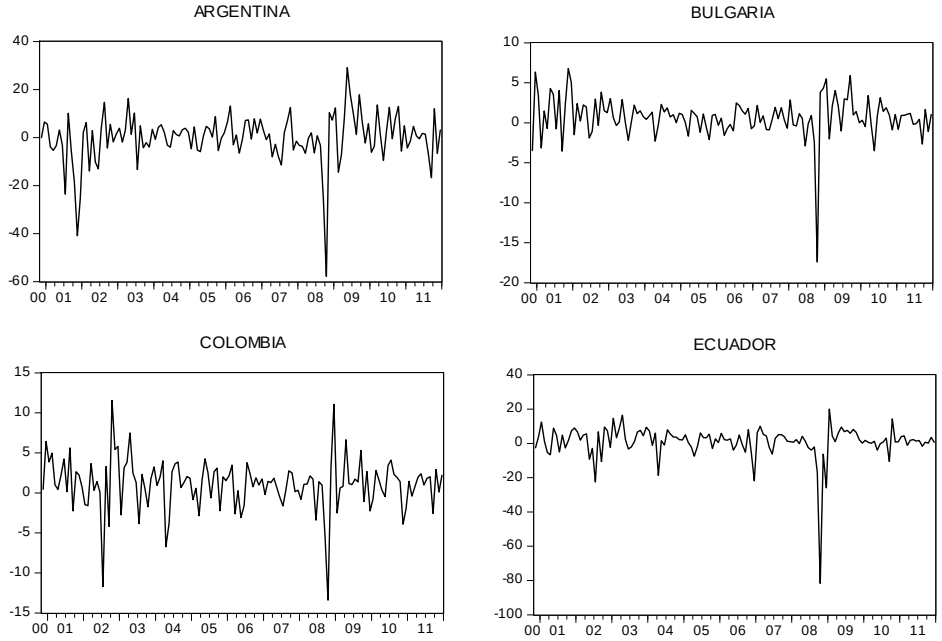

Figure 2. Monthly government bond index returns of frontier markets in the period October 2000 to December 2011. All returns are calculated as logarithmic first differences of the bond indices times 100.

Table 2 contains the pairwise unconditional correlations between the bond index returns for the markets under investigation. All emerging and frontier markets (except Ecuador) have positive correlations with the US bond market, ranging from 0.01 for Argentina to 0.67 for China. In addition, the correlations between markets within the emerging markets group are relatively high, being generally higher than the correlations with the US market.

Table 2. Unconditional correlations of monthly bond index returns

This table provides unconditional correlation coefficients for all pairs of bond markets from October 2000 to December 2011.

	US	Argen.	Brazil	Bulg.	China	Colom.	Ecuad.	Mal.	Mex.	Peru	Phil.	Pol.	Russ.	S.Africa
Argentina	0.01													
Brazil	0.06	0.31												
Bulgaria	0.12	0.46	0.46											
China	0.67	0.37	0.16	0.56										
Colombia	0.21	0.43	0.70	0.60	0.41									
Ecuador	-0.08	0.48	0.38	0.63	0.30	0.46								
Malaysia	0.66	0.45	0.28	0.66	0.87	0.52	0.43							
Mexico	0.49	0.46	0.58	0.63	0.59	0.75	0.37	0.74						
Peru	0.23	0.40	0.67	0.62	0.44	0.80	0.50	0.57	0.69					
Philippines	0.18	0.41	0.43	0.66	0.39	0.59	0.41	0.60	0.69	0.63				
Poland	0.57	0.46	0.30	0.69	0.85	0.54	0.43	0.85	0.72	0.54	0.56			
Russia	0.12	0.42	0.48	0.79	0.43	0.61	0.56	0.57	0.71	0.60	0.68	0.63		
South Africa	0.43	0.54	0.31	0.69	0.73	0.60	0.48	0.81	0.72	0.64	0.59	0.78	0.69	
Turkey	0.08	0.44	0.58	0.65	0.36	0.58	0.41	0.48	0.59	0.51	0.55	0.47	0.62	0.54

2.2 Macroeconomic factors

The impact of macroeconomic factors on the international co-movement between bond markets is examined using monthly data on inflationary environment, monetary policy stance, and business cycle patterns. Both domestic and global macroeconomic factors are used as explanatory variables. The consumer price indices (CPI), the three-month interbank interest rates (IIR), and the industrial production indices (IP) of the emerging and frontier markets are used to proxy domestic inflationary environment, domestic monetary policy stance and domestic business cycle patterns, respectively.[6] The corresponding variables for the USA represent the global macroeconomic factors.

Given the evidence of increased business cycle synchronization across different countries worldwide (see e.g. Fiess 2007; Papageorgiou, Michaelides & Milios 2010, Lee 2012); we want to avoid a potential problem that the domestic business cycle variable can incorporate global business cycle component. Hence, we use approach by Anderson, Mansi & Reeb (2003) and estimate domestic business cycle patterns without the global business cycle component. In other words, we

[6] The data sources for the consumer price indices, the industrial production indices, and the interbank interest rates are Thomson Datastream and the Global Financial Database. The data on the three-month interbank interest rates for Ecuador, Peru and Colombia were not available, so we used one-month interbank interest rates instead.

estimate a regression for each country separately with domestic industrial production index as the dependent variable and global industrial production index as the independent variable. The error term from this regression incorporates the domestic business cycle patterns without the influence or impact of global business cycle fluctuations. We denote this error term as IPET and use it as a measure of domestic business cycle patterns in the multivariate regression analysis performed later on (given by Equation 4 in Methodology section).

In addition to macroeconomic factors we use global bond market uncertainty, based on an implied volatility measure (the Merrill Lynch Option Volatility Estimate MOVE Index), as an explanatory variable.[7] The MOVE Index is a yield curve weighted index of the normalized implied volatility on 1-month Treasury options which are weighted on two-, five-, ten-, and thirty-year contracts and is a widely-followed measure of government bond volatility.

3 Methodology

The econometric framework comprises two parts. In the first part, we employ the Dynamic Conditional Correlation GARCH model (DCC-GARCH) proposed by Engle (2002) to estimate time-varying conditional correlations among the examined bond markets. Following Engle (2002), the vector of n bond returns is the demeaned vector, $r_t = r_t' - \mu$, and it is specified as follows:

(1) $$r_t \mid \Phi_{t-1} \sim N(0, H_t)$$
$$H_t \equiv D_t R_t D_t,$$

where H_t is the conditional covariance matrix; R_t is the (n x n) time-varying correlation matrix; D_t is the (n x n) diagonal matrix of time-varying standard deviations from univariate GARCH models with $\sqrt{h_{ii,t}}$ on the i^{th} diagonal, i = 1, 2, …, n. The conditional covariance matrix H_t is estimated in a two-stage procedure. In the first stage, univariate GARCH models are fitted for each of the bond return series (see Equation 2):

(2) $$h_{i,t} = \omega_i + a_i \varepsilon_{i,t-1}^2 + b_i h_{i,t-1}, \qquad i = 1,2,\ldots, n$$

[7] Data source for the MOVE Index is Thomson Datastream.

The residuals from the first stage are then standardized and used to estimate the parameters of the conditional correlation, specified in the following DCC equation:

(3)

$$q_{ij,t} = \bar{\rho}_{ij}(1 - \alpha - \beta) + \beta q_{ij,t-1} + \alpha \varepsilon_{i,t-1}\varepsilon_{j,t-1}$$

$$\rho_{ij,t} = \frac{q_{ij,t}}{\sqrt{q_{ii,t}}\sqrt{q_{jj,t}}} \qquad i, j = 1,2,\ldots, n, \text{ and } i \neq j.$$

where $\bar{\rho}_{ij}$ is the unconditional correlation of $\varepsilon_{i,t}$ and $\varepsilon_{j,t}$; α and β are non-negative scalar parameters satisfying a condition that their sum is less than unity (the estimated DCC model is mean reverting as long as $\alpha + \beta < 1$), while $\rho_{ij,t}$ denotes the conditional correlations between returns of market i and market j. As proposed by Engle (2002), the DCC model can be estimated in a two-step procedure to maximize the log-likelihood function. The theoretical and empirical properties of the DCC model and detailed estimation procedure are described in Engle & Sheppard (2001). Since our aim is to specifically model the dynamics between two markets at a time (emerging/frontier market versus the US market), we use a bivariate framework of the DCC model to obtain the conditional correlations between each of emerging/frontier and the US bond market returns.

In the second part of our analysis, we regress obtained pairwise (emerging/frontier and the US bond market returns) conditional correlations on the global and domestic macroeconomic factors and global bond market uncertainty factor using ordinary least squares (OLS) regressions. Specifically, we estimate the following regression model:

(4)

$$\rho_{ij} = \gamma + \varphi_1 IP_i + \varphi_2 IPET_j + \varphi_3 CPI_i + \varphi_4 CPI_j + \varphi_5 IIR_i + \varphi_6 IIR_j + \varphi_7 MOVE_i + \varepsilon_{ij}$$

where the dependent variable (ρ_{ij}) is the estimated pairwise conditional correlation coefficient between the bond returns of the US market and the emerging/frontier markets, such that i = USA and j = Argentina, Brazil, Bulgaria, China, Colombia, Ecuador, Malaysia, Mexico, Peru, Philippines, Poland, Russia, South Africa, and Turkey; IP_i is the industrial production index of the USA; $IPET_j$ is proxy for domestic business cycle fluctuations; *CPI* is the consumer price index; *IIR* is the three-month interbank interest rate, and MOVE is Merrill Lynch Option Volatility Estimate MOVE Index used as a measure of global bond market uncertainty.

4 Empirical results

4.1 Bond returns co-movement between emerging/frontier markets and the US market

In this section, we report the results of the dynamics of bond returns co-movement between emerging/frontier markets and the US market obtained by applying the DCC-GARCH (1,1) model. Table 3 presents a summary of the estimation results of the DCC model (given by Equation 3) in a bivariate framework and descriptive statistics of estimated dynamic conditional correlations.[8] The coefficients α and β in the DCC equation are non-negative and the sum of $\alpha + \beta < 1$ for all countries, designating mean-reverting nature of the dynamic correlation process. In addition, the estimates of parameters α and β in the DCC equation are statistically highly significant for almost all countries (with the exception of Argentina, Malaysia and Mexico, where parameter α is not statistically significant), indicating the presence of a substantial time-varying co-movement. On an average, the bond return conditional correlations with the US market are positive for all emerging markets, while two frontier markets (Argentina and Ecuador) exhibit negative average correlations. The average conditional correlations with the USA range from -0.082 for Argentina to 0.761 for China.

[8] Full estimation results from variance equations are not reported here due to space considerations, but can be supplied by the corresponding author upon request.

Table 3. Summary results from DCC-GARCH (1,1) model in bivariate framework and descriptive statistics of estimated dynamic conditional correlations with the US market

	α	β	Mean	Median	Min	Max	SD
Frontier markets							
Argentina	0.008	0.948***	-0.082	-0.083	-0.136	-0.033	0.025
	(0.040)	(0.350)					
Bulgaria	0.171*	0.826***	0.293	0.166	-0.527	0.931	0.447
	(0.087)	(0.092)					
Colombia	0.172***	0.736***	0.193	0.225	-0.497	0.764	0.257
	(0.030)	(0.057)					
Ecuador	0.171**	0.671***	-0.049	-0.060	-0.491	0.652	0.215
	(0.071)	(0.158)					
Emerging markets							
Brazil	0.107***	0.800***	0.156	0.205	-0.313	0.525	0.194
	(0.035)	(0.098)					
China	0.315***	0.677***	0.761	0.925	-0.265	0.992	0.291
	(0.002)	(0.006)					
Malaysia	0.111	0.880***	0.731	0.798	0.212	0.925	0.204
	(0.085)	(0.100)					
Mexico	0.168	0.825**	0.503	0.504	-0.174	0.923	0.287
	(0.468)	(0.395)					
Peru	0.125***	0.749***	0.239	0.263	-0.322	0.651	0.182
	(0.032)	(0.092)					
Philippines	0.096**	0.774***	0.188	0.203	-0.216	0.561	0.144
	(0.042)	(0.131)					
Poland	0.293***	0.693***	0.638	0.766	-0.305	0.982	0.340
	(0.008)	(0.013)					
Russia	0.181***	0.818***	0.289	0.215	-0.516	0.912	0.450
	(0.035)	0.046					
S. Africa	0.100***	0.899***	0.485	0.462	-0.090	0.891	0.299
	(0.026)	(0.040)					
Turkey	0.132***	0.809***	0.080	0.070	-0.428	0.593	0.213
	(0.024)	(0.071)					

Note: Figures in parentheses are standard errors. *, **, *** denote statistical significance at the 10%, 5% and 1% levels, respectively.

Evolutions of dynamic conditional correlations with the US market over time for each emerging and frontier market in the sample are displayed in Figures 3 and 4, respectively. The figures demonstrate that there is a considerable variation in the patterns of the correlation dynamic path across the countries. Interestingly, there is only one country (Malaysia) that shows positive correlations with the US mar-

ket during the entire sample period: while there is also only one country (Argentina) that exhibits negative correlations with the US market during the same period.

With the exception of those two countries, all other countries have relatively unstable correlation patterns over time with episodes of negative correlation during certain periods. For example, China, Mexico, Poland, and South Africa have predominantly positive correlations most of the time, with just a few short periods of negative correlation. On the other hand, Brazil, Russia, Turkey, and Ecuador sustained longer time intervals of negative correlation.

From the perspective of the US investor, the potential diversification benefits are higher among the frontier markets than among the emerging counterparts. In particular, Argentina and Ecuador have the highest diversification potential, given the prominent negative correlation pattern with the US market over time. However, the asset allocation management and diversification strategies applied to emerging/frontier markets should account for very sudden and sharp changes in the dynamic correlation patterns of those markets. Some of the countries in the sample exhibit unexpected correlation changes of a large magnitude in a very short time period (see Figures 3 and 4). For instance, the dynamic conditional correlation of the Russian bond market and the US market was negative and amounted to -0.16 in May 2003, while the following month, June 2003, the corresponding correlation suddenly increased to a positive 0.41 and in August 2003 it reached the level of 0.77. Similar behavior was observed in the bond markets of China, Malaysia, Mexico, and Turkey at certain points. Overall, the correlation dynamics results suggest that emerging/frontier bond markets taken as a single group constitute a good alternative source of diversification benefits for US investors.

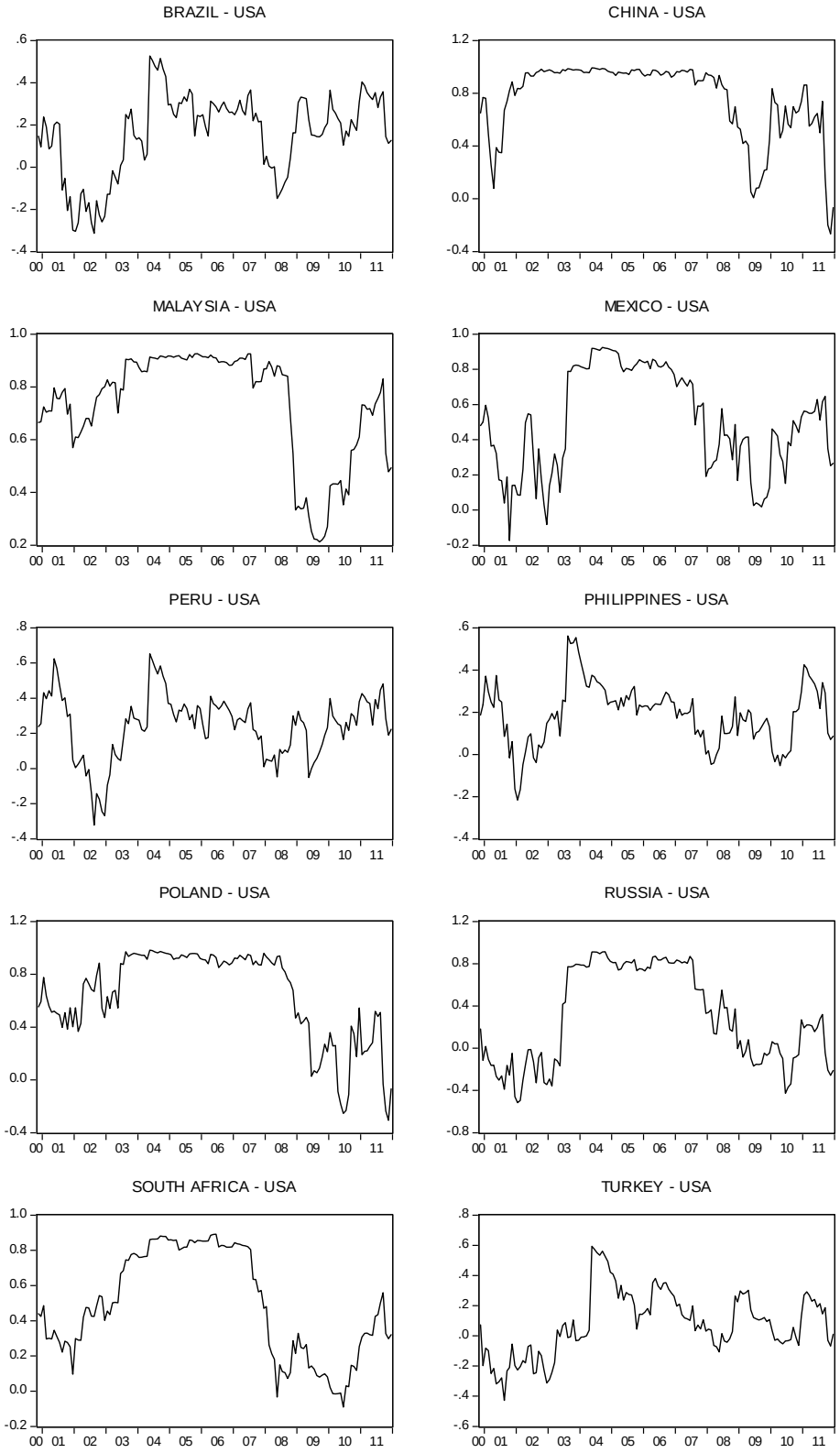

Figure 3. Dynamic conditional correlations between emerging markets and the US government bond market in the period October 2000 to December 2011.

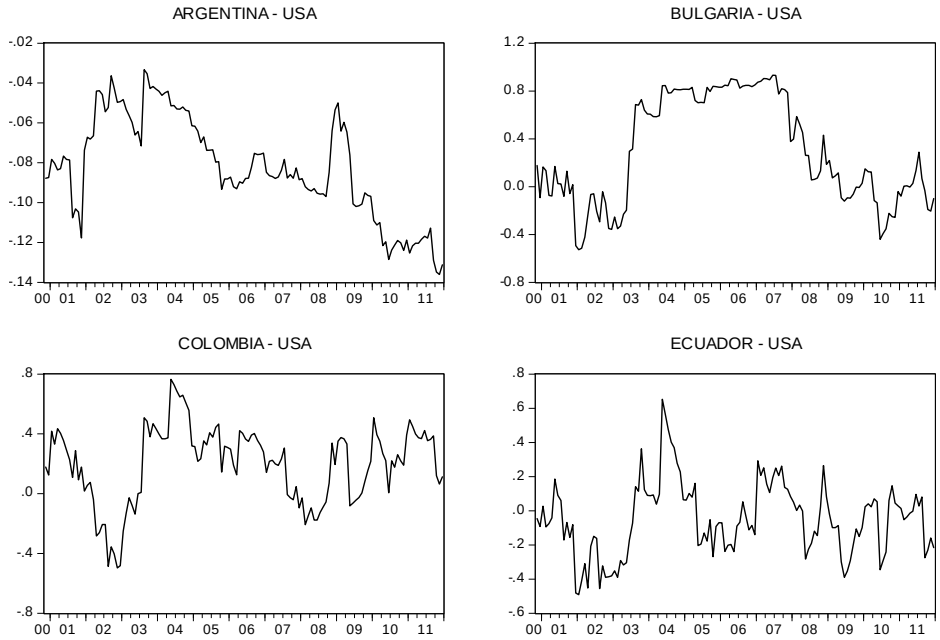

Figure 4. Dynamic conditional correlations between frontier markets and the US government bond market in the period October 2000 to December 2011.

4.2 Impact of macroeconomic factors on bond returns co-movement

The results on the impact of macroeconomic factors on the bond return co-movement, obtained by running the regressions described in Equation (4) are presented in Table 4. The interpretation of our results has two different dimensions. The first dimension adopts a group perspective on the emerging/frontier markets, while the second dimension refers to the country-specific analysis. In common with most multi-country studies, there are slight differences in terms of the significance of the explanatory factors across markets in the regression model (see Table 4). In summary, the results reveal several important findings. First, for each individual country there is at least one statistically significant macroeconomic variable of interest, while for certain countries there are even five (of six macroeconomic factors in the regression) statistically significant factors affecting the bond return co-movement with the US market. The explanatory power of the model (as measured by R-squared) differs substantially across countries, ranging from 17% (Ecuador) to 82% (Malaysia).

With respect to the relative importance of global versus domestic factors, the results suggest that domestic macroeconomic factors play a more important role than their global counterparts in explaining bond return co-movement between the emerging/frontier markets and the US market. This is evident from the fact that in

the most of the emerging/frontier markets in the sample, the number of significant domestic factors is higher than the number of significant global factors. In only four countries (China, Ecuador, Malaysia, and Mexico), are global macroeconomic factors more dominant than domestic factors.

Second, the most influential macroeconomic factors of all the global and domestic factors are domestic monetary policy and domestic inflationary environment, as those factors are statistically significant for nine of the fourteen emerging/frontier markets. On the other hand, domestic business cycle fluctuation factor is statistically significant for eight countries from the sample. Third, considering the global factors separately, the global business cycle fluctuation factor is found to be of higher importance than the other two global macroeconomic factors. Our findings on the importance of business cycle fluctuations for international bond return co-movement are in line with those of Hunter & Simon (2005), who documented that differences in business cycle conditions may explain the time-varying correlations between the US and the UK, and the US and German bond returns.

Turning our attention to the country-specific dimension of the results, the analysis reveals considerable variation in the importance of macroeconomic factors among various emerging/frontier bond markets. In particular, the bond markets of Colombia, Ecuador, Philippines, and Russia are the least affected by macroeconomic fundamentals, while for Bulgaria, Malaysia, and South Africa macroeconomic factors play an important role in the co-movement dynamics with the US market. It is interesting to note that six markets (Colombia, Brazil, Peru, Philippines, Russia and Turkey) are not affected by global macroeconomic factors at all. Examining the average dynamic correlations of those six markets with the US market reveals them to be far lower than correlations for the markets where global macroeconomic factors exert a greater influence (China and Malaysia, for instance). This observation suggests that greater exposure of the emerging/frontier bond markets to global macroeconomic conditions might be associated with a higher correlation of emerging/frontier markets with the US market.

Table 4. Relationship of bond market co-movement and macroeconomic factors

This table presents estimation results from a regression model linking dynamic conditional correlations with a number of domestic and global macroeconomic factors and the global bond market uncertainty factor (Equation 4). The explanatory variables include IP (the Industrial Production Index as a proxy for global business cycle fluctuations), IPET (a proxy for domestic business cycle fluctuations), CPI (the Consumer Price Index as a proxy for inflation environment), IIR (the three-month interbank interest rate as a proxy for monetary policy stance), and MOVE (Merrill Lynch Option Volatility Estimate MOVE Index as a proxy for global bond market uncertainty). Figures in parentheses are the Newey-West robust standard errors. *, **, *** denote statistical significance at the 10%, 5% and 1% levels, respectively.

	γ	IP_{USA}	$IPET_{DOMESTIC}$	CPI_{USA}	$CPI_{DOMESTIC}$	IIR_{USA}	$IIR_{DOMESTIC}$	$MOVE$	R^2
Frontier markets									
Argentina	0.0866	-0.0016**	-0.0000***	-0.0000	-0.0016***	0.0042**	-0.0002***	0.0002***	0.79
	(0.0632)	(0.0006)	(0.0000)	(0.0000)	(0.0002)	(0.0018)	(0.0000)	(0.0000)	
Bulgaria	-3.6284***	0.0589***	0.0276***	-0.0007	-0.0003***	0.0809**	-0.1230**	0.0001	0.65
	(1.0673)	(0.0099)	(0.0059)	(0.0008)	(0.0001)	(0.0394)	(0.0528)	(0.0017)	
Colombia	1.0384	-0.0133	-5.8866*	0.0021	7.1378	-0.0366	0.0457	-0.0052***	0.24
	(0.8222)	(0.0109)	(3.3586)	(0.0014)	(6.9598)	(0.408)	(0.0330)	(0.0019)	
Ecuador	-2.1212*	0.0323**	0.0000	0.0004	-0.0082	-0.0556	-0.0038	0.0002	0.17
	(1.0788)	(0.0143)	(0.0000)	(0.0003)	(0.0059)	(0.0438)	(0.0249)	(0.0008)	
Emerging markets									
Brazil	0.7482	0.0088	0.0000***	0.0000	-0.0005***	-0.0029	-0.0257***	-0.0037***	0.49
	(0.5536)	(0.0076)	(0.0000)	(0.0001)	(0.0001)	(0.0188)	(0.0081)	(0.0006)	
China	-3.3743***	0.0659***	-0.0360	0.0014**	-0.1412***	-0.0913***	-0.0393	0.0001	0.62
	(0.8370)	(0.0107)	(0.0373)	(0.0006)	(0.0399)	(0.0230)	(0.0401)	(0.0007)	
Malaysia	-2.3029***	0.0401***	0.0020	0.0006***	-0.0382***	-0.0494***	0.1220***	-0.0007*	0.82
	(0.4071)	(0.0047)	(0.0087)	(0.0001)	(0.0101)	(0.0108)	(0.0383)	(0.0004)	
Mexico	-1.2789	0.0410***	-0.0162	0.0011**	-0.2429**	-0.0104	-0.0027	-0.0035***	0.57
	(0.9356)	(0.0133)	(0.0399)	(0.0005)	(0.0981)	(0.0335)	(0.0108)	(0.0010)	
Peru	-1.8080	-0.0011	-0.0121**	0.0002	0.0257**	-0.0178	0.0270***	-0.0030***	0.33
	(1.1201)	(0.0076)	(0.0056)	(0.0003)	(0.0108)	(0.0238)	(0.0060)	(0.0007)	
Philippines	0.2109	0.0026	0.0000*	0.0003	-0.0695	-0.0063	-0.0127	-0.0008	0.18
	(0.7882)	(0.0084)	(0.0000)	(0.0006)	(0.0788)	(0.0206)	(0.0120)	(0.0005)	
Poland	-2.1059**	0.0299***	-0.0122***	0.0003	-0.0013	0.0317	-0.0402***	0.0020***	0.74
	(0.8825)	(0.0100)	(0.0019)	(0.0003)	(0.0010)	(0.0247)	(0.0084)	(0.0005)	
Russia	-1.758	0.0312	0.1536	-0.0002	-0.0679	0.0552	-0.0485***	0.0007	0.56
	(2.0267)	(0.0240)	(0.1796)	(0.0006)	(0.0501)	(0.0468)	(0.0172)	(0.0012)	
S. Africa	-3.9878***	0.0730***	0.1318***	-0.0004	-0.1340***	-0.0414*	-0.0504**	-0.0006	0.69
	(1.2007)	(0.0137)	(0.0197)	(0.0007)	(0.0206)	(0.0247)	(0.0237)	(0.0010)	
Turkey	0.7017	0.0015	0.0011	0.0003	-0.0075**	0.0232	-0.0109***	0.0000	0.57
	(0.4886)	(0.0074)	(0.0031)	(0.0004)	(0.0030)	(0.0173)	(0.0021)	(0.0006)	

4.3 Impact of global bond market uncertainty on bond returns co-movement

The final part of the analysis involved the investigation of the influence of global bond market uncertainty on time variations in international bond return co-movement dynamics. The literature suggests that US bond market volatility is a significant factor in explaining bond market volatility in European developed markets (Skintzi & Refenes 2006). Market participants also tend to interpret a rise in the implied volatility index as a signal of increased perceived market risk (uncertainty) and as a cue to revise asset allocation decisions more frequently. Therefore, the a priori expectation is that global bond market uncertainty will affect the changes in bond return co-movement in the international context.

The estimation results, shown in Table 4, reveal that the coefficient on the global bond market uncertainty variable is highly statistically significant (at the 1% level) in six countries, namely Argentina, Brazil, Colombia, Mexico, Peru, and Poland.[9] This finding indicates that uncertainty on the future movements in the US bond market might be seen as one of the factors that drive co-movement dynamics between emerging/frontier bond markets and the US market. However, the statistically insignificant coefficients in certain countries suggest that apart from bond market uncertainty there might be uncertainty arising from other asset classes that influences bond market co-movement in emerging/frontier markets. One potential explanation is that bond market co-movement in emerging/frontier markets might be affected by stock market uncertainty, since emerging markets' bonds are sometimes perceived as 'equity like' assets due to higher country risk in emerging economies (see Kelly, Martins & Carlson 1998).

5 Conclusions

This paper investigates the dynamics of emerging/frontier government bond markets co-movement with the US market and the driving forces behind the time-varying co-movement. In particular, we examine whether domestic and global macroeconomic factors and global bond market uncertainty play an important role in explaining the dynamics of bond return co-movement in emerging/frontier markets.

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[9] The statistical significance at the 10% level is shown for Malaysia.

The empirical results of this study are threefold. First, we find considerable variation in the patterns of the correlation dynamic paths across the countries. Brazil, Russia, Turkey, and Ecuador sustained longer time intervals of negative correlation with the US market, while on the other hand China, Mexico, Poland, and South Africa had predominantly positive correlations with very short episodes of negative correlation. The results on correlation dynamics collectively suggest that emerging/frontier bond markets taken as a single group constitute a good alternative source of diversification benefits for US investors. More specifically, frontier markets appear to have higher diversification potential than emerging markets. We also document very sudden and sharp changes in the dynamic correlation patterns, suggesting such changes are a feature of emerging/frontier bond markets that international diversification strategies should take into account.

Second, the results of our analysis indicate that domestic and global macroeconomic factors can explain time variations in the bond return co-movement between emerging/frontier markets and the US government bond market. In particular, domestic macroeconomic factors are found to be of higher relative importance compared to global factors. Specifically, of the complete set domestic and global factors investigated, domestic monetary policy and domestic inflationary environment are identified as the most prominent variables affecting bond return co-movement, while the global business cycle fluctuation factor is the most influential among just the global factors.

Finally, our empirical findings demonstrate that global bond market uncertainty, based on an implied volatility measure, significantly affects the bond return co-movement dynamics between emerging/frontier markets and the US market. Hence, our results indicate that uncertainty around the future movements on the US bond market might have explanatory power in driving co-movement dynamics in emerging/frontier bond markets.

This study has both important academic and practical implications. We provide new insights into the field of international bond market co-movement, given our evidence from the emerging/frontier markets perspective. In addition, we contribute a new dimension to the literature by providing the analysis of driving forces behind time-varying bond return co-movement, with special emphasis on macroeconomic factors and bond market uncertainty. Our co-movement analysis also has practical implications for investors and fund managers in terms of international diversification strategies. For instance, the low level of dynamic interaction of certain emerging/frontier markets with the US bond market, identified in our study, might help international investors select target countries with the greatest diversification potential.

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