2013

An investigation into the volatility and cointegration of emerging European stock markets

Anna Golab
Edith Cowan University

An Investigation Into The Volatility And Cointegration Of Emerging European Stock Markets.

By

Anna Golab

A thesis submitted in fulfilment of the requirements for the degree of Doctor of Philosophy

Edith Cowan University
Perth, Australia

March 2013
EDITH COWAN UNIVERISTY

USE OF THESIS

ABSTRACT

This dissertation examines the interaction between European Emerging markets, including cointegration, volatility, correlation and spillover effects. This study is also concerned with the process of the enlargement of the European Union and how this affects the emerging markets of newcomers. The twelve emerging markets studied are Bulgaria, the Czech Republic, Cyprus, Estonia, Hungry, Latvia, Lithuania, Malta, Poland, Romania, Slovakia and Slovenia, which are all progressing very rapidly in their reforms and domestic economic stability.

The majority of prior studies on stock market comovements and integration have concentrated on mature developed markets or the advanced emerging markets of the Czech Republic, Hungary and Poland whilst the behaviour and interrelationship of other Central and Eastern European equity markets has been neglected. This study fills that gap.

There are two key aspects investigated in this study. Firstly the cointegration between studied emerging markets and secondly the volatility and spillover effects.

The cointegration analysis examines the short and long run behaviour of the twelve emerging stock markets and assesses the impact of the EU on stock market linkages as revealed by the time series behaviour of their stock market indices. The adopted time-series framework incorporates the Johansen procedure, Granger Causality tests, Variance Decompositions and Impulse Response analyses. The cointegration results for both pre- and post- EU periods confirm the existence of long run relationships between markets. Granger Causality relationships are indentified among the most advanced emerging markets. The Variance Decomposition analyses find evidence of regional integration amongst the markets. Furthermore, the Impulse Response function illustrates that the shocks in returns for all twelve markets persist for very short time periods.

The volatility and spillover analysis applies several univariate models of Autoregressive Conditional Heteroscedasticity, including GARCH, GJR and EGARCH. The models used in the analysis of cross market effects include CCC, diagonal BEKK, VARMA GARCH and VARMA AGARCH. Overall, the econometric analysis using

these models shows stock market integration during the pre-EU period, however interdependence of the markets is established for the post-EU period. The results provide important information on the impact of the accession of new countries to the EU, with clear evidence of stability in Central and Eastern Europe markets and integration within the region.

This study has important implications for investors wishing to diversify across national markets, such as the implications of growing asset correlations, if they are displayed, and whether investors should diversify outside the Central and Eastern European countries. It could be argued that the former Eastern block economies constitute emerging markets which typically offer attractive risk adjusted returns for international investors. Moreover, stock market comovement is of considerable interest to policy makers from a perspective of the effects on the macroeconomy, the planning of monetary policy and impact of the degree of stock market comovements on the stability of international monetary policy.

DECLARATION

I certify that this thesis does not, to the best of my knowledge and belief:

(i) incorporate without acknowledgment any material previously submitted for a degree or diploma in any institution of higher education.

(ii) contain any material previously published or written by another person except where due reference is made in the text; or

(iii) contain any defamatory material.

I also grant permission for the Library at Edith Cowan University to make duplicate copies of my thesis as required.

Signature:

Date: 4th March 2013

ACKNOWLEDGEMENTS

Firstly I would like to thank Professor Dave Allen for his motivation and guidance in the topic I have chosen; for his invaluable assistance and great support in his role as my supervisor. I am also grateful to him for giving me several opportunities to participate in a number of international conferences; which broadened my knowledge and built my confidence as a young researcher.

I would also like to thank Associate Professor Robert Powell for his invaluable guidance and very helpful comments and suggestion as my associated supervisor, and also for his patience and attention to detail in editing a number of versions of my thesis.

I would like to express my gratitude to Dr Ghialy Yap, my secondary Associate Supervisor, for her emotional support, friendship and guidance through the econometric analysis.

My thanks also go to Associate Professor Zhaoyong Zhang and Dr Lee Lim for their review of the proposal. I found their comments and suggestions very helpful and these improved the structure and methodology of my research.

I wish to thank all my colleagues and ECU staff members. Special thanks go to Mark Waring for his support, friendship and motivation which helped me complete my study; to Bev Lurie who always had time to listen, help and assist on a number of occasions, handling several study and scholarship issues; and to Sue Stenmark who was very helpful in dealing with my conference travelling expenses and overall support.

Special thanks go to my husband and children for their unconditional love, tolerance, understanding and support during my study; and to my parent for their strong belief in me and "over the ocean" support.

Finally, I acknowledge the support of the many other people who willingly participated in the study and without whom this thesis would have been impossible..

TABLE OF CONTENTS

List of Tables

List of Figures

LIST OF ABBREVIATIONS

ADF	*Augmented Dickey-Fuller test*
AIC	*Akaike Information Selection Criteria*
ARCH	*Autoregressive Conditional Heteroscedasticity*
ARMA	*Autoregressive Moving Average*
BEKK	*Baba-Engle-Kraft-Kroner model*
CCC	*Constant Conditional Correlation model*
CEE (countries)	*Central and Eastern European (countries)*
ECB	*European Central Bank*
ECM	*Error Correction Model*
ECSC	*European Coal and Steel Community*
ECT	*Error Correction Term*
EGARCH	*Exponential GARCH*
EMU	*European Monetary Union*
ERM	*The Exchange Rate Mechanism*
EU	*European Union*
FDI	*Foreign Direct Investment*
FEVD	*Forecast Variance Error Decomposition*
FT index	*Fiancial Times index*
FTSE	*Financial Times Stock Exchange*
GARCH	*Generalised Autoregressive Conditional Heteroscedasticity*
GJR	*Asymmetric GARCH (Glosten, Jagannathan and Runkle model)*
IMF	*International Monetary Fund*
IR	*Impulse Response*
MSCI	*Morgan Stanley Capital International*
NATO	*North Atlantic Treaty Organization*
OECD	*Organization for Economic Cooperation and Development*
OLS	*Ordinary Least Squares*
PP	*Phillips – Perron test*
QMLE	*Quasi-Maximum Likelihood Estimator*
SBC	*Schwarz Bayesian Selection Criteria*
UN	*United Nations*
UNESCO	*United Nations Educational, Scientific, and Cultural*

	Organization
VaR	*Value – at – risk*
VARMA- AGARCH	*Vector ARMA-AGARCH*
VARMA-GARCH	*Vector ARMA-GARCH*
VECM	*Vector Error Correction Model*
WTO	*World Trade Organisation*

Chapter 1: Introduction

This thesis deals with interactions between European Emerging markets, investigating aspects such as cointegration and volatility, correlations and spillovers. This chapter provides an introduction to this topic, including background on the inclusion of these emerging markets into the European Union, the research objectives and questions, the benefits of the study, and an outline of the structure of the thesis.

1.1 Background

The vision of a united Europe began to take form as far back as the eighteenth century. After the American War of Independence (1775-1783) the idea of the United States of Europe was shared by several proponents, particularly George Washington, Marquis de Lafayette, Immanuel Kant and Tadeusz Kosciuszko (Kant, 1795; Rodrigues and Baldwin, 1918; Fabre, 1886; Suo 2012). In 1849 in Paris Victor Hugo during his speech at the International Peace Congress used the term "United Sates of Europe", saying "A day will come when all nations on our continent will form a European brotherhood... A day will come when we shall see... the United States of America and the United States of Europe face to face, reaching out for each other across the seas" (Gilpin, 1849). However, historical events including the First and Second World Wars and the subsequent beginnings of communism and totalitarianism eras across the whole of Europe shattered the vision. The European Union idea came to life after World War II when a European Coal and Steel Community (ECSC) was established by Belgium, France, Germany, Italy, Luxemburg and the Netherlands (May, 1950). Since then another 21 countries joined EU. In 1973 Denmark, Ireland and the United Kingdom formally became members of the Union, in 1981 – Greece, in 1986 – Spain and Portugal, in 1995 Austria, Finland and Sweden, in 2004 the Czech Republic, Cyprus, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia and Slovenia, and finally in 2007 Bulgaria and Romania.

After World War II and the beginning of EU, the member states became a huge influence on the entire Europe. The EU influenced Germany to merge their two halves, known in history as the fall of the Berlin Wall (1989). This and several other characteristic events, such as Velvet Revolution, Solidarity movement or fall of Iron

Curtin (which are described in Chapter 2), pressed the Soviet Union to crumble in 1991. From that day the Central and Eastern European (CEE) countries were free to make their own decisions about the future. Many European countries decided that the future lay within the family of democratic European nations. Currently the EU is a union of 27 countries and the enlargement process continues to this day. Full details of these countries and the enlargements' process are provided in the next Chapter.

Although the EU was created to achieve the political goal of peace, its dynamism and success also springs from its involvement in economics, as the EU became a major world trading partner. The EU is also focusing on its investment policies to provide investors and investments with legal certainty and a stable, predictable, fair and properly regulated environment in which to conduct their business, in line with existing international rules. As a member of the World Trade Organisation (WTO), the EU supports the rule-based system. This system provides a degree of legal certainty and transparency in the conduct of international trade. The WTO sets conditions under which its members can defend themselves against unfair exporting and importing practices. Moreover, the EU considers Foreign Direct Investment (FDI) as a key means to promote economic development and social growth. The current phase of globalisation has noticed a dramatic increase in FDI. FDI represents one of the most important instruments through which a national economy can encourage production, know-how imports, increase in employment, infrastructure development and poverty reduction. The benefits achieved through the increase in FDI have created strong competition in the global market of free capital, with market participants seeking to attract as many and as diverse FDI as possible. International rules on FDI contribute to improving the business climate by increasing legal certainty for investors and by reducing the perceived risk of investment. In this respect, the interdependence and complementarities between trade and FDI is widely recognised. The general trend in the global FDI market is the removal of geographic borders between developing countries and developed ones. In the past few years, those developing markets have not only represented a growing FDI market, but have also been aimed at attracting capital intensive investments.

The phenomenon of emerging markets has been discussed by several authors, such as Sidaway and Pryke (2000), Fratzscher (2002), Phengpis, Apilado and Swanson (2004), Harrison and Moore (2009), Shanahan and O'Keefe (2010), Swedroe (2010). As emerging markets have attracted significant attention from investors and policy makers, they are becoming an increasingly important political and economic force. Those markets represent an enormous opportunity for entrepreneurs, multinationals and investors but also pose a threat for products, jobs and resources. They have the potential to redefine the way business is done, but still remain shrouded by myths and disbelievers in the power of small markets. After the downfall of communism, European markets have opened to foreign investors, thus attracting much needed foreign capital for economic development. There are several other reasons contributing to this increased investment and can be summarised as follows (based on above publications and ECB Statistics Pocket Book 2012):

- Emerging economies are expected to grow three to four times faster than developed markets;
- Emerging market economies are much tighter with their spending than developed economies (fiscal balances are smaller and as a result, they have manageable debt loads). Due to this fact the credit ratings of many emerging market have improved in the last few years;
- The diversification the emerging markets provide is a great benefit for investors;
- Emerging markets financial players, pension funds and insurance companies attract large buyers.

1.2 Research objectives

This dissertation investigates interactions between the Eastern European block countries and applies time-series analysis to examine the relationship between stock market index returns, cointegration and volatility.

The objectives of the study stem from the enlargements of the EU. The study focuses on the latest and largest enlargement in the history of the EU where ten, and subsequently another two countries, have been accepted. All prior research has been limited mainly to the four CEE emerging markets of the Czech Republic, Hungary, Poland and Slovakia with the addition of one of the European developed markets of Germany, France or UK. This dissertation expands this analysis to the twelve new member states of the growing EU.

The aim of this study is to ascertain the inter-relationships between those twelve emerging markets without including any developed market in the analysis. This is due the fact that most of those markets are relatively small and any bigger one can influence the overall outcome, not clearly showing cointegration and volatility relationships between the twelve. Integration of the European markets is very important due to the growing economies of America and Asia. To be competitive, the small European markets see a number of advantages linked to the expansion and creation of one EU with the same regulations, trade policy, laws and currency. Economic advantages include elimination of the currency exchange fees from the cost of doing business between the European states, efficient price comparison and stimulation of economic growth through one currency policy which encourages stability and efficiency, and the fact that international investors will likely diversify their portfolios with euro, encouraging more investment in Europe.

These interdependencies are examined by testing cointegration, volatility and spillover effects across markets to answer questions concerning issues of financial integration between emerging markets. Further discussion on results shows variations between more and less developed countries, the dynamics and comparison between the pre- and the post- EU time periods, the examination of the euro currency influence, and differences in the speed of change of the twelve emerging markets, as some of the countries are progressing more rapidly and adjusting more quickly to the new European position than others.

1.3 Research questions

Particularly, this study attempts to find answers to the following questions:

a) Cointegration analysis

- Does a long run relationship exist in the European markets?
- How do the cointegration findings differ between the pre- and post-EU periods?
- What is the speed of adjustment of the CEE markets from pre- to post-EU periods?

- How significant is the Granger causality effect for the twelve emerging markets?
- Is there regional interdependence between the twelve markets?

b) Volatility and spillover effects analysis

- What is the relationship between stock market index return volatility for the CEE markets?
- How are the various GARCH specifications applicable to modelling volatility for the studied European emerging markets?
- How do the volatility findings differ between pre- and post-EU periods?
- Do spillover effects exist between the twelve CEE countries?
- How do the spillover results differ between pre- and post-EU periods?

All the research questions are used to form hypotheses to be tested in this dissertation. Those hypotheses can be found in the Chapter 3: Empirical Data (from H_1 to H_4), Chapter 4: Cointegration (from H_5 to H_8) and Chapter 5: Volatility and Spillovers (from H_9 to H_{11}).

1.4 Significance of the Study

This study concentrates on the twelve emerging markets, which are part of the EU's largest enlargement ever. The countries concerned are: Bulgaria, the Czech Republic, Cyprus, Estonia, Hungry, Latvia, Lithuania, Malta, Poland, Romania, Slovakia and Slovenia. These CEE countries have been in process of liberalization from the communist regime at the end of the 1980s through to the beginning of the 1990s. During this time the CEE countries have established functioning stock markets as part of the transaction process. Throughout the process of preparing for admission to EU these equity markets have been modelled along similar paths of joining procedures to those in developed market economies.

This dissertation is a valuable source of information for investors and researchers, as such information is vital in setting up guiding principles for investment and portfolio selection. It is important for investors to know how EU emerging markets perform and influence each other and to understand trends in each of the countries' markets in order to make informed investment decisions. In addition, potential investors may use this knowledge to minimise risks when planning their investment portfolio. This dissertation is also a good source of information for researchers, as the results that emerge from this study will form a platform for debates on this subject by providing researchers with answers on how the small emerging markets behave as new members of the EU, how the countries have progressed and how they are cointegrated with each other. The research will provide some answers on the debate on the importance of the EU in world financial markets.

This research further contributes to empirical literature on economic and financial activity and stock market growth in CEE countries. This thesis appears to be the pioneering work in such a wide field of study, as there is no existing work which investigates all twelve of the emerging EU countries. The reason for this is that the past studies on stock market volatility, cointegration and comovements have concentrated mainly on mature developed markets or advanced emerging markets such as the Czech Republic, Hungary and Poland whilst the behaviour and inter-relationship of all others has been neglected. Of these, the Czech Republic has the most developed and industrialized economy in the CEE. The aim of this research is to relate the remaining nine emerging markets of the EU to the above three, with the Czech Republic being the primary reference point.

Moreover, the literature analysis shows evidence of a lack of extensive analysis of pre- and post-EU stock market index returns, and of influences of the expansion of the euro zone on these markets and the interaction between them. Little attention is given to the investment potential in CEE equity markets only. Thus the literature lacks a model which analyses the interaction and integration of these markets at a regional and global level. This thesis fills that gap.

1.5 Publications and Conferences

Three working papers have been produced from this study and submitted to various international journals for publication.

- “Volatility and correlation for stock markets in the emerging economies of Central and Eastern Europe: implications for European investors” by D. Allen, A. Golab and R. Powell; SAFE & FEMARC Working Paper Series, July 2010, published on SSRN website; sent to Journal of Emerging Market Finance.
- "The Comovements of Emerging Stocks Markets of CEE: Impact of EU Enlargement" by D. Allen, A. Golab, R. Powell and G. Yap; published in FIBAC Congress proceedings; sent to Emerging Markets Finance & Trade Journal
- “Volatility and Spillover effects of Central and Eastern Europe: Impact of EU. Enlargement" by D. Allen, A. Golab, R. Powell and G. Yap; accepted by “Emerging Markets and Global Economy: A Handbook”, Elsevier, Academic Press.

The following papers have been presented at various international and local conferences:

- “Openness and Growth Lessons for Transition and Development” - summer academy Akademie fur Politische Bilding Tutzing, Munich, Germany, 14-16 July 2010
- FIRN Doctoral tutorial and workshop, Melbourne, 28-30 September 2010
- FIBAC conference, Antalya, Turkey, 18-22 April 2012
- Workshop on New Developments in Empirical Finance, SAFE ECU, 26 July 2012

1.6 Organisation of the Study

This dissertation is divided into six chapters. Following this introductory chapter, chapter two gives an overview of the EU and describes the twelve countries’ EU incorporation history and their markets. Chapter three describes data used, including descriptive statistics on the twelve stock market indices, and provides stationarity and non normality and correlation tests, in order to provide greater insight into the data. In chapter four the cointegration analysis is presented and findings summarised. This is followed by the volatility and spillover effects study in chapter five. Finally, chapter six concludes the dissertation.

Chapter 2: European Union

As an important feature of the markets analysed in this thesis is that they all form part of the European Union, this chapter provides a brief description of the European Union, including its background, formation, structure, importance of creation of the single market and currency. In the second part of the chapter all twelve markets are introduced, together with their historical background and economy outline.

2.1 Introduction

The EU is a unique economic and political partnership between 27 democratic European countries (see Figure 2.1). All the 27 member countries follow a common policy for carrying out their domestic and international trade; however the EU primary objective is to create regional economic and political integration, and has thereby developed a single market ensuring by law the freedom of movement of people, goods, services and capital (called Schengen area).

The EU has developed a limited role in foreign policy, having representation at the WTO (where, the EU plays a crucial role in the decision-making process), G8 summits and United Nations (UN). A common currency has been adopted by 17 member states of the EU creating the Euro zone (see Figure 2.2).

The EU was created in 1949[1] from Western European nations[2] and was called the Council of Europe. This was the first step towards cooperation between European countries, which were very determined to stop all the destruction and killing brought about by the Second World War. On 18th April 1951the six countries, namely: Germany, France, Italy, Belgium, Netherlands and Luxemburg, signed the Schuman plan – a treaty to run their heavy industry of coal and steel under a common management (ECSC), to prevent weapon making and turning against each other.

[1] All historical details obtained from Ruszkowski, Gornicz & Zurek, "Lexicon of European Integration", PWN, 2004

[2] After the Second World War Europe was split into East and West as the 40 year long Cold War began.

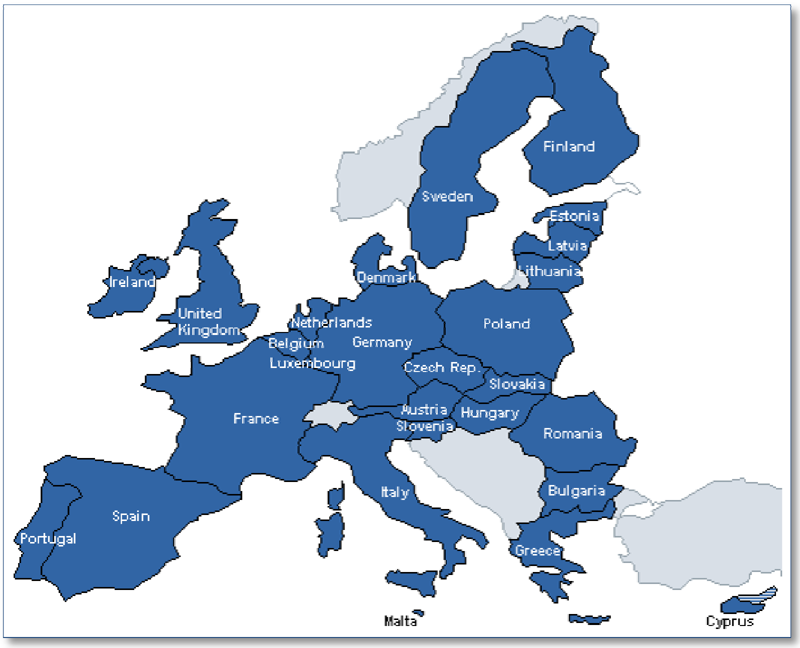


Figure 2.1: The European Union Member States (source: http://fra.europa.eu).

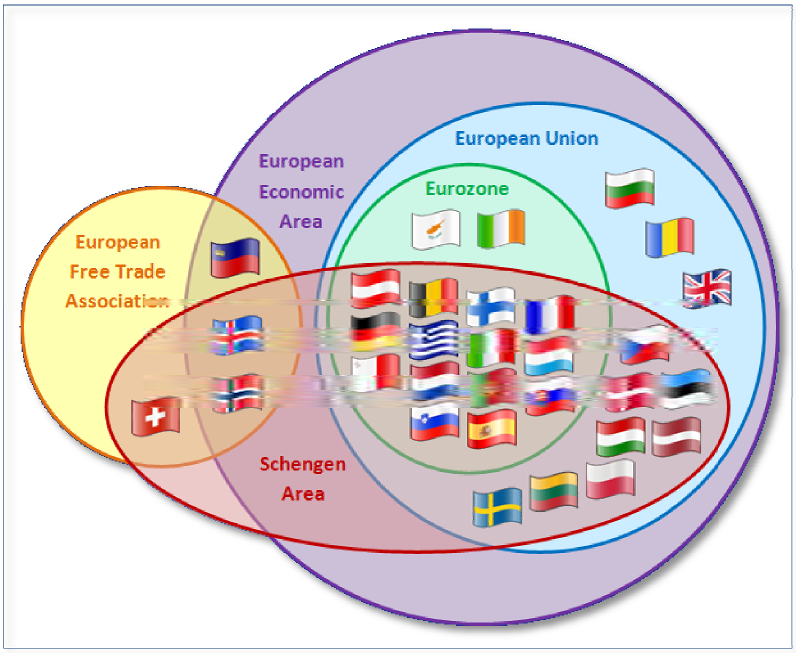


Figure 2.2: Venn diagram showing the relationships between various supranational European organizations: Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Island, Latvia, Lithuania, Lichtenstein, Luxemburg, Malta, Nederland, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, UK; (source: http://en.eurorelocation.net, December 2010; since then Estonia joined the Euro zone on 1st January 2011).

Since then the EU has been through seven enlargements, which are illustrated in Figure 2.3. The last two enlargements took place on the 1st May 2004 and comprised the Czech Republic, Cyprus, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia and Slovenia, and then on the 1st January 2007: Bulgaria and Romania. The 2004 expansion was the largest in the EU history. For the first time the EU was expanded by 10 countries, whereas the previous numbers were usually no more than three. Moreover the expansion happened on 1st May and not on 1st January as in the past. Some authors argue that the reason for this was simple – healing the division in Europe. Those twelve above named countries are the subject of the econometric analysis of this thesis.

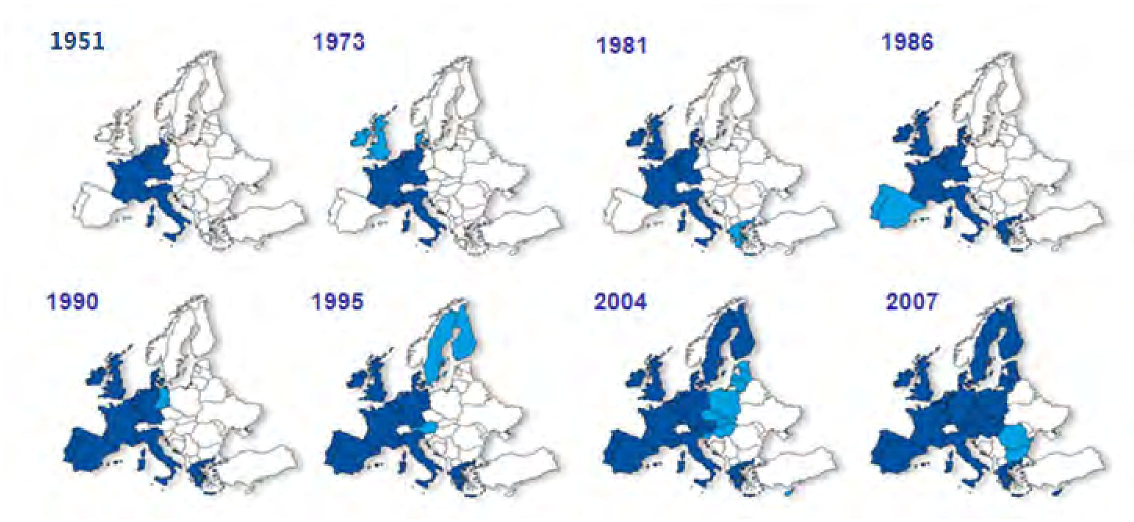


Figure 2.3: The Eight Enlargements: 1951: Germany, France, Italy, Belgium, Netherlands and Luxemburg; 1973 Denmark, Ireland and United Kingdom; 1981: Greece; 1986: Spain and Portugal; 1995: Austria, Finland and Sweden; 2004: the Czech Republic, Cyprus, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia and Slovenia; 2007 Bulgaria and Romania (source: http://fra.europa.eu).

Any European country can join the union, provided it has a stable democracy that guarantees the rule of law, human rights and the protection of minorities, and it must also have a functioning market economy and a civil service capable of applying EU laws in practice. Therefore there is always a long pre-accession period before a country can officially become a member of the EU. With the example of the twelve, the (historical) process was as follows: in 1989 we observed the fall of the Berlin Wall, which historians called the end of Communism, and this was the time when the EU economic help began. Three years later, in 1992, criteria were set for a country who wished to join the EU. Those criteria included democracy and rule of law, a functioning market economy and the ability to implement EU laws. In 1998 formal negotiations on enlargement began and finally, the 2002 Copenhagen summit agreed on enlargement. As a consequence the two already mentioned enlargements took place.

2.2 Frontier markets

The proposed empirical analysis in this thesis is important to highlight the differences between more developed emerging markets and frontier markets. All of the discussed frontier markets follow and accept EU laws and regulation in order to be able to obtain emerging market status in the near future (see Table 2.1). According to the FTSE group, the Czech Republic, Hungary and Poland are regarded as Advanced Emerging Markets. Of these, the Czech Republic has the most developed and industrialized economy in CEE.

The aim of this research is to relate the remaining nine emerging markets of the EU to the above three, with the Czech Republic being the primary reference point. This dissertation explores a number of important aspects of portfolio selection and investment opportunities and their implications for CEE based investors through cointegration analysis of these markets pre- and post- EU expansion. This paper specifically deals with inter-relationships between our twelve emerging markets.

The term *"emerging markets"* is used to describe a nation's social or business activity in the process of rapid growth and industrialisation. Currently, there are approximately 30 emerging markets in the world, in which the Czech Republic, Hungary and Poland are listed as the advanced emerging markets. The other seven EU member states to be studied are recognised as the frontier markets and two, namely Latvia and Malta are not defined. The term *"frontier markets"* is used to describe a subset of emerging markets. Frontier markets are investable but have lower market capitalisation and liquidity than the more developed emerging markets. The frontier equity markets are typically pursued by investors seeking high, long term returns and low correlations with other markets. Some countries (e.g. Estonia), countries of relatively high development levels, are too small to be considered as an emerging market.

Table 2.1: Emerging and Frontier Markets of the CEE markets

EU Members	EMU	Schengen Area	Emerging Markets		Frontier Markets	
			FTSE[1]	MSCI[2]	FTSE[1]	MSCI[2]
Bulgaria					✓	✓
Czech Rep		✓	✓*	✓		
Cyprus	✓				✓	
Estonia	✓	✓			✓	✓
Hungary		✓	✓*	✓		
Latvia		✓				
Lithuania		✓			✓	✓
Malta	✓	✓				
Poland		✓	✓*	✓		
Romania					✓	✓
Slovakia	✓	✓			✓	
Slovenia	✓	✓			✓	✓

EMU – European Monetary Union; Schengen Area - represents a territory where the free movement of people, goods, services and capital; ([1]) Source: www.ftse.com; ([2]) Source: www.msci.com; (*) those markets are defined as advanced emerging markets.

2.3 Single market

The single market is one of the EU's greatest achievements. Restrictions on trade and free competition between member countries have gradually been eliminated, thus helping standards of living to rise. Unfortunately the single market has not yet become a single economy, as some sectors are still subject to national laws. This is because there is an existence on number of barriers: physical, technical, tax and public contracts; which every single country needs to face and deal with. Over the years the EU has introduced a number of policies to help ensure that as many businesses and consumers as possible benefit from opening up the single market. This is very important to achieve a goal of single market by EU members, as freedom to provide services is beneficial, as it stimulates economic activities.

EU countries account for an ever smaller percentage of the world's population (see Figure 2.4). They must therefore continue pulling together if they are to ensure economic growth and be able to compete on the world stage with other major economies. No individual EU country is strong enough to go it alone in world trade. Therefore countries switch to the single market, which provides companies with a fundamental platform for competing effectively on world markets. The single market is the EU's main economic engine, enabling most goods, services, money and people to move freely. Another key objective is to develop this huge resource to ensure that Europeans can draw the maximum benefit.

The creation of the single market and the corresponding increase in trade and general economic activity transformed the EU into a major trading power. The EU is trying to sustain economic growth by investing in transport, energy and research, while also seeking to minimise the environmental impact of further economic development.

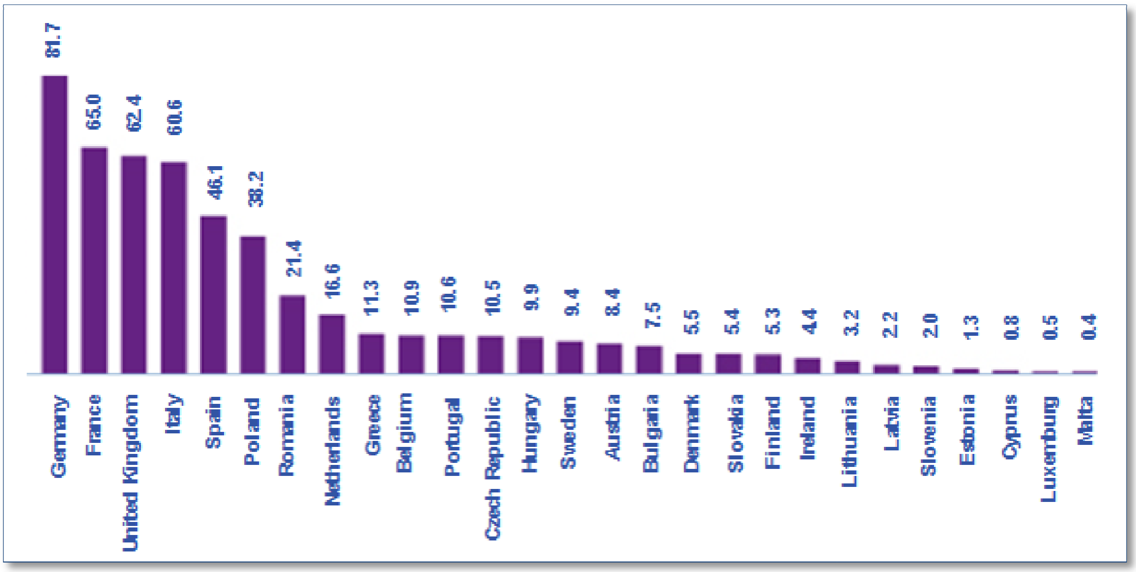


Figure 2.4: Population in millions of the 27 EU country members as at December 2011, 502 millions in total (source: http://fra.europa.eu).

2.4 Single currency

All the EU countries will be expected to join the European Monetary Union (EMU) in the more or less distant future. A single currency policy has been formally adopted by the Treaty of the EU of 1992. The EMU designates the zone of countries within the EU which share the same monetary policy and currency – the euro – and currently there are 17 EU members in the EMU zone (Figure 2.5).

The euro is designed to help build a single market by easing travel of citizens and goods, eliminating exchange rate problems, providing price transparency, creating a single financial market, price stability and low interest rates, and providing a currency used internationally and protected against shocks by the large amount of internal trade within the euro zone. The euro and the monetary policies of those countries, who have adopted a single currency agreement with the EU, are under the control of the European Central Bank (ECB). The ECB is the one of the world's most important central banks (Oreziak, 2004). The role of the ECB seems to be simple by definition - manages the euro and safeguards price stability, as illustrated in Figure 2.6. The main purpose of the ECB is to keep prices (hence inflation) under control and the financial system stable (Scheller, 2006). Moreover, the euro has become a major reserve currency, alongside the US dollar. During the 2008 financial crisis, having a common currency protected euro zone countries from competitive devaluation and from attack by speculators.

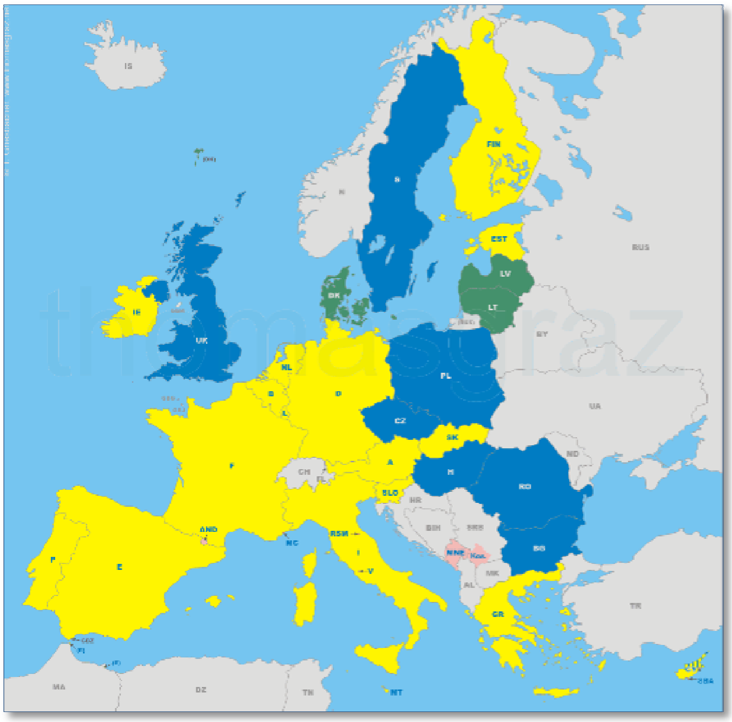


Figure 2.5: Euro zone map (○ European countries using the euro: Euro zone, ● European countries not using the euro: non-ERM[3] II countries, ● European countries not using the euro: ERM II countries, ○ non-EU member but areas using the euro) source: http://www.thomasgraz.net.

[3] ERM – The Exchange Rate Mechanism

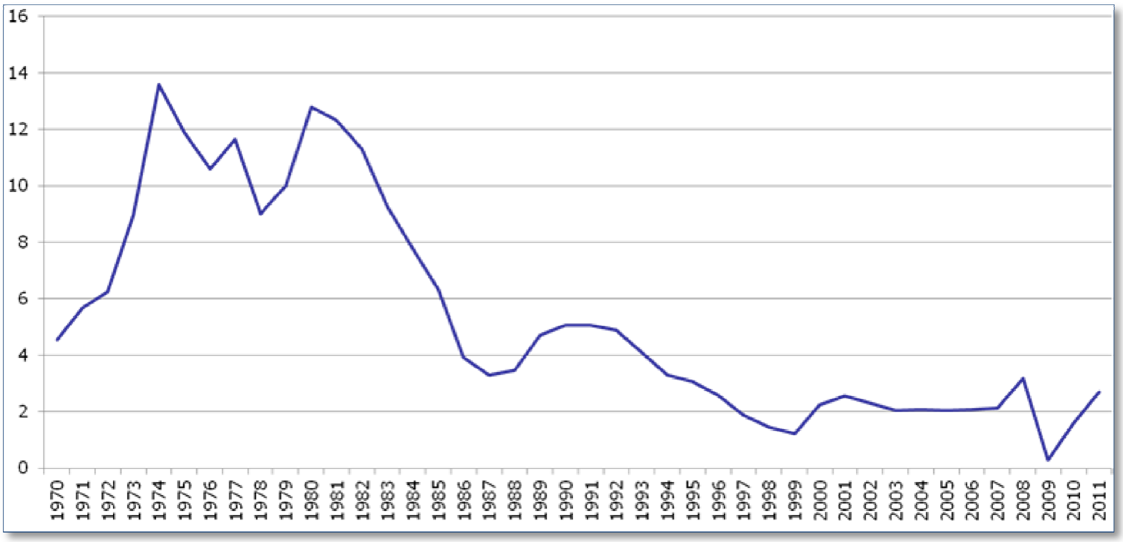


Figure 2.6: Average annual inflation on the 17-EU countries that uses the euro in 2012 (source: http://fra.europa.eu).

2.5 Regional policy

The regional policy of the EU has the stated aim of improving the economic wellbeing of certain regions in the EU. The most significant enlargement took place in May 2004, followed by accession of Bulgaria and Romania in January 2007. Most of these countries are poorer than the existing members and the impact of this means that the EU's average GDP per capita has been reduced (see Figure 2.7).

2.6 Emerging markets chronicle

Since its origin, the EU has established a single economic market across the territory of all its members. Considered as a single economy, the EU generates a GDP of €12,629 trillion (in 2011) according to the IMF[4] (see Figure 2.8). It is also the largest exporter of goods, the second largest importer and the biggest trading partner to several large countries such as India and China. The principal characteristics of the studied CEE markets are given in Table 2.2 and they mostly relate to the size of the country, its GDP and membership of several world organizations.

[4] IMF –International Monetary Fund

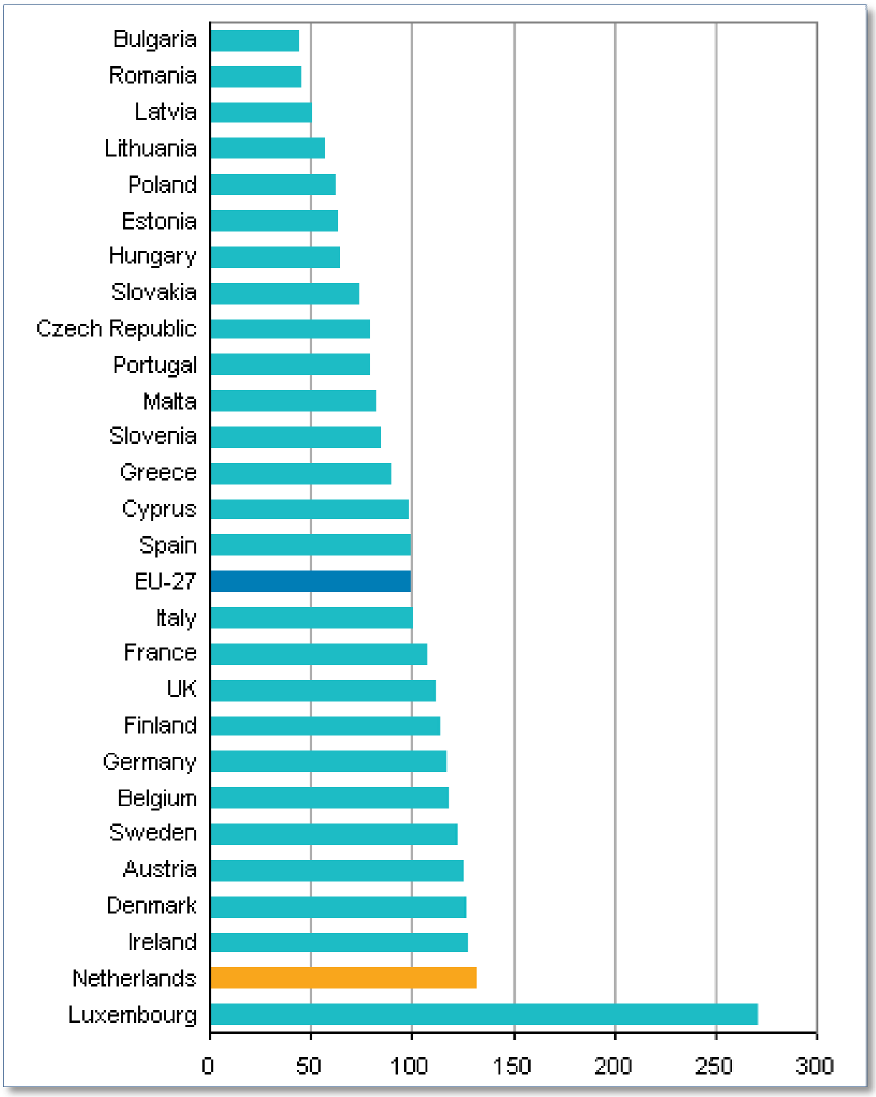
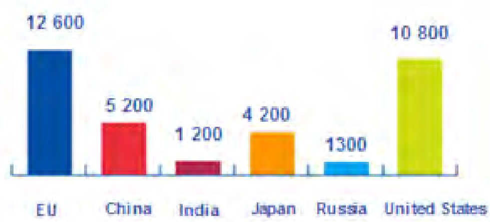


Figure 2.7: Volume index of per capita GDP, 2010 (Gasic & Kurkowiak, 2012).

a) 

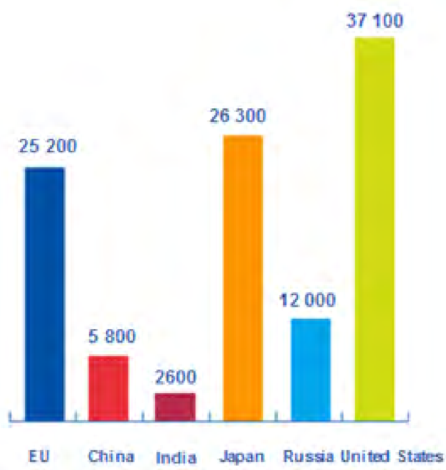
b) 

Figure 2.8: a) Size of economy: 2011 GDP in trillion of euro currency, b) Wealth per person: 2011 GDP per person (source: http://fra.europa.eu).

Table 2.2: Main characteristics of the CEE countries.

Country	Capital City	Total area (km^2)	Population (million)	GDP (per capita)		Currency	Monetary Union	Member of				
				PPP	nominal			NATO	WTO	OECD	UN	UNESCO
Bulgaria	Sofia	110,994	7.364	$13,789	$7,308	Lev (BGN)	*	✓	✓		✓	✓
Czech Rep	Prague	78,866	10.512	$27,165	$18,337	Koruna (CZK)	*	✓	✓	✓	✓	✓
Cyprus	Nicosia	9,251	1.099	$29,074	$30,570	Euro (EUR)	1 Jan 2008		✓		✓	✓
Estonia	Tallinn	45,227	1.340	$21,059	$16,636	Euro (EUR)	1 Jan 2011	✓	✓	✓	✓	✓
Hungary	Budapest	93,030	9.942	$19,891	$13,045	Forint (HUN)	*	✓	✓	✓	✓	✓
Latvia	Riga	64,589	2.217	$18,140	$13,316	Lats (LVL)	*	✓	✓		✓	✓
Lithuania	Vilnius	65,300	2.986	$20,088	$13,068	Litas (LTL)	*	✓			✓	✓
Malta	Valletta	316	0.452	$25,428	$21,028	Euro (EUR)	1 Jan2008		✓		✓	✓
Poland	Warsaw	312,685	38.186	$20,334	$13,540	Zloty (PLN)	*	✓	✓	✓	✓	✓
Romania	Bucharest	238,391	19.043	$12,838	$8,029	Leu (RON)	*	✓	✓		✓	✓
Slovakia	Bratislava	49,035	5.445	$24,284	$16,726	Euro (EUR)	1 Jan 2009	✓	✓	✓	✓	✓
Slovenia	Ljubljana	20,273	2.055	$28,648	$22,461	Euro (EUR)	1 Jan 2007	✓	✓	✓	✓	✓

Source: World Economic Outlook Database, April 2012
All EU members are legally obliged to join the euro zone. Latvia and Lithuania members have acceded to ERM II, in which they must spend two years, before they can adopt the euro. The obligated members who must first join ERM II before they can adopt the euro are: Bulgaria, the Czech Republic, Hungary, Poland and Romania; *Expected entry dates are: Bulgaria: 2014, the Czech Republic: 2017, Hungary: 2014, Latvia: 2014, Lithuania: 2014, Poland: 2015, Romania: 2015; NATO – North Atlantic Treaty Organization; WTO – World Trade Organization; OECD – Organization for Economic Cooperation and Development; UN – United Nations; UNESCO – United Nations Educational, Scientific, and Cultural Organization.

2.6.1 Bulgaria

Bulgaria is located in the heart of the Balkans, in south east Europe, and is bordered by Romania, the Black Sea, Serbia, Republic of Macedonia, Greece and Turkey.

Bulgaria's history dates back to the early 7^{th} century. In its history the country was under the power of the Byzantine Empire, Mongol invasion and the Ottoman Empire. Bulgaria participated in the First and Second World Wars. After World War II, as with many other countries, Bulgaria became a communist state. In 1990 the regime broke and the country started its transmission to democracy and free market capitalism.

Bulgaria's economy is defined as a free market economy and is a mixture of a large, advanced private sector and state owned enterprises. After a history of ups and downs in the economy, in recent years Bulgaria has experienced rapid economic growth, which is driven by significant amounts of bank lending, consumption and foreign direct investment. The economy primarily relies on industry and agriculture. Bulgaria's main exports are light industrial products and food and wines, which are successfully competing in European markets. Therefore the main export commodities are footwear, iron and steel, machinery and equipment. The country imports machinery and equipment; metals and ores; chemicals and plastics; fuels, minerals, and raw materials. Main trading partners are Russia, Germany, Romania, Italy, Greece and Turkey.

2.6.2 Czech Republic

The Czech Republic is a landlocked country in Central Europe and is bordered by Poland, Germany, Austria and the Slovak Republic.

For several decades the Czech lands fell under Habsburg rule and later become part of the Austrian Empire; then in 1918, the independent Republic of Czechoslovakia was formed, after World War I. Subsequently the country fell under German regime and further under the Soviet Union. Before World War II Czechoslovakia was one if the few states in the world, and the only in central Europe, which remained a democracy until 1938 – the time when communism took over. In 1989 the communist regime collapsed after the Velvet Revolution. The Czech Republic became an independent state in January 1993 after Czechoslovakia split into its two constituent parts.

The Czech Republic has one of the most developed and industrialised economies in Central and Eastern Europe. The country has an export-driven economy, which remains sensitive to changes in the economic performance of its main export market - Germany. The other trading partners include Slovakia, Poland, France, Austria, the UK and Russia as well as the US and China. Mostly they trade motor vehicles, machinery, iron, steel, chemicals, raw materials, and consumer goods. The motor vehicles industry remains the largest single industry, and, together with its upstream suppliers, accounts for nearly 24% of Czech manufacturing, of which over 80% is exported. Next to the production of automobiles, other industrial areas include engineering products, cement, sheet glass and ceramics, wood, paper products, and footwear. The chief crops are maize, sugar, beet, potatoes, wheat, barley and rye.

2.6.3 Cyprus

Cyprus is an island in the eastern Mediterranean, situated south of Turkey; the country is a former British colony, which became independent in 1960.

Cyprus has an open, free-market, services-based economy with some light manufacturing and it is claimed that the country has one of the most advanced economies in the region. The island's main economic activities are: tourism, clothing and craft (which includes embroidery, pottery and copper work), exports and merchant shipping – where, tourism, financial services and real estate are the most important sectors. For the Cypriot economy trade is very important, with most exports, such as consumer goods, petroleum and lubricants, machinery, transport equipment being imported mainly from Greece, Israel, UK, Italy and Germany; its export trading partners are Greece and Germany.

2.6.4 Estonia

Estonia is the most northerly of the Baltic countries, and is bordered with the Baltic Sea, the Gulf of Finland, Russia and Latvia.

The Estonians were an independent nation until the 13th century A.D., when the country was subsequently conquered by Denmark, Germany, Poland, Sweden, and Russia. During World War I the Russian empire collapsed and Estonia regained her independence. Estonia's independence lasted for only 22 years, until World War II. During the War Estonia was occupied by the Soviet Union, then the Third Reich, and was then again under the Soviet Union regime. Estonia regained its independence on 20 August 1991. Today the country has gained recognition for its economic freedom, its adoption of new technologies and is one of the world's fastest growing economies.

Estonia is considered one of the most liberal economies in the world, ranking 14th in the Heritage Foundation's 2011 Economic Freedom Index. Its 2011 score was 0.5 points higher than in 2010 due to significant improvements in Estonia's liberal economic monetary and labour policies and macroeconomic stability. These reforms have fostered exceptionally strong growth and better living standards than those of most new EU member states.

Driven by liberal economic policies and fiscal discipline, the Estonian economy grew quickly, at an average annual rate of 8% from 2000 to 2007. The economy is mostly driven by engineering, food products, metals, chemicals and wood products. Estonia has several natural resources, such as oil shale, phosphorus, limestone, and blue clay. Estonia is a net exporter of electricity, using locally mined oil shale to fire its power plants and trades with Finland, Sweden, Russia, Germany, Latvia and Lithuania. However, it imports all of its natural gas from Russia. Alternative energy sources are wind and biomass. An undersea electricity cable allows Estonia to trade electricity with Finland. Other import trading partners are Norway, Netherlands, Russia, the US and Cyprus.

2.6.5 Hungary

Hungary is a landlocked state in Central Europe, which is bordered by Slovakia, the Ukraine, Romania, Serbia, Croatia, Slovenia and Austria.

The foundations of Hungary were laid in the late 9th Century (1000). The country remained independent for several hundred years. During World War I, two-thirds of its territory was lost under the Treaty of Trianon, and shortly thereafter had four decades of communism. Hungary regained its independence after the collapse of the Eastern Block.

Today Hungary is a high income economy, and in the last decade was listed as the 10th most economically dynamic area (source: ECB statistical database). Hungary has made the transition from a centrally planned to a market economy. The private sector accounts for more than 80% of GDP and foreign ownership of and investment in Hungarian firms is widespread. The economy is an export based one, particularly to Germany. Other major markets are Austria, Italy, France, the U.K., Romania and Poland. Hungary's main manufactured exports include machinery and equipment, food products, raw materials, fuels and electricity. Imports mainly relate to machinery and equipment and other manufactured goods. The major EU suppliers are Germany, Austria, Slovakia, Russia and China.

2.6.6 Latvia

Latvia is located in the north of Europe. It is bordered by Estonia, Lithuania, the Russian Federation, Belarus and the Baltic Sea.

By the 10th century, the area that is today Latvia was inhabited by several Baltic tribes who had formed the ethnic core of the Latvian people. Subsequently the region came under the control of Germans, Poles, Swedes, and finally, Russians. Latvia declare its independence in 1918, but World War II and the German-Soviet Nonaggression Pact of 1939 steadily pushed Latvia under Soviet influence, culminating in Latvia's annexation by the Soviet Union in 1940. The country re-established its independence in 1991 following the fall of the Berlin Wall and breakup of the Soviet Union.

Latvia is a small, open economy with exports contributing significantly to its growth. Due to its geographical location, transit services are highly developed, along with timber and wood-processing, agriculture and food products, and manufacturing of machinery and electronic devices. Major sectors of the country's economy are retail and wholesale trade, real estate, renting and business activities, manufacturing, transport, storage and communication. Export growth contributed to the economic strength; however the bulk of the country's economic activity in the services sector cannot be omitted. Latvia's trading partners are Russia, Lithuania, Estonia, Poland, Germany, Sweden and Finland. The country exports food products, wood and wood products, metals, machinery and equipment, and textiles; at the same time importing machinery and equipment, consumer goods, chemicals, fuels and vehicles.

2.6.7 Lithuania

Lithuania is a country in northern Europe. It borders the Baltic Sea, Latvia, Belarus, Poland and Russia (Kaliningrad Oblast).

During the 14th century the country was the largest in Europe. After regaining its independence at the end of World War I, it subsequently lost it again to the Soviet Union and then again to Germany during World War II. Finally, after the war, Lithuania was re-occupied by the Soviet Union, from which it broke free and restored its independence in 1990.

During the EU pre accession period, the Lithuanian economy underwent transformation and moved to a market economy. The process of privatisation and the development of new companies slowly moved Lithuania towards a free market economy. Lithuania has privatised nearly all formerly state-owned enterprises. Currently more than 79% of the economy's output is generated by the private sector. The country's natural resources are limestone, clay, sand, gravel, iron ore and granite. Major sectors of the Lithuanian economy are wholesale and retail trade, manufacturing, transport and communications. Most of Lithuania's trade is conducted within the EU (Germany, Poland, Latvia, Estonia and the Netherlands) and Russia in particular. The country exports and imports mostly mineral products, machinery and equipment, chemicals, textiles, foodstuffs, metals and plastics. Presently Lithuania has begun to unbundle its energy networks in order to reduce its dependence on Russian energy.

2.6.8 Malta

Malta is a group of seven islands in the Mediterranean Sea. From a location point of view, for decades Malta was a strategic island on the sea, and was therefore was under the power of the Phoenicians, Romans, Sicilians, French and finally the British (1814). In 1964 Malta became independent.

Malta is known for its world heritage sites, therefore tourism is important for the island; however, it also has an expanding services sector, with another main resource being limestone. The island has transformed itself into a freight transhipment point, a financial centre, and a tourist destination. Therefore the economy is dependent on foreign trade and tourism. Malta's trading partners are Germany, France, Italy and the UK. At the same time Malta produces only about 20% of its food needs, has limited fresh water supplies, and has few domestic energy sources.

2.6.9 Poland

Poland is in Central Europe. It is bordered by Germany, the Czech Republic, Slovakia, Ukraine, Belarus, Lithuania, Russia (Kaliningrad Oblast) and the Baltic Sea. Poland's written history begins with the reign of Mieszko I, who accepted Christianity for himself and his kingdom in AD 966. That began the Piast Dynasty (996 – 1385). Subsequently, the Jagiellon Dynasty spanned the history of Poland. This monarchy survived many upheavals but eventually went into decline, which ended with the third and final partition of Poland by Prussia, Russia, and Austria in 1795. Poland regained its independence after World War I, in 1918, but was later occupied by Nazi Germany and the Soviet Union during World War II. Since October 1956, Poland was under the communist regime. While retaining most traditional communist economic and social aims, Polish internal life was liberalised. On August 31, 1980, the Solidarity movement began to be led by Lech Walesa, who was later on elected as national chairman of the union.

Strong economic growth potential, a large domestic market, tariff-free access to the EU, and political stability are the top reasons why other foreign companies do business in Poland. As the number of opportunities for trade and investment has attracted foreign investors into all sectors, Poland is considered to have one of the healthiest economies of the post communist countries. It is an excellent example of the transmission from a centrally planned economy to a capitalistic market economy. Polish trade is dominated by the EU as around 60% of its imports and 80% of exports come from or go to EU member states. Neighbouring Germany is by far Poland's most important trading partner, accounting for a quarter of the value of Polish trade. Most Polish imports are energy and capital goods (such as crude oil, passenger cars, pharmaceuticals, car parts and computers) needed for industrial retooling and for manufacturing inputs. Similarly, its major exports are cars, machinery, furniture, home appliances and iron/steel products. Moreover, Poland remains a net exporter of food products overall, including confectionery, processed fruit and vegetables, meat, and dairy products. The Polish natural resources are coal, copper, sulphur, natural gas, silver, lead and salt.

2.6.10 Romania

Romania is located in south east Europe. The country shares a border with Hungary, Serbia, Ukraine, Republic of Moldavia and Bulgaria.

Romania's history records several periods of time in which Romania was under the power of the Roman Empire, the Bulgarian Empire, the Kingdom of Hungary and the Ottoman Empire. As a nation, the country was formed by the act of merging Moldavia and Wallachia in 1859. Consequently it gained its autonomy in 1878. At the end of World War II, parts of Romania were occupied by the Soviet Union, and the communism era began. With the fall of the Berlin Wall and Iron Curtin in 1989, Romania started its political and economic reforms.

Romania is a country of considerable potential: rich agricultural lands, diverse energy sources (coal, oil, natural gas, hydro and nuclear) and a substantial industrial base encompassing almost the full range of manufacturing activities. Despite the above, Romania was in a three year recession period ending in 2000. The country came out from it thanks to strong demand in EU export markets. After accession to the EU, the economic situation of the country quickly improved and returned to positive growth in 2011. The several commodities Romania exports include machinery and equipment, metals and metal products, textiles and footwear, chemicals, agricultural products, minerals and fuels. The main trading partners are Germany, Italy, France and Hungary. Romania has considerable natural resources such as oil, salt, natural gas, coal, iron, copper and timber. Metal working, petrochemicals and mechanical engineering are the main industries.

2.6.11 Slovakia

Slovakia is a landlocked country in Central Europe bordering the Czech Republic, Austria, Poland, Ukraine and Hungary.

The history of Slovakia goes back to the 5th century, and during various times in the past Slovakia has been part of the Samos Empire, Great Moravia, the Kingdom of Hungary, the Habsburg Empire and Czechoslovakia. Czechoslovakia became a Communist nation within Soviet-dominated Eastern Europe. In 1989 Soviet influence collapsed and Czechoslovakia once more became free. Slovakia became an independent state in January 1993 after Czechoslovakia split into constituent parts.

Slovakia has made significant economic reforms since its separation from the Czech Republic; and all these reforms were conducted on the platforms of taxation, healthcare, pensions, and social welfare systems. This process helped Slovakia consolidate its budget and get on track to join the EU in 2004 and consequently to adopt the euro in January 2009. The country's major privatization process is nearly complete and the Slovakian banking sector is almost entirely in foreign hands. Slovakia is one of the countries which were not affected by the European slowdown. Despite this fact, Slovakia's economic growth exceeded expectations. Germany is Slovakia's largest trading partner. Other major partners include the Czech Republic, Italy, Russia, Austria, Hungary, Poland and France. Slovakia imports nearly all of its oil and gas from Russia, and its export markets are primarily EU countries. Trading commodities include machinery and electrical equipment, mineral products, vehicles, base metals, plastics, chemicals and minerals. Slovakia's natural resources are antimony, mercury, iron, copper, lead, zinc, magnesite, limestone, lignite and uranium.

2.6.12 Slovenia

Slovenia is a country in Central Europe and is bordered by Italy, Austria, Hungary, Croatia and the Adriatic Sea.

Slovenia was one of Yugoslavia's six constituted republics, and today is a vibrant democracy, although the roots of this democracy go back deep in Slovene history.

From as early as the 9th century, Slovenia had fallen under foreign rulers, including partial control by Bavarian dukes and the Republic of Venice, and the Habsburg Empire from the 14th century until 1918. Nevertheless, Slovenia never adopted German influences and therefore retained its unique Slavic language and culture. In 1918, Slovenia joined with other southern Slav states in forming the Kingdom of Serbs, Croats, and Slovenes as part of the peace plan at the end of World War I. During World War II Slovenia was renamed under a Serbian monarch, the Kingdom of Yugoslavia, and fell to the alliance powers. Subsequently, the communist era began and Slovenia became Yugoslavia's most prosperous republic. Finally, Slovenia regained independence in 1991, as Yugoslavia fell apart.

As a young independent republic, Slovenia pursued economic stabilisation and further political openness while emphasising its Western outlook and central European heritage. Today Slovenia is a stable democracy with a growing regional profile. It has increased its international engagement, playing a significant role relative to its size.

Slovenia's economy is highly dependent on foreign trade. About three quarters of its trade is with the EU, and the vast majority of this is with Germany, Italy, Austria, Croatia and France. The country exports mainly manufactured goods, machinery and transport equipment, chemicals, and food. Similarly, its import trading is dominated by machinery and transport equipment, manufactured goods, chemicals, fuels and lubricants and food.

Despite economic success, Slovenia faces some challenges. A big portion of the economy remains in state hands and FDI in Slovenia has lagged behind the region average, and taxes remain relatively high.

2.7 European Union's enlargement, crisis and prognosis

Although the periods investigated in this thesis were prior to the European Sovereign debt crisis, for completeness brief mention is included here on this crisis and its current and potential future impact on the enlargement of the EU. This enlargement process has developed among the European Communities over the past few decades. Currently there are 27 member states, with six more countries, namely: Croatia, Iceland, Montenegro, Serbia, the Former Yugoslav Republic of Macedonia and Turkey, still to join. Economic problems being experienced by some of the candidates, as well as some current member states, have resulted in a more cautious and careful EU enlargement policy, rules and mechanisms (Report: Financial Integration in Europe, 2012). Affecting the current enlargement process is the difference of opinion between member states in the region on the issue of continuing the enlargement process and its direction. The UK, Spain, Sweden and Poland are among those member states proponents who believe in the "open door" principle, but the opponents, in particular France and Netherlands, demand that limits to the structure be set. As consequence of this disagreement, the EU enlargement policy involves a continuous process of negotiation, which naturally slows down the EU enlargement process (Szymanski, 2012). The growing scepticism among some of the governments of EU member states about the continuation of the EU enlargement process arises from a phenomenon called "creeping nationalism" of the EU enlargement (after Hillion, 2010), which has intensified in the face of the economic crisis in the EU.

In the wake of the global economic meltdown of 2008, the European Union has been struggling with a slow moving but unshakable sovereign crisis that has underscored the flaws behind the common currency, the euro. The turmoil has brought down governments, pushed a number of countries into a second recession and exposed deep rifts between regions (Forester, 2013). As was clearly seen during 2011, the Euro zone crisis has had a major impact on European and global markets. Sovereign downgrades resulted in corporate and bank credits suffering downgrades as well. This in turn caused the secondary markets, in particular high yield, to trade off, which in turn made it harder to price and sell new deals (European Commission Report, 2011; George, 2012).

Chapter 3: Empirical Data

This chapter summarises the data used in this study and includes descriptive statistics. In order to provide a better understanding of the data and the markets involved before embarking on the detailed cointegration, volatility and spillover analysis in later chapters, this chapter also undertakes some statistical tests on the data for normality, non-stationarity and correlations between countries.

3.1 Introduction

The statistical data used in this study consists of the closing prices of the daily stock market indices in the twelve CEE stock markets[5] (Bulgaria, the Czech Republic, Cyprus, Estonia, Hungry, Latvia, Lithuania, Malta, Poland, Romania, Slovakia and Slovenia). The data is obtained from DataStream's database for the period from January 1995 to May 2011[6]. The twelve countries joined the EU during the latest two enlargements which took place on 1st May 2004 for the Czech Republic, Cyprus, Estonia, Hungry, Latvia, Lithuania, Malta, Poland, Slovakia and Slovenia and 1st January 2007 for Bulgaria and Romania. Based on those two accession dates the sample period is divided into three phases: one pre-EU period (January 1995 - April 2004) and two post-EU periods (May 2004 - May 2012 for the first enlargement and January 2007 - May 2012 for the second and final enlargement). One common currency, the euro is used to express stock market prices in order to provide comparable findings (after Scheicher (2001) and Syriopouls (2007)). The common currency is assumed for a euro-based investor, who does not hedge currency risk. Appendix A provides further discussion on the choice of euro currency, showing no significant difference in the primary data analysis between domestic currency and the euro. Appendix B presents stock exchange data information which includes the name of the stock market used in the analysis, availability of data and specific remarks for some stock exchanges.

[5] SOFIX (Bulgaria), SEPX (Czech Republic), CYSE (Cyprus), OMX Tallinn Stock Exchange (Estonia), BUX (Hungry), OMX Riga Stock Exchange (Latvia), OMX Vilnius Stock Exchange (Lithuania), MSE (Malta), WIG (Poland), BET (Romania), SAX (Slovakia) and SBI (Slovenia)

[6] At 01/01/1995 data exists for 5 out of 12 studied markets, which is a sufficient number of observations for the statistical analysis. Those 5 are: the Czech Republic, Hungary, Poland, Slovakia and Slovenia. The other data is available as follows: Estonia, Malta from 1996, Romania from 1997, Bulgaria, Latvia, Lithuania from 2000 and Cyprus from 2004.

The CEE countries have made significant progress towards integration with the world economy over the past decade. Those economies are characterised by stable performance and higher growth rates compared to the previous years, so called “old European economies” (Nord, 2000). Trading links with the EU have strengthened considerably, accounting for as much as 60-70% of the total trade in many CEE countries, and the competitive position has improved. Table 3.1 provides information on the stock exchanges of the twelve markets, including the market capitalization, the number of companies and turnover. According to the recent studies of Egan and Ovanessoff (2011), Giannetti and Ongena (2009), Backe, Egert and Zumer (2005), Havlik (2003) in terms of capitalization, turnover and number of trade securities, the CEE stock markets move on a growth path. And such the number of listed companies of the twelve studied markets constitutes 25% of the EU total number in 2010 (as in the Table 3.1 below), which is 5% of the EU market capitalization. At the same time the size and liquidity of the markets remain low in comparison to international markets. Nerveless, the CEE stock exchanges have an organization comparable to the developed European exchanges (Syriopoulos, 2007). Out of the twelve studied stock markets the Polish stock market appears to be the largest, covering approximately 55% of the capitalization of the whole studied region. This can be compared to the Czech Republic market capitalization of 15%, followed by the 10% of the Romanian market at the end of 2010 (based on data collected in below Table 3.1). In terms of the total trading value the Polish stock market dominated again in the region with approximately 64% of traded stock, followed by stock markets of Hungary (22%) and the Czech Republic (12%).

This study of the twelve European markets falls between two time zones. The time difference between Bulgaria, Cyprus, Estonia, Hungary, Latvia, Lithuania, and Romania in the one zone, and the Czech Republic, Hungary, Malta, Poland, Slovakia and Slovenia in the other, is one hour. As this is not a major concern, the time zone factor hasn’t been taken into consideration in this analysis.

Table 3.1: Institutional background

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Market capitalization of listed companies (in mln US$)																
Bulgaria	61	7	2	992	706	617	505	733	1,755	2,804	5,086	10,325	21,793	8,858	7,103	7,276
Cyprus	2,516	2,355	2,011	2,618	6,950	4,351	6,187	4,990	4,804	4,880	6,583	15,900	29,479	7,955	4,993	6,834
Czech Rep	15,664	18,077	12,786	12,045	11,796	11,002	9,331	15,893	17,663	30,863	38,345	48,604	73,420	48,850	52,688	43,056
Estonia	0	0	1,101	519	1,789	1,846	1,483	2,430	3,790	6,203	3,495	5,963	6,037	1,951	2,654	2,260
Hungary	2,399	5,273	14,975	14,028	16,317	12,021	10,367	13,110	16,729	28,711	32,576	41,935	47,651	18,579	28,288	27,708
Latvia	10	151	338	382	391	563	697	715	1,141	1,655	2,527	2,705	3,111	1,609	1,824	1,252
Lithuania	157	900	1,693	1,074	1,138	1,588	1,199	1,463	3,510	6,463	8,183	10,191	10,134	3,625	4,477	5,661
Malta	154	472	461	785	1,916	2,046	1,376	1,383	1,830	2,841	4,097	4,504	5,633	3,572	1,982	2,399
Poland	4,564	8,390	12,135	20,461	29,577	31,279	26,017	28,750	37,165	71,102	93,873	149,054	207,322	90,233	135,277	190,235
Romania	100	57	627	1,016	873	1,069	2,124	4,561	5,584	11,786	20,588	32,784	44,925	19,923	30,325	32,385
Slovakia	1,235	2,182	1,826	965	1,060	1,217	1,558	1,904	2,779	4,410	4,393	5,574	6,971	5,079	4,672	4,150
Slovenia	311	663	1,625	2,450	2,180	2,547	2,839	4,606	7,134	9,677	7,899	15,182	28,963	11,772	11,766	9,428
Listed domestic companies, total																
Bulgaria	26	15	15	998	828	503	399	354	356	332	331	347	369	334	376	390
Cyprus	41	39	49	54	60	120	145	154	152	149	144	141	141	135	128	123
Czech Rep	1635	1588	276	261	164	131	94	78	63	54	36	29	32	28	16	16
Estonia			27	26	25	23	17	14	14	13	15	16	18	18	16	15
Hungary	42	45	49	55	66	60	57	48	49	47	44	41	41	41	43	48
Latvia	17	34	51	69	70	64	63	62	56	39	45	40	41	35	34	33
Lithuania	351	460	607	63	54	54	54	51	48	43	43	44	40	41	40	39
Malta	5	6	6	7	7	10	12	12	13	13	13	14	15	18	20	20
Poland	65	83	143	198	221	225	230	216	203	225	248	267	328	349	354	569
Romania	7	17	76	5753	5825	5555	5140	4870	4484	4030	3747	2478	2096	1824	1824	1383
Slovakia	18	816	872	837	469	493	515	354	306	258	209	173	153	120	107	90
Slovenia	17	21	26	28	28	38	38	35	134	140	116	100	87	84	76	71
Stocks traded, total value (in mln US$)																
Bulgaria	4	0	0	12	54	58	70	172	197	511	1,388	1,509	5,498	1,651	401	198
Cyprus	301	462	292	616	6,649	9,261	3,436	622	306	176	409	4,304	5,338	2,269	947	632
Czech Rep	3,630	8,431	7,071	4,807	4,120	6,582	3,349	6,083	8,797	17,663	41,040	32,875	41,934	43,034	20,606	14,083
Estonia	0	0	1,484	922	285	326	220	241	564	828	2,478	972	2,096	783	374	322
Hungary	355	1,641	7,472	16,042	14,395	12,150	4,818	5,941	8,300	13,011	23,911	31,183	47,497	30,802	25,940	26,466
Latvia	0	12	84	85	45	228	165	124	145	110	96	111	140	42	20	27
Lithuania	37	47	233	221	290	202	210	182	198	464	741	2,094	1,024	489	303	296
Malta	16	14	22	56	335	185	47	53	42	94	151	255	89	74	18	27
Poland	2,770	5,538	7,951	8,918	11,149	14,631	7,432	5,842	8,498	16,569	29,974	55,041	84,568	67,955	55,778	77,464
Romania	1	6	268	596	317	236	256	403	442	943	3,399	4,260	8,095	3,675	1,885	1,702
Slovakia	832	2,321	2,155	1,032	474	896	966	789	664	655	69	90	30	22	175	174
Slovenia	345	401	351	702	733	465	794	1,003	732	1,170	788	1,019	2,713	1,408	1,021	272

Source: Standard & Poor's, Global Stock Markets Factbook and supplemental S&P data; Catalog Sources World Development Indicators; Data is in current US dollars

3.2 Descriptive Statistics

Table 3.2 provides descriptive statistics for the daily returns for the pre- and post-EU periods[7]. Daily returns are defined as logarithmic price relatives: $R_t = ln(P_t/P_{t-1}) \times 100$. In every case the return series has a mean value close to zero and a distribution characterized by non-normality (Jarque-Bera statistics). The highest mean of returns in the pre-EU period can be observed in Bulgaria (0.154) and Latvia (0.095) stock markets. A negative average return is observed in the Czech Republic (-0.006). In the post-EU period four countries, namely Bulgaria, Cyprus, Romania and Slovenia reported negative returns of -0.089, -0.009, -0.047 and -0.021 respectively. The highest mean return is assigned to Poland (0.049). If the data is normally distributed, then the mean and variance would completely describe the distribution of the data and the higher moments of skewness and kurtosis would provide no additional information about that distribution. However, the data contains positive skewness for two markets for the pre-EU period and on three occasions in the post-EU period. All other values for skewness are negative which implies that the distribution has a long left tail, whereas the relevant Jarque-Bera statistics indicate rejection of the normality hypothesis. All markets generate kurtosis statistics more than 3 (which is the benchmark for a normal distribution) which indicates the series is characterised by leptokurtosis. This means that the distribution of the data contains a greater number of observations in the tails than that found in a normal distribution. Whilst it is possible to individually test the significance of the skewness and kurtosis, the more common approach is the joint test based on calculation of Jarque-Bera statistics with comparison to critical values, as shown in Table 3.2. Overall the skewness, kurtosis and Jarque-Bera test values support the statement that the residuals are not normally distributed. This is observable in Figure 1, where QQ-plots show how the distribution of the standardized residuals deviates from the normal. Based on this statistical analysis the Quasi-Maximum Likelihood Estimator (QMLE), a sufficient condition for multivariate volatility models, will be applied for the purposes of further volatility GARCH model analysis in Chapter 5.

[7] For clarity, in the first part of this chapter the statistical analysis of the descriptive data is divided into two phases, being pre- and post-EU. There is no need to divide the analysis of the post-EU period into two time frames (which is done later in the chapter), as the results of the descriptive data analysis in the first part of this chapter show the same statistical outcomes for both post-EU periods.

Table 3.2: Descriptive statistics of selected markets

	Mean	Median	Max	Min	St Dev	Skew	Kurtos	Jarque-Bera	Normality p-value
Pre-EU period									
Bulgaria	0.154	0.050	21.054	-20.893	1.856	-0.444	38.660	85624.18	0.000
Czech Rep	-0.006	0.000	5.930	-6.716	1.312	-0.238	5.299	603.6	0.000
Cyprus	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Estonia	0.059	0.55	12.866	-21.576	1.981	-1.192	21.585	30196.4	0.000
Hungary	0.038	0.000	13.321	-19.483	1.797	-1.031	17.564	31348.1	0.000
Latvia	0.095	0.888	10.190	-14.720	1.863	-1.109	18.172	11061.1	0.000
Lithuania	0.070	0.035	4.580	-10.216	0.886	-1.176	21.143	15759.3	0.000
Malta	0.044	0.000	9.572	-7.589	0.793	2.571	34.716	93648.3	0.000
Poland	0.053	0.000	15.051	-17.714	2.283	-0.220	9.103	5309.1	0.000
Romania	0.028	0.001	11.863	-12.875	1.885	-0.159	9.135	3806.1	0.000
Slovakia	0.020	0.000	27.554	-12.452	1.720	2.232	41.320	171973.9	0.000
Slovenia	0.048	0.000	11.017	-11.344	1.255	-0.307	15.629	17951.9	0.000
Post-EU period									
Bulgaria	-0.089	0.000	7.289	-11.369	1.629	-0.894	10.056	2519.4	0.000
Czech Rep	0.039	0.068	14.469	-16.580	1.773	-0.412	16.497	13989.9	0.000
Cyprus	-0.009	0.000	12.123	-12.135	2.318	-0.017	6.388	835.5	0.000
Estonia	0.038	0.024	12.944	-7.045	1.251	0.300	12.598	7075.6	0.000
Hungary	0.036	0.134	15.402	-18.578	2.113	-0.164	11.212	5167.9	0.000
Latvia	0.005	0.000	10.053	-7.904	1.447	0.151	9.137	2888.2	0.000
Lithuania	0.027	0.000	11.865	-13.515	1.346	-0.020	22.386	28750.5	0.000
Malta	0.013	0.000	4.738	-4.536	0.795	0.197	9.085	2845.4	0.000
Poland	0.049	0.108	9.811	-11.126	1.719	-0.365	7.647	1692.8	0.000
Romania	-0.047	0.064	11.203	-14.399	2.281	-0.498	7.944	1209.6	0.000
Slovakia	0.015	0.000	11.880	-14.810	1.178	-1.693	31.193	61686.12	0.000
Slovenia	-0.021	0.000	7.681	-8.299	1.081	-0.742	14.805	9934.1	0.000

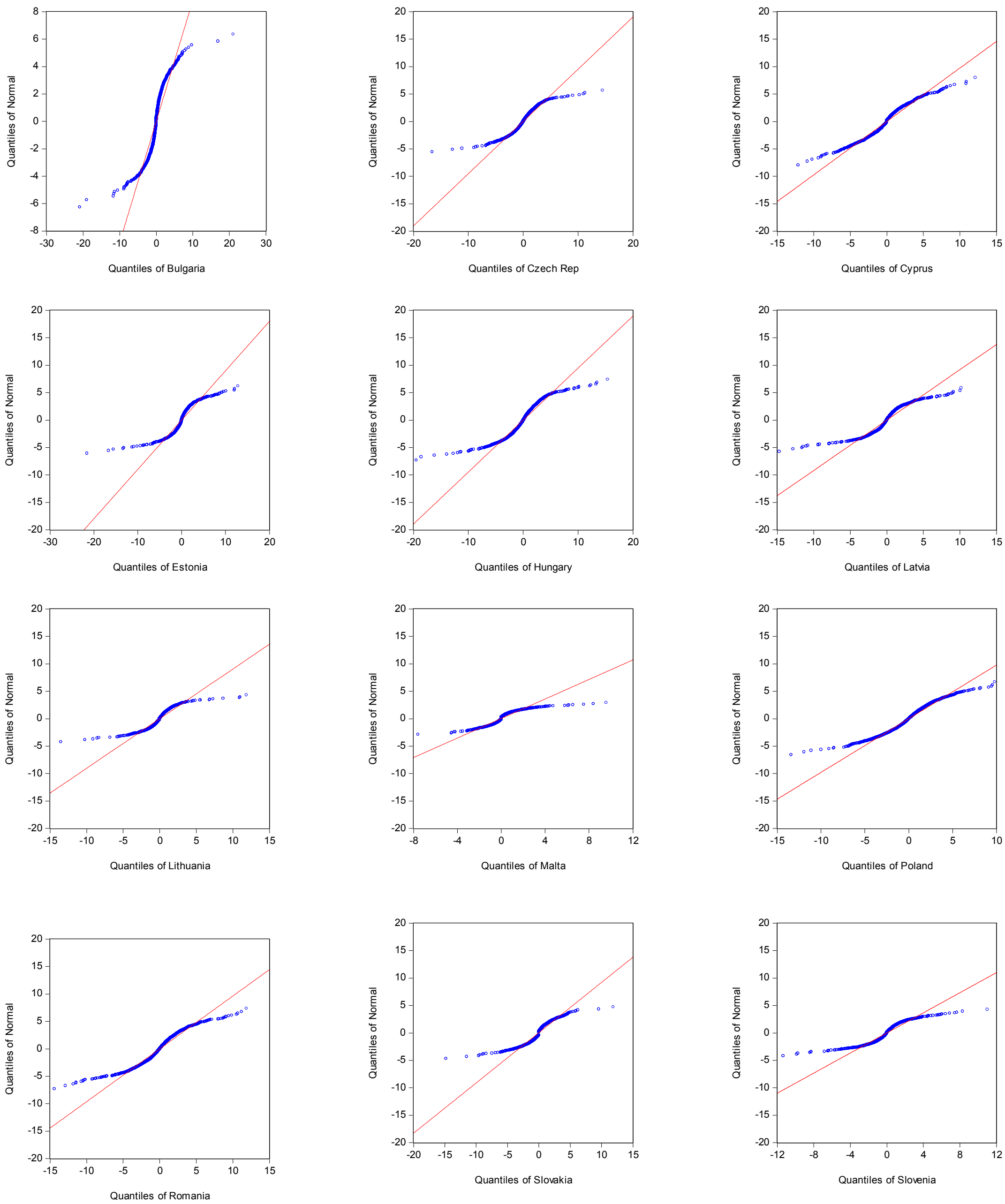


Figure 3.1: QQ plot of daily log returns

3.3 Research hypotheses tested

Hypotheses tested for the purpose of data analysis are formulated below (given in the alternate format):

- H_1: The stock price indices are non-stationarity and integrated at the same order.
- H_2: The stock returns are stationary in the data sample.
- H_3: There is an absence of autocorrelation in the stock returns of each market.
- H_4: There is significant correlation in stock returns between CEE countries.

3.4 Tests of the normality of sample data

The first stage in the data analysis is to test whether the time series are stationary. In the data analysis of the series we employ informal and formal tests of stationarity. The one informal test is classified as the preliminary visual (graphical) examination of the series. This allows the identification of any structural breaks and gives an idea of the trends evident in the data set. Figure 3.2 and Figure 3.3 plot the variables in their levels and in their first differences against time. All graphs have been divided by a vertical line into two parts showing pre- and post-EU phases.

Figure 3.2 shows visible symptoms of non-stationarity as a series does not have a constant mean when graphed. On the other hand, Figure 3.3 shows that all variables become stationary with the first difference as fluctuations around mean zero are observable. Volatility, measured by the standard deviation of daily returns, shows that Polish and Estonian stock markets are the most volatile in pre-EU periods. For the post-EU period they are Cyprus, Romania and Hungary. The market with the lowest volatility is Malta in both periods. The graph of the return series clearly shows volatility clustering, where large (small) changes tend to be followed by large (small) changes of either sign. The volatility clustering absorbs both good (positive variation) and bad (negative oscillation) news.

Both graphs show some common trends, which occur during certain periods of time, such as the 1998 Russian crisis, the late 1990s/early 2000s internet “bubble”, the 9/11 terrorist attacks on the World Trade Centre, the 2007 global financial market turmoil, and the 2009 world financial downturn. Those massive fluctuations are evident in both Figures.

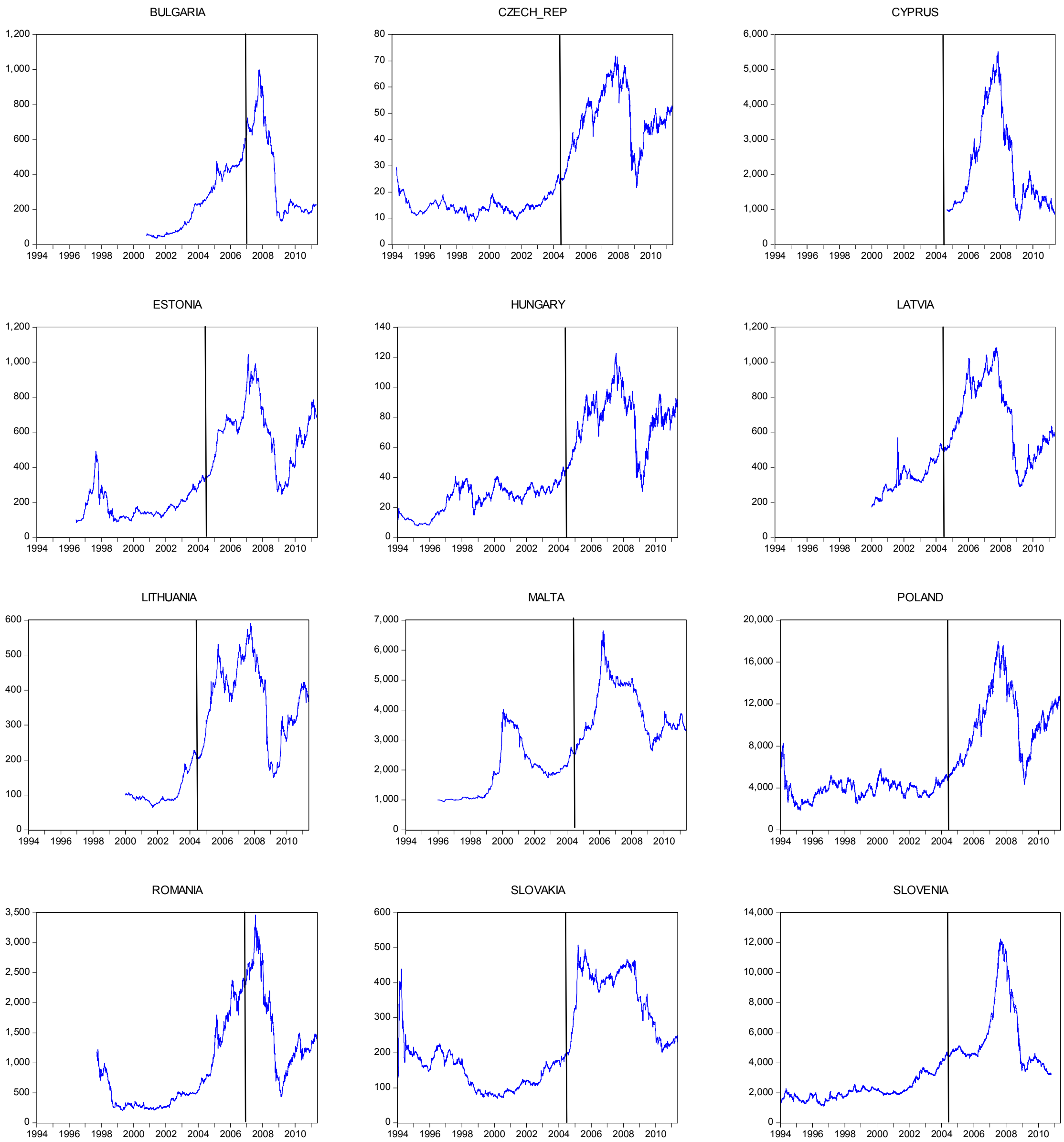


Figure 3.2: Price series dynamics of stock markets in CEE
Note: Graphs have been divided by a vertical line into two phases showing pre- and post-EU periods.

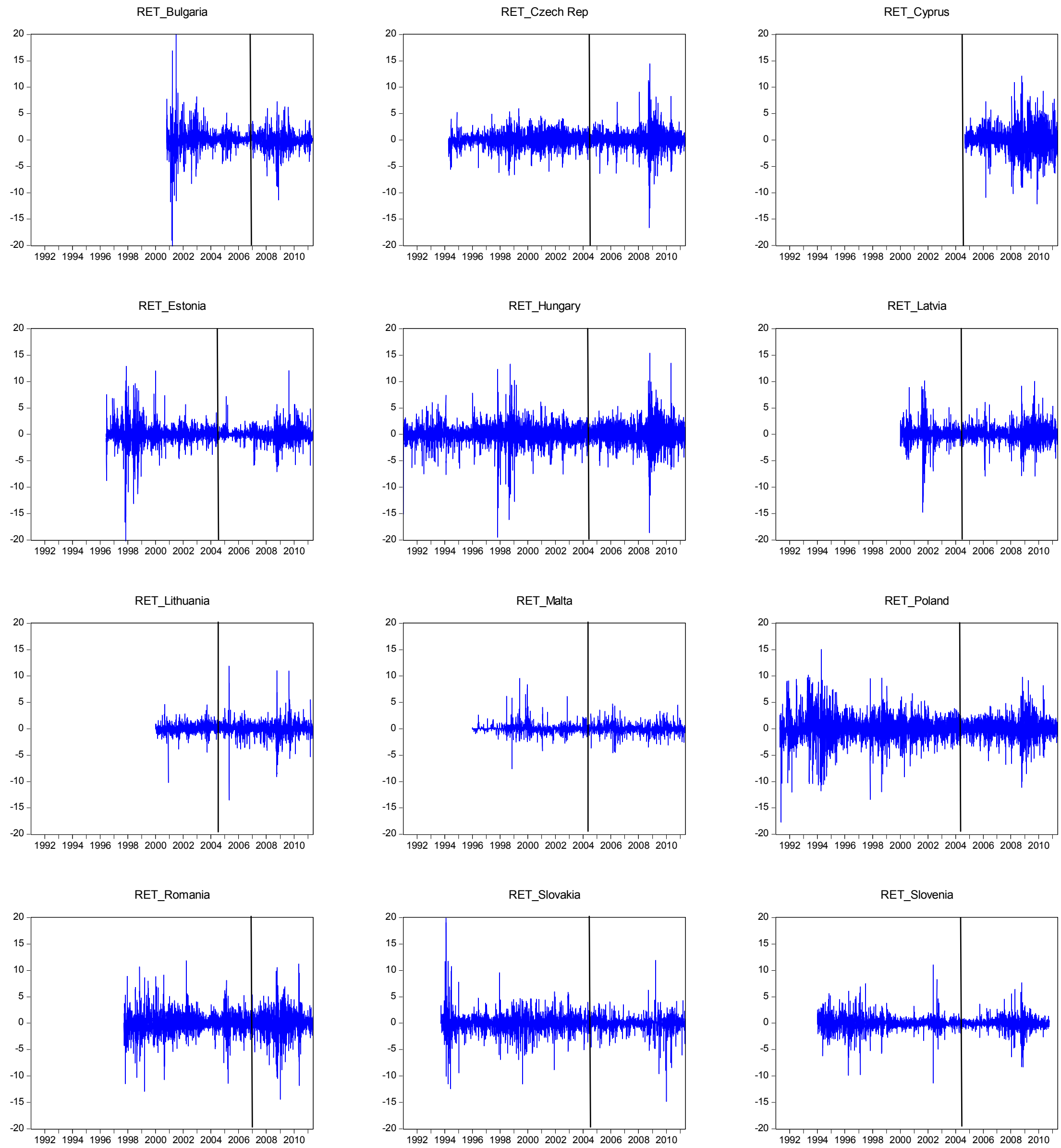


Figure 3.3: Return series dynamics of stock markets in the CEE
Note: Graphs have been divided by a vertical line into two phases showing pre- and post-EU periods.

3.5 Non-stationarity of the time series

A necessary condition in the time series analysis is to test each series for the presence of unit roots, which indicate whether the series are non-stationary and integrated of the same order. As we cannot do this based solely on the visual analysis of the series, as this is an informal test for stationarity, some formal tests should apply. Therefore, this dissertation uses the Augmented Dickey-Fuller test (1981), which is a modified version of the pioneer work of Dickey and Fuller (1979) and the Phillips-Perron (1988) non-parametric test. Both ADF and PP tests examine the null hypothesis: the price series contains a unit root (i.e. testing the series as *I(0)* against a null of *I(1)*). Both tests were performed using the maximum lag length in every case[8]. The results from ADF and PP tests indicate that the series are non-stationary in their levels. However, when all the variables in the series are differenced once, they become stationary.

Table 3.3 presents the results from the testing for the presence of unit roots. The results show all the price series to be first order integrated (*I(1)*) and the return series to be stationary at the 5% significance level. Moreover, this result is not sensitive to the presence of an intercept term and trend. Hence, the ADF and PP tests clearly indicate that the price series are non-stationary, which concords with economic theory that most economic variables are not stationary at their levels.

3.6 Pairwise correlation[9]

The prior expectation of this analysis is one of weak comovements between the studied countries (Scheicher, 2001; Syriopoulos, 2007); however some of the cross country correlations may be found to be significant.

In our data, the pre-EU period shows correlations on most occasions to be weak and the correlation coefficients on most occasions do not exceed a value of 0.2 (refer to Table 3.4). Moreover, there are several cases of negative correlation between markets. Most of those inverse relationships refer to the Bulgarian and Slovakian stock markets. In addition those two and another three (namely Latvia, Lithuania and Malta) remain isolated from all other markets, showing very weak correlation with the other markets. The highest correlation coefficient is recorded for Hungary - Poland (0.466), Hungary - the Czech Republic (0.400) and Poland - the Czech Republic (0.355). Estonia's stock market is different from all the other weakly correlated markets with an average correlation of 0.129 with Hungary, Latvia, Lithuania and Poland.

[8] Akaike Information Criterion and Schwarz Bayesian Criterion were employed to select the appropriate lag length.
[9] Pairwise correlation analysis is based on three time frames of pre-EU: 1995-2004, post-EU: 2004-2011 and post-EU: 2007-2011. This is due further comparison with the CCC and BEKK models.

Table 3.3: Unit root tests on price levels and first difference

	ADF test				PP test			
	v_t		Δv_t		v_t		Δv_t	
	Without trend	With trend	Without trend	With trend	Without trend	With trend	Without trend	With trend
Pre-EU period								
Bulgaria	1.991	-1.659	-23.496***	-23.663***	1.872	-1.697	-34.029***	-33.949***
CzechRep	-3.185**	-3.549**	-31.483***	-31.757***	-3.278**	-3.582**	-46.196***	-45.996***
Cyprus	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Estonia	-2.006	-2.078	-9.263***	-9.265***	-1.344	-1.445	-39.603***	-39593***
Hungary	-0.530	-2.347	-57.756***	-57.758***	-0.551	-2.402	-57.749***	-57.751***
Latvia	-0.951	-2.322	-17.858***	-17.852***	-1.168	-2.880	-27.706***	-27.696***
Lithuania	3.047	0.546	-19.778***	-20.351***	3.403	0.794	-29.886***	-29.910***
Malta	-0.956	-0.994	-29.794***	-29.789***	-0.898	-0.913	-29.429***	-29.423***
Poland	-2.137	-2.559	-36.354***	-36.349***	-2.235	-2.718	-51.499***	-51.492***
Romania	1.419	-1.844	-33.717***	-34.037***	-1.089	-0.721	-31.230***	-31.229***
Slovakia	-2.687*	-3.111	-15.488***	-15.485***	-2.748*	-3.148*	-57.267***	-57.261***
Slovenia	1.357	-0.136	-35.906***	-35.963***	0.977	-0.518	-43.736***	-43.714***
Post-EU period								
Bulgaria	-0.793	-1.116	-10.762***	-10.759***	-0.796	-1.121	-30.653***	-30.638***
CzechRep	-1.953	-1.803	-31.785***	-31.799***	-1.944	-1.790	-41.098***	-41.107***
Cyprus	-0.821	-1.199	-38.691***	-38.775***	-0.792	-1.189	-38.767***	-38.826***
Estonia	-1.402	-1.419	-20.710***	-20.717***	-1.490	-1.504	-38.983***	-38.968***
Hungary	-2.239	-2.174	-31.263***	-31.266***	-2.177	-2.107	-40.089***	-40.087***
Latvia	-0.963	-1.543	-43.902***	-43.923***	-1.065	-1.589	-44.191***	-44.189***
Lithuania	-1.504	-1.632	-14.988***	-15.022***	-1.584	-1.697	-39.602***	-39.577***
Malta	-1.327	-1.734	-23.189***	-23.311***	-1.370	-1.752	-30.839***	-30.908***
Poland	-1.554	-1.402	-40.453***	-40.452***	-1.590	-1.451	-40.539***	-40.537***
Romania	-1.109	-0.753	-31.159***	-31.166***	-1.089	-0.722	-31.230***	-31.229***
Slovakia	-1.480	-2.921	-42.040***	-42.238***	-1.562	-2.837	-42.614***	-42.596***
Slovenia	-0.421	-0.522	-28.747***	-28.822***	-0.288	-0.527	-30.469***	-30.540***

vt: variable in levels; Δvt: variable in first difference
Critical values/without trend: -3.434 at the 1% level; -2.864 at the 5% level; -2.568 at 10% level
Critical values/with trend: -3.962 at the 1% level; -3.412 at the 5% level; -3.128 at 10% level
MacKinnon (1996) one-sided p-value
Significance levels: *** 0.01, **0.05, *0.10.

The post-EU period shows an increase in stock markets' inter-relationships, with stronger correlations between countries. As such, we can see that the values of the correlation coefficients increased significantly after all the countries concerned had joined the EU. Table 3.5 and Table 3.6 demonstrate those correlation coefficients and, as previously, we can see a very strong relationship between three countries: the Czech Republic, Hungary and Poland. In the first post-EU period the average correlation coefficient equals to 0.694 and in the other it increases to 0.716. A striking fact is that after the last EU accession by Bulgaria and Romania on 1 January 2007, the correlation coefficient between these two is stronger than had been the case before they became EU members. Those two markets remain in significant correlation not only between each other but also with the other markets.

Both post-EU periods show comparable results with the presence of negative correlation coefficients. In the post-EU: 2004-2011 period, there is no evidence of an inverse relationship between countries, but in the post-EU: 2007-2011 period we observe a negative correlation coefficient for Malta and Slovakia. Moreover, as was pointed out before (for the pre-EU period), the stock markets of Malta and Slovenia remain isolated from the others.

Overall, the correlation coefficients between the CEE stock markets are found to be relatively low and on some occasions negative. In the post-EU period the correlation coefficients between the CEE markets are higher which indicates a strengthening of the relationship. The stock markets of the Czech Republic, Hungary and Poland have high and positive pairwise correlation, whereas the smaller markets of Malta and Slovakia remain isolated compared to their peers.

The increase in correlations in the post-EU period means that the scope for investors diversifying into these new markets has been diminished. Capiello et al (2006) found much higher correlations amongst bond indices across EU member states than is the case with equity indices. This is perhaps not surprising given the influence of common monetary policies. Jorion and Goetzemann (1999) undertake simulations of the characteristics of emerging markets and suggest that high returns and low covariances with developed markets are characteristics of 'emergence', but not necessarily long-term characteristics. They also point out that many of today's emerging markets are 're-emerging' markets that had previously been prominent but had, for various reasons, sunk from the sight of international investors. They include Poland, Romania and Czechoslovakia in this category noting that they had active equity markets in the 1920s.

Table 3.4: Correlation coefficient for pre-EU: 1995-2004 period

	Bulgaria	Czech Rep	Estonia	Hungary	Latvia	Lithuania	Malta	Poland	Romania	Slovakia	Slovenia
Bulgaria	1										
Czech Rep	0.027	1									
Estonia	0.093	0.135	1								
Hungary	0.041	0.400	0.180	1							
Latvia	0.019	0.085	0.121	0.064	1						
Lithuania	0.030	0.095	0.185	0.056	0.057	1					
Malta	0.050	0.009	0.030	0.051	0.012	0.020	1				
Poland	-0.033	0.355	0.207	0.466	0.068	0.071	0.045	1			
Romania	-0.027	0.132	0.029	0.161	0.056	0.001	0.006	0.154	1		
Slovakia	-0.012	0.004	-0.014	0.015	-0.011	-0.017	-0.008	0.018	-0.037	1	
Slovenia	0.012	0.064	0.050	0.113	0.003	-0.027	0.017	0.074	0.094	-0.001	1

Table 3.5: Correlation coefficient matrix for post-EU: 2004-2011 period

	Bulgaria	Czech Rep	Cyprus	Estonia	Hungary	Latvia	Lithuania	Malta	Poland	Romania	Slovakia	Slovenia
Bulgaria	1											
Czech Rep	0.307	1										
Cyprus	0.192	0.476	1									
Estonia	0.326	0.350	0.244	1								
Hungary	0.192	0.657	0.415	0.275	1							
Latvia	0.242	0.211	0.155	0.305	0.142	1						
Lithuania	0.350	0.365	0.235	0.495	0.275	0.316	1					
Malta	0.078	0.022	0.013	0.048	0.020	0.036	0.066	1				
Poland	0.260	0.718	0.458	0.307	0.706	0.160	0.298	0.026	1			
Romania	0.305	0.516	0.405	0.332	0.442	0.218	0.318	0.040	0.469	1		
Slovakia	0.065	0.038	0.005	0.092	0.026	0.021	0.049	0.002	0.002	0.044	1	
Slovenia	0.369	0.327	0.253	0.333	0.231	0.257	0.350	0.056	0.249	0.340	0.032	1

Table 3.6: Correlation coefficient matrix for post-EU: 2007-2011 period

	Bulgaria	Czech Rep	Cyprus	Estonia	Hungary	Latvia	Lithuania	Malta	Poland	Romania	Slovakia	Slovenia
Bulgaria	1											
Czech Rep	0.360	1										
Cyprus	0.215	0.522	1									
Estonia	0.366	0.390	0.261	1								
Hungary	0.235	0.675	0.461	0.302	1							
Latvia	0.289	0.245	0.163	0.328	0.160	1						
Lithuania	0.431	0.443	0.286	0.607	0.325	0.404	1					
Malta	0.101	0.050	-0.011	0.077	0.037	0.035	0.076	1				
Poland	0.304	0.758	0.516	0.338	0.714	0.171	0.366	0.054	1			
Romania	0.365	0.614	0.473	0.386	0.540	0.263	0.433	0.065	0.565	1		
Slovakia	0.059	0.025	-0.019	0.098	0.010	0.028	0.072	-0.020	-0.003	0.061	1	
Slovenia	0.427	0.361	0.267	0.368	0.268	0.309	0.429	0.085	0.272	0.395	0.042	1

Chapter 4: Cointegration analysis

This chapter provides an analytical analysis of cointegration for the twelve ECC markets, including background information for the study, literature review, applied methodology and widely described results of the econometric investigation. The chapter conclusion demonstrates the significance of the study for potential researchers, investors and policy makers.

4.1 Introduction

The extent of financial market cointegration is one of the most important issues for a large number of economic agents. The size and evolution of the cointegration between market returns in emerging equity markets are important for appropriate portfolio selection. In this chapter we examine the implications for European investors of the recent EU expansion to encompass former Eastern block economies. Capiello, Engle and Sheppard (2006) question whether the formation of EMU within the EU has increased the correlation of national assets. This clearly has important implications for investors wishing to diversify across national markets. Should investors diversify outside the CEE countries? It could be argued that the former Eastern block economies constitute emerging markets which typically offer attractive risk adjusted returns for international investors.

This chapter concentrates on the twelve emerging markets, which are part of the EU's largest enlargement ever. These CEE countries have been in process of liberalization from the communist regime at the end of the 1980s through to the beginning of the 1990s. During this time the CEE countries have established functioning stock markets as part of the transaction process. Throughout the process of preparing for admission to EU these equity markets have been modelled along similar paths of joining procedures to those in developed market economies.

According to the FTSE group, the Czech Republic, Hungary and Poland are regarded as Advanced Emerging Markets Economies. Of these, the Czech Republic has the most developed and industrialized economy in CEE. The aim of this research is to relate the remaining nine emerging markets of the EU to the above three, with Czech Republic being the primary reference point. This research explores a number of important aspects of portfolio selection and investment opportunities and their implications for CEE based investors through cointegration analysis of these markets pre- and post- EU expansion. This chapter specifically deals with inter-relationships between our twelve emerging markets and does not attempt to include any developed markets. This could form the basis of a future study which is recommended in Chapter 6.

4.2 Literature Review

Various aspects of equity market relationships have been explored in the literature, including volatility spillover effects, market correlation structures or market efficiency, and financial crisis contagion. Also the aspect of cointegration between markets has been broadly analysed (for a discussion of this type of approach, see Allen and MacDonald (1995)). A great number of studies have investigated possible linkages between the world's developed markets and in particular US and European stock markets. Authors have mainly used cointegration techniques to examine linkages and long-term relationships between developed and emerging markets. Among them are Scheicher (2001), Gilmore and McManus (2002, 2003), Gilmore, Lucey and McManus (2005), Voronkova (2004), Egert and Kocenda (2007), Syriopoulos (2007) and Fadhlaoui, Bellalah, Dherry, and Zouaouii (2009). The study of linkages between the principal emerging stock markets in Europe, namely the Czech Republic, Hungary and Poland, has been conducted by Scheicher (2001), who compared those three markets to the Financial Times (FT) index. He reported on the Granger Causality test and found similar influencing patterns between the countries studied, with FT having an impact in all three countries. Scheicher observed shocks' persistance and found that that in less than one week there is no measurable reaction to the innovations, and these results hold in all three main European markets.

Gilmore and McManus (2002) examined the posibility of diversification benefits for US investors in the three most important Central European equity markets, namely the Czech Republic, Hungary and Poland. They concluded that US investors can get a higher level of returns from diversification in CEE markets since there is no evidence of multilateral cointegrateion for those markets. In their publication in 2003 they, as the first ones, looked for evidence of long-term links of the equity markets of the Czech

Republic, Hungary and Poland with the German market. Again they found lack of cointegration. However, in a time period which includes the 2004 expansion, Gilmore, Lucey and McManus (2005) examined bilateral and multilateal cointegration properties of the German market and the three major CEE countries, and found evidence of an emerging long-term relationship between the German and UK markets and the Czech Republic, as well as cointegration within the group of CEE markets.These results are supported by Egert and Kocenda (2007) who reported no robust cointegrating relationship between the relatively new markets of the Czech Republic, Hungary and Poland and the developed ones of Germany, UK and France. Another study on the existence of long-term relationships between the three CEE markets of the Czech Repuclic, Hungary and Poland and the three developed markets of France, Germany and UK was undertaken by Voronkova (2004). She found evidence of stronger cointegration relationships than had previously been reported. As her paper accepted a more general view of cointegration, the author supported the hypothesis that the emerging CEE markets have become increasingly integrated with world markets. She claimed that international investors should be aware of the implications of this closer international integration for the purpose of risk management strategies.

Chelley-Steeley (2005) found evidence of markets moving away from the segmentation process in the equity markets of Hungary, Poland, the Czech Republic and Russia. While applying the variance decomposition model, the author found evidence of increased market integration.

Fadhlaoui, Bellalah, Dherry, and Zouaouii (2009) examined short and long-term relationships between G7 developed and three Central European emerging markets. The results showed no cointegration between the developed and emerging markets. These results indicate that the increase in financial integration degree and comovements between equity markets has not significantly affected the expected benefits from international diversification in these emerging markets. They explained these results, firstly by the recent emergence of those markets after liberalization from the communist regime in the 1990s, and secondly by the weak economic and financial relationship between the economies of these countries as a group with the economies of developed countries.

Another important topic for discussion is the implementation of one currency, € (euro), across the CEE countries and becoming a member of EMU. In 2007 Slovenia was the first of the studied twelve countries to adopt the European currency, followed by Malta and Cyprus in 2008, Slovakia in 2009 and Estonia in 2011. All the others are progressing towards being accepted into the EMU in the near future. Yang, Min and Li (2003) found that the long-run linkage between eleven developed European markets and the US generally strenghtened after the EMU, because long-run relationships are restored more quickly after system-wide shocks.This is evidenced by the non-member country (UK) showing lessened linkages. At the same time the athours agree that it is diffucult to disentangle the impact of the EMU from other channels that also might affect European stock market integration. A similar conclusion is found by Hardouvelis, Malliaropulos and Priestly (2006), who support the finding of increased stock market integration. Conversely, Syriopoulos (2007) found no dramatic shocks or any particular impact in the post-EMU period while testing cointegration relationships between the emerging markets of Poland, the Czech Republic, Hungary, Slovakia and the developed ones of Germany and the US.

Jorion and Goetzemann (1999) suggested that many emerging markets are actually re-emerging markets that for various reasons have gone through a period of relative decline. They pointed out that Poland, Romania and Czechoslovakia had active equity markets in the 1920s prior to being subsumed into the Eastern block. This means that the attractive returns apparently offered by emerging markets may be a temporary phenomenon, an observation they backed up by simulations.

Overall, the majority of past studies on stock market comovements and integration have concentrated mainly on mature developed markets or advanced emerging markets such as the Czech Republic, Hungary and Poland whilst the behaviour and inter-relationship of all others has been neglected. Little attention is given to the investment potential in CEE equity markets only. Thus the literature lacks a model which analyses the interaction and integration of these markets at a regional and global level. The purpose of this chapter is an attempt to fill this gap.

In this chapter, we examine the short and long run behaviour of CEE emerging stock markets and assess the impact of the EU on stock market linkages as revealed by the time series behaviour of their stock market indices. This includes the Johansen procedure, Granger Causality tests, Variance Decompositions and Impulse Response analyses. We also attempt to estimate an error correction model to integrate the dynamics of the short-run with the long-run adjustment process.

4.3 Empirical methodology

The main aim of this section is to examine the cointegration relationship between twelve European emerging stock markets. This is achieved by adoption of a time – series framework which incorporates: the Johansen procedure, Granger Causality tests, Variance Decompositions and Impulse Response analyses. The sections below provide descriptions of the methods used.

4.3.1 Non-stationarity of time series

A necessary condition in the cointegration analysis is to test each series for the presence of unit roots, which indicates whether the series are non-stationary and integrated of the same order. Therefore, we undertake this using the Augmented Dickey-Fuller test (1981), which is a modified version of the pioneer work of Dickey and Fuller (1979) and the Phillips-Perron (1988) non-parametric test. We employ Akaike Information Criterion and Schwarz Bayesian Criterion to select the appropriate lag length.

4.3.2 Cointegration analysis

Cointegration assesses the long-run link between economic variables. Cointegration of two or more time series suggests that there is a long-run or equilibrium relationship between them. Therefore, the economic interpretation of cointegration is that if two or more series are linked to form an equilibrium relationship spanning the long-run, then, even though the series themselves may be non-stationary, they move closely together over time and their difference will be stationary. Their long-run relationship is the equilibrium to which the system converges over time, and the error term can be interpreted as the disequilibrium error or the distance that the system is always from equilibrium at time t. Cointegration has emerged as a powerful technique for investigating common trends in multivariate time series, and provides a sound methodology for modeling both long-term and short-term dynamics in a system. In this paper we applied the Johansen (1991) cointegration testing framework to determine those relationships among all variables of the twelve CEE stock markets.

4.3.2.1 Johansen Cointegration Test

Let X_t denote a vector that includes *n* non-stationary variables (*n* = 11 for pre-EU series data and *n* = 12 for post-EU series data in this study). Assuming existence of cointegration, the data generating process of X_t can be appropriately developed in an error correction model (ECM) with $k - 1$ lags, we can express this using a general VAR model with *k* lags:

$$\Delta X_t = \Pi X_{t-1} + \sum_{i=1}^{k-1} \Gamma_i \Delta X_{t-i} + \mu + \varepsilon_t \quad (t = 1, \ldots, T) \tag{4.1}$$

where Δ represents the difference operator ($\Delta X_t = X_t - X_{t-1}$), X_t is a ($n \times 1$) vector of prices, Π is a ($n \times n$) coefficient matrix whose rank determines the number of cointegrating relationships, Γ_i is a ($n \times n$) matrix of short-run dynamics coefficients and $\varepsilon_t \sim iid(0, \Sigma)$ is a ($n \times 1$) vector of innovations. If the coefficient matrix Π has reduced rank $r < n$, then there exist $n \times r$ matrices α and β each with rank *r* such that $\Pi = \alpha\beta'$ and βX_t is stationary. X_t is stationary in a case when r = 0 which is equivalent to $\Pi = 0$. However, if the rank *r* = *n,* the coefficient matrix Π is of full rank and the variables X_t are non-stationary. *r* is a number of cointegrating relationships, the elements of α are known as the adjustment parameters in the vector error correction model (VECM) and each column of β is a cointegrating vector.

4.3.2.2 Vector Error Correction Model

Once the cointegration relationship is established, a vector error correction model (VECM) can be estimated. VECM is a restricted VAR designed for use with non-stationary series which are known to be cointegrated. The VECM has cointegration relations built into the specification so that it restricts the long-run behaviour of the endogenous variables to converge to their cointegration relationships while allowing for the short-run adjustment dynamics. The cointegration term is known as the error correction term (ECT) since the deviation from long-run equilibrium is corrected gradually through a series of partial short-run adjustments. In the presence of cointegration, the coefficient matrix Π can be expressed as a system of two matrices and defined as $\Pi = \alpha\beta'$. Thus the equation (4.1) can be rewritten in the below form:

$$\Delta X_t = \alpha\beta' X_{t-1} + \sum_{i=1}^{k-1} \Gamma_i \Delta X_{t-i} + \mu + \varepsilon_t \tag{4.2}$$

where α is a $k \times n$ matrix which represents the speed of adjustment of the cointegrated variables towards their equilibrium value, which also is known as ECT. A low value of α implies a fast adjustment to the long-run equilibrium.

4.3.3 Granger Causality

The Granger causality test is a technique for determining whether one time series is useful in forecasting another (Granger, 1969). Let $F(X_t|I_{t-1})$ be the conditional probability distribution of X_t given the bivariate information set I_{t-1} consisting of an *Lx*-length lagged vector the bivariate of X_t, say $X_{t-L_x}^{Lx} \equiv (X_{t-L_x}, X_{t-L_{x+1}}, \dots, X_{t-1})$, and an *Ly*-length lagged vector of Y_t say $Y_{t-L_y}^{Ly} \equiv \left(X_{t-L_y}, X_{t-L_{y+1}}, \dots, X_{t-1}\right)$. Given lags *Lx* and *Ly*, the time series $\{Y_t\}$ does not strictly Granger cause $\{X_t\}$ if:

$$F(X_t|I_{t-1}) = \left(X_t \middle| \left(I_{t-1} - Y_{t-L_y}^{L_y}\right)\right); \ where\ t = 1,2,\dots \tag{4.3}$$

If the above equation does not hold, then knowledge of past *Y* values helps to predict current and future *X* values, and *Y* is said to strictly Granger cause *X*. Bivariate regression for all possible pairs of *(X,Y)* series in the group can take a form of:

$$\Delta X_t = \sum_{i=1}^{q} \alpha_i X_{t-1} + \sum_{j=1}^{p} \beta_j Y_{t-1} + \upsilon_t$$

$$\Delta Y_t = \sum_{i=1}^{p} \alpha_i Y_{t-1} + \sum_{j=1}^{q} \beta_j X_{t-1} + u_t \tag{4.4}$$

where υ_t and u_t are white noise, p is the order of the lag for Y and q is the order of the lag for X. The test statistic is the standard Wald F-statistic which is calculated for joint hypothesis: $\beta_1 = \beta_2 = \cdots = \beta_j = 0$ for each equation. The null hypothesis is that x does not Granger cause y in the first regression and that y does not Granger cause x in the second regression.

4.3.4 Forecast Error Variance Decomposition

Forecast variance error decomposition (FEVD) indicates the amount of information each variable contributes to the other variable in a VAR model and determines how much of the forecast error variance of each variable can be explained by exogenous shocks to the other variables. This method provides a direct test on the information asymmetry pattern in the short-run dynamics sense (Yang, 2003). If a market informationally leads another, this market's returns should most significantly be explained by its own innovations and not as much by other markets' innovations. Instead, innovations from this market should be able to significantly explain other market returns.

If the MA representation in the first difference is given by

$$\Delta X_t = \mu + \sum_{l=0}^{\infty} \Theta_l \varepsilon_{t-l}, \quad t = 1,2,\dots,T \tag{4.5}$$

where Θ_l is the coefficient matrices in the MA representation (as demonstrated in Lutkepohl, 1991 and forwarded by Pesaran and Shin, 1998), the *n*-step ahead generalized forecast error variance decomposition of variable i due to the shock in variable j in the VAR is given by

$$\psi_{ij}(n) = \frac{\sigma_{ii}^{-1} \sum_{l=0}^{n} (e_i' \Theta_l \Sigma e_j)^2}{\sum_{l=0}^{n} (e_i' \Theta_l \Sigma \Theta_l' e_i)} \tag{4.6}$$

where *i,j = 1,2, ...,p*; σ_{ii} is the *ii*th element of the variance-covariance matrix Σ; $e_i$is the selection vector defined as $e_i = (0 \quad \dots \quad 0 \quad 1 \quad 0 \quad \dots \quad 0)'$ where 1 is the *i*th element in selection vector; $e_i' \Theta_l \Sigma \Theta_l' e_i$ is the *i*th diagonal element of the matrix $\Theta_l \Sigma \Theta_l'$, which also enters the persistence profile analysis.

4.3.5 Impulse Response

The concept of generalized impulse response (IR) function is set out in Pesaran and Shin (1998) where was shown that the concept can be applied to multvariate models such as VAR. This analysis deal with the three main issues. Firstly answer the question how the dynamic system was hit by shocks at time *t*. Secondly, investigate the state of the system at time *t–1*, before the system was hit by shocks. And finally illustrate the expectations about future shocks and how system might react over the interim period from *t + 1* to *t + N*. For this puprose equation (4.6) can be written as the sum of squares of the generalized responses of the shocks to the *i*th equation on the *j*th variable in the model, namely $\sum_{l=0}^{n} \left(GI_{ij,l}\right)^2$, where $GI_{ij,l}$ is given by

$$GI_{ij,N} = \frac{e_j' \Theta_N \Sigma e_i}{\sqrt{\sigma_{ii}}}, \quad i,j = 1,2, \dots, p \tag{4.7}$$

The above equation represents the generalized IR function of a unit shock at the horizon N. The generalized impulse responses are invariant to the ordering of the variables in the VAR. It is also worth to note that the two impulse responses coincide only for the first variable in the VAR, or when Σ is a diagonal matrix.

4.4 Research hypotheses tested

Hypotheses tested for the purpose of the cointegration analysis are formulated below (given in the alternate format) and are tested for differences between pre- and post-EU periods:

- H_5: There is at least one cointegrating vector between the CEE stock markets.
- H_6: A long-run relationship exists between the CEE countries.
- H_7: There is Granger causality between the CEE countries.
- H_8: There is regional integration between the CEE counties.

4.5 Empirical results

The empirical results section contains six subsections. The first one presents results of unit root tests and stationarity of the series, with the second discussing the Johansen procedure and establishing the long run relationship. Subsequently the vector error correction model is estimated. The next section discusses Granger Causality tests, where relationships among the most advanced emerging markets are indentified. The final section examines Variance Decompositions and Impulse Response analyses.

4.5.1 Cointegration analysis

The purpose of the cointegration test is to determine whether a group of non-stationary series is cointegrated or not. If such a relationship between variables exists, we can interpret this as a long-run equilibrium relationship among the variables. Long-run relationships help to assess whether cointegration exists between CEE emerging markets. This study employs Johansen's (1988) cointegration testing framework to determine the absence or the presence of the cointegrating relationship among all tested variables.

The first stage in the Johansen procedure is to test whether the time series are stationary. We tested for the presence of unit roots, where the null hypothesis of the ADF and PP tests assume that the series has a unit root and is non-stationary. We found all the price series to be first order integrated (*I(1)*) and the return series to be stationary at the 5% significance level (please refer to Chapter 3: "Empirical Data").

In the Johansen procedure we need to indentify the lag order (p) for VAR model. Therefore Akaike information and Schwarz Bayesian model selection criteria AIC and

SBC respectively) have been computed, to select the appropriate order of VAR(p). The selection is made by using a maximum lag length. The selection procedure involves choosing the VAR(p) model with the highest value of the AIC or the SBC. In practice SBC gives results with lower order VAR than AIC. A problematic/tricky phase is to choose the highest order of VAR, and to be sure that it is high enough, so the risk of over-parameterization can be avoided. Since we have a long (~5000 observations), high frequency series data, we can choose the higher order of the VAR (following AIC selection criterion). Therefore VAR(2) for pre-EU period, VAR(3) for 2004-2011 post-EU period and VAR(2) for 2007-2011 post-EU period have been chosen (please see Appendix C for numerical details).

Table 4.1: Johansen cointegration rank test results

Hypothesis		Eigenvalue test statistics		CV at 5% significance level		Trace test statistics		CV at 5% significance level	
Null	Alternative	Case 3	Case 5	Case 3	Case 5	Case 3	Case 5	Case 3	Case 5
pre-EU period, 1995 - 2004									
$r = 0$	$r \geq 1$	77.587 *	85.654 *	68.910	71.840	322.121 *	333.966 *	279.840	302.380
$r \leq 1$	$r \geq 2$	67.115 *	57.623	63.320	66.170	244.534 *	248.311	234.980	255.070
$r \leq 2$	$r \geq 3$	48.218	48.836	57.200	60.480	177.419	190.681	194.420	213.400
$r \leq 3$	$r \geq 4$	33.143	34.865	51.150	54.170	129.200	141.851	157.800	174.880
pre-EU period, 2004 - 2011									
$r = 0$	$r \geq 1$	105.381*	103.105*	74.610	77.730	411.225 *	454.043 *	328.520	352.130
$r \leq 1$	$r \geq 2$	63.087	78.842*	68.910	71.840	305.843 *	350.938 *	279.840	302.380
$r \leq 2$	$r \geq 3$	59.756	60.447	63.320	66.170	242.756 *	272.096 *	234.980	255.070
$r \leq 3$	$r \geq 4$	43.387	48.344	57.200	60.480	182.999	211.648	194.420	213.400
pre-EU period, 2007 - 2011									
$r = 0$	$r \geq 1$	86.966 *	92.410 *	74.610	77.730	358.518 *	395.674 *	328.520	352.130
$r \leq 1$	$r \geq 2$	50.122	66.276	68.910	71.840	271.552	303.264 *	279.840	302.380
$r \leq 2$	$r \geq 3$	47.546	49.959	63.320	66.170	221.430	236.988	234.980	255.070
$r \leq 3$	$r \geq 4$	45.861	46.949	57.200	60.480	173.884	187.028	194.420	213.400

Case 3: unrestricted intercept and no trend in the VAR.
Case 5: unrestricted intercept and unrestricted trend in the VAR.
r – number of cointegrating vectors.
*indicates rejection of null hypothesis (indicates number of cointegrating vectors) at 5% significance level.

The next step is to determine whether a group of CEE emerging markets is cointegrated or not. For this purpose a VECM is estimated for each sub-period discussed in the study. Two alternative models have been chosen to compare the behaviour of the data series: the first a model of unrestricted intercept and no trend specifications (Case 1) and the second a model of unrestricted intercept and trend specifications (Case 2). To find the existence of cointegrated vectors we applied standard maximum eigenvalue and trace test statistics. Those two statistics test the null hypothesis of r (number of cointegrating vectors) against the alternative hypothesis of n cointegrating relations.

The empirical findings, presented in Table 4.1, support the presence of at least one cointegrating vector in the pre-EU as well as in the post-EU period (in both cases). There are two cointegrating vectors in Case 1 for pre-EU period and in Case 2 for post-EU: 2004-2011 period. The presence of cointegrating vectors confirms the existence of a long-run relationship between CEE markets.

There is no single conclusion from both tests. Generally the trace test statistics suggest a higher number of cointegrating vectors than the eigenvalue test. Johansen and Juselius (1991) advised the examination of the estimated cointegrating vectors and based the choice on the interpretability of the cointegrating relations. Luinten and Khan (1999) showed that the trace statistics are more robust than the maximum eigenvalue test. Lutkepohl, Saikkonen and Trenkler (2001) also supported the common practice of using either both tests or applying the trace test exclusively. On the other hand, Seddighi and Shearing (1997) advocate the maximal eigenvalue test as a test with greater power than the trace one. In spite of this dispute, this analysis is based on the maximum eigenvalue test statistics as only from those statistics that we can get significant values in the VECM (vector error correction model).

For the pre-EU data, the statistics suggested two (Case 1) and one (Case 2), cointegrating vectors at the 5% significance level. Given this evidence in favour of at least one cointegrating vector, the data was normalized on the Czech Republic and Polish stock markets for Case 1 and on the Czech Republic market for Case 2[10] and was found to have a combination of negative and positive cointegrating vector values while Poland's variable equals zero (Table 4.2). Even though we developed and analysed two different case scenarios all of the results are similar in the specification of the error correction form. This implies that there are limitations for portfolio diversification

[10] In the case of one cointegrating vector, the model has been normalized on the Czech Republic data, as the most advanced emerging market; the FTSE group classified this market as advanced. In the case of two cointegrating vectors three markets have been taken into account: Czech Republic, Hungary and Poland, as those three are classified as advanced emerging markets. The combinations of two have been analysed, and cointegrating vectors have been normalized as: Czech Republic and Hungary, and Czech Republic and Poland. However, results presented in this paper only include Czech Republic and Polish markets, as the other analysis showed no significance for cointegrating vectors.

amongst those stock markets because they move closely together in the long run and share common trends. The coefficient of ECT has been calculated and equals -0.042(0.010) and -0.078(0.012) in Case 1 and Case 2 respectively, and is statistically significant, but rather small, suggesting that it would take a long time for the equation to return to its equilibrium once it is shocked.

For the post-EU: 2004-2011 period, the statistical test indicates one (Case 1) and two (Case 2) cointegrating vectors at the 5% significance level. We normalized the data in a similar way as for the previous case, however the outcome is different. We found a significant negative cofactor for most of the CCE markets, including Bulgaria, Cyprus, Estonia, Hungary, Latvia, Malta, Poland and Slovakia. A different finding is that the Lithuanian and Romanian coefficients are positive (see Table 4.3) and only the coefficient sign of Slovenia changes depending on the case scenario. In summary, during the years 2004-2011, the post-EU phase, there is no evident difference in the values of the long-run variables regardless of the case scenario. We normalized the second cointegrating vector for the Polish data but found no significance at a 5% level, so for brevity we do not show the full results here. The results for the VECM are presented in Table 4.3. The coefficients of the ECT, 0.009(0.003) and 0.008(0.003) respectively for the case scenarios, are statistically significant but again very small, which indicates a slow return to the equation's equilibrium.

The above results for the post-EU: 2004-2011 period are broadly in line with the post-EU:2007-2011 period (compare Table 4.3 with Table 4.4). The one difference is for the Cyprus coefficient of the cointegrating vector, which now is positive. The ECT is again positive but small and equal to 0.010(0.005) in both cases.

In terms of the speed of adjustment of the CEE emerging markets, all the stock markets in pre-EU and post-EU periods adjust back to the long-run equilibrium very slowly, with the pre-EU period having the fastest adjustment speed of nearly 8% as compared to the 1% of post-EU period. Interestingly, we found the coefficient of the ECT sign changes between pre- and post-EU periods from negative to positive.

Table 4.2: VECM for pre-EU: 1995-2004 period

Normalized cointegrating vectors										
Case 1: intercept and no trend in the VAR										
Bulgaria	Czech Rep	Estonia	Hungary	Latvia	Lithuania	Malta	Poland	Romania	Slovakia	Slovenia
-0.049**	1.000	0.014	-0.451**	0.009**	-0.027	0.002**	0.000	-0.033**	0.039**	0.005**
(0.028)		(0.018)	(0.119)	(0.003)	(0.026)	(0.001)		(0.011)	(0.028)	(0.002)
23.786**	0.000	4.101	42.303	1.257	-31.733**	-1.020**	1.000	15.683**	-13.938	-2.872**
(16.669)		(10.546)	(69.349)	(2.319)	(15.332)	(0.632)		(6.813)	(16.451)	(1.564)
Case 2: intercept and trend in the VAR										
Bulgaria	Czech Rep	Estonia	Hungary	Latvia	Lithuania	Malta	Poland	Romania	Slovakia	Slovenia
-0.003	1.000	0.029**	-0.396**	0.010**	-0.043**	-0.002**	0.000	-0.010**	0.032**	0.002**
(0.011)		(0.009)	(0.058)	(0.001)	(0.014)	(0.001)	(0.000)	(0.004)	(0.012)	(0.001)
Case 1						Case 2				
ECT(-1)	-0.042 (0.010) [0.000]**		ECT(-2)	0.000 (0.000) [0.224]		ECT(-1)	-0.078 (0.012) [0.000]**			

Note: number of cointegrating vectors $r = 2$ (Case 1) and $r = 1$(Case 2); normalized cointegrating vector shows the coefficient value with its asymptotic standard error in parentheses; ECT shows the coefficient value with its standard error in parentheses and t-ratio in square brackets; ** indicates significance at 5% level; * indicates significance at 10% level.

Table 4.3: VECM for post-EU: 2004-2011 period

Normalized cointegrating vectors

Case 1: intercept and no trend in the VAR

Bulgaria	Czech R	Cyprus	Estonia	Hungary	Latvia	Lithuania	Malta	Poland	Romania	Slovakia	Slovenia
-0.009	1.000	-0.000	-0.054**	-0.427**	-0.008	0.040	-0.012**	-0.004**	0.050**	-0.073**	0.002
(0.029)		(0.003)	(0.039)	(0.222)	(0.017)	(0.054)	(0.053)	(0.001)	(0.023)	(0.028)	(0.002)

Case 2: intercept and trend in the VAR

Bulgaria	Czech R	Cyprus	Estonia	Hungary	Latvia	Lithuania	Malta	Poland	Romania	Slovakia	Slovenia
-0.120**	1.000	-0.011**	-0.040	-0.501**	-0.069**	0.123**	-0.009**	0.000	0.038**	-0.040**	-0.002
(0.073)		(0.009)	(0.046)	(0.273)	(0.027)	(0.065)	(0.004)		(0.023)	(0.032)	(0.002)

Case 1		Case 2			
ECT(-1)	0.009	ECT(-1)	0.008	ECT(-2)	-0.000
	(0.003)		(0.003)		(0.000)
	[0.002]**		[0.023]**		[0.003]**

Note: number of cointegrating vectors $r = 1$ (Case 1) and $r = 2$[6] (Case 2); normalized cointegrating vector shows the coefficient value with its asymptotic standard error in parentheses; ECT shows the coefficient value with its standard error in parentheses and t-ratio in square brackets; ** indicates significance at 5% level; * indicates significance at 10% level.

Table 4.4: VECM for post-EU: 2007-2011 period

Normalized cointegrating vectors

Case 1: intercept and no trend in the VAR

Bulgaria	Czech R	Cyprus	Estonia	Hungary	Latvia	Lithuania	Malta	Poland	Romania	Slovakia	Slovenia
-0.104**	1.000	0.012**	-0.061**	-1.000**	-0.050**	0.150**	-0.003	-0.000	0.039**	-0.071**	0.000
(0.041)		(0.005)	(0.043)	(0.346)	(0.031)	(0.088)	(0.004)	(0.001)	(0.018)	(0.027)	(0.002)

Case 2: intercept and trend in the VAR

Bulgaria	Czech R	Cyprus	Estonia	Hungary	Latvia	Lithuania	Malta	Poland	Romania	Slovakia	Slovenia
-0.081**	1.000	0.004	-0.114**	-0.728**	-0.059**	0.208**	-0.012**	-0.001	0.041**	-0.227**	0.001
(0.047)		(0.006)	(0.082)	(0.376)	(0.043)	(0.138)	(0.009)	(0.002)	(0.023)	(0.130)	(0.002)

Case 1		Case 2	
ECT(-1)	0.010	ECT(-1)	0.010
	(0.005)		(0.004)
	[0.071]*		[0.012]**

Note: number of cointegrating vectors r = 1(Case 1 and 2); normalized cointegrating vector shows the coefficient value with its asymptotic standard error in parentheses; ECT shows the coefficient value with its standard error in parentheses and t-ratio in square brackets; ** indicates significance at 5% level; * indicates significance at 10% level.

In general we found that the number of cointegrating vectors remains the same in all the studied sub-periods and is equal to one. Even though there is evidence for two cointegrating vectors on some occasions, there is no significance in the normalized vector form solutions or the ECT is not conclusive but equal to zero. Therefore the conclusion on the impact of the EU enlargement on stock market linkages is not straightforward. However, as there is a presence of at least one cointegrating vector, this indicates that in all sub-periods a long-run relationship exists between all twelve studied stock market indices. The evidence of cointegration has several important implications. First of all, based on diagnostic tests, superior correlation has been ruled out. This means that relationships in which variables have no direct causal connection are eliminated; subsequently opening the alley to the existence of a unique channel for either uni-variate or bi-variate Granger causality effects. Secondly even where economic theory posits a long-run equilibrium function for a variable, disequilibrium could exist in the short run, as the cointegration vector does not capture the dynamic responses to the system. While the cointegration vector captures the long-run relationship between variables, it does not capture the dynamic response. These are encompassed by the ECT (as a part of ECM analysis), which is meant to measure short-run movements in the dependent variable in response to fluctuations in the independent variables and measures the speed of adjustment of the dependent variable to its long-run value. Thirdly, the investors have a difficult task in setting up their portfolios as several stock markets present similar behaviour with regards to internal and external shocks. This limits diversification opportunities as stock markets move closely together in the long run and share common trends. This is also an answer to the market globalization process of increasing economic integration between countries which could lead to a single European market. Finally, cointegrated stock market indices approach a common long-run equilibrium path, as common macro and micro economic policies are more integrated following EU regulations.

4.5.2 Granger Causality

The Granger causality test was applied to the first difference of the twelve stock markets in all sub-periods. Since the test is highly sensitive to the lag length level, the AIC selection criterion was used as reasonable estimate of the longest time over which one of the variables could help predict the other (see Appendix D for numerical results to lag length level test). Table 4.5 shows the results for the pre-EU Granger causality test based on the eleven-dimensional vector autoregression with one lag. Granger causality implies the highest influence to be that of the Czech Republic stock market over the other five CEE markets, namely Estonia, Hungary, Lithuania, Poland and Slovenia. There are also uni-variate Granger causality patterns as follows: Bulgaria influences Romania, Estonia influences Hungary and Lithuania, Hungary influences Lithuania and Slovenia, Poland influences Bulgaria and finally Slovakia influences Hungary. There is no evidence of bi-variate Granger causality during this time frame. We also found that the four stock markets of Latvia, Lithuania, Malta and Romania have no influence on any other stock markets.

The post-EU period (2004-2011) Granger causality test is based on the twelve-dimensional vector autoregression with two lags, and results are presented in Table 4.6. On this occasion we found that the highest influence among the developed emerging markets is exerted by the Czech Republic, Hungary and Poland on the other CEE markets. All of the CEE markets affect changes in the seven other stock markets, and between them only one feedback effect is observed, which exists between the Czech Republic and Poland. It is worth mentioning here, that as Hungarian and Polish stock markets have such a strong influence on other stock markets, the two markets do not appear to significantly influence each other. All the other causality effects are presented in Table 4.6. As for the pre-EU period, we do not account for a feedback effect. In the post-EU phase this bi-variate effect is observed for a number of markets and mostly relates to Bulgaria and Romania. We established that the Maltese stock market is isolated from all others, as it is the only one which does not appear to be caused by the others, nor does it have any influence on them.

For the other post-EU period 2007-2011, the results seems are somewhat different (refer to Table 4.7). The Granger causality effect is very strong again for the Czech Republic, which seems to have taken a lead role among all studied CEE countries. The role of Bulgarian and Cyprus stock markets is also significant as they influence six and seven other stock markets respectively. There are bi-variate effects between several countries, but this mostly relates to Bulgaria, Cyprus and Czech Republic stock markets. The position of the Slovakian stock market appears to be stronger as, in comparison to the other post-EU period, it is now caused only by one stock market (Malta – feedback effect) but itself influences the five other stock markets of the Czech Republic, Latvia, Lithuania, Malta and Slovenia.

The presence of Granger causality between CEE countries is expected because of the strong trade, economic ties and direct investment they have with each other. Furthermore, six of those countries share the euro as a common currency, thus they share common monetary policy. The implication of finding Granger causality among the CEE stock markets is that this implies that short term profit strategies can be formulated by investors in the sense that, if Granger causality is present, a movement in one stock market causes a preceding movement in the other stock markets. As a result, predicting the movement of the stock market that is being led is possible by assessing the movement of the leading stock market. In contrast, where Granger causality is not found then interdependencies are absent among those stock markets and thus portfolio diversification is beneficial in the short run. The downside of Granger causality not being present is that short term profit strategies cannot be formulated because the movement of one stock market does not cause a movement in another stock market.

Table 4.5: Granger Causality test for returns, pre-EU period, 1995-2004

y_t Granger causes x_t	Bulgaria	Czech Rep	Estonia	Hungary	Latvia	Lithuania	Malta	Poland	Romania	Slovakia	Slovenia
Bulgaria	–	0.005	0.010	0.047	0.048	0.717	0.253	0.022	5.118*	0.728	0.330
Czech Rep	1.820	–	7.834*	7.622*	0.342	7.032*	0.146	9.105*	0.004	2.618	9.159*
Estonia	1.780	0.133	–	7.383*	0.439	25.240*	0.181	0.327	3.473	0.086	0.004
Hungary	1.343	0.520	0.000	–	2.126	6.612*	0.275	0.025	3.003	0.048	9.869*
Latvia	1.331	1.314	0.353	0.004	–	0.403	1.020	0.337	0.453	0.044	0.019
Lithuania	0.011	2.239	1.872	2.934	1.467	–	2.983	0.303	0.395	0.040	1.832
Malta	3.172	1.339	0.224	2.267	0.117	2.894	–	0.074	0.871	0.355	0.577
Poland	3.989*	0.007	0.914	1.604	0.362	0.668	0.104	–	0.008	0.102	0.295
Romania	0.002	1.025	4.660	0.412	0.451	0.332	0.023	0.011	–	0.448	1.069
Slovakia	0.020	0.569	0.551	4.005*	0.185	0.893	0.003	0.030	3.209	–	0.362
Slovenia	2.154	0.151	1.247	0.024	0.044	0.032	0.206	0.679	0.111	1.796	–

The table reports *F*-statistics (Wald statistics test); * indicates significance at the 5% level.

Table 4.6: Granger Causality test for returns, post-EU period, 2004-2011

y_t Granger causes x_t	Bulgaria	Czech Rep	Cyprus	Estonia	Hungary	Latvia	Lithuania	Malta	Poland	Roman	Slovakia	Slovenia
Bulgaria	–	4.952*	9.742*	1.840	1.654	3.897*	6.052*	2.149	1.789	7.896*	2.256	11.008*
Czech Rep	20.150*	–	2.653	12.813*	2.287	17.279*	12.496*	1.553	6.305*	9.676*	0.624	16.753*
Cyprus	49.428*	2.900	–	8.421*	0.589	13.240*	7.163*	0.924	1.362	5.927*	0.726	34.550*
Estonia	3.704*	0.885	0.833	–	0.003	12.394*	8.486*	1.708	1.582	0.262	4.128*	1.997
Hungary	14.608*	13.139*	2.040	15.952*	–	11.927*	14.311*	3.019	0.079	8.585*	0.849	14.183*
Latvia	1.609	0.196	0.054	0.198	0.107	–	3.397*	0.768	0.703	1.701	3.839*	0.902
Lithuania	1.053	0.131	1.608	1.032	0.703	15.449*	–	2.101	1.681	0.009	3.741*	0.313
Malta	0.140	1.637	0.105	0.454	1.294	0.190	0.392	–	1.206	1.125	1.738	0.388
Poland	18.032*	15.568*	0.899	21.951*	1.901	19.260*	14.985*	0.968	–	16.522*	0.757	17.641*
Romania	18.416*	2.140	2.459	2.519	1.989	4.807*	2.746	2.121	3.371*	–	1.591	5.606*
Slovakia	0.338	3.861*	3.637*	2.482	0.593	2.102	2.278	1.665	2.279	4.262*	–	4.295*
Slovenia	4.972*	0.779	0.664	1.134	0.150	3.839	0.070	0.875	0.195	4.906*	0.618	–

The table reports *F*-statistics (Wald statistics test); * indicates significance at the 5% level.

Table 4.7: Granger Causality test for returns, post-EU period, 2007-2011

y_t Granger causes x_t	Bulgaria	Czech Rep	Cyprus	Estonia	Hungary	Latvia	Lithuania	Malta	Poland	Roman	Slovakia	Slovenia
Bulgaria	–	3.430*	9.419*	0.803	0.691	4.749*	3.946*	3.667*	2.131	5.326	1.112	8.183*
Czech Rep	14.268*	–	3.752*	8.373*	3.050*	16.312*	13.963*	1.861	8.070*	5.776*	0.554	11.669*
Cyprus	42.114*	2.233	–	5.795*	0.289	14.143*	9.044*	4.277*	0.513	6.932*	0.875	25.544*
Estonia	1.948	0.527	0.784	–	0.023	11.358*	4.180*	3.244*	1.165	0.322	4.351	1.353
Hungary	10.605*	11.583*	2.388	10.208*	–	12.006*	15.735*	2.994	0.346	5.788*	0.181	10.275*
Latvia	0.983	0.208	0.984	0.114	0.037	–	0.349	1.863	1.206	0.552	3.002	0.897
Lithuania	2.970	0.875	3.105*	0.340	1.207	11.877*	–	4.916*	4.028*	0.481	1.860	0.662
Malta	0.786	1.965	0.364	0.075	1.277	0.267	2.095	–	0.742	1.027	3.065*	0.865
Poland	14.183*	13.344*	0.060	16.264*	0.356	17.890*	12.553*	0.777	–	12.934*	0.003	12.152*
Romania	12.239*	1.874	3.208*	1.738	1.595	0.267	1.494	1.354	2.256	–	1.891	4.542
Slovakia	1.401	5.584*	2.002	1.578	0.941	17.890*	3.478*	3.102*	1.771	4.977	–	4.284*
Slovenia	4.014*	0.894	0.511	0.801	0.369	4.943*	1.213	1.852	0.344	2.834	0.979	–

The table reports *F*-statistics (Wald statistics test); * indicates significance at the 5% level.

4.5.3 Forecast Error Variance Decomposition of returns

The variance decomposition results of 1-day, 3-day, 5-day and 10-day horizon ahead forecast error variances of each stock market are shown in Table 4.8 to Table 4.10. In those tables each row indicates the percentage of forecast error variance which is explained by innovations in the particular columns. The evidence of the least affected stock market could be beneficial for investors for portfolio diversification purposes.

The results in Table 4.8 show that in the pre-EU period, the Czech Republic stock market is the most influential. While no other market studied can explain more than 1 percent of the Czech Republic error variance, the Czech Republic (based on a horizon of 5 days) explains 3.08 percent for Lithuania, 9.03 percent for Estonia, 17.18 percent for Poland and 19.7 percent for Hungary of forecast error variance. On average, the Czech Republic market explains 5.33 percent of the error variance, which value can be compared with 1.36 percent for Hungary and 1.32 percent for Estonia. Besides, the Czech Republic innovation accounts for 95.91 percent of its own variance. As the Czech Republic partially explains Polish and Lithuanian stock markets, the innovation in the Poland market is also explained 8.56 percent by Hungary and in Lithuania 7.83 percent by Estonia respectively. Table 4.8 also provides evidence that most of the studied countries act like a follower in CEE stock markets. Innovations in those markets fail to explain any substantial part of error variances of the others.

The post-EU: 2004-2011 period is mostly dominated by the two stock markets of Cyprus and the Czech Republic, which two on average can explain 8.66 percent and 7.22 percent, respectively, of the forecast error variances of the other studied CEE markets. The Cyprus stock market explains nine other stocks, from 2.85 percent (for Latvia) to 20.26 percent (for Poland), at the same time explaining 92.54 percent of its own innovations. In comparison, the Czech Republic market explains shocks to the other eight, whilst explaining only 71.8 percent of its own. The other noteworthy contribution is from the Bulgarian stock market which an average explains 4.09 percent of forecast error variances of another nine. As for the previous post-EU time period there are a number of exogenous variables, as they explain more than 90% of their own innovation. The Maltese and Slovakian markets appear the most exogenous, with Poland and Hungary being the least.

The post-EU: 2007-2011 period seems to be quite similar to the previous post-EU period. We can again observe a leading role of three markets: Bulgaria, the Czech Republic and Cyprus, as markets which explain the most number of shocks in the other CEE markets. The difference is only regarding the average percentage of explained variables, which now constitutes 10.69 percent for Cyprus and 5.76 percent for Bulgaria. The Czech Republic percentage stays the same. The increase in percentage value of variables explained by innovation is on average higher in comparison to the previous period, while at the same time we can observe a decrease in the percentage of self explained variables.

Table 4.8: Forecast Error Variance Decomposition of returns, pre-EU period, 1995-2004

	Horizon (days)	Percentage of forecast error variance explained by innovations in: Bulgaria	CzechRep	Estonia	Hungary	Latvia	Lithuania	Malta	Poland	Romania	Slovakia	Slovenia
Bulgaria	1	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3	97.84	0.16	0.45	0.26	0.16	0.02	0.48	0.22	0.04	0.02	0.36
	5	97.55	0.17	0.49	0.26	0.18	0.04	0.63	0.25	0.05	0.02	0.36
	10	97.52	0.17	0.49	0.26	0.18	0.04	0.64	0.25	0.05	0.02	0.36
Czech Rep	1	0.01	99.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3	0.29	95.99	0.20	0.68	0.13	0.53	0.46	0.18	1.11	0.24	0.19
	5	0.30	95.91	0.20	0.68	0.15	0.53	0.48	0.18	1.12	0.25	0.20
	10	0.30	95.91	0.20	0.68	0.15	0.53	0.48	0.18	1.12	0.25	0.20
Estonia	1	0.47	6.82	92.72	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3	0.46	9.04	88.35	0.13	0.03	0.03	0.28	0.40	0.71	0.20	0.37
	5	0.47	9.03	88.26	0.14	0.05	0.04	0.28	0.42	0.74	0.20	0.37
	10	0.47	9.03	88.26	0.14	0.05	0.04	0.28	0.42	0.74	0.20	0.37
Hungary	1	0.10	20.08	1.73	78.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3	0.12	19.71	1.72	76.66	0.01	0.35	0.03	0.06	0.36	0.78	0.19
	5	0.13	19.71	1.73	76.62	0.01	0.35	0.03	0.07	0.37	0.79	0.20
	10	0.13	19.71	1.73	76.62	0.01	0.35	0.03	0.07	0.37	0.79	0.20
Latvia	1	0.01	0.63	0.25	0.10	99.00	0.00	0.00	0.00	0.00	0.00	0.00
	3	0.25	0.67	0.34	0.79	97.28	0.06	0.08	0.34	0.10	0.08	0.01
	5	0.33	0.67	0.35	0.80	97.11	0.08	0.08	0.37	0.10	0.09	0.01
	10	0.34	0.67	0.36	0.81	97.09	0.08	0.08	0.37	0.10	0.09	0.01
Lithuania	1	0.07	0.99	5.86	0.09	0.00	92.99	0.00	0.00	0.00	0.00	0.00
	3	0.25	3.01	7.80	0.19	0.23	87.70	0.19	0.39	0.08	0.03	0.13
	5	0.25	3.08	7.83	0.22	0.26	87.49	0.22	0.40	0.09	0.03	0.13
	10	0.25	3.08	7.83	0.22	0.26	87.49	0.22	0.40	0.09	0.03	0.13
Malta	1	0.00	0.07	0.24	0.27	0.00	0.12	99.31	0.00	0.00	0.00	0.00
	3	0.28	0.53	0.27	0.30	0.32	0.31	97.54	0.01	0.04	0.00	0.41
	5	0.35	0.63	0.28	0.31	0.32	0.39	97.18	0.01	0.07	0.01	0.46
	10	0.35	0.64	0.28	0.31	0.32	0.40	97.14	0.01	0.08	0.01	0.45
Poland	1	0.01	17.43	0.87	8.63	0.12	0.05	0.05	72.84	0.00	0.00	0.00
	3	0.22	17.19	0.92	8.56	0.20	0.27	0.27	72.02	0.13	0.15	0.07
	5	0.23	17.18	0.92	8.56	0.21	0.29	0.31	71.93	0.14	0.15	0.07
	10	0.23	17.18	0.92	8.56	0.22	0.29	0.32	71.93	0.14	0.15	0.07
Romania	1	0.19	1.50	0.16	1.89	0.18	0.00	0.08	0.34	95.66	0.00	0.00
	3	1.03	1.50	0.61	2.01	0.26	0.06	0.44	0.35	93.57	0.04	0.14
	5	1.04	1.50	0.61	2.02	0.26	0.06	0.44	0.36	93.53	0.04	0.14
	10	1.04	1.50	0.61	2.02	0.26	0.06	0.44	0.36	93.53	0.04	0.14
Slovakia	1	0.03	0.21	0.20	0.00	0.05	0.01	0.00	0.21	0.07	99.21	0.00
	3	1.13	0.44	0.49	0.12	0.05	0.04	0.12	0.62	0.26	96.66	0.07
	5	1.15	0.44	0.49	0.12	0.05	0.04	0.13	0.62	0.28	96.60	0.07
	10	1.15	0.44	0.50	0.12	0.05	0.04	0.13	0.62	0.28	96.60	0.07
Slovenia	1	0.04	0.36	0.13	0.34	0.04	0.34	0.01	0.16	0.20	0.41	97.98
	3	0.14	0.83	0.22	0.48	0.07	0.39	0.11	0.33	0.56	0.68	96.18
	5	0.15	0.83	0.24	0.48	0.07	0.39	0.11	0.33	0.57	0.68	96.15
	10	0.15	0.83	0.24	0.48	0.07	0.39	0.11	0.33	0.57	0.68	96.15

Table 4.9: Forecast Error Variance Decomposition of returns, post-EU period, 2004-2011

	Horizon (days)	Percentage of forecast error variance explained by innovations in: Bulgaria	CzechRep	Cyprus	Estonia	Hungary	Latvia	Lithuania	Malta	Poland	Romania	Slovakia	Slovenia
Bulgaria	1	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3	91.83	0.52	5.63	0.46	0.05	0.30	0.02	0.03	0.07	0.60	0.02	0.46
	5	91.41	0.53	5.81	0.47	0.05	0.30	0.02	0.04	0.17	0.60	0.02	0.57
	10	91.41	0.53	5.82	0.47	0.05	0.30	0.02	0.04	0.17	0.60	0.02	0.57
Czech Rep	1	4.83	74.54	20.63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3	4.96	71.90	20.00	0.10	1.28	0.02	0.07	0.24	0.82	0.03	0.38	0.20
	5	4.96	71.81	19.98	0.11	1.28	0.03	0.08	0.24	0.83	0.03	0.38	0.26
	10	4.96	71.80	19.98	0.11	1.28	0.03	0.08	0.24	0.83	0.03	0.38	0.27
Cyprus	1	4.59	0.00	95.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3	5.11	0.42	92.65	0.04	0.06	0.03	0.12	0.03	0.56	0.27	0.39	0.32
	5	5.11	0.43	92.54	0.07	0.06	0.04	0.13	0.04	0.57	0.28	0.39	0.34
	10	5.11	0.43	92.54	0.07	0.06	0.04	0.13	0.04	0.57	0.28	0.39	0.34
Estonia	1	4.16	5.62	3.25	86.98	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3	4.25	6.41	5.06	82.62	0.47	0.06	0.03	0.06	0.62	0.09	0.28	0.04
	5	4.29	6.41	5.11	82.47	0.47	0.07	0.03	0.07	0.67	0.09	0.28	0.04
	10	4.29	6.41	5.11	82.46	0.47	0.07	0.03	0.07	0.67	0.09	0.28	0.04
Hungary	1	1.41	26.94	15.44	0.29	55.92	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3	1.53	26.95	15.20	0.28	54.82	0.00	0.08	0.14	0.68	0.21	0.08	0.04
	5	1.53	26.93	15.20	0.29	54.78	0.01	0.09	0.14	0.69	0.21	0.08	0.06
	10	1.53	26.93	15.20	0.29	54.77	0.01	0.09	0.14	0.69	0.21	0.08	0.06
Latvia	1	4.38	1.29	1.33	4.59	0.02	88.39	0.00	0.00	0.00	0.00	0.00	0.00
	3	4.55	1.95	2.82	4.92	0.06	84.48	0.48	0.10	0.24	0.08	0.30	0.02
	5	4.60	1.95	2.85	4.92	0.06	84.37	0.48	0.10	0.26	0.08	0.30	0.04
	10	4.60	1.95	2.85	4.92	0.06	84.36	0.48	0.10	0.26	0.08	0.30	0.05
Lithuania	1	5.93	4.85	3.06	8.47	0.11	1.27	76.31	0.00	0.00	0.00	0.00	0.00
	3	6.36	5.67	4.29	8.68	0.36	1.23	72.47	0.09	0.17	0.15	0.28	0.24
	5	6.37	5.68	4.30	8.67	0.36	1.24	72.31	0.11	0.22	0.16	0.29	0.29
	10	6.37	5.68	4.31	8.67	0.36	1.24	72.30	0.11	0.22	0.16	0.29	0.30
Malta	1	0.36	0.01	0.06	0.04	0.00	0.07	0.17	99.28	0.00	0.00	0.00	0.00
	3	0.64	0.12	0.17	0.14	0.17	0.09	0.26	98.01	0.04	0.11	0.25	0.00
	5	0.67	0.12	0.19	0.14	0.17	0.09	0.28	97.88	0.05	0.14	0.25	0.01
	10	0.67	0.12	0.19	0.14	0.17	0.09	0.28	97.88	0.05	0.14	0.25	0.01
Poland	1	3.73	27.80	20.48	0.60	10.12	0.01	0.00	0.03	37.22	0.00	0.00	0.00
	3	3.84	27.50	20.27	0.68	10.34	0.04	0.05	0.14	36.63	0.27	0.17	0.07
	5	3.84	27.49	20.26	0.69	10.33	0.04	0.05	0.15	36.61	0.27	0.17	0.09
	10	3.84	27.49	20.26	0.69	10.33	0.04	0.05	0.15	36.61	0.27	0.17	0.09
Romania	1	5.09	6.26	11.68	1.39	1.06	0.38	0.48	0.03	0.33	73.29	0.00	0.00
	3	5.49	7.01	12.37	1.40	1.35	0.49	0.46	0.16	1.13	69.36	0.35	0.44
	5	5.54	7.01	12.47	1.41	1.35	0.50	0.46	0.16	1.14	69.17	0.34	0.44
	10	5.54	7.01	12.47	1.41	1.35	0.50	0.46	0.16	1.14	69.17	0.34	0.44
Slovakia	1	0.52	0.09	0.01	0.17	0.03	0.09	0.00	0.01	0.22	0.00	98.86	0.00
	3	0.71	0.34	0.15	0.53	0.10	0.28	0.23	0.23	0.33	0.10	96.98	0.02
	5	0.72	0.36	0.17	0.56	0.11	0.29	0.23	0.23	0.33	0.11	96.86	0.03
	10	0.72	0.36	0.17	0.56	0.11	0.29	0.23	0.23	0.34	0.11	96.86	0.03
Slovenia	1	7.64	1.80	2.66	1.67	0.09	1.40	0.62	0.00	0.01	1.45	0.01	82.66
	3	7.32	2.48	8.99	1.42	0.11	1.19	0.61	0.06	0.11	1.37	0.43	75.91
	5	7.40	2.57	8.91	1.41	0.12	1.22	0.61	0.06	0.13	1.36	0.44	75.77
	10	7.40	2.57	8.91	1.41	0.12	1.22	0.61	0.06	0.13	1.36	0.44	75.77

Table 4.10: Forecast Error Variance Decomposition of returns, post-EU period, 2007-2011

	Horizon (days)	Percentage of forecast error variance explained by innovations in: Bulgaria	CzechRep	Cyprus	Estonia	Hungary	Latvia	Lithuania	Malta	Poland	Romania	Slovakia	Slovenia
Bulgaria	1	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3	89.79	0.57	7.11	0.41	0.03	0.37	0.21	0.22	0.11	0.31	0.25	0.62
	5	89.23	0.61	7.32	0.41	0.04	0.37	0.21	0.26	0.27	0.31	0.25	0.72
	10	89.22	0.61	7.33	0.41	0.04	0.37	0.21	0.26	0.27	0.31	0.25	0.72
Czech Rep	1	6.83	69.07	24.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3	6.73	65.53	22.68	0.07	1.87	0.01	0.19	0.42	1.11	0.06	0.89	0.44
	5	6.72	65.39	22.62	0.09	1.88	0.04	0.20	0.42	1.12	0.06	0.90	0.56
	10	6.72	65.38	22.62	0.09	1.88	0.04	0.20	0.42	1.12	0.06	0.90	0.58
Cyprus	1	6.18	0.00	93.82	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3	6.91	0.81	89.37	0.01	0.12	0.01	0.36	0.12	0.88	0.42	0.29	0.69
	5	6.91	0.82	89.16	0.04	0.14	0.04	0.38	0.12	0.89	0.42	0.31	0.76
	10	6.91	0.82	89.16	0.04	0.14	0.04	0.38	0.12	0.89	0.42	0.31	0.77
Estonia	1	5.40	7.04	3.47	84.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3	5.28	7.61	5.20	79.23	0.50	0.06	0.01	0.04	1.15	0.53	0.24	0.14
	5	5.29	7.61	5.25	79.04	0.51	0.07	0.01	0.06	1.22	0.55	0.24	0.15
	10	5.29	7.61	5.25	79.04	0.51	0.07	0.01	0.06	1.22	0.55	0.24	0.15
Hungary	1	2.63	24.56	18.94	0.39	53.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3	2.63	25.01	18.44	0.38	51.96	0.01	0.25	0.09	0.58	0.32	0.18	0.14
	5	2.63	24.99	18.41	0.39	51.90	0.03	0.25	0.10	0.59	0.32	0.19	0.19
	10	2.63	24.99	18.41	0.39	51.89	0.03	0.25	0.10	0.59	0.32	0.19	0.20
Latvia	1	7.12	1.92	1.31	4.96	0.12	84.57	0.00	0.00	0.00	0.00	0.00	0.00
	3	7.45	2.96	3.69	5.63	0.21	78.65	0.26	0.01	0.27	0.16	0.66	0.05
	5	7.51	2.99	3.74	5.62	0.22	78.43	0.27	0.01	0.29	0.17	0.67	0.09
	10	7.50	2.99	3.74	5.62	0.22	78.42	0.27	0.01	0.29	0.17	0.67	0.10
Lithuania	1	9.65	7.26	4.99	14.97	0.05	3.20	59.87	0.00	0.00	0.00	0.00	0.00
	3	9.96	8.16	7.12	14.91	0.59	2.92	54.38	0.59	0.24	0.09	0.70	0.36
	5	9.96	8.18	7.14	14.86	0.59	2.92	54.15	0.59	0.32	0.10	0.70	0.49
	10	9.96	8.18	7.14	14.85	0.59	2.92	54.13	0.59	0.32	0.10	0.70	0.51
Malta	1	0.76	0.17	0.00	0.12	0.07	0.00	0.08	98.81	0.00	0.00	0.00	0.00
	3	1.50	0.25	0.73	0.44	0.22	0.06	0.22	95.13	0.29	0.45	0.65	0.05
	5	1.58	0.27	0.83	0.45	0.24	0.07	0.22	94.86	0.31	0.45	0.66	0.05
	10	1.59	0.27	0.84	0.45	0.24	0.07	0.22	94.84	0.31	0.45	0.66	0.05
Poland	1	5.47	25.53	25.29	0.64	8.83	0.10	0.02	0.10	34.01	0.00	0.00	0.00
	3	5.59	25.33	24.35	0.66	9.55	0.14	0.40	0.16	33.22	0.17	0.21	0.21
	5	5.60	25.30	24.32	0.69	9.55	0.15	0.40	0.17	33.18	0.18	0.22	0.25
	10	5.60	25.30	24.32	0.69	9.55	0.15	0.40	0.17	33.17	0.18	0.22	0.26
Romania	1	7.27	7.55	17.10	1.57	1.88	0.60	1.87	0.00	0.19	61.96	0.00	0.00
	3	7.51	7.87	17.93	1.52	2.00	0.60	1.80	0.21	1.64	57.60	0.64	0.69
	5	7.51	7.88	18.07	1.55	2.00	0.62	1.80	0.22	1.64	57.38	0.64	0.70
	10	7.51	7.88	18.07	1.55	2.00	0.62	1.80	0.22	1.64	57.37	0.64	0.70
Slovakia	1	0.76	0.06	0.03	0.44	0.01	0.01	0.06	0.07	0.06	0.12	98.39	0.00
	3	0.86	0.28	0.22	0.95	0.10	0.16	0.10	0.59	0.11	0.25	96.37	0.00
	5	0.86	0.30	0.25	0.96	0.12	0.16	0.11	0.59	0.11	0.26	96.27	0.01
	10	0.86	0.30	0.25	0.96	0.12	0.16	0.11	0.59	0.11	0.26	96.26	0.01
Slovenia	1	9.50	1.79	2.36	1.79	0.07	2.69	0.66	0.01	0.06	1.70	0.01	79.38
	3	8.77	2.66	9.77	1.52	0.08	2.24	0.64	0.09	0.12	1.58	0.51	72.03
	5	8.82	2.85	9.65	1.50	0.10	2.25	0.64	0.09	0.15	1.59	0.51	71.85
	10	8.81	2.85	9.65	1.50	0.10	2.25	0.64	0.09	0.16	1.59	0.51	71.85

4.5.4 Impulse Response

The pattern of dynamic responses of each CEE stock market is presented in Figure 4.1 to Figure 4.3. These graphs illustrate to what extent the shock of one market is persistent in terms of its effect on the other markets in the system. The impulse response function of each CEE market is traced over a ten day time frame from a unitary standard deviation shock.

Shocks to most of the markets in the pre-EU period seem to cause very small or almost no fluctuations in any other markets (see Figure 4.1). We can observe some responsiveness by Poland to innovations which affect Hungary and the Czech Republic. Those innovations in the Polish stock market are rapidly transmitted to all the other markets, however after day 3 they fade away. Similar behaviour is observable for Estonia and Hungary, where innovations are transmitted to the Czech Republic, Malta, Lithuania, Romania, Slovakia and Slovenia. Conversely in those cases the responses to shocks are quicker and they diminish after day 2.

A different pattern appears after EU enlargement in 2004. Results in Figure 4.2 illustrate significant responses in several markets. In comparison to the previous period, almost all markets respond dramatically to Polish shocks in the first few days and then rapidly taper off. A similar pattern of responses is observed for shocks in Romania, Lithuania and Slovenia. The responsiveness to shocks in the Czech Republic and Hungary seems to be significant as they influence each other as well as Cyprus and Bulgaria. Slovakia and Malta appear to be isolated, with shocks in these markets not impacting other markets. This pattern is also apparent for the post-EU, 2007-2011 period.

In view of our findings that many of the responses are complete in about three days after a shock, the pattern of impulse response emerging from the VAR analysis seems to be broadly consistent with the concept of informationally efficient European stock markets. Implications for investors are that it would be difficult to earn unusual profits by investing in a particular market, knowing that information is available at the time the investment is made.

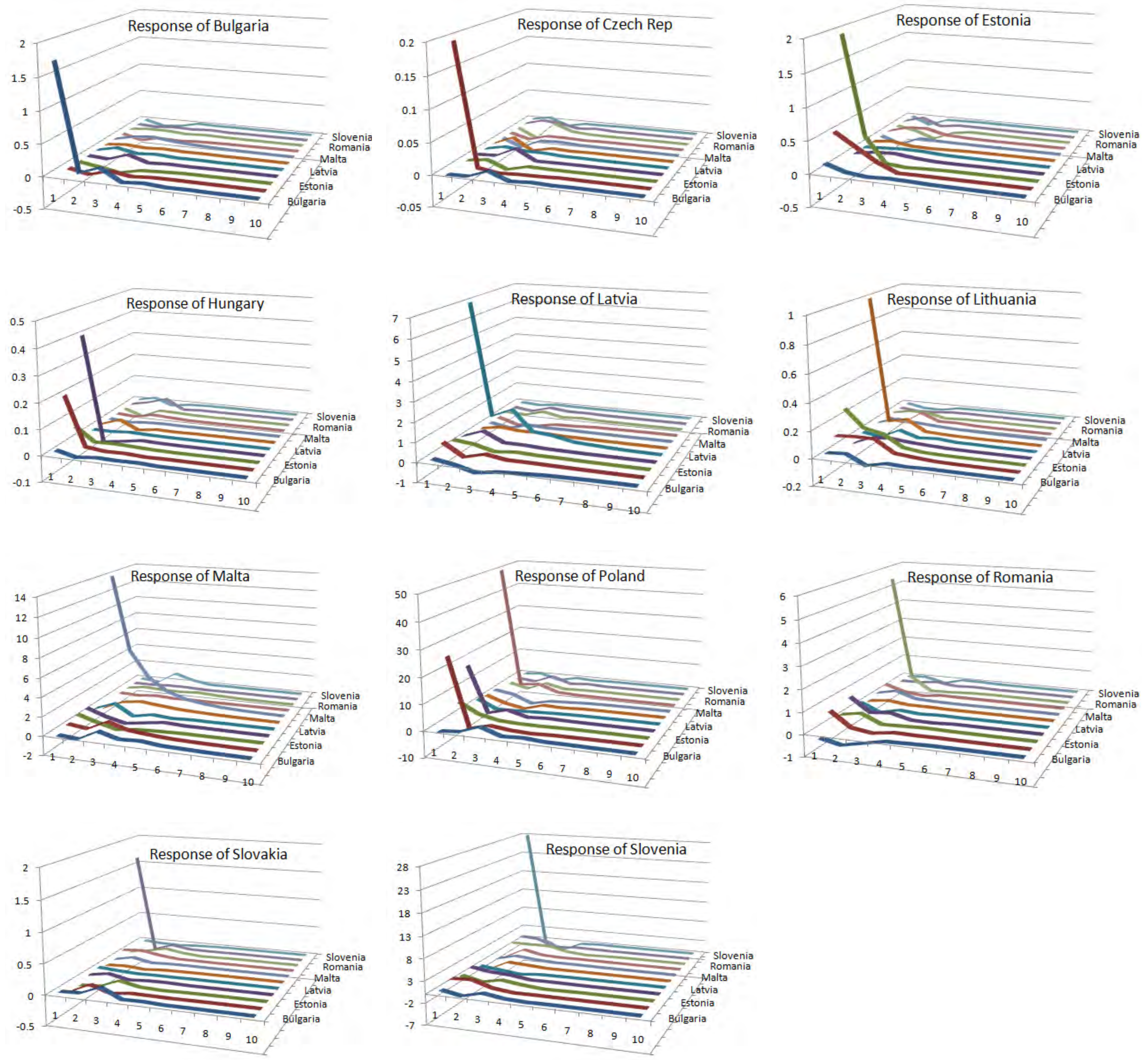


Figure 4.1: Impulse Response of CEE stock markets to Cholesky One S.D. Innovations, pre-EU period, 1995-2004

Note: The eleven lines on the above graphs are representing markets of Bulgaria, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Romania, Slovakia and Slovenia.

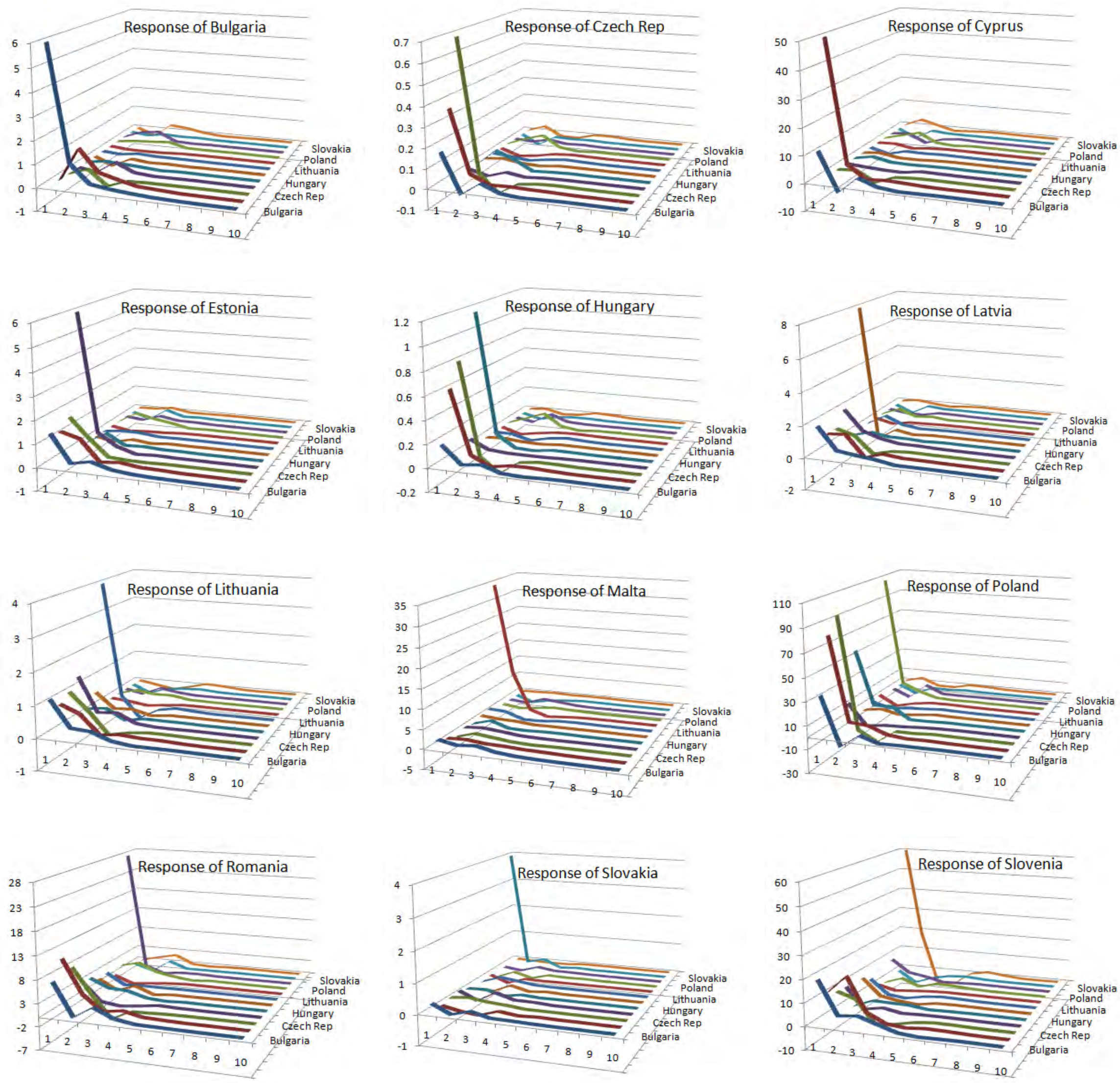


Figure 4.2: Impulse Response of CEE stock markets to Cholesky One S.D. Innovations, post-EU period, 2004-2011
Note: The eleven lines on above graphs are representing markets of Bulgaria, Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Romania, Slovakia and Slovenia.

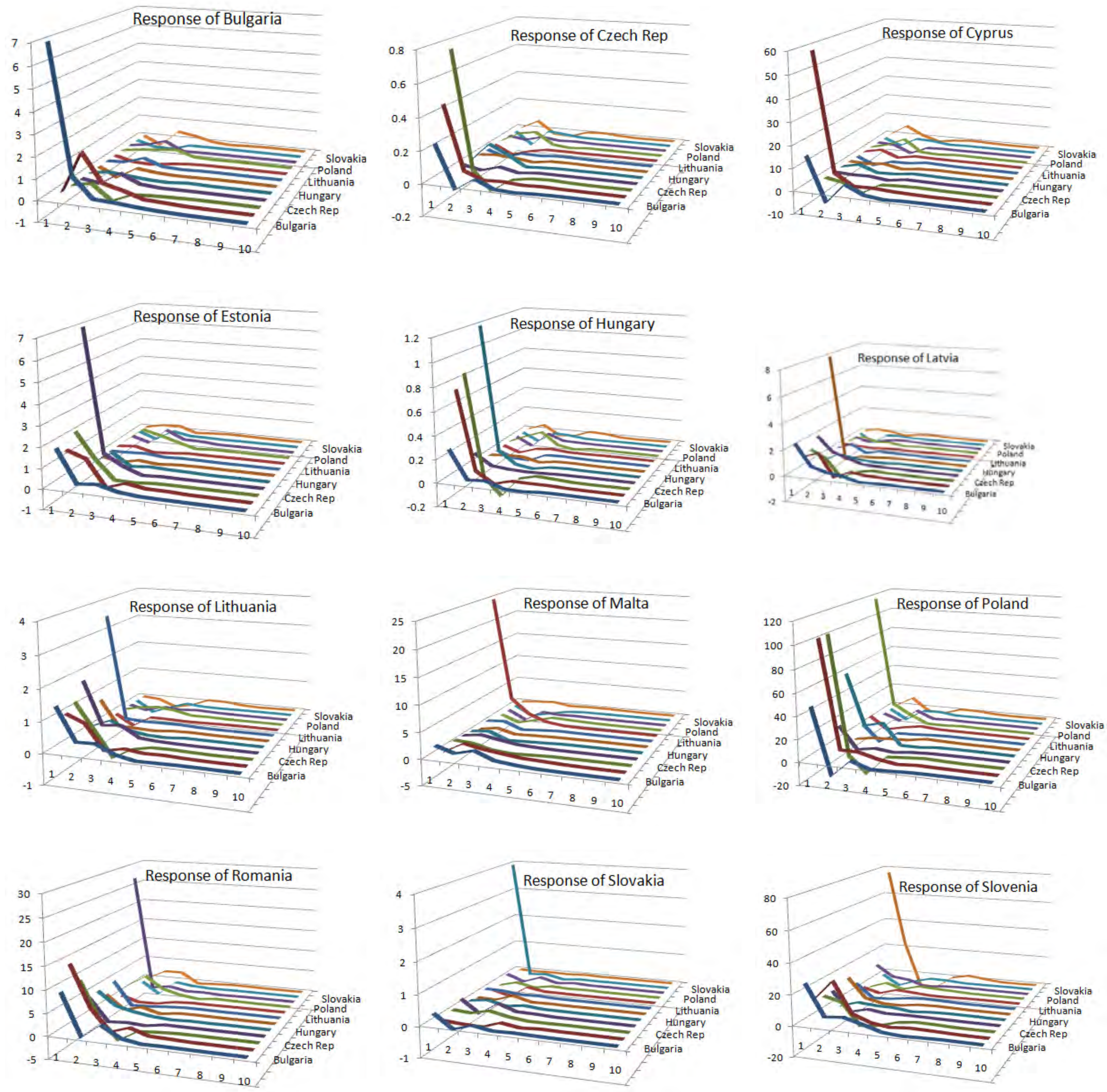


Figure 4.3: Impulse Response of CEE stock markets to Cholesky One S.D. Innovations, post-EU period, 2007-2011
Note: The eleven on above graphs are representing markets of Bulgaria, Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Romania, Slovakia and Slovenia.

4.6 Conclusion

In summary, having established that all stock indexes are *I(1)* variables, our VAR analysis significantly rejects non-cointegration among all alternative sets of twelve stock markets. The Johansen analysis produces evidence of the existence at least one cointegrating vector and existence of a long-run relationship between the CEE countries. Results from the VECM are consistent with the FEVD, showing a greater degree of integration between CEE emerging markets after accession to the EU. The Impulse Response function illustrates that the shocks' impact on returns dies out in less than one week. Granger causality relationships have also been indentified between CEE markets, showing dominance of the more advanced emerging markets of the Czech Republic, Hungary and Poland. The significance of those three markets has already been recognized by the FTSE and MSCI groups as advanced emerging markets. Furthermore, Estonia has developed into a strong international player through its membership in the EU. On the other hand the Maltese and Slovakian stock markets appear to display more self-directed independent behaviour than their peers.

As the majority of past studies on stock market comovements and integration have concentrated mainly on mature developed markets or advanced emerging markets only, we tested the behaviour and inter-relationship of CEE emerging markets only. We can argue that our results show growing investment potential in those equity markets and provide good opportunities for European investors as well as important indications for economic stability, growth and integration of the CEE markets in the post-EU period. We detected no dramatic shocks during the accession phase in the post-EU period. This could be explained by the fact that those macroeconomic policies have been subject to an adjustment process for a long period of time. Throughout the process of preparing for admission to the EU these equity markets have been modelled along similar paths of joining procedures to those in developed market economies. Moreover, we documented regional integration among the twelve countries. Given this information, EU based investors may observe stock market behaviours in one group of markets as one investment opportunity instead of single separate classes of assets. Ideally, an investor based in the more developed markets of the EU would like to be able to invest in these Euro-denominated 'emerging markets' and benefit from risk diversification. Paradoxically, the diversification benefits appear to be reduced in terms of the findings of increased cointegration. On the other hand, there is also evidence of a lowering of average risk, in terms of variance based measures post-joining the EU.

Those emerging markets are progressing very rapidly in their reforms and stability in domestic economies while in the process of becoming members of the EU. Please remember that the aim and the greatest achievement of creation of the EU is to develop a single market through a standardised system of laws which apply in all member states. Thus restrictions between member countries on trade and free competition have gradually been eliminated. As an outcome of those reforms and expansion, the EU has more influence on the world stage when it speaks with a single voice in international affairs.

A future extension of our study could consider the effects of developed markets on our cointegration analysis with the objective of verifying the assumption that the relationships between emerging EU markets would be broadly preserved.

Chapter 5: Volatility and Spillover Effects

This chapter provides an analysis of volatility and spillover effects across the twelve CEE markets, including background information for the study, literature review, details of the applied methodology and discussion of the results of the econometric investigation. The chapter conclusion demonstrates the significance of the study for researchers, investors and policy makers.

5.1 Introduction

The CEE stock markets have become of interest to many international financial researchers and policy-makers during the last decade. Former Eastern block economies became a source of investment attention to investors due to their better diversification opportunities. These markets have become more attractive and accessible for investors due to the unification of restrictions on transactions', a number of reforms in a EU accession process, and an increase in financial transparency. Moreover, EU expansion creates a unique landscape for new financial investigation and analysis.

It could be argued that the CEE economies form a unique emerging markets structure, which typically offer attractive risk adjusted returns for international investors. Besides, both theoretical models and practical concerns motivate researchers towards focusing on volatility spillovers between financial markets. An accurate characterisation of volatility spillovers has direct implications for portfolio management and asset allocation.

This chapter investigate a number of important aspects of portfolio selection and investment opportunities and their implications for CEE based investors through modelling volatility spillovers and conditional correlations between more and less developed markets in periods before and after the date of the recent EU expansion. Specifically this section deals with cross market relationships between our twelve emerging markets and does not attempt to include any developed markets (this is broadly explained in Chapter 4).

5.2 Literature review

The transmission of volatility between markets and the comovement of stock markets has been extensively investigated in recent years. Globalization has brought about market integration, especially in stock markets, a fact which attracted the researchers interest about the transmission of volatility among markets.

The investigation of the determinants of cross country financial interdependence has been studied in a large empirical literature aiming at identifying the role of a set of factors of influence, such as trade intensity (Forbes & Chinn, 2004), financial development (Dellas & Hess, 2005), and business cycle synchronization (Walti, 2005). All of these papers concentrate on similar topics; however their results and conclusions are slightly different. These concerns might be partly explained by the nature of the econometric approaches (cross-section vs. time-series), the measurement of market co-movement and by the nature and the measurement of explanatory factors.

Volatility modelling has been one of the most active and successful areas of research in time series econometrics and economic forecasting in recent decades. The modelling of the risk-expected return relationship is of central importance in modern financial theory and of key practical importance to investors. Risk is typically characterised by uncertainty and measures such as the variance or volatility of a time series. Since 1982 when Engle introduced the Autoregressive Conditional Heteroscedasticity (ARCH) model, variants and developments from this model have been effectively applied to numerous economic and financial datasets in the modelling of financial time series. The original ARCH model generated a huge family of direct descendants. This includes Bollerslev's (1986) model of generalised ARCH (GARCH), Glosten, Jagannathan and Runkle (1992) asymmetric extension of GARCH - GJR model and the Exponential version of GARCH - EGARCH model proposed by Nelson (1991). These three models are currently the most popular and successful time series model used to capture time-varying conditional volatility, the extensive kurtosis and asymmetric effects in financial time series data. Although univariate GARCH models define the volatility of a given financial series and assume independence in the conditional variance across countries, they do not capture cross market interdependent effects in volatility (or spillovers). This assumption may not be reasonable as researchers wish to know/investigate how shocks to variables can be correlated with each other and how those volatility shocks to one variable might affect the volatility of other related variables. To accommodate those spillover effects in conditional volatility, several models have been developed. Prominent multivariate GARCH models are: the Constant Conditional Correlation (CCC) models of Bollerslev (1990), the diagonal Baba-Engle-Kraft-Kroner (BEKK) model of Engle and Kroner (1995), vector ARMA-GARCH (VARMA-GARCH) model proposed by Ling and McAleer (2003) and vector ARMA- asymmetric GARCH (VARMA- AGARCH) model described by Chan, Hoti, McAleer (2002). These models are the major focus and concern for the purpose of this thesis.

During the past few years a few empirical studies have been undertaken on four of the twelve mentioned CEE emerging markets: the Czech Republic, Hungry, Poland and Slovakia. These papers mainly examine correlations in stock returns and their volatility in the Polish and Slovakian stock markets (Hranaiova, 1999), time varying co-movements while applying Engle's (2002) GARCH models between developed economies such as France, Germany and the UK and emerging ones; Czech Republic, Hungry and Poland (Scheicher, 2001) then (Egert & Kocenda, 2007)). Worthington & Higgs (2004) analysed market efficiency using methods applying the serial correlation coefficient, ADF (Augmented Dickey-Fuller), PP (Phillips-Perron) and KPSS (Kwiatkowski, Phillips, Schmidt and Shin) unit root tests and MVR (multiple variance ration) tests. Another paper constructed in a random walk framework is the paper by Cuaresma and Hlouskova (2005). An alternative issue to market efficiency is the issue of the degree of financial integration amongst the stock exchange markets in the Czech Republic, Hungry, Poland and Slovakia in comparison with the euro zone market (Babetskii, Komarek, & Komarkova, 2007). The EMU equity market's volatility and correlation vs. US ones is also the subject of a paper written by Kearney and Poti (2008) and for global markets that of Capiello et al (2006). Another approach, adopted by Bruggemann and Trenkler (2007) discusses the catching up process in the Czech Republic, Hungry and Poland by investigating GDP behaviour. The spillover effects of emerging markets have also been extensively investigated. Most studies focused on volatility spillovers within developed financial markets, so the relationship between the emerging markets of different regions remains relatively under-explored. For instance Worthington (2000) investigated price linkage in Asian equity markets, Kasch-Haroutounian and Price (2001) examined stock markets in Central Europe and Sola, Spagnolo and Spagnolo (2002) analysed volatility links between the stock markets of Thailand, South Korea and Brazil. More recently Li and Majerowska (2008), Fedorova and Vaihekoski (2009) studied the linkages between Eastern European markets and Russia. Saleem (2009) investigated the international linkages of the Russian markets. On the other hand Christiansen (2010) investigated volatility spillovers from the US and aggregate asset markets into the European national asset markets. Harrison and Moore (2009) disussed the stock market indices comovements and the cross market volatility of the ten Eastern European countries.

Jorion and Goetzemann (1999) suggested that many emerging markets are actually re-emerging markets that for various reasons have gone through a period of relative decline. They pointed out that Poland, Romania and Czechoslovakia had active equity markets in the 1920s prior to being subsumed in the Eastern block. This means that the attractive returns apparently offered by emerging markets may be a temporary phenomenon, an observation they backed up by simulations.

Overall, the majority of past studies of stock market comovements and integration have concentrated mainly on mature developed markets or advanced emerging markets such as the Czech Republic, Hungary and Poland whilst the behaviour and inter-relationship of all others has been neglected. Little attention is given to the investment potential in CEE equity markets only. Thus the literature lacks a model which analyses the interaction and integration of these markets at a regional and global level. The purpose of this dissertation is an attempt to fill this gap.

This chapter examines the short and long run behaviour of the CEE emerging stock markets and assesses the impact of the EU on stock market linkages as revealed by the time series behaviour of their stock market indices. This includes the application of univariate GARCH models that have found extensive applications in the financial literature, and multivariate VARMA GARCH models to test volatility spillovers and conditional correlations between markets. Univariate GARCH models such as GARCH (1, 1), GJR and EGARCH will be used to test the volatility persistence in the stock market returns. The multivariate VARMA GARCH models of CCC, BEKK, VARMA GARCH and VARMA AGARCH will be used to test for the existence of cross market effects, and in the case of the first two: to test for the conditional correlation.

5.3 Methodology

The purpose of the empirical analysis is to model the volatility and spillover effects of the twelve emerging markets in their pre-EU and post-EU pre and post accession periods. The analysis is based on the Engle (1982) development of a time-varying volatility model using an ARCH process. The original ARCH model generated a huge family of direct descendants, with the most popular being Bollerslev's (1986) model which generalised ARCH (GARCH). This univariate GARCH model is used to test for the persistence of volatility in stock market returns. To accommodate the movements of positive and negative shocks Nelson (1991) proposed the Exponential GARCH (EGARCH) model and Glosten, Jagannathan and Runkle (1992) proposed GJR model to test for asymmetric effects. McAleer (2005) recommends these three univariate models as being satisfactory in the specification of volatility.

Thereafter, the volatility spillovers, asymmetric effects and conditional correlation across and within the twelve markets will be analysed, using four multivariate GARCH models, namely CCC, the diagonal BEKK, VARMA-GARCH and VARMA-AGARCH models. For multivariate conditional volatility models, McAleer (2005) recommends use of the QMLE estimation technique. Additionally, for the purpose of model identification, fitting and validation of an Autoregressive Moving Average model is used.

5.3.1 Univariate GARCH models

The purpose of this section is to capture time-varying volatility in the twelve emerging markets in the specified periods of time. The three models based on ARCH processes that are used are specified below.

5.3.1.1 GARCH

The GARCH (*p, q*) model describes a process ε_t if it satisfies the equations

$$\varepsilon_t = \eta_t\sqrt{h_t} \tag{5.1}$$

Where ε_t represents the shock to the variable, η_t is a standardized residual defined as $\eta_t \sim iid(0,1)$ and $\sqrt{h_t}$ denotes volatility, given as

$$h_t = \omega + \sum_{i=1}^{p} \alpha_i \varepsilon_{t-i}^2 + \sum_{i=1}^{q} \beta_i h_{t-i} \tag{5.2}$$

where for the GARCH process to exist, $\omega > 0$, $\alpha > 0$ and $\beta \geq 0$ and are sufficient conditions for the conditional variances to be positive. The conditional variance depends on the constant value of ω, the ARCH effects (or error/reaction coefficient α), captures the short run persistence to the shocks and represents news about volatility from the previous period, and the GARCH effects (or lag/persistence coefficient β), indicate the contribution of shocks to long run persistence, which is the last period's forecast variance. Both parameters (α and β) are sensitive to the historic data used for the model. The size of the parameters α and β determine the short run dynamic of the resulting volatility time series. A large GARCH lag coefficient β indicates that shocks to conditional variance take a long time to die out, so volatility is "persistent". Large ARCH error coefficients α mean that volatility reacts quite intensively to market movements and so if α is relatively high and β is relatively low then volatility tends to be more "spiky". The parameters in the above model are usually obtained by the maximum likelihood estimation (MLE) method or QMLE where normality of η_t is not observed.

Bollerslev (1986) shows that the necessary and sufficient condition for the second moment to exist for the GARCH (1, 1) process is that $\alpha + \beta < 1$. In a study by Ling and McAleer (2002a) we can find those conditions for the existence of the second moment of ε_t for the univariate GARCH (*p, q*) model. Ling and McAleer (2003) proved that the QMLE for GARCH (*p, q*) is consistent if the second moment is finite, that is $(\varepsilon_t^2) < \infty$.

In the absence of the second moments of the unconditional shocks for a GARCH (1, 1) process, the log-moment condition should be applied (McAleer, 2005). In his paper the author summarises univariate and multivariate financial volatility models and the dispute about log-moment conditions. He follows the finding of Nelson (1991) and defines the log-moment condition for GARCH (1, 1) as:

$$E(\log(\alpha_1\eta_t^2 + \beta_1)) < 0 \quad (5.3)$$

which conditions can be satisfied even if $\alpha + \beta > 1$ (Nelson, 1991). McAleer points out that the above condition is important in deriving the statistical properties of the QMLE.

5.3.1.2 GJR

A frequently used alternative specification for the conditional volatility process is the model proposed by Glosten, Jarannathan, & Runkle (1993) called GJR, which extends the simple GARCH model to allow for asymmetric effects and to accommodate differential impacts on the conditional variance, h_t, between positive and negative shocks. The GJR (*p, q*) model is defined as:

$$h_t = \omega + \sum_{i=1}^{p}(\alpha_i + \gamma_i I(\varepsilon_{t-i}))\varepsilon_{t-i}^2 + \sum_{i=1}^{q}\beta_i h_{t-i} \quad (5.4)$$

For GJR (1, 1) the sufficient conditions for conditional variance $h_t > 0$, are $\omega > 0$, $\alpha_1 \geq 0, \alpha_1 + \gamma_1 \geq 0, \beta_1 \geq 0$. Moreover, the indicator variable of $I(\eta_t)$ should have the same sign as ε_t, and therefore takes the value of 1 if $\varepsilon_t < 0$ and 0 otherwise. This η_t accommodates the differential impact between positive and negative shocks, and these asymmetric effects are captured by the coefficient of γ, with $\gamma \geq 0$. This coefficient contributes to the expected short run persistence of $\alpha_1 + \gamma_1/2$ and the expected long run persistence of $\alpha_1 + \gamma_1/2 + \beta_1$.

The existence of the second moment condition for the GJR (1, 1) model under symmetry of η_t is given by $\alpha_1 + \gamma/2 + \beta_1 > 1$ (Ling, McAleer, 2002b). In the case of absence of second moments of the unconditional shocks of the GJR (1, 1), McAleer et al. (2005) established the log-moment conditions as

$$E(\log((\alpha_1 + \gamma_1 I(\eta_t))\eta_t^2 + \beta_1)) < 0 \quad (5.5)$$

This condition is sufficient for consistency and asymptotic normality of the QMLE.

5.3.1.3 EGARCH

An alternative specification to capture asymmetric behaviour in the conditional variance of h_t is the Exponential GARCH (EGARCH) model (Nelson, 1991). This model is defined as

$$\log h_t = \omega + \sum_{i=1}^{p} \alpha_i |\eta_{t-i}| + \sum_{i=1}^{p} \gamma_i \eta_{t-i} + \sum_{i=1}^{q} \beta_i \log h_{t-i} \tag{5.6}$$

As EGARCH is a model of the logarithmic relationship in conditional volatility, from this definition we know that all parameters are positive, and for that reason $h_t > 0$. As no restrictions applying on the perimeters, we know that equation 5.6 should satisfy $|\beta| < 1$. Following the findings of Nelson (1991) and Shephard (1996), McAleer (2005) summarises this condition as being sufficient for stationarity, sufficient condition for existence of the moments, consistency and asymptotic normality of the QMLE of EGARCH (1, 1).

5.3.2 Multivariate GARCH models

The purpose of this section is to capture interdependence (or spillover) effects in the volatility across the twelve markets. To accommodate spillovers in conditional volatility, from several different multivariate GARCH models, the four that have been chosen and which are defined below as are widely discussed and mathematically proven in the recent papers of McAleer (2005) and McAleer, Chan, Hoti, Lieberman (2008).

Let us consider the following specification for the conditional mean and conditional variance for the returns on stock indices:

$$\begin{aligned} y_t &= E(y_t|F_{t-1}) + \varepsilon_t, \\ \varepsilon_t &= D_t \eta_t \end{aligned} \tag{5.7}$$

where y_t is the $n \times 1$ vector of returns, η_t is a sequence of iid random vectors, F_t is the past information available up to time t, $D_t = diag(\sqrt{h_{1t}}, \dots, \sqrt{h_{mt}})$ is a diagonal matrix of conditional variance on historical data (F_t), m is a number of market's index returns and t number of observation for daily returns.

5.3.2.1 The Constant Conditional Correlation (CCC) model

The CCC GARCH model was introduced by Bollerslev (1990). This model assumes that the conditional variance of the shocks to index return j, $j = 1, \dots, m$, follows a univariate GARCH (p, q) process defined as

$$h_{jt} = \omega_j + \sum_{i=1}^{p} \alpha_{ji}\varepsilon_{t-i}^2 + \sum_{i=1}^{q} \beta_{ji}h_{t-i} \tag{5.8}$$

Where α_{ji} and β_{ji} represents the ARCH effects (the sort persistence of shocks to return j) and the GARCH effects (the contribution of shocks to long run persistence, namely $\sum_{i=1}^{p} \alpha_{ji} + \sum_{i=1}^{q} \beta_{ji}$) respectively. This model assumes the independence of conditional variances; therefore there are no volatility spillovers except in the calculations of the conditional correlations. And this is because $\Gamma = \{\rho_{ji}\}$ is the matrix of constant conditional correlations given as:

$$\Gamma = D_t^{-1} Q_t D_t^{-1} \tag{5.9}$$

where $\rho_{ji} = \rho_{ij}$ for $i, j = 1, \dots, m$ and each conditional correlation coefficient is estimated from the standardized residuals in equations (5.7) and (5.8)[11].

5.3.2.2 The Diagonal BEKK

The BEKK model is a preliminary version of Engle and Kroner (1995). The main feature is that it does not need any restrictions on parameters to get positive definiteness of the H_t matrix, given its quadratic structure. In its first order form the models can be written as:

$$H_t = C'C + A'\varepsilon_{t-1}\varepsilon_{t-1}'A + B'H_{t-1}B \tag{5.10}$$

where A, B and C are $n \times n$ parameter matrices with C being lower triangle. The elements of matrix A measure the effect of shocks on the conditional variances. The matrix B shows how past conditional variances affect the current levels of conditional variances, so in other words, the degree of volatility persistence in conditional volatility among the markets.

[11] A relationship clarification between conditional correlations and conditional variances is provided in a paper by Engle, 2002

The diagonal BEKK is the simplified version of (10) in which A and B are diagonal matrices. This model trivially satisfies the equation $B = AD$ where D is a diagonal matrix. The elements of the covariance matrix H_t depends only on past values of itself and past values of $\varepsilon_t \varepsilon_t^{'}$, which means that the variances depend only on past own squared residuals, and the covariances depend only on past own gross products of residuals.

5.3.2.3 VARMA GARCH

To explain the relationship between the volatility across different markets Ling and McAleer (2003) developed the vector ARMA GARCH model (VARMA GARCH). The authors claimed that h_{jt} should incorporate the interdependence of conditional variances across all markets. That is, h_{jt} should include all past information of ε_{jt} and ε_{it}, where $j \neq i$. Ling and McAleer define the vector specification for the multivariate conditional variance as:

$$H_t = W + \sum_{i=1}^{r} A_i \vec{\varepsilon}_{t-i} + \sum_{j=1}^{s} B_j H_{t-j} \tag{5.11}$$

where $H_t = (h_{1t}, \dots, h_{mt})'$, $\vec{\varepsilon} = (\varepsilon_{it}^2, \dots, \varepsilon_{mt}^2)'$, and W, A_i and B_j are $m \times m$ matrices (for $i = 1, \dots, r$ and $i = 1, \dots, s$ elements respectively for matrix A_i and B_j)with typical elements of α_{ji} and β_{ji}. This model assumes that negative and positive shocks of the same magnitude have identical impact on the conditional variance.

5.3.2.4 VARMA AGARCH

As an extension of the VARMA GARCH model to accommodate asymmetric behaviour of positive and negative shocks Chan, Hoti, McAleer (2002) proposed the following specification for the conditional variance, which is simply an extension to equation (5.11) to accommodate asymmetries with respect to ε_{it}:

$$H_t = W + \sum_{i=1}^{r} A_i \vec{\varepsilon}_{t-i} + \sum_{i=1}^{r} C_j I_{t-i} \, \vec{\varepsilon}_{t-i} + \sum_{j=1}^{s} B_j H_{t-j} \tag{5.12}$$

where C_i are $m \times m$ matrices for $i = 1, \dots, r$ and $I_t = diag(I_{1t}, \dots, I_{mt})$. Moreover, the indicator variable of I_t is having the same sign as ε_t, and therefore takes the value of 1 if $\varepsilon_t < 0$ and 0 otherwise.

5.3.3 The Model's specifications

5.3.3.1 ARMA

An Autoregressive Moving Average (ARMA) model provides a parsimonious description of a stationary stochastic process in terms of two polynomials: autoregression and moving average. The general ARMA model was described by Peter Whittle (1951) and later popularized by George Box and Gwilym Jenkins (1971). ARMA is used to model current returns using lagged returns and errors. With regards to the specification of the univariate GARCH models it is assumed the efficient market hypothesis stands: current asset returns are correct and can be explained by past information.

An ARMA (*r, s*) model (where *r* is an order of the autoregressive part and *s* is the order of the moving average part) can be specified as:

$$X_t = c + \varepsilon_t + \sum_{i=1}^{r} \varphi_i X_{t-i} + \sum_{i=1}^{s} \theta_i \varepsilon_{t-i} \tag{5.13}$$

Where X_t is a given time series, $\varphi_1, \dots, \varphi_p$ and $\theta_1, \dots, \theta_p$ are perimeters, ε_t is the white noise. The error term ε_t is generally assumed to be independent identically distributed random variables (iid) sampled from a normal distribution with zero mean of $\varepsilon_t \sim N(0, \sigma^2)$ where σ^2 is the variance.

Appendix E shows the ARMA model specification for all the markets. All the values are statistically significant at the 5% level.

As mentioned previously, GARCH models are considered very useful tools for modelling the persistence of risk in asset returns. Moreover, the specification of the models used is one of the most difficult and important tasks. McAleer (2005, p. 247) states that "it will typically be satisfactory to use univariate GARCH (1,1), GJR (1,1), EGARCH (1,1)".

5.3.3.2 QMLE

Under the assumption of conditional normality, the parameters of the multivariate GARCH models of any of the previously specified models can be estimated by the maximum likelihood estimation (MLE) function of

$$\hat{\theta} = arg_{\theta} min \frac{1}{2} \sum_{t=1}^{n} (log|Q_t| + \varepsilon_t' Q_t^{-1} \varepsilon_t) \tag{5.14}$$

Where θ denotes all the unknown vector parameters to be estimated, and $|Q_t|$ denotes the determinant of Q_t. The MLE for θ is asymptotically normal. However, in the case when η_t does not follow a joint multivariate distribution, the above equation is defined as quasi–MLE (QMLE) (McAleer, 2005). The consistency and asymptotic normality of the QMLE is a sufficient condition for multivariate GARCH analysis as it allows valid conclusions to be drawn and facilitates the subsequent testing.

5.3.3.3 Diagnostic tests

5.3.3.3.1 Testing for serial correlation

Although there are several tests of autocorrelation, the Breusch-Godfrey (BG) test, also called the Lagrange multiplier (LM) test, has been chosen for the purpose of this study. As it is desirable to examine a joint test for autocorrelation, the BG test will allow examination of the relationship between residuals u_t and several of its lagged values at the same time (the regressed value may appear as an explanatory variable). Moreover, the BG test is a more general test for autocorrelation up to the r^{th} order. As the BG test is sensitive to the lag length, lags have been specified in advance based on Akaike and Schwarz information criteria.

To illustrate the BG test, let's assume that the error term, u_t, follows the r^{th} order autoregressive, AR(r), scheme as follows:

$$u_t = \rho_1 u_{t-1} + \rho_2 u_{t-2} + \cdots + \rho_r u_{t-r} + \varepsilon_t \quad (5.15)$$

Where ε_t is a white noise error term, defined as $\varepsilon_t \sim N(0, \sigma_\varepsilon^2)$.

The null and alternative hypotheses to be tested are defined as

$$H_0: \rho_1 = 0 \; and \; \rho_2 = 0 \; and \cdots and \; \rho_r = 0$$
$$H_1: \rho_1 \neq 0 \; or \; \rho_2 \neq 0 \; or \; \cdots or \; \rho_r \neq 0 \quad (5.16)$$

This means that under the null hypothesis there is no serial correlation of any order; the current error is not related to any of its *r* previous values.

Appendix F shows the serial correlation test for all of the markets. All the markets give enough statistical evidence to support the alternative hypothesis, confirming the evidence of serial correlation.

5.3.3.3.2 Testing for an autoregressive conditional heteroscedasticity

Prior to running the various models on the data, it is essential to test for evidence of an autoregressive conditional heteroscedasticity in the residuals of the twelve time series regressions. This assessment is based on the LM test and this detects the kind of heteroscedasticity that invalidates the Ordinary Least Squares (OLS) statistics. As the actual error terms are unknown and are only estimated, the OLS residual, $\hat{u}_t$, is an estimate of the error u_t for observation (Lee, 1991). To illustrate the this test, the equation 5.15 can be rewritten in the below form

$$\hat{u}_t^2 = \rho_1 \hat{u}_{t-1}^2 + \rho_2 \hat{u}_{t-1}^2 + \cdots + \rho_m \hat{u}_{t-m}^2 \quad (5.17)$$

The null hypothesis assumes that $\hat{u}_t$ is a white noise, while the alternative hypothesis assumes the existence of ARCH effects.

$$H_0: \rho_1 = \rho_2 = \cdots = \rho_m = 0$$
$$H_1: \rho_k \neq 0 \quad (5.18)$$

Where ρ_i represents the populations of autocorrelated function of the squared time series, with $1 \leq k \leq m$. The hypothesis test is computed from the regression of the squared residuals $\hat{u}_t^2$ on its own lagged values $\hat{u}_{t-m}^2$, where *m* is the ARCH order.

The tests undertaken for this diagnostic test are the ARCH LM test, the Breusch-Pagan-Godfrey (BPG) test and, on some occasions, the White test (mostly as the decisive test where the ARCH LM and BPG test results were inconclusive). Appendix G shows the heteroscedasticity tests results for all of the markets. There is enough statistical evidence to show that the ARCH effect is present in all markets. As the test results are statistically significant, conditional volatility models should be used instead of an OLS regression.

5.4 Research hypotheses tested

Hypotheses tested for the purpose of the volatility and cross market analysis are formulated below (given in the alternate format) and are tested for differences between pre- and post-EU periods:

- H_9: Conditional volatility exists for each CEE stock market
- H_{10}: There are observable asymmetric effects in the volatility for each CEE stock market
- H_{11}: There is evidence of volatility spillovers between the CEE counties.

5.5 Empirical Results

This section presents the results of models of the volatility and spillover effects of the twelve EU countries studied. The discussion is divided into two sections: univariate GARCH models and multivariate ones (as specified in the Methodology section of this chapter). The estimates for the models are given in the tables below and the log-moment conditions are evaluated at their sample mean values.

5.5.1 Univariate GARCH models

5.5.1.1 GARCH (1, 1)

The estimated parameters, and hence conditional volatility, are presented in Table 5.1. All estimates of α and β are positive, and therefore satisfy the sufficient condition for $h_t > 0$. However, for the GARCH process to be stationary, the parameters in the variance equation must satisfy the $\alpha + \beta < 1$ condition. The results are very close to one, indicating that volatility shocks are quite persistent, which is often observed in high frequency financial data and is a characteristic of emerging markets. The closer the sum to one, the less stable the variance will be in the long run, and the more permanent will be changes in the level of volatility as a consequence of "volatility shocks".

On some occasions the sum is more than one; this means the second moment condition for GARCH (1, 1) is not satisfied. This happened on four occasions, namely, Bulgaria, Estonia, Malta and Slovenia, although the failure is only marginal for the last three countries.

Even though four countries fail to satisfy the second moment condition, all of them comply with the log-moment condition, which is still consistent with QMLE and asymptotically normal.

For all countries $\beta \geq \alpha$, with Bulgaria being the exception. It seems that for this country the ARCH effect is much stronger in comparison to all other countries.

In the time period where ten of the twelve countries are already in the EU, and another two in their accession period (2004 – 2011), the second moment condition is not satisfied for all the markets. Bulgaria, Cyprus and Estonia show the sum of α and β exceed the value of one. However, as previously noted, this failure is only minor. In the previous period this condition has not been satisfied by Malta, though now the value is the smallest in comparison to all the other studied markets. Please concede that again all values in the table below indicate persistency in volatility shocks.

The post-EU: 2007 – 2011 time frame shows that almost all countries comply with the GARCH (1, 1) second order condition. The exception is Bulgaria; however this failure to comply with condition of $\alpha + \beta < 1$ is only marginal and, in comparison to the other two periods, the increase of sufficient condition fulfilment is observable.

As the second moment condition is not satisfied in all the markets for the post-EU period, the log-moment condition was calculated. And as before, the results indicate that this condition is satisfied, which means that QMLE are consistent and asymptotically normal. Still the volatility shocks are very persistent, but this is typical of emerging market performance.

The conditional variance plot of the GARCH (1,1) model is presented in Appendix I Figure I.1 and shows a great deal of volatility over the defined time period with a number of fairly large spikes. Such spikes are normally associated with the arrival of major news to the market which has an influence on price adjustment. The last high spike visible in almost all the countries and observed on this graph is at the end of 2008, during the global financial crisis. The evidence of volatility justifies the modelling of time varying conditional variances as opposed to the standard assumption of homoscedasticity.

Table 5.1: Estimated GARCH (1, 1) model on return series

	Parameters						Moments	
	ω		α		β		Log	Second
Pre-EU period: 1995 -2004								
Bulgaria	**1.512**	**(0.064)**	**1.284**	**(0.064)**	**0.056**	**(0.018)**	-0.511	1.340
Czech Rep	**0.036**	**(0.004)**	**0.121**	**(0.011)**	**0.864**	**(0.010)**	-0.014	0.985
Estonia	**0.031**	**(0.004)**	**0.104**	**(0.005)**	**0.898**	**(0.003)**	-0.038	1.005
Hungary	**0.265**	**(0.020)**	**0.224**	**(0.007)**	**0.711**	**(0.011)**	-0.059	0.934
Latvia	**0.083**	**(0.009)**	**0.163**	**(0.014)**	**0.813**	**(0.012)**	-0.030	0.975
Lithuania	**0.265**	**(0.041)**	**0.248**	**(0.043)**	**0.429**	**(0.081)**	N/C	0.677
Malta	**0.007**	**(0.001)**	**0.174**	**(0.008)**	**0.859**	**(0.005)**	-0.016	1.033
Poland	**0.184**	**(0.022)**	**0.147**	**(0.010)**	**0.810**	**(0.012)**	-0.029	0.958
Romania	**0.139**	**(0.018)**	**0.201**	**(0.013)**	**0.783**	**(0.011)**	-0.028	0.983
Slovakia	**0.047**	**(0.003)**	**0.064**	**(0.003)**	**0.916**	**(0.004)**	-0.013	0.980
Slovenia	**0.021**	**(0.002)**	**0.207**	**(0.009)**	**0.818**	**(0.005)**	-0.016	1.025
Post-EU period: 2004 - 2011								
Bulgaria	**0.038**	**(0.004)**	**0.291**	**(0.021)**	**0.731**	**(0.014)**	-0.028	1.021
Czech Rep	**0.043**	**(0.009)**	**0.145**	**(0.014)**	**0.843**	**(0.014)**	-0.015	0.989
Cyprus	**0.027**	**(0.006)**	**0.095**	**(0.008)**	**0.906**	**(0.007)**	-0.004	1.001
Estonia	**0.008**	**(0.001)**	**0.155**	**(0.009)**	**0.867**	**(0.005)**	-0.007	1.023
Hungary	**0.066**	**(0.016)**	**0.103**	**(0.010)**	**0.881**	**(0.013)**	-0.012	0.985
Latvia	**0.037**	**(0.005)**	**0.105**	**(0.007)**	**0.881**	**(0.007)**	-0.013	0.986
Lithuania	**0.069**	**(0.006)**	**0.197**	**(0.013)**	**0.778**	**(0.011)**	-0.036	0.975
Malta	**0.116**	**(0.008)**	**0.258**	**(0.025)**	**0.558**	**(0.027)**	N/C	0.817
Poland	**0.034**	**(0.009)**	**0.079**	**(0.008)**	**0.908**	**(0.009)**	-0.008	0.988
Romania	**0.153**	**(0.018)**	**0.198**	**(0.013)**	**0.776**	**(0.013)**	-0.031	0.974
Slovakia	**0.003**	**(0.000)**	**0.023**	**(0.001)**	**0.976**	**(0.001)**	-0.002	0.999
Slovenia	**0.024**	**(0.002)**	**0.207**	**(0.013)**	**0.775**	**(0.012)**	-0.031	0.982
Post-EU period: 2007 - 2011								
Bulgaria	**0.067**	**(0.012)**	**0.300**	**(0.029)**	**0.711**	**(0.018)**	-0.025	1.011
Czech Rep	**0.036**	**(0.011)**	**0.154**	**(0.020)**	**0.844**	**(0.019)**	-0.014	0.998
Cyprus	**0.054**	**(0.018)**	**0.084**	**(0.009)**	**0.912**	**(0.009)**	-0.004	0.997
Estonia	**0.055**	**(0.010)**	**0.138**	**(0.014)**	**0.847**	**(0.013)**	-0.004	0.986
Hungary	**0.091**	**(0.023)**	**0.114**	**(0.014)**	**0.871**	**(0.015)**	-0.011	0.984
Latvia	**0.021**	**(0.006)**	**0.087**	**(0.009)**	**0.909**	**(0.007)**	-0.013	0.997
Lithuania	**0.069**	**(0.009)**	**0.208**	**(0.023)**	**0.768**	**(0.016)**	-0.033	0.976
Malta	**0.162**	**(0.015)**	**0.264**	**(0.036)**	**0.417**	**(0.049)**	N/C	0.681
Poland	**0.053**	**(0.017)**	**0.097**	**(0.012)**	**0.890**	**(0.012)**	-0.008	0.987
Romania	**0.121**	**(0.026)**	**0.206**	**(0.016)**	**0.786**	**(0.016)**	-0.029	0.993
Slovakia	**0.006**	**(0.000)**	**0.023**	**(0.001)**	**0.975**	**(0.001)**	-0.002	0.999
Slovenia	**0.058**	**(0.010)**	**0.239**	**(0.026)**	**0.731**	**(0.026)**	-0.027	0.970

Note: The two entries corresponding to each parameter are their estimates and standard error in parentheses. Bold denotes significance at 5% level. Bollerslev-Wooldridge (1992) robust t-ratios is used for parameter estimation

5.5.1.2 GJR (1, 1)

GJR is a simple extension of GARCH with an additional term added to account for possible asymmetries. The conditional variance $h_t > 0$ condition has been satisfied for all the studied time periods, as show in Table 5.2 and graphically presented in Appendix I Figure I.3.

In the pre-EU period the second moment condition of $\alpha_1 + \gamma/2 + \beta_1 > 1$ failed on three occasions, namely Bulgaria, Malta and Slovenia, although the failure is not significant for the last two countries. The most extreme case belongs to the Bulgarian stock market, and arises from very high estimates of the short run persistence in shocks (α). Even though some of the markets fail to satisfy the second moment condition, all comply with the log-moment condition, which specify that the QMLE are consistent and asymptotically normal. The α and β parameters are positive and significant, except in the one case of Slovakia for post-EU period 2007-2011. And again, in the case of Bulgaria in pre-EU period, the ARCH effect is stronger than the GARCH one.

On some occasions, namely the Czech Republic, Hungary, Poland and Slovenia for the post-EU 2004 – 2011 and additionally Cyprus in post-EU 2007 – 2011, $\gamma \geq \alpha$. This suggests that negative shocks have a more significant impact on the conditional variance than positive ones, however the excess of γ over α is minimal in some cases.

In the case of the GJR model the asymmetric effects are captured by the coefficient of γ, with $\gamma \geq 0$, which measures the contribution to both short run and to long run persistence (as discussed above). The γ coefficient is significant on almost all occasions except for Bulgaria, Latvia, Lithuania and Slovenia in the pre-EU period, for Estonia, Malta and Slovakia in the post-EU period: 2004-2011 period and for Estonia, Malta and Romania in the post-EU: 2007-2011 period. The positive value of γ in the case of most of the countries suggests the leverage effect is present. It implies that conditional variance persists more strongly after a large negative shock than after a large positive shock of the same magnitude. Even though that γ coefficient is negative at times and on one occasion the coefficient α contains a negative sign, all markets satisfy the condition of $\alpha + \gamma > 0$, which implies the conditional variance is correctly defined.

Table 5.2: Estimated GJR (1, 1) model on return series

	Parameters								Moments	
	ω		α		γ		β		Log	Second
Pre-EU period: 1995 -2004										
Bulgaria	**1.475**	**(0.063)**	**1.399**	**(0.126)**	-0.286	(0.174)	**0.067**	**(0.019)**	-0.492	1.324
Czech Rep	**0.038**	**(0.005)**	**0.105**	**(0.012)**	**0.031**	**(0.015)**	**0.861**	**(0.011)**	-0.015	0.983
Estonia	**0.086**	**(0.001)**	**0.156**	**(0.012)**	**0.046**	**(0.013)**	**0.817**	**(0.007)**	-0.025	0.997
Hungary	**0.304**	**(0.021)**	**0.164**	**(0.014)**	**0.142**	**(0.018)**	**0.686**	**(0.012)**	N/C	0.922
Latvia	**0.077**	**(0.009)**	**0.156**	**(0.020)**	-0.018	(0.021)	**0.827**	**(0.012)**	-0.027	0.975
Lithuania	**0.244**	**(0.040)**	**0.198**	**(0.038)**	0.116	(0.062)	**0.455**	**(0.078)**	N/C	0.712
Malta	**0.014**	**(0.001)**	**0.342**	**(0.014)**	**-0.182**	**(0.01)**	**0.787**	**(0.006)**	-0.032	1.038
Poland	**0.187**	**(0.022)**	**0.103**	**(0.013)**	**0.079**	**(0.015)**	**0.813**	**(0.013)**	-0.030	0.955
Romania	**0.137**	**(0.018)**	**0.157**	**(0.017)**	**0.078**	**(0.022)**	**0.786**	**(0.012)**	-0.027	0.983
Slovakia	**0.049**	**(0.003)**	**0.077**	**(0.005)**	**-0.025**	**(0.006)**	**0.914**	**(0.003)**	-0.013	0.979
Slovenia	**0.020**	**(0.002)**	**0.218**	**(0.013)**	-0.023	(0.016)	**0.819**	**(0.005)**	-0.015	1.026
Post-EU period: 2004 - 2011										
Bulgaria	**0.039**	**(0.004)**	**0.252**	**(0.024)**	**0.076**	**(0.030)**	**0.729**	**(0.014)**	-0.027	1.019
Czech Rep	**0.058**	**(0.010)**	**0.087**	**(0.017)**	**0.107**	**(0.018)**	**0.836**	**(0.016)**	-0.014	0.977
Cyprus	**0.037**	**(0.007)**	**0.079**	**(0.009)**	**0.038**	**(0.012)**	**0.900**	**(0.007)**	-0.004	0.999
Estonia	**0.008**	**(0.001)**	**0.163**	**(0.013)**	-0.011	(0.014)	**0.866**	**(0.006)**	-0.006	1.023
Hungary	**0.074**	**(0.016)**	**0.060**	**(0.013)**	**0.071**	**(0.016)**	**0.884**	**(0.013)**	-0.015	0.980
Latvia	**0.036**	**(0.005)**	**0.072**	**(0.008)**	**0.053**	**(0.010)**	**0.887**	**(0.007)**	-0.013	0.986
Lithuania	**0.089**	**(0.009)**	**0.167**	**(0.018)**	**0.114**	**(0.028)**	**0.740**	**(0.015)**	-0.036	0.964
Malta	**0.117**	**(0.008)**	**0.251**	**(0.029)**	0.015	(0.037)	**0.557**	**(0.028)**	N/C	0.816
Poland	**0.046**	**(0.009)**	**0.029**	**(0.012)**	**0.081**	**(0.014)**	**0.909**	**(0.010)**	-0.008	0.979
Romania	**0.169**	**(0.020)**	**0.167**	**(0.013)**	**0.061**	**(0.023)**	**0.770**	**(0.014)**	-0.030	0.968
Slovakia	**0.009**	**(0.000)**	**0.024**	**(0.002)**	0.000	(0.001)	**0.968**	**(0.001)**	-0.001	0.993
Slovenia	**0.024**	**(0.002)**	**0.115**	**(0.014)**	**0.172**	**(0.024)**	**0.779**	**(0.012)**	-0.030	0.981
Post-EU period: 2007 - 2011										
Bulgaria	**0.067**	**(0.011)**	**0.231**	**(0.035)**	**0.120**	**(0.041)**	**0.715**	**(0.019)**	-0.025	1.006
Czech Rep	**0.051**	**(0.013)**	**0.086**	**(0.022)**	**0.119**	**(0.025)**	**0.843**	**(0.020)**	-0.013	0.989
Cyprus	**0.065**	**(0.018)**	**0.043**	**(0.010)**	**0.088**	**(0.017)**	**0.908**	**(0.009)**	-0.004	0.995
Estonia	**0.057**	**(0.010)**	**0.125**	**(0.017)**	0.026	(0.021)	**0.845**	**(0.013)**	-0.004	0.984
Hungary	**0.085**	**(0.023)**	**0.053**	**(0.019)**	**0.092**	**(0.023)**	**0.884**	**(0.016)**	-0.011	0.984
Latvia	**0.012**	**(0.006)**	**0.096**	**(0.009)**	**0.032**	**(0.012)**	**0.912**	**(0.007)**	-0.012	0.997
Lithuania	**0.079**	**(0.011)**	**0.158**	**(0.026)**	**0.118**	**(0.036)**	**0.752**	**(0.020)**	-0.033	0.970
Malta	**0.161**	**(0.015)**	**0.274**	**(0.042)**	-0.022	(0.054)	**0.421**	**(0.051)**	N/C	0.683
Poland	**0.042**	**(0.011)**	**0.022**	**(0.011)**	**0.091**	**(0.016)**	**0.915**	**(0.011)**	-0.008	0.983
Romania	**0.130**	**(0.028)**	**0.177**	**(0.028)**	0.049	(0.031)	**0.785**	**(0.017)**	-0.029	0.988
Slovakia	**0.066**	**(0.005)**	**-0.012**	**(0.000)**	**0.040**	**(0.002)**	**0.941**	**(0.005)**	-0.002	.0948
Slovenia	**0.063**	**(0.011)**	**0.103**	**(0.023)**	**0.229**	**(0.040)**	**0.742**	**(0.025)**	-0.027	0.959

Note: The two entries corresponding to each parameter are their estimates and standard error in parentheses. Bold denotes significance at 5% level. Bollerslev-Wooldridge (1992) robust t-ratios is used for parameter estimation

5.5.1.3 EGARCH (1, 1)

The EGARCH model always yields a positive conditional variance for any choice of the unknown parameter due to its logarithmic form. The one condition for the EGARCH model to be specified correctly is that $|\beta| < 1$. As shown in Table 5.3, all the β estimates satisfy this condition. The mean value of β is 0.919 for 1995-2004 period, 0.834 for 2004-2011 period and 0.939 for 2007-2011 period , varying between 0.952 and 0.968, 0.410 and 0.981, 0.936 and 0.982 respectively. All the β estimates suggest that all moments exist, with the estimates likely to be consistent and asymptotically normal.

According to the results presented in Table 5.3 the leverage effects of the γ parameter are mostly negative. In this case, for $\gamma < 0$, the positive shock generates less volatility than negative ones. The γ coefficient is significant on almost all occasions except for Latvia and Slovenia in pre-EU period, for Estonia and Malta in both post-EU periods. The plots of this model can be found in Appendix I Figure I.2.

Table 5.3: Estimated EGARCH (1, 1) model on return series

	Parameters							
	ω		α		γ		β	
Pre-EU period: 1995 -2004								
Bulgaria	**-0.112**	**(0.011)**	**0.265**	**(0.017)**	**0.142**	**(0.019)**	**0.953**	**(0.004)**
Czech Rep	**-0.151**	**(0.011)**	**0.215**	**(0.015)**	**-0.035**	**(0.009)**	**0.963**	**(0.004)**
Estonia	**-0.201**	**(0.009)**	**0.336**	**(0.012)**	**-0.020**	**(0.006)**	**0.962**	**(0.003)**
Hungary	**-0.192**	**(0.007)**	**0.437**	**(0.009)**	**-0.066**	**(0.007)**	**0.873**	**(0.006)**
Latvia	**-0.225**	**(0.012)**	**0.362**	**(0.021)**	0.015	(0.013)	**0.954**	**(0.005)**
Lithuania	**-0.433**	**(0.053)**	**0.442**	**(0.054)**	**-0.083**	**(0.025)**	**0.652**	**(0.056)**
Malta	**-0.197**	**(0.006)**	**0.255**	**(0.009)**	**0.039**	**(0.005)**	**0.952**	**(0.002)**
Poland	**-0.146**	**(0.011)**	**0.278**	**(0.016)**	**-0.055**	**(0.009)**	**0.949**	**(0.005)**
Romania	**-0.192**	**(0.012)**	**0.359**	**(0.019)**	**-0.044**	**(0.012)**	**0.932**	**(0.006)**
Slovakia	**-0.112**	**(0.005)**	**0.206**	**(0.005)**	**0.016**	**(0.005)**	**0.968**	**(0.002)**
Slovenia	**-0.240**	**(0.007)**	**0.345**	**(0.010)**	0.010	(0.007)	**0.955**	**(0.002)**
Post-EU period: 2004 - 2011								
Bulgaria	**-0.355**	**(0.017)**	**0.491**	**(0.025)**	**-0.047**	**(0.014)**	**0.942**	**(0.005)**
Czech Rep	**-0.195**	**(0.017)**	**0.276**	**(0.023)**	**-0.066**	**(0.011)**	**0.972**	**(0.004)**
Cyprus	**-0.126**	**(0.012)**	**0.205**	**(0.016)**	**-0.032**	**(0.009)**	**0.981**	**(0.003)**
Estonia	**-0.169**	**(0.009)**	**0.243**	**(0.014)**	-0.003	(0.007)	**0.981**	**(0.002)**
Hungary	**-0.130**	**(0.014)**	**0.196**	**(0.019)**	**-0.050**	**(0.010)**	**0.980**	**(0.004)**
Latvia	**-0.133**	**(0.008)**	**0.202**	**(0.011)**	**-0.034**	**(0.007)**	**0.977**	**(0.003)**
Lithuania	**-0.237**	**(0.010)**	**0.350**	**(0.015)**	**-0.035**	**(0.012)**	**0.940**	**(0.005)**
Malta	**-0.436**	**(0.029)**	**0.416**	**(0.029)**	0.014	(0.018)	**0.779**	**(0.018)**
Poland	**-0.098**	**(0.013)**	**0.146**	**(0.017)**	**-0.066**	**(0.010)**	**0.981**	**(0.003)**
Romania	**-0.182**	**(0.010)**	**0.335**	**(0.015)**	**-0.046**	**(0.012)**	**0.939**	**(0.007)**
Slovakia	**0.348**	**(0.025)**	**0.166**	**(0.020)**	**0.081**	**(0.016)**	**-0.410**	**(0.062)**
Slovenia	**-0.262**	**(0.012)**	**0.320**	**(0.016)**	**-0.099**	**(0.011)**	**0.949**	**(0.005)**
Post-EU period: 2007 - 2011								
Bulgaria	**-0.328**	**(0.024)**	**0.474**	**(0.035)**	**-0.069**	**(0.020)**	**0.936**	**(0.009)**
Czech Rep	**-0.184**	**(0.025)**	**0.258**	**(0.033)**	**-0.073**	**(0.014)**	**0.982**	**(0.005)**
Cyprus	**-0.084**	**(0.013)**	**0.165**	**(0.019)**	**-0.064**	**(0.011)**	**0.977**	**(0.005)**
Estonia	**-0.167**	**(0.015)**	**0.260**	**(0.023)**	-0.014	(0.012)	**0.962**	**(0.005)**
Hungary	**-0.119**	**(0.017)**	**0.185**	**(0.024)**	**-0.070**	**(0.014)**	**0.982**	**(0.004)**
Latvia	**-0.116**	**(0.182)**	**0.018**	**(0.014)**	**-0.027**	**(0.008)**	**0.979**	**(0.004)**
Lithuania	**-0.257**	**(0.020)**	**0.374**	**(0.030)**	**-0.048**	**(0.016)**	**0.939**	**(0.007)**
Malta	**-0.571**	**(0.052)**	**0.433**	**(0.041)**	0.027	(0.025)	**0.671**	**(0.036)**
Poland	**-0.094**	**(0.016)**	**0.144**	**(0.021)**	**-0.094**	**(0.014)**	**0.982**	**(0.004)**
Romania	**-0.209**	**(0.014)**	**0.362**	**(0.019)**	**-0.049**	**(0.018)**	**0.950**	**(0.009)**
Slovakia	**-0.040**	**(0.003)**	**0.099**	**(0.007)**	**-0.047**	**(0.004)**	**0.971**	**(0.001)**
Slovenia	**-0.266**	**(0.022)**	**0.351**	**(0.031)**	**-0.121**	**(0.018)**	**0.939**	**(0.010)**

Note: The two entries corresponding to each parameter are their estimates and standard error in parentheses. Bold denotes significance at 5% level. Bollerslev-Wooldridge (1992) robust t-ratios is used for parameter estimation

5.5.2 Multivariate GARCH models

5.5.2.1 The Constant Conditional Correlation (CCC) model

As was explained before in the context of the CCC model the multivariate effects across the twelve data series are determined solely through the constant conditional correlation matrix.

The calculated constant conditional correlations among the twelve markets are summarised in Table 5.4, Table 5.5 and Table 5.6 and graphically presented in Appendix J, Figures from J.1 to J.3. The two entries for each pair of markets are their estimates and the Bollerslev-Wooldridge robust t-ratio. For the pre-EU period only a few pairs are significant at the 5% level, with the highest being 0.472 between Hungary and Poland. The other two high values of 0.455 and 0.416 are parameter estimates for the Czech Republic – Poland and the Czech Republic – Hungary respectively. All other significant values are less than 0.267. Please notice that this highly significant relationship exists for the three main CEE studied countries of the Czech Republic, Hungary and Poland. These three show as well that the relationship exists between the other markets of Estonia, Latvia, Lithuania, Romania and Slovenia. Thus it is worth mentioning that the Estonian stock market shows a number of significant conditional correlations between itself and five other markets.

For the post-EU: 2004-2011 period the number of significant relationship increases, though the highest value belongs to the same pair of markets, namely: Hungary – Poland with a coefficient of 0.701. Very strong conditional correlations are recorded as well for the Czech Republic – Hungary (0.626) and the Czech Republic – Poland (0.671). It is also worth a mention that the Bulgarian, Cyprus, Estonian and Romanian markets show a number of significant relationships between each other and other markets. Even though most of the markets report the existence of conditional correlations (cross market relationships), Malta and Slovakia stay isolated from the others as well from each other.

There are plenty of similarities between both post-EU periods, with the only difference being that the estimated parameters for post-EU: 2007-2011 are even higher, so the relationships in conditional correlations are even stronger. The other difference is that

Cyprus takes a prime role between the Czech Republic, Hungary and Poland with correlation coefficients of 0.525, 0.456 and 0.529 respectively. Next to Cyprus, the Romanian stock markets show a very strong relationship with Cyprus (0.425), the Czech Republic (0.539), Hungary (0.491) and Poland (0.522).

The second panel of Table 5.4. Table 5.5 and Table5.6 show the CCC GARCH parameters' estimates. Here it is observable that ARCH and GARCH effects are significant for most of the twelve countries with only a few exceptions. These are: the parameters of β for Slovenia in pre –EU period and α and β for Slovakia in both post-EU periods. These results are very similar to the GARCH (1, 1) model, which was described earlier in this chapter. This is the GARCH effect which is taking the major role in the modelling of volatility spillover effects among the stock markets.

The major drawback of the CCC model is that it assumes a constant conditional correlation between the volatilities. Allowing for more dynamics in the conditional correlation could improve the results of the multivariate model.

Table 5.4: Multivariate regression analysis results for CCC GARCH (1, 1) model; pre-EU: 1995-2004

	Bulgaria	Czech Rep	Estonia	Hungary	Latvia	Lithuania	Malta	Poland	Romania	Slovakia	Slovenia
Panel A: Constant Conditional Correlation Matrix											
Bulgaria	1										
Czech Rep	0.011	1									
	(0.312)										
Estonia	**0.072**	**0.267**	1								
	(2.101)	**(8.417)**									
Hungary	0.013	**0.455**	**0.245**	1							
	(0.386)	**(16.143)**	**(7.511)**								
Latvia	0.043	**0.121**	**0.094**	**0.112**	1						
	(1.241)	**(3.439)**	**(2.567)**	**(3.397)**							
Lithuania	0.013	**0.079**	**0.206**	0.045	0.033	1					
	(0.414)	**(2.405)**	**(6.736)**	(1.413)	(0.902)						
Malta	0.043	0.024	0.057	**0.064**	0.022	0.007	1				
	(1.627)	(0.756)	(1.599)	**(1.973)**	(0.683)	(0.245)					
Poland	-0.026	**0.416**	**0.233**	**0.472**	**0.134**	**0.068**	0.050	1			
	(-0.838)	**(13.753)**	**(7.064)**	**(16.919)**	**(3.177)**	**(2.068)**	(1.597)				
Romania	-0.041	**0.123**	0.064	**0.180**	**0.097**	0.036	0.025	**0.181**	1		
	(-1.231)	**(3.820)**	(1.851)	**(5.805)**	**(3.118)**	(0.923)	(0.830)	**(5.122)**			
Slovakia	0.003	-0.028	-0.043	-0.024	0.000	-0.041	0.007	0.026	-0.012	1	
	(0.099)	(-0.759)	(-1.483)	(-0.755)	(0.009)	(-1.240)	(0.245)	(0.718)	(-0.385)		
Slovenia	0.040	**0.078**	**0.071**	**0.111**	0.025	-0.031	0.021	0.037	0.037	0.043	1
	(1.448)	**(2.885)**	**(2.326)**	**(3.957)**	(0.820)	(-1.272)	(0.684)	(1.247)	(1.152)	(0.840)	
Panel B: CCC GARCH model estimates											
ω	0.066	**0.084**	**0.080**	0.292	**0.117**	0.370	**0.078**	0.299	0.021	0.278	**0.168**
	(1.618)	**(2.573)**	**(2.885)**	(1.845)	**(2.740)**	(1.866)	**(3.572)**	(1.872)	(1.686)	(1.919)	**(1.999)**
α	**0.122**	**0.064**	**0.126**	**0.072**	**0.212**	**0.193**	**0.157**	**0.078**	**0.081**	**0.149**	**1.245**
	(2.941)	**(3.349)**	**(3.648)**	**(2.520)**	**(3.083)**	**(2.150)**	**(3.418)**	**(2.322)**	**(2.327)**	**(2.323)**	**(2.059)**
β	**0.884**	**0.886**	**0.803**	**0.791**	**0.747**	**0.368**	**0.667**	**0.789**	**0.915**	**0.678**	0.194
	(32.641)	**(26.540)**	**(17.356)**	**(8.646)**	**(10.958)**	**(2.550)**	**(10.478)**	**(8.347)**	**(31.107)**	**(5.285)**	(1.270)

Note: The two entries corresponding to each parameter are their estimates and Bollerslev-Wooldridge (1992) robust t-ratios in parentheses. Bold denotes significance at 5% level

Table 5.5 Multivariate regression analysis results for CCC GARCH(1, 1) model; post-EU: 2004-2011

	Bulgaria	Cyprus	Czech Rep	Estonia	Hungary	Latvia	Lithuania	Malta	Poland	Romani	Slovakia	Slovenia
Panel A: Constant Conditional Correlation Matrix												
Bulgaria	1											
Cyprus	**0.154**	1										
	(5.862)											
Czech Rep	**0.186**	**0.405**	1									
	(7.549)	**(16.842)**										
Estonia	**0.216**	**0.197**	**0.275**	1								
	(7.935)	**(7.383)**	**(10.118)**									
Hungary	**0.118**	**0.350**	**0.626**	**0.230**	1							
	(4.855)	**(14.103)**	**(35.693)**	**(8.088)**								
Latvia	**0.155**	**0.123**	**0.145**	**0.253**	**0.110**	1						
	(6.007)	**(4.803)**	**(5.798)**	**(8.854)**	**(4.245)**							
Lithuania	**0.225**	**0.176**	**0.289**	**0.379**	**0.240**	**0.222**	1					
	(9.229)	**(6.259)**	**(9.630)**	**()9.197**	**(9.012)**	**(7.382)**						
Malta	0.035	0.023	0.016	0.025	0.035	0.043	**0.055**	1				
	(1.347)	(0.854)	(0.599)	(1.252)	(1.323)	(1.715)	**(2.283)**					
Poland	**0.174**	**0.396**	**0.671**	**0.247**	**0.701**	**0.119**	**0.248**	0.037	1			
	(6.979)	**(15.826)**	**(39.194)**	**(8.966)**	**(45.596)**	**(4.517)**	**(8.767)**	(1.495)				
Romania	**0.224**	**0.324**	**0.412**	**0.257**	**0.363**	**0.016**	**0.246**	0.036	**0.400**	1		
	(8.390)	**(12.588)**	**(16.572)**	**(10.073)**	**(15.154)**	**(6.872)**	**(7.394)**	(1.280)	**(15.999)**			
Slovakia	0.051	0.031	0.048	**0.084**	0.045	0.017	**0.063**	-0.014	0.008	0.048	1	
	(1.577)	(0.935)	(1.334)	**(2.710)**	(1.503)	(0.551)	**(2.315)**	(-0.490)	(0.241)	(1.566)		
Slovenia	**0.201**	**0.163**	**0.175**	**0.192**	**0.119**	**0.027**	**0.186**	0.026	**0.162**	**0.238**	0.009	1
	(7.227)	**(6.591)**	**(6.732)**	**(8.069)**	**(4.477)**	**(4.574)**	**(7.014)**	(0.908)	**(6.011)**	**(7.669)**	(0.361)	
Panel B: CCC GARCH model estimates												
ω	**0.053**	**0.043**	**0.095**	**0.017**	**0.105**	**0.035**	**0.110**	**0.101**	**0.073**	**0.379**	**1.174**	**0.041**
	(4.507)	**(3.226)**	**(5.029)**	**(2.880)**	**(3.472)**	**(2.204)**	**(2.531)**	**(3.807)**	**(3.950)**	**(3.446)**	**(4.585)**	**(3.601)**
α	**0.280**	**0.073**	**0.094**	**0.090**	**0.075**	**0.091**	**0.175**	**0.278**	**0.046**	**0.180**	0.130	**0.224**
	(7.431)	**(5.482)**	**(5.116)**	**(4.578)**	**(4.721)**	**(4.014)**	**(5.336)**	**(5.420)**	**(4.457)**	**(3.650)**	(1.906)	**(5.420)**
β	**0.727**	**0.918**	**0.859**	**0.902**	**0.894**	**0.896**	**0.756**	**0.582**	**0.924**	**0.730**	-0.040	**0.738**
	(24.057)	**(67.187)**	**(42.830)**	**(44.139)**	**(43.897)**	**(34.605)**	**(10.764)**	**(8.644)**	**(63.497)**	**(11.907)**	(-1.578)	**(19.310)**

Note: The two entries corresponding to each parameter are their estimates and Bollerslev-Wooldridge (1992) robust t-ratios in parentheses. Bold denotes significance at 5% level

Table 5.6: Multivariate regression analysis results for CCC GARCH (1, 1) model; post-EU: 2007-2011

	Bulgaria	Cyprus	Czech Rep	Estonia	Hungary	Latvia	Lithuania	Malta	Poland	Romani	Slovakia	Slovenia
Panel A: Constant Conditional Correlation Matrix												
Bulgaria	1											
Cyprus	**0.199**	1										
	(5.987)											
Czech Rep	**0.268**	**0.525**	1									
	(8.779)	**(19.345)**										
Estonia	**0.308**	**0.245**	**0.366**	1								
	(10.792)	**(7.732)**	**(12.388)**									
Hungary	**0.193**	**0.456**	**0.660**	**0.294**	1							
	(6.482)	**(15.899)**	**(31.346)**	**(8.705)**								
Latvia	**0.229**	**0.156**	**0.192**	**0.309**	**0.129**	1						
	(7.007)	**(4.693)**	**(5.999)**	**(10.169)**	**(3.780)**							
Lithuania	**0.317**	**0.253**	**0.381**	**0.541**	**0.317**	**0.325**	1					
	(10.789)	**(7.993)**	**(12.181)**	**(13.882)**	**(9.710)**	**(10.853)**						
Malta	0.056	0.012	0.041	0.069	0.055	0.053	**0.084**	1				
	(1.633)	(0.342)	(1.221)	(1.856)	(1.623)	(1.498)	**(2.562)**					
Poland	**0.243**	**0.529**	**0.736**	**0.313**	**0.724**	**0.134**	**0.339**	**0.069**	1			
	(7.754)	**(19.752)**	**(43.383)**	**(10.197)**	**(39.609)**	**(3.863)**	**(10.772)**	**(2.286)**				
Romania	**0.295**	**0.452**	**0.539**	**0.331**	**0.491**	**0.233**	**0.382**	0.063	**0.522**	1		
	(9.306)	**(14.846)**	**(19.975)**	**(10.291)**	**(18.871)**	**(7.329)**	**(11.514)**	(1.752)	**(18.976)**			
Slovakia	0.032	-0.005	0.018	**0.076**	0.014	0.010	0.044	-0.034	0.007	0.053	1	
	(0.951)	(-0.143)	(0.465)	**(2.346)**	(0.412)	(0.289)	(1.566)	(-1.093)	(0.190)	(1.525)		
Slovenia	**0.283**	**0.188**	**0.210**	**0.270**	**0.168**	**0.202**	**0.270**	**0.069**	**0.192**	**0.302**	0.020	1
	(8.967)	**(5.763)**	**(6.485)**	**(9.566)**	**(5.188)**	**(5.792)**	**(8.564)**	**(2.093)**	**(5.757)**	**(7.757)**	(0.547)	
Panel B: CCC GARCH model estimates												
ω	**0.105**	**0.032**	**0.084**	**0.052**	**0.091**	0.011	**0.082**	**0.145**	**0.072**	**0.397**	0.006	**0.077**
	(3.440)	**(2.270)**	**(4.398)**	**(2.895)**	**(2.763)**	(1.360)	**(2.866)**	**(3.736)**	**(3.053)**	**(2.143)**	(1.367)	**(3.364)**
α	**0.270**	**0.047**	**0.095**	**0.083**	**0.086**	**0.065**	**0.149**	**0.301**	**0.056**	**0.140**	0.027	**0.215**
	(5.439)	**(4.676)**	**(4.630)**	**(3.645)**	**(4.342)**	**(3.497)**	**(5.349)**	**(4.082)**	**(4.611)**	**(2.203)**	(1.843)	**(4.895)**
β	**0.709**	**0.950**	**0.875**	**0.896**	**0.895**	**0.934**	**0.805**	**0.423**	**0.923**	**0.778**	**0.974**	**0.733**
	(14.877)	(102.728)	**(46.328)**	**(36.480)**	**(41.977)**	**(49.120)**	**(19.062)**	**(4.159)**	**(60.763)**	**(9.018)**	**(76.432)**	**(16.496)**

Note: The two entries corresponding to each parameter are their estimates and Bollerslev-Wooldridge (1992) robust t-ratios in parentheses. Bold denotes significance at 5% level

5.5.2.2 The Diagonal BEKK

To circumvent the restrictive assumption of a constant correlation between the conditional volatilities, the diagonal BEKK model is estimated. With the diagonal BEKK model we examine results of the time-varying variance-covariance equation (5.10) in the system of the twelve markets. The values reported in the tables below illustrate the relationship in terms of shocks and volatility spillovers lying on diagonal (elements of α and β), and conditional covariance via the off diagonal elements.

The diagonal elements of α capture the ARCH effects, while the diagonal elements of β measure the GARCH effect. As shown in Table 5.7, Table 5.8 and Table 5.9, the estimated parameters are all statistically significant with only one exception of the α parameter for Slovakia. The significance of those parameters indicates a strong GARCH (1, 1) process which is driving the conditional variance of the twelve markets. In other words, the conditional variance is affected by its own past shocks and volatility. The illustrations for the models are presented in Appendix J, Figures from J.4 to J.6.

The off diagonal elements capture cross market effects in the covariance matrix. In Table 5.7 we find evidence of the pre-EU relationship between markets. The two entries for each pair of markets are their estimated parameters and the Bollerslev-Wooldridge robust t-ratio. As in the previous model for the pre-EU period, only a few pairs of markets show significance at the 5% level. This mainly relates to the stock markets of the Czech Republic, Estonia, Hungary and Poland. In the both post-EU periods the covariance matrix shows that the cross market relationship exists between markets of the Czech Republic, Cyprus, Estonia, Hungary, Lithuania, Poland and Romania. The isolated markets of Malta and Slovakia do not interfere with any other markets. The cross market affiliation is limited for Bulgaria, Slovakia and Latvia.

Table 5.7: Multivariate regression analysis results for Diagonal BEKK model; pre-EU: 1995-200ia4

	Bulgaria	Czech Rep	Estonia	Hungary	Latvia	Lithuania	Malta	Poland	Romania	Slovakia	Slovenia
Panel A: Covariance Matrix											
Bulgaria	–										
Czech Rep	0.007	–									
	(1.352)										
Estonia	0.007	**0.053**	–								
	(1.183)	**(4.060)**									
Hungary	0.003	**0.069**	**0.045**	–							
	(0.889)	**(2.404)**	**(4.239)**								
Latvia	0.002	**0.020**	**0.011**	**0.021**	–						
	(0.746)	**(2.728)**	**(2.121)**	**(3.126)**							
Lithuania	0.008	**0.034**	**0.048**	0.018	0.006	–					
	(0.476)	**(1.969)**	**(2.944)**	(1.323)	(0.608)						
Malta	0.005	0.007	0.006	0.015	0.006	0.000	–				
	(0.588)	(0.925)	(0.905)	(1.691)	(0.781)	(0.052)					
Poland	-0.001	**0.084**	**0.057**	**0.098**	**0.035**	0.029	0.014	–			
	(-0.251)	**(2.693)**	**(4.038)**	**(2.861)**	**(3.169)**	(1.618)	(1.626)				
Romania	-0.001	**0.017**	0.005	**0.023**	0.002	0.008	0.001	**0.036**	–		
	(-0.593)	**(2.543)**	(1.072)	**(2.929)**	(0.606)	(0.566)	(0.098)	**(2.844)**			
Slovakia	0.007	-0.005	-0.009	-0.003	-0.002	-0.016	0.003	0.009	0.000	–	
	(1.042)	(-0.576)	(-1.394)	(-0.421)	(-0.313)	(-1.101)	(0.457)	(0.807)	(-0.058)		
Slovenia	0.226	**0.102**	**0.073**	**0.157**	0.079	-0.009	0.009	0.057	0.063	0.054	–
	(0.560)	**(2.745)**	**(0.011)**	**(3.374)**	(1.583)	(-0.377)	(0.431)	(1.341)	(1.836)	(1.054)	
Panel B: BEKK model estimates											
ω	0.008	0.146	**0.094**	**0.143**	**0.064**	**0.369**	**0.131**	**0.248**	**0.021**	0.210	**0.486**
	(0.817)	(1.950)	**(3.432)**	**(2.130)**	**(2.411)**	**(2.900)**	**(4.420)**	**(2.256)**	**(2.014)**	(1.870)	**(2.582)**
α	**0.148**	**-0.096**	**0.253**	**-0.065**	**0.258**	**0.281**	**0.381**	**-0.152**	**0.196**	**0.228**	**0.598**
	(4.725)	**(-3.751)**	**(7.523)**	**(-2.753)**	**(5.126)**	**(3.886)**	**(6.970)**	**(-4.365)**	**(4.356)**	**(4.389)**	**(5.672)**
β	**0.988**	**0.953**	**0.921**	**0.964**	**0.950**	**0.686**	**0.742**	**0.931**	**0.978**	**0.902**	**-0.241**
	(251.622)	**(40.518)**	**(47.970)**	**(58.811)**	**(63.237)**	**(7.358**	**(13.481)**	**(31.345)**	**(113.667)**	**(19.181)**	**(-2.435)**

Note: The two entries corresponding to each parameter are their estimates and Bollerslev-Wooldridge (1992) robust t-ratios in parentheses. Bold denotes significance at 5% level

Table 5.8 Multivariate regression analysis results for Diagonal BEKK model; post-EU: 2004-2011

	Bulgaria	Cyprus	Czech Rep	Estonia	Hungary	Latvia	Lithuania	Malta	Poland	Romani	Slovakia	Slovenia
Panel A: Covariance Matrix												
Bulgaria	–											
Cyprus	-0.001	–										
	-(0.433)											
Czech Rep	-0.001	**0.012**	–									
	(-0.425)	**(4.158)**										
Estonia	0.001	0.001	**0.004**	–								
	(0.940)	(1.002)	**(1.986)**									
Hungary	-0.002	**0.008**	**0.025**	**0.004**	–							
	(-0.913)	**(3.041)**	**(5.168)**	**(2.257)**								
Latvia	0.001	0.002	0.002	**0.003**	0.001	–						
	(0.767)	(1.093)	(1.227)	**(2.217)**	(0.714)							
Lithuania	**0.005**	**0.007**	**0.011**	**0.013**	**0.017**	**0.009**	–					
	(2.026)	**(2.042)**	**(2.893)**	**(4.413)**	**(3.472)**	**(3.034)**						
Malta	0.005	0.009	0.006	0.004	0.019	0.012	0.005	–				
	(0.633)	(0.735)	(0.650)	(0.559)	(1.469)	(1.414)	(0.695)					
Poland	0.001	**0.007**	**0.021**	**0.004**	**0.025**	0.002	**0.011**	0.014	–			
	(0.422)	**(3.263)**	**(5.347)**	**(2.419)**	**(4.813)**	(1.095)	**(3.121)**	(1.337)				
Romania	0.002	**0.010**	**0.013**	**0.006**	**0.016**	0.005	**0.013**	0.006	**0.014**	–		
	(0.786)	**(2.513)**	**(3.346)**	**(2.466)**	**(3.444)**	(1.719)	**(2.493)**	(0.417)	**(3.546)**			
Slovakia	**0.003**	0.000	0.001	**0.004**	0.001	-0.001	**0.005**	0.004	-0.001	0.002	–	
	(3.022)	(0.561)	(0.820)	**(3.499)**	(0.682)	(-0.797)	**(2.703)**	(0.493)	-(0.657)	(1.678)		
Slovenia	0.001	0.003	0.002	0.002	0.000	0.001	0.001	-0.004	0.003	**0.007**	0.000	–
	(0.404)	(1.510)	(0.944)	(1.209)	(-0.125)	(0.510)	(0.475)	(-0.560)	(1.516)	**(2.171)**	(-0.224)	
Panel B: BEKK model estimates												
ω	**0.014**	**0.017**	**0.038**	**0.018**	**0.046**	**0.025**	**0.078**	**0.242**	**0.032**	**0.082**	0.003	**0.022**
	(4.368)	**(3.705)**	**(5.559)**	**(5.074)**	**(4.081)**	**(3.205)**	**(6.887)**	**(6.509)**	**(4.730)**	**(4.543)**	(0.927)	**(4.727)**
α	**0.220**	**0.142**	**0.197**	**0.196**	**0.148**	**0.193**	**0.280**	**0.537**	**0.145**	**0.179**	**-0.108**	**0.327**
	(12.342)	**(11.165)**	**(10.118)**	**(9.717)**	**(7.907)**	**(9.044)**	**(8.664)**	**(9.541)**	**(8.892)**	**(8.974)**	**(-5.464)**	**(13.907)**
β	**0.974**	**0.988**	**0.973**	**0.975**	**0.983**	**0.976**	**0.934**	**0.594**	**0.984**	**0.974**	**0.994**	**0.937**
	(279.155)	**(567.603)**	**(293.065)**	**(279.514)**	**(308.753)**	**(203.441)**	**(111.873)**	**(8.917)**	**(360.749)**	**(186.818)**	**(365.879)**	**(132.965)**

Note: The two entries corresponding to each parameter are their estimates and Bollerslev-Wooldridge (1992) robust t-ratios in parentheses. Bold denotes significance at 5% level

Table 5.9: Multivariate regression analysis results for Diagonal BEKK model; post-EU: 2007-2011

	Bulgaria	Cyprus	Czech Rep	Estonia	Hungary	Latvia	Lithuania	Malta	Poland	Romani	Slovakia	Slovenia
Panel A: Covariance Matrix												
Bulgaria	–											
Cyprus	0.000	–										
	(0.014)											
Czech Rep	0.003	**0.032**	–									
	(1.117)	**(5.769)**										
Estonia	**0.010**	**0.014**	**0.021**	–								
	(3.034)	**(2.659)**	**(4.266)**									
Hungary	0.002	**0.026**	**0.036**	**0.020**	–							
	(0.439)	**(4.739)**	**(6.060)**	**(3.932)**								
Latvia	0.003	0.003	0.002	**0.013**	0.002	–						
	(1.421)	(0.981)	(0.777)	**(3.587)**	(0.488)							
Lithuania	**0.010**	**0.014**	**0.016**	**0.034**	**0.019**	**0.012**	–					
	(3.037)	**(2.218)**	**(3.942)**	**(7.073)**	**(3.845)**	**(3.514)**						
Malta	0.017	0.010	0.017	0.018	0.024	0.017	0.014	–				
	(1.742)	(0.605)	(1.263)	(1.705)	(1.572)	(1.591)	(1.431)					
Poland	0.005	**0.026**	**0.039**	**0.019**	**0.044**	0.002	**0.017**	0.027	–			
	(1.717)	**(4.852)**	**(6.094)**	**(4.148)**	**(6.001)**	(0.613)	**(4.049)**	(1.876)				
Romania	**0.022**	**0.101**	**0.072**	**0.041**	**0.081**	**0.020**	**0.036**	0.014	**0.085**	–		
	(2.620)	**(5.946)**	**(6.155)**	**(4.182)**	**(5.206)**	**(2.354)**	**(4.200)**	(0.786)	**(6.395)**			
Slovakia	0.001	0.001	0.002	0.003	0.001	0.000	0.002	-0.005	0.000	0.005	–	
	(1.034)	(0.454)	(1.060)	(1.340)	(0.474)	(-0.383)	(1.129)	(-0.498)	(0.257)	(0.917)		
Slovenia	**0.018**	0.019	0.012	**0.027**	0.008	0.011	**0.012**	0.006	0.014	**0.039**	0.004	–
	(2.707)	(1.933)	(1.690)	**(3.509)**	(0.891)	(1.906)	**(2.158)**	(0.625)	(1.787)	**(3.469)**	(1.277)	
Panel B: BEKK model estimates												
ω	**0.019**	**0.055**	**0.055**	**0.078**	**0.066**	**0.016**	**0.061**	**0.188**	**0.058**	**0.336**	**0.005**	**0.105**
	(4.513)	**(4.577)**	**(6.431)**	**(6.505)**	**(6.477)**	**(4.123)**	**(7.441)**	**(10.985)**	**(5.293)**	**(7.904)**	**(21.352)**	**(6.635)**
α	**0.194**	**0.131**	**0.208**	**0.160**	**0.184**	**0.174**	**0.224**	**0.451**	**0.157**	**0.257**	-0.014	**0.406**
	(20.211)	**(15.626)**	**(27.009)**	**(16.045)**	**(23.831)**	**(18.226)**	**(23.537)**	**(15.145)**	**(18.955)**	**(18.257)**	-(1.058)	**(18.144)**
β	**0.977**	**0.990**	**0.970**	**0.968**	**0.977**	**0.983**	**0.955**	**0.650**	**0.980**	**0.929**	**0.999**	**0.875**
	(468.162)	**(813.010)**	**(413.091)**	**(244.928)**	**(532.163)**	**(547.273)**	**(248.508)**	**(20.118)**	**(420.521)**	**(119.918)**	**(5460.578)**	**(69.430)**

Note: The two entries corresponding to each parameter are their estimates and Bollerslev-Wooldridge (1992) robust t-ratios in parentheses. Bold denotes significance at 5% level

5.5.2.3 CCC and BEKK models summary

The main difference between the CCC and the BEKK conditional volatility models is that they estimate the conditional correlation in a different way. While the CCC estimates the conditional correlation through the decomposition of the covariance matrix as the product of correlations with standard deviation, The BEKK directly models the covariance matrix.

Both models differ in their analysis, yet both of them reveal some similarities at the conclusion of their application. Their common findings are as follows:

In the pre-EU period

- There is a limited number of significant values in the conditional correlation matrix or covariance matrix,
- The significance and hence the cross market effects are mostly related to the stock markets of the Czech Republic, Hungary and Poland.

For the post-EU: 2004 -2011 period

- The number of significant cross market effects increases,
- Next to the major three markets the dominant role is observable for the markets of Cyprus, Estonia, Romania and Slovenia,
- Two markets, namely Malta and Slovakia are not associated with any other markets in the CEE.

For the post-EU: 2007 -2011 period

- There are plenty of similarities to the previous time frame, showing there is no structural change after the second EU enlargement.

In the next two sections multivariate VARMA models will be used to test for the spillover effects of volatility. This will be done using data for eight markets. The decrease in parameters is due to computational problems. In their paper, McAleer, Chan, Hoti and Lieberman (2008, p. 1556) point out that a large number of parameters can cause numerical problems. Moreover "*... not all multivariate GARCH models are able to accommodate convenient two-step estimation methods.*" Unfortunately that was an issue in this analysis, therefore the four markets of Latvia, Lithuania, Malta and Slovakia are not part of the further analysis.[12] Additionally, the preliminary analysis of the multivariate model have shown that the pre-EU period is going to be calculated from 2000, and not as previously from 1995.This is due the different commencement dates for the various stock market's data availability. Even though the pre-EU period becomes shorter by five years, there is a large enough number of observations to provide unbiased conclusion for this multivariate analysis.

5.5.2.4 VARMA GARCH

Using the data on the eight markets, namely Bulgaria, the Czech Republic, Cyprus, Estonia, Hungary, Poland, Romania and Slovenia the volatility spillover effects between markets and direction of the flow of the volatility from one market to another can affect the stock market returns for those countries.

The conditional mean is modelled in each case based on an ARMA (*r, s*) process, defined before, with correct specification of *r* and *s* for each country (please refer to the Appendix E for the parameters of *r* and *s*). This conditional mean equation gives an aggregate measure of relative risk aversion. The results from this analysis show insignificance autocorrelation in almost every case. For the pre-EU period only Romania seems to show significance in the mean equation, for post-EU: 2004-2011 period this is the Polish and Slovenian stock markets and post-EU: 2007-2011 period

[12] The elimination process of the four markets is based on the previous volatility modelling of univariate and multivariate GARCH and of cointegration analysis. This is documented that those markets are not cointegrated with others and drifting away from the entire group.

only the Slovenian. In the next step the conditional volatility is estimated through the two VARMA models of VARMA GARCH and VARMA AGARCH. [13]

In the pre-EU period the conditional variance generally is affected by its own previous short run (α) and long run (β) shocks. There are a few cross market effects which confirm that volatility spillovers are observed (Table 5.10). As such, the Czech Republic is affected by previous short run and long run shocks from Hungary; Hungary only affects the Czech Republic through its previous long run behaviour. Moreover the Hungarian stock market is affected by β shocks from Romania and α shocks from Poland. Of all the markets analysed the Polish one is mainly affected by previous short and/or long shocks in several countries, namely Bulgaria, the Czech Republic, Hungary, Romania and Slovenia. The least affected are the markets of Estonia and Romania. All in all for the pre-EU period the markets appear to stand in a stronger independent position, showing only minimal cross markets interdependence.

The post-EU: 2004-2011 period evidence suggests we can observe slightly different relationships between markets. The least affected markets are the Czech Republic and Poland. The first one is affected by α shocks from Bulgaria and β shocks from Hungary and Poland. The other is influenced by α shocks from Bulgaria and Slovenia and β shocks in Slovenia. The most highly affected is the Slovenian stock market, which is influenced by previous short run and/or long run shocks from almost all the studied countries. There are three markets pairs which appear to be affecting each other. They are: Bulgaria – Slovenia, the Czech Republic – Hungary and Poland – Romania. In summary, all the eight markets are generally affected by their own previous short run and long run shocks, plus volatility spillovers are observable.

The other post-EU: 2007-2011 period shows again different results from the previous two periods (Table 5.12). Thus it is observable that there are no spillover effects between Cyprus and any other market. Cyprus is affected only by its own previous short run and long run shocks. There are a few spillover effects between the others, and as such Bulgaria is affected only by one country – Estonia. The Czech Republic is affected

[13] The full results which include the conditional mean, conditional variance of own and spillover effects for both models have been placed in Appendix H (Tables from H.1 to H.6). Tables presented in the text are summaries of shocks and volatility effects in the system. Appendix K (Figures from K.1 to K.6) provides diagrams with the conditional variance for studied models.

by previous past long run shocks from Bulgaria, Romania and Slovenia. Poland is mostly affected by both α and β from Poland. The most affected is the Hungarian stock market with short and long runs past shocks from all but Slovenia.

These different results from both post-EU periods could be related to differences in sample size. The second time frame contains daily observations from a period of four years in comparison to seven years in the first one. This could violate the properties of QMLE for Multivariate GARCH model in regards to the sample size. Therefore I would have greater confidence in the results from the post-EU:2004-2011 period.

Table 5.10: Summary of volatility spillovers between pairs of returns series, pre-EU: 1995-2004

			Number of volatility spillovers			
			VARMA GARCH		VARMA AGARCH	
No	Returns		ARCH effect	GARCH effect	ARCH effect	GARCH effect
1	Bulgaria	Czech Rep				
2	Bulgaria	Estonia	1 →		1 →	
3	Bulgaria	Hungary				
4	Bulgaria	Poland	1 ←	1 ←	1 ←	1 ←
5	Bulgaria	Romania				
6	Bulgaria	Slovenia	2 ↔	2 ↔	2 ↔	2 ↔
7	Czech Rep	Estonia				
8	Czech Rep	Hungary	1 →	2 ↔		
9	Czech Rep	Poland		1 ←		1 ←
10	Czech Rep	Romania				
11	Czech Rep	Slovenia	1 ←	1 →	1 ←	1 →
12	Estonia	Hungary			1 ←	
13	Estonia	Poland				
14	Estonia	Romania				
15	Estonia	Slovenia	1 →		1 →	1 ←
16	Hungary	Poland	1 →	1 ←	2 ↔	1 ←
17	Hungary	Romania		1 →	1 ←	1 ←
18	Hungary	Slovenia			1 →	
19	Poland	Romania		2 ↔		1 →
20	Poland	Slovenia	1 →		1 →	1 →
21	Romania	Slovenia		1 →		

Note: The symbol → (←) indicate the direction of volatility spillovers from A returns to B returns (B returns to A returns), ↔ means they are interdependent, if left blank means there are none volatility spillovers between pairs of returns. The numbers indicate the number of volatility spillover effects associated with each market pair.

Table 5.11: Summary of volatility spillovers between pairs of returns series, post-EU: 2004-2011

			Number of volatility spillovers			
			VARMA GARCH		VARMA AGARCH	
No	Returns		ARCH effect	GARCH effect	ARCH effect	GARCH effect
1	Bulgaria	Czech Rep	1 ←	1 →		
2	Bulgaria	Cyprus				
3	Bulgaria	Estonia	1 ←	1 ←	1 →	
4	Bulgaria	Hungary	2 ↔	1 →		
5	Bulgaria	Poland	1 ←		1 ←	1 ←
6	Bulgaria	Romania	1 ←	1 →	1 ←	
7	Bulgaria	Slovenia	1 ←	1 ←		
8	Cyprus	Czech Rep	1 →	1 →		
9	Cyprus	Estonia	2 ↔	1 →		1 ←
10	Cyprus	Hungary		1 ←		2 ↔
11	Cyprus	Poland				
12	Cyprus	Romania	2 ↔	1 →	2 ↔	1 →
13	Cyprus	Slovenia	1 ←	1 ←	1 ←	2 ↔
14	Czech Rep	Estonia	1 ←	1 ←	1 →	1 →
15	Czech Rep	Hungary		2 ↔		1 ←
16	Czech Rep	Poland		2 ↔	1 ←	
17	Czech Rep	Romania				
18	Czech Rep	Slovenia				
19	Estonia	Hungary				
20	Estonia	Poland				1 →
21	Estonia	Romania	1 →			
22	Estonia	Slovenia		1 ←	2 ↔	2 ↔
23	Hungary	Poland		1 →		1 ←
24	Hungary	Romania	1 →		1 →	1 →
25	Hungary	Slovenia		2 ↔		1 ←
26	Poland	Romania	1 ←	1 ←		
27	Poland	Slovenia	1 →	2 ↔	1 →	2 ↔
28	Romania	Slovenia	1 ←	1 ←		

Note: The symbol → (←) indicate the direction of volatility spillovers from A returns to B returns (B returns to A returns), ↔ means they are interdependent, if left blank means there are none volatility spillovers between pairs of returns. The numbers indicate the number of volatility spillover effects associated with each market pair.

Table 5.12: Summary of volatility spillovers between pairs of returns series, post-EU: 2007-2011

			Number of volatility spillovers							
			VARMA GARCH				VARMA AGARCH			
No	Returns		ARCH effect		GARCH effect		ARCH effect		GARCH effect	
1	Bulgaria	Czech Rep								
2	Bulgaria	Cyprus							1	←
3	Bulgaria	Estonia	1	→	1	→				
4	Bulgaria	Hungary	1	←	1	←			1	←
5	Bulgaria	Poland								
6	Bulgaria	Romania	1	←	1	←				
7	Bulgaria	Slovenia								
8	Cyprus	Czech Rep	1	←			1	→		
9	Cyprus	Estonia	1	←						
10	Cyprus	Hungary			1	←	1	←	1	←
11	Cyprus	Poland	1	←			1	←		
12	Cyprus	Romania	1	←					1	→
13	Cyprus	Slovenia	1	←			1	←	1	→
14	Czech Rep	Estonia	1	←	2	↔	1	←	1	←
15	Czech Rep	Hungary			1	←			1	←
16	Czech Rep	Poland	1	←	1	←				
17	Czech Rep	Romania	1	←	2	↔			1	←
18	Czech Rep	Slovenia			2	↔			1	←
19	Estonia	Hungary								
20	Estonia	Poland								
21	Estonia	Romania	1	→	2	↔	2	↔	1	←
22	Estonia	Slovenia			1	←			1	←
23	Hungary	Poland	1	→	1	←				
24	Hungary	Romania	2	↔	1	←	1	←	1	←
25	Hungary	Slovenia			2	↔			2	↔
26	Poland	Romania	1	←	1	←			1	←
27	Poland	Slovenia	1	←	1	→				
28	Romania	Slovenia			1	←	2	↔	1	←

Note: The symbol → (←) indicate the direction of volatility spillovers from A returns to B returns (B returns to A returns), ↔ means they are interdependent, if left blank means there are none volatility spillovers between pairs of returns. The numbers indicate the number of volatility spillover effects associated with each market pair.

5.5.2.5 VARMA AGARCH

The estimated results of the VARMA AGARCH model are presented in Table 5.10 - Table 5.12. Similar to the previous model the significant autocorrelation for the conditional mean equation is limited to Slovenia in both post-EU periods and Hungary in post-EU: 2007-201 period. The estimates of the conditional variances show significant positive asymmetric effects on the conditional volatility in the one case of Hungary in the pre-EU period, Cyprus, Hungary, Romania and Slovakia in both post-EU periods, plus Poland in the post-EU: 2004-2011 period.

In terms of multivariate spillover effects on the conditional variance, for the pre-EU period, the markets are mostly affected by their long run shocks (β). The Estonian and Romanian stock markets are as well affected by their own short run shocks (α). There is a demonstrable existence of spillover effects between the markets, and as such the most limited influence is on the Czech Republic and Estonia. The first contains long run shocks and the other short run shocks from Slovenia. Interestingly, Hungary is affected by previous short run shocks only from Estonia, Poland and Slovenia. The most affected one is the Polish stock market and the spillover effects are recorded from previous short run shocks from Bulgaria, Hungry and Slovenia, and the long run shocks from Bulgaria, the Czech Republic, Hungary, Romania and Slovenia.

For the post-EU: 2004-2011 period spillover effects exist, but the interdependence is different. As such the least affected this time is Bulgaria, which is influenced only by the previous short run shocks from Estonia. In comparison with the previous time frame, the Czech Republic is no longer affected by Slovenia but by the previous shocks from Cyprus and Estonia. Moreover, the Estonian stock market is not only affected by Slovenia but also by the previous long run shocks from Poland. Similarly the most affected market is Poland and this cross market effect is between this country and five others; namely Bulgaria, the Czech Republic, Hungary, Romania and Slovenia. The same relationship is observable for the stock market pairs of Bulgaria – Estonia and Bulgaria and Poland (Table 5.11).

The post-EU: 2007-2011 period is again differentiated from the previous post-EU: 2004-2011 period due to the same reason as defined previously. We can see that the stock markets of Bulgaria and the Czech Republic are affected only by their own previous α (Bulgaria only) and β (both markets) shocks, and no spillover effects are observable. In the previous two time frames Poland was the most affected of markets, however this time all parameters are not significant, neither for its owns effects or for the cross market ones. Therefore for the VARMA AGARCH model the conclusion is made only on the first two time frames.

5.5.2.6 VARMA GARCH and VARMA AGARCH models summary

As summarised in Table 5.10, Table 5.11 and Table 5.12, we observe several similarities between the results of those two models. In the pre-EU period there is the same cross market relationship between Bulgaria – Estonia, Bulgaria – Poland, Bulgaria – Slovenia, the Czech Republic – Poland and the Czech Republic – Slovenia. The inverse relationship in spillover effects is found only for Hungary – Romania. For the post-EU:2004-2011 period we can see that there are a number of very similar results for both models. However, the identical links are viewed between Cyprus – Romania and Poland – Slovenia. There is as well an opposite relationship demonstrated by the stock markets of the Czech Republic – Estonia and Hungary – Poland.

Unlike the case of VARMA GARCH model no volatility spillover effects are observable for

- The pre-EU period for: Estonia – Hungary and Hungary – Slovenia.
- The post-EU:2004-2011 period for: Bulgaria – the Czech Republic, Bulgaria – Hungary, Bulgaria – Slovenia, Cyprus – the Czech Republic, Estonia – Romania and Romania – Slovenia.

Unlike the case of the VARMA AGARCH model no volatility spillovers effects are evident for

- The pre-EU period for: the Czech Republic – Hungary and Romania – Slovenia.
- The post-EU: 2004-2011 period for: Estonia – Poland, Bulgaria – Hungary, Bulgaria – Slovenia, Cyprus – the Czech Republic and Romania – Slovenia.

5.6 Conclusion

In summary, this chapter analysed the changes in relationships in terms of volatility and spillover effects across the twelve CEE markets. Three univariate and four multivariate GARCH models of the conditional variance were examined. A sufficient condition for the consistency and asymptotic normality of QMLE was established for the three univariate GARCH models. The log-moment and the second moment conditions are satisfied; therefore all models are correctly specified.

Univariate GARCH models show that volatility shocks are quite persistent. Strong GARCH effects are observable in almost all cases, which mean that a market's volatility depends on its own lagged square residual and volatility. The GJR and EGARCH models captured the presence of asymmetric effects in the volatility of the markets. The estimated coefficients from the conditional mean returns equations indicate that all examined markets are highly integrated, reacting to their own country market information. Multivariate VARMA GARCH models show that spillover effects exist between countries. For each time frame discussed, there is evidence of interdependence between the Czech Republic, Hungary and Poland and the others. In the multivariate framework the conditional correlations were estimated showing the interaction among the volatility of market returns. This estimation was calculated via the CCC and the diagonal *BEKK* models. Overall, the correlation values are high and positive, showing dominance of the three markets of the Czech Republic, Hungary and Poland; however the Cyprus, Estonian, Romanian and Slovenian markets are grouped between those countries that are interdependent between each other and the others.

It is not a surprise that the significant role of the Czech Republic, Hungarian and Polish markets was evident. These markets have already been recognized by the FTSE and MSCI groups as advanced emerging markets. Furthermore, Estonia has developed into a strong international player through its membership in the EU. On the other hand the Maltese and Slovakian stock markets appear to display more self-directed independent behaviour than their peers.

As the majority of past studies on stock market comovements and integration have concentrated mainly on mature developed markets or advanced emerging markets, this dissertation tested the behaviour and inter-relationship of all the CEE emerging markets only. The results show growing investment potential in those equity markets and that they provide good opportunities for European investors as well as important indications for economic stability, growth and integration of the CEE markets in the post-EU period. No dramatic shocks during the accession phase in the post-EU period have been detected. This could be explained by the fact that those macroeconomic policies have been subject to an adjustment process for a long period of time. Throughout the process of preparing for admission to the EU, these equity markets have been propelled along similar paths (via the joining procedures) to those in developed market economies. Moreover, regional integration among the twelve countries was documented. Given this information, EU based investors may observe stock market behaviour in one group of markets as one investment opportunity instead of single separate classes of assets. Ideally, an investor based in the more developed markets of the EU would like to be able to invest in these Euro-denominated ‘emerging markets’ and benefit from risk diversification. Paradoxically, the diversification benefits appear to be reduced in terms of the findings of increased cointegration. On the other hand, there is also evidence of a lowering of average risk, in terms of variance based measures post-joining the EU.

These emerging markets are progressing very rapidly in their reforms and stability in domestic economies while in the process of becoming members of the EU. It is to be borne in mind that the aim and the greatest achievement of the creation of the EU is the development of a single market through a standardised system of laws which apply in all member states. Thus restrictions between member countries on trade and free competition have gradually been eliminated. As an outcome of those reforms and expansion, the EU has more influence on the world stage when it speaks with a single voice in international affairs.

A future extension of this study could consider the effects of developed markets on our cointegration analysis with the objective of verifying the assumption that the relationships between emerging EU markets would be broadly preserved.

Chapter 6: Conclusion, limitations and suggestions for future research

This chapter discusses the conclusion drawn from the dissertation, indentifies the limitations of the study and gives suggestions for future research.

6.1 Conclusion

The main motivation for this research was to investigate inter-relationships between the emerging markets of EU's latest newcomers. To do so, this dissertation employed both cointegration and volatility data analysis applying time-series econometrics techniques. The first leg of the econometrics analysis incorporates: the Johansen procedure, Granger Causality tests, Variance Decompositions and Impulse Response analyses. The second leg of econometric analysis includes three univariate ARCH models, namely GARCH, EGARCH and GJR, and the multivariate modelling encapsulate in the following models: CCC, BEKK, VARMA-GARCH and VARMA-AGARCH.

This study attempted to answer several questions regarding the markets' relationships, as listed in Chapter 1, and in the outcomes are summarised below.

Firstly, it was found that cointegration between markets exists. This was confirmed by the existence of one, and on some occasions, two cointegrating vectors between these CEE countries and this confirms the existence of a long-run relationship (refer to Chapter 4).

Secondly, the ECM indicated a slow return to the equation equilibrium, once it is shocked; and this is regardless of the case scenario and period studied. The overall results differ between the pre-EU and the post-EU periods, yet there are plenty of similarities between both post-EU periods.

Thirdly, in terms of the speed of adjustment of the CEE markets, all stock markets in all periods studied adjust back to the long-run equilibrium. The results vary between 8% for the pre-EU period and 1% for the post-EU one.

Subsequently, the Granger Causality tests show uni-variate patterns between the CEE stock markets. However in both post-EU periods the markets studied show several uni- and bi-variate effects.

Our findings also show that the volatility shocks are quite persistent, and there is the presence of asymmetric effects in the volatility. There is clear evidence of cross-market effects for the CEE stock index returns, and also bidirectional shock and volatility spillovers between their stock returns exist in a statistically significant sense too (refer to Chapter 5).

The difference between the pre- and the post-EU periods is apparent. In summary, in the pre-EU periods the relationships seem to be rather arbitrary, but they still show dominance of the Czech Republic, Hungarian and Polish stock markets. The post-EU period shows more integration between the markets with an increase in number of significant results for the analysis of cointegration and cross market effects. Besides, the post-EU markets appear to be more correlated in comparison with the pre-EU period (see Chapter 3).

The study demonstrates that regional interdependence exists. There is strong evidence that three markets, namely the Czech Republic, Hungary and Poland are the 'leaders' for the twelve markets studied, all the others being the followers. In terms of the remainder, its worthy of mention of the involvement of Cyprus, Estonia, Slovenia Bulgaria and Romania. The Maltese and Slovakian stock markets appear to be mostly drifting away from their peers showing self-directed interdependent behaviour. In the markets of the post Soviet Union; namely Latvia, Lithuania and Estonia, the first two show plenty of similarities in the analysis. Estonia, on the other hand, has proved its rapid and strong economical expansion when it became an EU member. Additionally there is no regionalism from the EMU point of view. There is no observable special distinction between euro and non euro countries.

Finally, this study evaluates the importance of including the several implications for investors and policy makers. An accurate assessment of the degree of comovement and volatility between the CEE countries' stock markets is important for several reasons: for investors there are benefits from portfolio diversification but only if the returns from stock markets are not significantly correlated. Stock market investigation is also of considerable interest to policy makers because of the direct impact on collective wealth. The investors can choose to hold either a highly correlated portfolio or an uncorrelated or only weakly correlated portfolio, which then differentiates the investment return/risk combinations achieved by the investor. Through the wealth channel, the impact on the distribution of equity stock market shocks and the differing levels of stock market comovement imply different effects on the macroeconomy. This effect has important implications not only for policy makers but also for the planning of monetary policy and the timing of monetary intervention.

6.2 Limitations of the study

This thesis has provided a comprehensive analysis of the interaction between twelve European markets. Nonetheless, as is generally the case with all studies, there are some limitations which necessitate consideration and reflection. Firstly, the CEE countries stock markets have been created in different ways and at different times, making it somewhat difficult to determine an ideal starting date for the dataset. Also emerging markets generally experience some start up problems during their first stages of their development, however these are generally consistent across the markets (Claessense at al., 2000). These arise from several factors, such as: low liquidity, high investment risk (so stock prices were volatile in comparison to the current stock market performance or to developed markets). The absence of reliable information about the companies traded on the CEE markets, as information disclosure was inaccurate or incomplete and was based on different accounting standards. In addition, data for every stock market was not available from 1995; therefore the results could be influenced by these technical shortcomings. However, it was important for this study to capture information at an early stage of the first major emerging market enlargement of the EU, and therefore it was decided that the empirical analysis would commence at 1995 when the data for at least 5 key markets to the study was available (and this included the markets of the Czech Republic, Hungary, Poland, Slovakia and Slovenia).

As discussed in Chapter 4, the results from the Johansen cointegration analysis showed the existence of two cointegrating vectors on a few occasions, however further analysis of the normalized vector showed no significance in results. Therefore the results presented in this dissertation only include the Czech Republic and Polish markets, as the other analysis showed no significance for cointegrating vectors and had to be omitted (refer to Chapter 4). Even though the cointegration analysis was based on the above two markets as the reference point, this should not influence the overall outcome, as it was demonstrated that these markets are the leaders for all others.

Finally, multivariate VARMA GARCH analysis was performed only for eight out of twelve markets due to computation problems. Not every multivariate GARCH model is able to be computed when a large number of parameters cause lack of iteration convergence (as discussed by McAleer et al (2008)). After several trials attempting to overcome this limitation, four stock markets had to be excluded from further analysis. Those markets were: Latvia, Lithuania, Malta and Slovakia. The elimination process was based on the results from the previous cointegration and correlation analysis, as well as the univariate GARCH investigation. As a result markets which previously showed lack of neither significant cointegration nor correlation with others were eliminated, as it was unlikely that any cross market effects would be demonstrated at this point. This limitation was discussed in detail in Chapter 5.

6.3 Suggestions for future research

The opportunity exists for future research to develop this study further and to extend these research findings.

1. As the EU is still growing, a future analysis of the EU member states is important to check for the impact of any additional countries on the interrelationships between the CEE countries. Countries in line are: Croatia, Iceland, Turkey, Montenegro Serbia and the former Yugoslav Republic of Macedonia. Ongoing analysis is also important due to the very dynamic nature of the major players in the process, both in terms of the European Union and the candidature countries.

2. This thesis has demonstrated evidence of interrelationships between the CEE emerging markets, and the next step could be the addition to the analysis of the European advanced markets, to check the cointegration and volatility results

hold with this addition when the EU is considered as a comprehensive group of countries.

3. For a closer look at the cross – sectional samples of the data set, panel data techniques could be applied to cointegration modelling. This could be used by researchers and policy makers to undertake more in depth analysis of the particular stages of the Union creation process in different accession periods, including pre-accession, accession and post-accession. The cross sectional categories could also be expanded to include three different state levels: candidate states, European Union and member states.

4. The GARCH modelling undertaken in this study could be expanded by the application of additional models, such the generalized autoregressive conditional correlation (GARCC) model of McAleer et al, (2008).which helps avoid some computation al problems,

5. A future study could also undertake Markowitz portfolio analysis to create different scenarios of portfolio diversification. Such an analysis would benefit investors who wish to invest in a portfolio of European markets.

6. Given the current European crisis, a future study could investigate the impact of this crisis on the interrelationships between European markets.

Appendix A

A.1 Descriptive Statistics

Summary of Table A.1: Stock market descriptive statistics of daily returns measured in € and Table A.2: Stock market descriptive statistics of daily returns measured in domestic currency.

The tables below present basic statistics for daily returns. There is no significant difference in the statistical behaviour of these two groups of series. On both occasions the distribution is left skewed with the exception of Malta and Slovakia, where we observe a positive value. The mean, on average, is close to zero and the distributions are characterised by non-normality (Jarque-Bera statistics). All markets generate kurtosis statistics more than 3 (which is the benchmark for a normal distribution) which indicates the series are characterised by leptokurtosis. This means that the distribution of the data contains a greater number of observations in the tails than that found in a normal distribution.

Volatility measured by the standard deviation of daily returns again shows similar results for different currencies. A slight change in the volatility can be observable for Hungarian stock market, where higher volatility is for euro (1.912) then for domestic currency (1.689).

Table A.1: Stock market descriptive statistics of daily returns measured in €

	Mean	Median	Max	Min	St Dev	Skew	Kurtos	Jarque-Bera	Normality p-value
Bulgaria	0.053	0.022	21.054	-20.894	1.769	-0.564	30.455	86709.8	0.000
Czech Rep	0.012	0.000	14.469	-16.580	1.518	-0.347	14.323	23933.0	0.000
Cyprus	-0.009	0.000	12.123	-12.135	2.318	-0.017	6.388	835.5	0.000
Estonia	0.049	0.042	12.866	-21.576	1.677	-0.972	24.026	72455.6	0.000
Hungary	0.037	0.053	15.402	-19.483	1.912	-0.637	14.744	30896.5	0.000
Latvia	0.039	0.010	10.190	-14.720	1.618	-0.556	15.655	19940.3	0.000
Lithuania	0.043	0.015	11.867	-13.515	1.192	-0.220	24.966	59654.5	0.000
Malta	0.029	0.000	9.572	-7.589	0.794	1.480	23.010	68418.5	0.000
Poland	0.052	0.026	15.051	-17.714	2.102	-0.252	9.415	9040.8	0.000
Romania	0.004	0.013	11.863	-14.399	2.021	-0.327	8.856	5149.6	0.000
Slovakia	0.018	0.000	27.554	-14.810	1.527	1.610	44.391	331009.3	0.000
Slovenia	0.022	0.000	11.017	-11.344	1.192	-0.422	15.708	29596.9	0.000

Table A.2: Stock market descriptive statistics of daily returns measured in domestic currency

	Mean	Median	Max	Min	St Dev	Skew	Kurtos	Jarque-Bera	Normality p-value
Bulgaria	0.053	0.003	21.073	-20.899	1.770	-0.569	30.447	86661.7	0.000
Czech Rep	0.005	0.000	12.364	-16.185	1.404	-0.444	15.412	28797.9	0.000
Cyprus	-0.009	0.000	12.123	-12.135	2.318	-0.017	6.388	835.5	0.000
Estonia	0.049	0.042	12.866	-21.576	1.677	-0.972	24.026	72455.6	0.000
Hungary	0.059	0.006	13.616	-18.033	1.689	-0.541	14.764	30898.0	0.000
Latvia	0.045	0.000	10.179	-14.705	1.602	-0.613	16.736	23498.0	0.000
Lithuania	0.043	0.015	11.867	-13.515	1.192	-0.220	24.966	59654.5	0.000
Malta	0.029	0.000	9.572	-7.589	0.794	1.480	23.010	68418.5	0.000
Poland	0.074	0.000	14.783	-11.344	1.885	-0.032	10.112	11043.4	0.000
Romania	0.048	0.000	11.544	-13.116	1.853	-0.257	9.403	6122.7	0.000
Slovakia	0.018	0.000	27.554	-14.810	1.527	1.610	44.391	331009.3	0.000
Slovenia	0.022	0.000	11.017	-11.344	1.192	-0.422	15.708	29596.9	0.000

A.2 Stationarity of time series

As summarised in Table A.3: Unit root tests on price level measured in € and Table A.4: Unit root tests on price level measured in domestic currency, the preliminary statistical outcomes appear to be almost identical regardless of the currency we are working with. The price series is stationary at the first difference (the ADF and PP tests clearly indicate that the return data is stationary). Each of the test scores are below the critical value of a 1% significance level and this results is not sensitive to the presence of an intercept term and trend.

Table A.3: Unit root tests on price level measured in €

	ADF test				PP test			
	v_t		Δv_t		v_t		Δv_t	
	Without trend	With trend	Without trend	With trend	Without trend	With trend	Without trend	With trend
Bulgaria	-1.991	-0.706	-16.590***	-16.650***	-1.245	-0.770	-48.171***	-47.970***
Czech Rep	-0.481	-2.346	-28.052***	-28.080***	-0.544	-2.433	-63.612***	-63.619***
Cyprus	-0.821	-1.199	-38.691***	-38.775***	-0.792	-1.189	-38.767***	-38.826***
Estonia	-1.206	-1.773	-14.902***	-14.900***	-1.035	-1.625	-57.429***	-57.423***
Hungary	-0.886	-2.415	-30.738***	-30.737***	-0.907	-2.517	-68.675***	-68.671***
Latvia	-1.588	-1.163	-35.126***	-35.149***	-1.562	-1.109	-52.772***	-52.774***
Lithuania	-1.204	-1.281	-12.871***	-12.874***	-1.158	-1.200	-51.181***	-51.171***
Malta	-1.334	-0.717	-32.231***	-32.253***	-1.385	-0.971	-41.349***	-44.343***
Poland	-0.898	-1.965	-66.642***	-66.638***	-1.001	-2.115	-67.138***	-67.134***
Romania	-0.945	-1.607	-53.570***	-53.568***	-1.042	-1.690	-54.190***	-54.183***
Slovakia	-1.581	-1.476	-23.347***	-23.354***	-1.707	-1.684	-71.837***	-71.812***
Slovenia	-1.449	-1.380	-10.384***	-10.406***	-1.186	-0.599	-49.663***	-49.667***

v_t: variable in levels; Δv_t: variable in first difference
Critical values/without trend: -3.434 at the 1% level; -2.864 at the 5% level; -2.568 at 10% level
Critical values/with trend: -3.962 at the 1% level; -3.412 at the 5% level; -3.128 at 10% level
MacKinnon (1996) one-sided p-value
Significance levels: *** 0.01, **0.05, *0.10

Table A.4: Unit root tests on price level measured in domestic currency

	ADF test				PP test			
	v_t		Δv_t		v_t		Δv_t	
	Without trend	With trend	Without trend	With trend	Without trend	With trend	Without trend	With trend
Bulgaria	-1.199	-0.705	-16.596***	-16.656***	-1.245	-0.769	-48.242***	-48.041***
Czech Rep	-0.862	-2.467	-63.596***	-63.057***	-0.879	-2.470	-63.070***	-63.075***
Cyprus	-0.821	-1.199	-38.691***	-38.775***	-0.792	-1.189	-38.767***	-38.826***
Estonia	-1.206	-1.773	-14.902***	-14.900***	-1.035	-1.625	-57.429***	-57.423***
Hungary	-0.648	-2.362	-35.151***	-35.151***	-0.608	-2.310	-69.545***	-69.541***
Latvia	-1.451	-0.891	-35.823***	-35.845***	-1.461	-0.936	-53.282***	-53.292***
Lithuania	-1.204	-1.281	-12.871***	-12.874***	-1.158	-1.200	-51.181***	-51.171***
Malta	-1.334	-0.717	-32.231***	-32.253***	-1.385	-0.971	-41.349***	-44.343***
Poland	-0.691	-1.847	-67.163***	-67.159***	-0.686	-1.980	-67.592***	-67.586***
Romania	-0.888	-1.196	-55.145***	-55.138***	-0.955	-1.316	-55.685***	-55.678***
Slovakia	-1.581	-1.476	-23.347***	-23.354***	-1.707	-1.684	-71.837***	-71.812***
Slovenia	-1.449	-1.380	-10.384***	-10.406***	-1.186	-0.599	-49.663***	-49.667***

v_t: variable in levels; Δv_t: variable in first difference
Critical values/without trend: -3.434 at the 1% level; -2.864 at the 5% level; -2.568 at 10% level
Critical values/with trend: -3.962 at the 1% level; -3.412 at the 5% level; -3.128 at 10% level
MacKinnon (1996) one-sided p-value
Significance levels: *** 0.01, **0.05, *0.10

A.3 Pairwise correlation

To get a preliminary picture of correlation between markets, the simple correlation coefficient was computed and results are presented in Table A.5: Correlation coefficient matrix measured in € and Table A.6: Correlation coefficient matrix measured in domestic currency. Both tables show the same behaviour of daily returns with no significant influence from the currency used.

Table A.5: Correlation coefficient matrix measured in €

	Bulgaria	Czech Rep	Cyprus	Estonia	Hungary	Latvia	Lithuania	Malta	Poland	Roman	Slovakia	Slovenia
Bulgaria	1											
Czech Rep	0.186	1										
Cyprus	0.192	0.476	1									
Estonia	0.219	0.212	0.244	1								
Hungary	0.126	0.523	0.415	0.209	1							
Latvia	0.126	0.159	0.155	0.225	0.109	1						
Lithuania	0.216	0.301	0.235	0.405	0.226	0.216	1					
Malta	0.062	0.015	0.013	0.036	0.036	0.025	0.053	1				
Poland	0.130	0.465	0.458	0.237	0.424	0.119	0.231	0.037	1			
Romania	0.168	0.354	0.405	0.148	0.310	0.151	0.238	0.023	0.313	1		
Slovakia	0.029	0.034	0.005	0.020	0.036	0.007	0.028	-0.004	0.019	0.002	1	
Slovenia	0.205	0.163	0.253	0.142	0.148	0.150	0.250	0.034	0.100	0.230	0.031	1

Table A.6: Correlation coefficient matrix measured in domestic currency

	Bulgaria	Czech Rep	Cyprus	Estonia	Hungary	Latvia	Lithuania	Malta	Poland	Roman	Slovakia	Slovenia
Bulgaria	1											
Czech Rep	0.189	1										
Cyprus	0.192	0.473	1									
Estonia	0.219	0.214	0.244	1								
Hungary	0.120	0.482	0.391	0.205	1							
Latvia	0.128	0.143	0.157	0.215	0.090	1						
Lithuania	0.216	0.303	0.235	0.405	0.222	0.217	1					
Malta	0.062	0.014	0.013	0.036	0.038	0.025	0.053	1				
Poland	0.119	0.396	0.451	0.229	0.346	0.090	0.226	0.029	1			
Romania	0.165	0.326	0.387	0.134	0.240	0.127	0.241	0.026	0.232	1		
Slovakia	0.029	0.035	0.005	0.020	0.037	0.005	0.028	-0.004	0.017	0.008	1	
Slovenia	0.206	0.169	0.253	0.142	0.146	0.153	0.250	0.034	0.083	0.232	0.031	1

A.4 Graphical display

The figures below show the price series for all twelve stock markets. The observable differences between both graphs are due to the exchange rates for six countries, where adjustment to euro was applied. However, the overall conclusion remains as above, that all stock markets show similar behaviour and react to major financial events in similar manner.

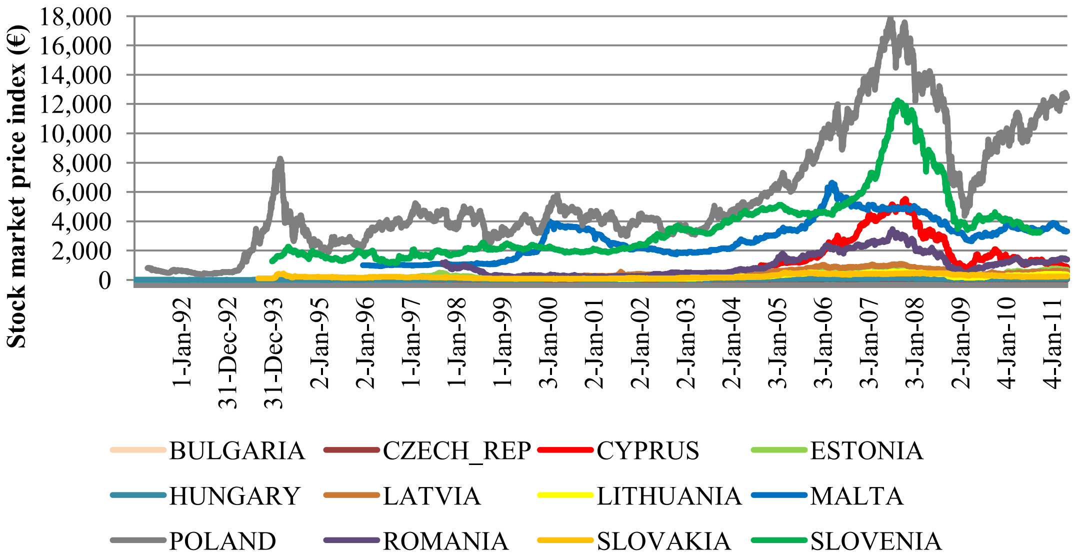


Figure A.1: Stock market price index measured in €

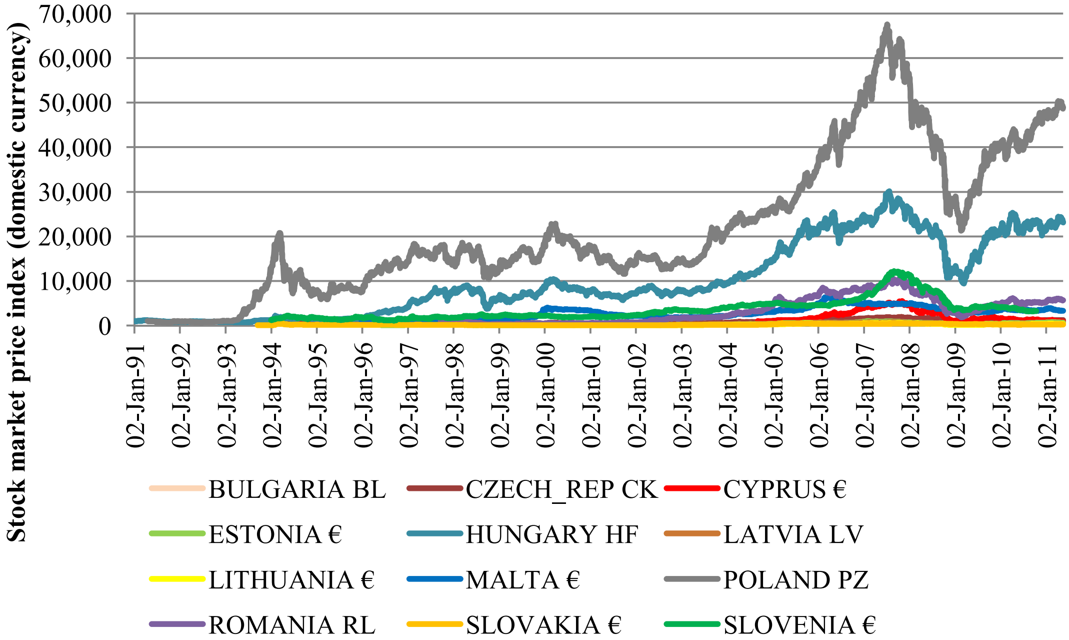


Figure A.2: Stock market price index measured in domestic currency

Overall, for the purpose of this dissertation all the twelve markets will be analysed in euro. The reasons can be summarised as below:

- There is no significant difference in the basic statistics;
- Both currencies show stationarity in first differences of price series;
- The correlation matrices show very similar daily returns behaviour;
- This dissertation includes a discussion of the EMU (European Monetary Union) whose goal is to hold one currency for all European countries. The expected entry dates for countries still using € in the near future are: Bulgaria, Hungary and Latvia: 2014, Poland and Romania: 2015, the Czech Republic: 2017.

Appendix B

Table B.1: Stock Market Collected Data Information

Country	Stock Exchange Name	Stock Market Index	Data Accessibility From	Currency Data Availability	Remarks
Bulgaria	BSE Bulgarian Stock Exchange	SOFIX	Oct 20, 2000	BL, Euro	
Czech Rep	PSE Prague Stock Exchange	PX	Apr 6, 1994	CK, Euro	2nd biggest stock exchange in Central and Eastern Europe
Cyprus	CSE Cyprus Stock Exchange	CYSE	Sep 3, 2004	Euro	
Estonia	Tallinn Stock Exchange	OMXT	Jun 3, 1996	Euro	Part of NASDAQ OMX Group
Hungary	BSE Budapest Stock Exchange	BUX	Jan 2, 1991	HF, Euro	
Latvia	Riga Stock Exchange	OMXR	Jan 3, 2000	LV, Euro	Part of NASDAQ OMX Group
Lithuania	VSE Vilnius Stock Exchange	OMXV	Jan 3, 2000	Euro	Part of NASDAQ OMX Group
Malta	MSE Malta Stock Exchange	SE MSE	Dec 27, 1995	Euro	
Poland	WSE Warsaw Stock Exchange	WIG	April 16, 1991	PZ, Euro	
Romania	Bucharest Stock Exchange	BET	Sep 19, 1997	RL, Euro	
Slovakia	BSSE Bratislava Stock Exchange	SAX	Sep 14, 1993	Euro	
Slovenia	LJSE Ljubljana Stock Exchange	SBI	Dec 31, 1993	Euro	June 2008 bought by Vienna Stock Exchange

Note: BL – Bulgarian Lev, CK – Czech Koruna, HF – Hungarian Forint, LV – Latvian Lats, PZ – Polish Zloty, RL – Romanian Leu

Appendix C

Table C.1: Test statistics for the lag length of VAR model

Lag length (p)	LL	AIC	SBC
pre-EU period, 1995 - 2004			
3	-25722.3	-26096.3	-26996.8
2	-25815.9	-26068.9*	-26678.0
1	-26001.7	-26133.7	-26451.5*
0	-45933.6	-45944.6	-45971.1
post-EU period, 2004-2011			
4	-71048.2	-71636.2	-73214.9
3	-71174.4	-71618.4*	-26996.8
2	-71339.9	-71639.9	-26678.0
1	-71670.4	-71826.4	-26451.5*
0	-112479.0	-112479.0	-45971.1
post-EU period, 2007-2011			
3	-44206.1	-44650.1	-45735.4
2	-44349.0	-44649.1*	-45382.3
1	-44568.8	-44724.8	-45106.1*
0	-66787.8	-66799.8	-66829.1

Note: *indicates lag order selection at 5% significance level, LL: Log likelihood ratio, AIC: Akaike information criterion, SBC: Schwarz information criterion

Appendix D

Table D.1: Test statistics for the lag length of VAR model (return series)

Lag length (p)	LL	AIC	SBC
pre-EU period, 1995 - 2004			
3	-25773.8	-26147.8	-27048.1
2	-25851.3	-26104.3	-26713.4
1	-25953.2	-26085.2*	-26402.9
0	-26158.9	-26169.9	-26196.4*
post-EU period, 2004-2011			
3	-71210.6	-71642.6	-72802.3
2	-71340.4	-71628.4*	-72401.5
1	-71513.6	-71657.6	-72044.1
0	-71876.7	-71876.7	-71876.7*
post-EU period, 2007-2011			
3	-44281.3	-44725.3	-45810.6
2	-44389.8	-44689.8*	-45423.1
1	-44536.3	-44690.3	-45071.6
0	-44774.5	-44786.5	-44815.8*

*indicates lag order selection at 5% significance LEVEL, LL: Log likelihood ratio, AIC: Akaike information , criterion, SBC: Schwarz information criterion

Appendix E

Table E.1: ARMA (*r, s*) models specification

	Pre-EU		Post-EU 01		Post-EU 02	
	AR*(r)*	MA*(s)*	AR*(r)*	MA*(s)*	AR*(r)*	MA*(s)*
Bulgaria	1	1	1	1	1	1
Czech Rep	1	1	2	2	3	3
Cyprus	–	–	2	2	2	2
Estonia	2	2	1	1	1	1
Hungary	2	1	2	1	1	1
Latvia	1	1	2	1	2	2
Lithuania	1	1	1	1	1	1
Malta	1	1	1	1	2	1
Poland	2	2	3	3	2	2
Romania	2	1	2	2	1	1
Slovakia	1	1	2	2	1	1
Slovenia	2	1	1	2	1	2

Note: All results are significant at 5% level. Post-EU 01 stands for period of 2004-2011 and Post-EU 02 for 2007-2011.

Appendix F

Table F.1:Diagnostic tests: Testing serial correlation - Breusch-Godfrey LM Test

PRE-EU period 1995 – 30th April 2004

Bulgaria	F-statistic	13.95717	Prob. F(1,918)	0.0002
	Obs*R-squared	13.77809	Prob. Chi-Square(1)	0.0002
Czech Republic	F-statistic	2.774921	Prob. F(4,2428)	0.0257
	Obs*R-squared	11.08103	Prob. Chi-Square(4)	0.0257
Estonia	F-statistic	95.39842	Prob. F(1,2062)	0.0000
	Obs*R-squared	91.26841	Prob. Chi-Square(1)	0.0000
Hungary	F-statistic	6.318750	Prob. F(3,2431)	0.0003
	Obs*R-squared	18.84053	Prob. Chi-Square(3)	0.0003
Latvia	F-statistic	18.50834	Prob. F(6,1122)	0.0000
	Obs*R-squared	101.6792	Prob. Chi-Square(6)	0.0000
Lithuania	F-statistic	12.72153	Prob. F(2,1127)	0.0000
	Obs*R-squared	24.94757	Prob. Chi-Square(2)	0.0000
Malta	F-statistic	222.9091	Prob. F(1,2175)	0.0000
	Obs*R-squared	202.3735	Prob. Chi-Square(1)	0.0000
Poland	F-statistic	29.15063	Prob. F(1,2433)	0.0000
	Obs*R-squared	28.82918	Prob. Chi-Square(1)	0.0000
Romania	F-statistic	104.4928	Prob. F(1,1723)	0.0000
	Obs*R-squared	98.63244	Prob. Chi-Square(1)	0.0000
Slovakia	F-statistic	1.354250	Prob. F(8,2426)	0.2119
	Obs*R-squared	10.82585	Prob. Chi-Square(8)	0.2118
Slovenia	F-statistic	69.96609	Prob. F(2,2432)	0.0000
	Obs*R-squared	132.4821	Prob. Chi-Square(2)	0.0000

POST-EU01 period 1st May 2004 – 1st May 2011

Bulgaria	F-statistic	53.17626	Prob. F(1,1834)	0.0000
	Obs*R-squared	51.73424	Prob. Chi-Square(1)	0.0000
Czech Republic	F-statistic	11.90153	Prob. F(2,1833)	0.0000
	Obs*R-squared	23.53638	Prob. Chi-Square(2)	0.0000
Cyprus	F-statistic	9.847261	Prob. F(1,1744)	0.0017
	Obs*R-squared	9.803202	Prob. Chi-Square(1)	0.0017
Estonia	F-statistic	45.04446	Prob. F(1,1834)	0.0000
	Obs*R-squared	44.01260	Prob. Chi-Square(1)	0.0000
Hungary	F-statistic	16.19614	Prob. F(2,1833)	0.0000
	Obs*R-squared	31.88188	Prob. Chi-Square(2)	0.0000
Latvia	F-statistic	2.523247	Prob. F(6,1829)	0.0195

	Obs*R-squared	15.07266	Prob. Chi-Square(6)	0.0197
Lithuania	F-statistic	37.45329	Prob. F(1,1834)	0.0000
	Obs*R-squared	36.74376	Prob. Chi-Square(1)	0.0000
Malta	F-statistic	159.9440	Prob. F(1,1834)	0.0000
	Obs*R-squared	147.2745	Prob. Chi-Square(1)	0.0000
Poland	F-statistic	18.62558	Prob. F(1,1834)	0.0000
	Obs*R-squared	18.45843	Prob. Chi-Square(1)	0.0000
Romania	F-statistic	11.38737	Prob. F(1,1834)	0.0008
	Obs*R-squared	11.32945	Prob. Chi-Square(1)	0.0008
Slovakia	F-statistic	3.127332	Prob. F(2,1833)	0.0441
	Obs*R-squared	6.243597	Prob. Chi-Square(2)	0.0441
Slovenia	F-statistic	54.05743	Prob. F(2,1681)	0.0000
	Obs*R-squared	101.7628	Prob. Chi-Square(2)	0.0000

POST-EU02 period 2007-2011

Bulgaria	F-statistic	17.15475	Prob. F(3,1137)	0.0000
	Obs*R-squared	49.40891	Prob. Chi-Square(3)	0.0000
Czech Republic	F-statistic	8.641638	Prob. F(2,1138)	0.0002
	Obs*R-squared	17.06960	Prob. Chi-Square(2)	0.0002
Cyprus	F-statistic	5.851167	Prob. F(1,1139)	0.0157
	Obs*R-squared	5.831484	Prob. Chi-Square(1)	0.0157
Estonia	F-statistic	27.77907	Prob. F(1,1139)	0.0000
	Obs*R-squared	27.16531	Prob. Chi-Square(1)	0.0000
Hungary	F-statistic	11.74203	Prob. F(2,1138)	0.0000
	Obs*R-squared	23.06990	Prob. Chi-Square(2)	0.0000
Latvia	F-statistic	2.391360	Prob. F(14,1126)	0.0027
	Obs*R-squared	32.94548	Prob. Chi-Square(14)	0.0029
Lithuania	F-statistic	25.99552	Prob. F(1,1139)	0.0000
	Obs*R-squared	25.46009	Prob. Chi-Square(1)	0.0000
Malta	F-statistic	59.00341	Prob. F(1,1139)	0.0000
	Obs*R-squared	56.19591	Prob. Chi-Square(1)	0.0000
Poland	F-statistic	12.74895	Prob. F(1,1139)	0.0004
	Obs*R-squared	12.62997	Prob. Chi-Square(1)	0.0004
Romania	F-statistic	3.946034	Prob. F(1,1139)	0.0472
	Obs*R-squared	3.939315	Prob. Chi-Square(1)	0.0472
Slovakia	F-statistic	1.599775	Prob. F(18,1122)	0.0530
	Obs*R-squared	28.55083	Prob. Chi-Square(18)	0.0542
Slovenia	F-statistic	54.32096	Prob. F(1,987)	0.0000
	Obs*R-squared	51.59161	Prob. Chi-Square(1)	0.0000

Appendix G

Table G.1: Diagnostic tests: Testing heteroscedasticity – BPG test, ARCH LM test and White test

PRE-EU period 1995 – 30th April 2004

Bulgaria	BPG test	F-statistic	5.766445	Prob. F(1,918)	0.0165
		Obs*R-squared	5.742934	Prob. Chi-Square(1)	0.0166
		Scaled explained SS	75.39517	Prob. Chi-Square(1)	0.0000
	ARCH LM test	F-statistic	56.91930	Prob. F(1,917)	0.0000
		Obs*R-squared	53.70962	Prob. Chi-Square(1)	0.0000
Czech Republic	BPG test	F-statistic	30.11730	Prob. F(1,2433)	0.0000
		Obs*R-squared	29.77350	Prob. Chi-Square(1)	0.0000
		Scaled explained SS	61.19538	Prob. Chi-Square(1)	0.0000
	ARCH LM test	F-statistic	51.99408	Prob. F(4,2426)	0.0000
		Obs*R-squared	191.9495	Prob. Chi-Square(4)	0.0000
Estonia	BPG test	F-statistic	153.0353	Prob. F(1,2062)	0.0000
		Obs*R-squared	142.6004	Prob. Chi-Square(1)	0.0000
		Scaled explained SS	1466.350	Prob. Chi-Square(1)	0.0000
	ARCH LM test	F-statistic	36.95546	Prob. F(1,2061)	0.0000
		Obs*R-squared	36.33972	Prob. Chi-Square(1)	0.0000
Hungary	BPG test	F-statistic	169.6160	Prob. F(1,2433)	0.0000
		Obs*R-squared	158.6922	Prob. Chi-Square(1)	0.0000
		Scaled explained SS	1259.906	Prob. Chi-Square(1)	0.0000
	ARCH LM test	F-statistic	82.06210	Prob. F(3,2428)	0.0000
		Obs*R-squared	223.8906	Prob. Chi-Square(3)	0.0000
Latvia	BPG test	F-statistic	87.10589	Prob. F(1,1127)	0.0000
		Obs*R-squared	80.99998	Prob. Chi-Square(1)	0.0000
		Scaled explained SS	694.2577	Prob. Chi-Square(1)	0.0000
	ARCH LM test	F-statistic	83.55965	Prob. F(6,1116)	0.0000
		Obs*R-squared	348.1140	Prob. Chi-Square(6)	0.0000
Lithuania	BPG test	F-statistic	83.27341	Prob. F(1,1128)	0.0000
		Obs*R-squared	77.68597	Prob. Chi-Square(1)	0.0000
		Scaled explained SS	781.0338	Prob. Chi-Square(1)	0.0000
	ARCH LM test	F-statistic	3.394360	Prob. F(2,1125)	0.0339
		Obs*R-squared	6.765995	Prob. Chi-Square(2)	0.0339
Malta	BPG test	F-statistic	530.7548	Prob. F(1,2175)	0.0000
		Obs*R-squared	427.0355	Prob. Chi-Square(1)	0.0000
		Scaled explained SS	7192.525	Prob. Chi-Square(1)	0.0000
	ARCH LM test	F-statistic	220.8365	Prob. F(1,2174)	0.0000

		Obs*R-squared	200.6568	Prob. Chi-Square(1)	0.0000
Poland	BPG test	F-statistic	24.75298	Prob. F(1,2433)	0.0000
		Obs*R-squared	24.52382	Prob. Chi-Square(1)	0.0000
		Scaled explained SS	69.75208	Prob. Chi-Square(1)	0.0000
	ARCH LM test	F-statistic	288.1266	Prob. F(1,2432)	0.0000
		Obs*R-squared	257.8189	Prob. Chi-Square(1)	0.0000
Romania	BPG test	F-statistic	0.290765	Prob. F(1,1723)	0.5898
		Obs*R-squared	0.291053	Prob. Chi-Square(1)	0.5895
		Scaled explained SS	1.161329	Prob. Chi-Square(1)	0.2812
	ARCH LM test	F-statistic	116.2331	Prob. F(1,1722)	0.0000
		Obs*R-squared	109.0101	Prob. Chi-Square(1)	0.0000
	White test	F-statistic	12091980	Prob. F(1,1723)	0.0000
		Obs*R-squared	1724.754	Prob. Chi-Square(1)	0.0000
		Scaled explained SS	6881.932	Prob. Chi-Square(1)	0.0000
Slovakia	BPG test	F-statistic	73.69883	Prob. F(1,2433)	0.0000
		Obs*R-squared	71.59083	Prob. Chi-Square(1)	0.0000
		Scaled explained SS	353.3305	Prob. Chi-Square(1)	0.0000
	ARCH LM test	F-statistic	7.756755	Prob. F(8,2418)	0.0000
		Obs*R-squared	60.72656	Prob. Chi-Square(8)	0.0000
Slovenia	BPG test	F-statistic	21.74572	Prob. F(1,2433)	0.0000
		Obs*R-squared	21.57080	Prob. Chi-Square(1)	0.0000
		Scaled explained SS	191.5808	Prob. Chi-Square(1)	0.0000
	ARCH LM test	F-statistic	273.4037	Prob. F(2,2430)	0.0000
		Obs*R-squared	446.9158	Prob. Chi-Square(2)	0.0000

POST-EU01 period 1st May 2004 – 1st May 2011

Bulgaria	BPG test	F-statistic	175.0723	Prob. F(1,1834)	0.0000
		Obs*R-squared	159.9906	Prob. Chi-Square(1)	0.0000
		Scaled explained SS	882.3328	Prob. Chi-Square(1)	0.0000
	ARCH LM test	F-statistic	329.8810	Prob. F(1,1833)	0.0000
		Obs*R-squared	279.8729	Prob. Chi-Square(1)	0.0000
Czech Republic	BPG test	F-statistic	20.39576	Prob. F(1,1834)	0.0000
		Obs*R-squared	20.19343	Prob. Chi-Square(1)	0.0000
		Scaled explained SS	156.3073	Prob. Chi-Square(1)	0.0000
	ARCH LM test	F-statistic	153.2217	Prob. F(2,1831)	0.0000
		Obs*R-squared	262.9390	Prob. Chi-Square(2)	0.0000
Cyprus	BPG test	F-statistic	0.095474	Prob. F(1,1744)	0.7574
		Obs*R-squared	0.095579	Prob. Chi-Square(1)	0.7572
		Scaled explained SS	0.257235	Prob. Chi-Square(1)	0.6120
	ARCH LM test	F-statistic	62.03320	Prob. F(1,1743)	0.0000

		Obs*R-squared	59.97005	Prob. Chi-Square(1)	0.0000
	White test	F-statistic	1.56E+08	Prob. F(1,1744)	0.0000
		Obs*R-squared	1745.980	Prob. Chi-Square(1)	0.0000
		Scaled explained SS	4699.047	Prob. Chi-Square(1)	0.0000
Estonia	BPG test	F-statistic	14.36163	Prob. F(1,1834)	0.0002
		Obs*R-squared	14.26558	Prob. Chi-Square(1)	0.0002
		Scaled explained SS	82.63971	Prob. Chi-Square(1)	0.0000
	ARCH LM test	F-statistic	77.59707	Prob. F(1,1833)	0.0000
		Obs*R-squared	74.52677	Prob. Chi-Square(1)	0.0000
Hungary	BPG test	F-statistic	4.879576	Prob. F(1,1834)	0.0273
		Obs*R-squared	4.871935	Prob. Chi-Square(1)	0.0273
		Scaled explained SS	24.85040	Prob. Chi-Square(1)	0.0000
	ARCH LM test	F-statistic	109.3815	Prob. F(2,1831)	0.0000
		Obs*R-squared	195.7356	Prob. Chi-Square(2)	0.0000
Latvia	BPG test	F-statistic	5.163141	Prob. F(1,1834)	0.0232
		Obs*R-squared	5.154261	Prob. Chi-Square(1)	0.0232
		Scaled explained SS	20.94748	Prob. Chi-Square(1)	0.0000
	ARCH LM test	F-statistic	49.60693	Prob. F(6,1823)	0.0000
		Obs*R-squared	256.8487	Prob. Chi-Square(6)	0.0000
Lithuania	BPG test	F-statistic	0.034759	Prob. F(1,1834)	0.8521
		Obs*R-squared	0.034796	Prob. Chi-Square(1)	0.8520
		Scaled explained SS	0.371674	Prob. Chi-Square(1)	0.5421
	ARCH LM test	F-statistic	193.6676	Prob. F(1,1833)	0.0000
		Obs*R-squared	175.3519	Prob. Chi-Square(1)	0.0000
Malta	BPG test	F-statistic	8.916936	Prob. F(1,1834)	0.0029
		Obs*R-squared	8.883468	Prob. Chi-Square(1)	0.0029
		Scaled explained SS	35.87634	Prob. Chi-Square(1)	0.0000
	ARCH LM test	F-statistic	135.7271	Prob. F(1,1833)	0.0000
		Obs*R-squared	126.5077	Prob. Chi-Square(1)	0.0000
Poland	BPG test	F-statistic	37.58507	Prob. F(1,1834)	0.0000
		Obs*R-squared	36.87046	Prob. Chi-Square(1)	0.0000
		Scaled explained SS	122.4068	Prob. Chi-Square(1)	0.0000
	ARCH LM test	F-statistic	50.23610	Prob. F(1,1833)	0.0000
		Obs*R-squared	48.94938	Prob. Chi-Square(1)	0.0000
Romania	BPG test	F-statistic	78.40819	Prob. F(1,1834)	0.0000
		Obs*R-squared	75.27548	Prob. Chi-Square(1)	0.0000
		Scaled explained SS	291.3445	Prob. Chi-Square(1)	0.0000
	ARCH LM test	F-statistic	226.4302	Prob. F(1,1833)	0.0000
		Obs*R-squared	201.7546	Prob. Chi-Square(1)	0.0000
Slovakia	BPG test	F-statistic	192.5282	Prob. F(1,1834)	0.0000
		Obs*R-squared	174.4272	Prob. Chi-Square(1)	0.0000

		Scaled explained SS	2630.427	Prob. Chi-Square(1)	0.0000
	ARCH LM test	F-statistic	0.037096	Prob. F(2,1831)	0.9636
		Obs*R-squared	0.074310	Prob. Chi-Square(2)	0.9635
	White test	F-statistic	7.42E+34	Prob. F(2,1833)	0.0000
		Obs*R-squared	1836.000	Prob. Chi-Square(2)	0.0000
		Scaled explained SS	27687.56	Prob. Chi-Square(2)	0.0000
Slovenia	BPG test	F-statistic	70.04749	Prob. F(1,1682)	0.0000
		Obs*R-squared	67.32693	Prob. Chi-Square(1)	0.0000
		Scaled explained SS	464.1903	Prob. Chi-Square(1)	0.0000
	ARCH LM test	F-statistic	344.2091	Prob. F(2,1679)	0.0000
		Obs*R-squared	489.1064	Prob. Chi-Square(2)	0.0000

POST-EU02 period 2007-2011

Bulgaria	BPG test	F-statistic	110.2488	Prob. F(1,1139)	0.0000
		Obs*R-squared	100.6957	Prob. Chi-Square(1)	0.0000
		Scaled explained SS	455.1884	Prob. Chi-Square(1)	0.0000
	ARCH LM test	F-statistic	123.8392	Prob. F(3,1134)	0.0000
		Obs*R-squared	280.8250	Prob. Chi-Square(3)	0.0000
Czech Republic	BPG test	F-statistic	8.856308	Prob. F(1,1139)	0.0030
		Obs*R-squared	8.803408	Prob. Chi-Square(1)	0.0030
		Scaled explained SS	58.69610	Prob. Chi-Square(1)	0.0000
	ARCH LM test	F-statistic	92.40661	Prob. F(2,1136)	0.0000
		Obs*R-squared	159.3732	Prob. Chi-Square(2)	0.0000
Cyprus	BPG test	F-statistic	4.539150	Prob. F(1,1139)	0.0333
		Obs*R-squared	4.529071	Prob. Chi-Square(1)	0.0333
		Scaled explained SS	9.539338	Prob. Chi-Square(1)	0.0020
	ARCH LM test	F-statistic	22.03612	Prob. F(1,1138)	0.0000
		Obs*R-squared	21.65552	Prob. Chi-Square(1)	0.0000
Estonia	BPG test	F-statistic	7.437804	Prob. F(1,1139)	0.0065
		Obs*R-squared	7.402525	Prob. Chi-Square(1)	0.0065
		Scaled explained SS	31.82132	Prob. Chi-Square(1)	0.0000
	ARCH LM test	F-statistic	45.55703	Prob. F(1,1138)	0.0000
		Obs*R-squared	43.88045	Prob. Chi-Square(1)	0.0000
Hungary	BPG test	F-statistic	0.905725	Prob. F(1,1139)	0.3415
		Obs*R-squared	0.906595	Prob. Chi-Square(1)	0.3410
		Scaled explained SS	4.283378	Prob. Chi-Square(1)	0.0385
	ARCH LM test	F-statistic	65.76391	Prob. F(2,1136)	0.0000
		Obs*R-squared	118.1909	Prob. Chi-Square(2)	0.0000
	White test	F-statistic	1.14E+08	Prob. F(1,1139)	0.0000
		Obs*R-squared	1140.989	Prob. Chi-Square(1)	0.0000

		Scaled explained SS	5390.815	Prob. Chi-Square(1)	0.0000
Latvia	BPG test	F-statistic	13.12640	Prob. F(1,1139)	0.0003
		Obs*R-squared	12.99964	Prob. Chi-Square(1)	0.0003
		Scaled explained SS	42.35052	Prob. Chi-Square(1)	0.0000
	ARCH LM test	F-statistic	14.21166	Prob. F(14,1112)	0.0000
		Obs*R-squared	171.0434	Prob. Chi-Square(14)	0.0000
Lithuania	BPG test	F-statistic	1.453125	Prob. F(1,1139)	0.2283
		Obs*R-squared	1.453822	Prob. Chi-Square(1)	0.2279
		Scaled explained SS	10.37622	Prob. Chi-Square(1)	0.0013
	ARCH LM test	F-statistic	520.2990	Prob. F(1,1138)	0.0000
		Obs*R-squared	357.6803	Prob. Chi-Square(1)	0.0000
	White test	F-statistic	12524325	Prob. F(1,1139)	0.0000
		Obs*R-squared	1140.896	Prob. Chi-Square(1)	0.0000
		Scaled explained SS	8142.809	Prob. Chi-Square(1)	0.0000
Malta	BPG test	F-statistic	13.00737	Prob. F(1,1139)	0.0003
		Obs*R-squared	12.88309	Prob. Chi-Square(1)	0.0003
		Scaled explained SS	45.62982	Prob. Chi-Square(1)	0.0000
	ARCH LM test	F-statistic	65.97536	Prob. F(1,1138)	0.0000
		Obs*R-squared	62.46965	Prob. Chi-Square(1)	0.0000
Poland	BPG test	F-statistic	12.97361	Prob. F(1,1139)	0.0003
		Obs*R-squared	12.85002	Prob. Chi-Square(1)	0.0003
		Scaled explained SS	38.19181	Prob. Chi-Square(1)	0.0000
	ARCH LM test	F-statistic	26.05409	Prob. F(1,1138)	0.0000
		Obs*R-squared	25.51571	Prob. Chi-Square(1)	0.0000
Romania	BPG test	F-statistic	42.22193	Prob. F(1,1139)	0.0000
		Obs*R-squared	40.78423	Prob. Chi-Square(1)	0.0000
		Scaled explained SS	141.3694	Prob. Chi-Square(1)	0.0000
	ARCH LM test	F-statistic	147.5550	Prob. F(1,1138)	0.0000
		Obs*R-squared	130.8483	Prob. Chi-Square(1)	0.0000
Slovakia	BPG test	F-statistic	172.8642	Prob. F(1,1139)	0.0000
		Obs*R-squared	150.3495	Prob. Chi-Square(1)	0.0000
		Scaled explained SS	2699.969	Prob. Chi-Square(1)	0.0000
	ARCH LM test	F-statistic	2.497798	Prob. F(18,1104)	0.0005
		Obs*R-squared	43.94450	Prob. Chi-Square(18)	0.0006
Slovenia	BPG test	F-statistic	39.57895	Prob. F(1,987)	0.0000
		Obs*R-squared	38.13013	Prob. Chi-Square(1)	0.0000
		Scaled explained SS	181.3109	Prob. Chi-Square(1)	0.0000
	ARCH LM test	F-statistic	226.9522	Prob. F(1,986)	0.0000
		Obs*R-squared	184.8620	Prob. Chi-Square(1)	0.0000

Appendix H

Table H.1: VARMA GARCH conditional mean and variance; pre-EU: 1995-2004

	Conditional mean			Conditional variance														
				Own effects			Spillover effects											
Bulgaria							CzechRep		Estonia		Hungary		Poland		Romania		Slovenia	
	C	AR	MA	C	α	β	α	β	α	β	α	β	α	β	α	β	α	β
	0.170	-0.112	-0.017	**4.995**	**0.229**	**0.467**	-0.059	-0.109	**-0.190**	-0.153	-0.011	-0.067	-0.074	-0.082	-0.017	-0.059	**-0.023**	**-0.067**
	1.878	-0.277	-0.042	**3.071**	**1.892**	**3.101**	-0.689	-0.628	**-7.442**	-0.649	-0.217	-0.351	-1.485	-0.371	-0.717	-0.812	**-5.620**	**-3.056**
Czech Rep							Bulgaria		Estonia		Hungary		Poland		Romania		Slovenia	
	C	AR	MA	C	α	β	α	β	α	β	α	β	α	β	α	β	α	β
	0.102	-0.530	0.529	0.038	0.017	**0.937**	0.003	-0.002	0.014	-0.004	**0.046**	**-0.057**	0.028	-0.003	0.006	-0.001	-0.002	**0.011**
	2.681	-1.589	1.580	0.795	1.210	**24.616**	1.369	-1.147	0.828	-0.165	**2.206**	**-2.003**	1.568	-0.096	0.604	-0.111	-1.574	**2.226**
Estonia							Bulgaria		CzechRep		Hungary		Poland		Romania		Slovenia	
	C	AR	MA	C	α	β	α	β	α	β	α	β	α	β	α	β	α	β
	0.105	0.245	-0.178	**0.291**	**0.257**	**0.471**	-0.001	0.001	-0.012	0.026	0.026	-0.023	0.004	-0.001	0.002	-0.006	**-0.003**	0.000
	3.409	0.583	-0.415	**2.678**	**4.360**	**4.408**	-1.224	0.374	-1.310	1.190	1.086	-0.730	0.241	-0.047	0.186	-0.717	**-5.258**	0.075
Hungary							Bulgaria		CzechRep		Estonia		Poland		Romania		Slovenia	
	C	AR	MA	C	α	β	α	β	α	β	α	β	α	β	α	β	α	β
	0.044	-0.013	-0.005	**0.526**	0.001	**0.391**	0.002	-0.003	-0.022	**0.326**	0.145	-0.011	**0.108**	-0.025	0.024	**-0.064**	-0.001	0.006
	0.999	-0.358	-0.161	**2.694**	0.047	**2.339**	0.360	-0.382	-0.733	**3.030**	2.111	-0.124	**2.509**	-0.399	1.189	**-5.530**	-0.795	0.677
Poland							Bulgaria		CzechRep		Estonia		Hungary		Romania		Slovenia	
	C	AR	MA	C	α	β	α	β	α	β	α	β	α	β	α	β	α	β
	0.037	-0.537	0.581	**0.292**	**0.054**	**0.826**	**-0.005**	**0.011**	-0.027	**0.079**	-0.004	0.034	0.021	**-0.075**	-0.001	**-0.023**	**-0.004**	0.000
	0.801	-1.342	1.509	**3.159**	**1.945**	**13.107**	**-8.472**	**2.779**	-1.328	**1.897**	-0.113	0.732	0.781	**-1.969**	-0.077	**-2.011**	**-6.372**	-0.203
Romania							Bulgaria		CzechRep		Estonia		Hungary		Poland		Slovenia	
	C	AR	MA	C	α	β	α	β	α	β	α	β	α	β	α	β	α	β
	0.062	**0.040**	**0.098**	**1.785**	**0.218**	**0.311**	0.002	0.001	0.140	-0.060	0.028	-0.111	0.021	-0.054	0.006	**-0.156**	0.007	**-0.039**
	1.169	**2.621**	**2.486**	**5.723**	**4.310**	**2.512**	0.485	0.094	1.612	-0.718	0.492	-1.629	0.482	-0.678	0.237	**-2.000**	0.436	**-7.184**
Slovenia							Bulgaria		CzechRep		Estonia		Hungary		Poland		Romania	
	C	AR	MA	C	α	β	α	β	α	β	α	β	α	β	α	β	α	β
	0.087	0.018	**0.348**	**0.244**	**0.473**	**-0.080**	**-0.001**	**-0.007**	**0.034**	0.000	-0.003	**-0.036**	-0.003	-0.020	0.003	0.003	-0.001	0.140
	3.051	0.544	**6.926**	**2.160**	**3.925**	**-2.975**	**-5.003**	**-3.024**	**2.450**	0.008	-1.557	**-5.376**	-0.334	-0.978	0.798	0.129	-0.228	1.285

Note: The two entries corresponding to each parameter are their estimates and Bollerslev-Wooldridge (1992) robust t-ratios. Bold denotes significance at 5% level

Table H.2: VARMA GARCH conditional mean and variance; post-EU: 2004-2011

	Conditional mean			Conditional variance																
				Own effects			Spillover effects													
Bulgaria							Czech Rep		Cyprus		Estonia		Hungary		Poland		Romania		Slovenia	
	C	AR	MA	C	α	β	α	β	α	β	α	β	α	β	α	β	α	β	α	β
	0.038	**0.464**	**-0.271**	0.068	**0.365**	**0.482**	0.000	**0.067**	0.001	-0.007	-0.004	-0.007	**-0.010**	**-0.032**	0.007	0.041	-0.001	**0.041**	0.014	-0.029
	1.294	**4.010**	**-2.114**	1.449	**6.849**	**6.960**	0.034	**2.501**	0.464	-0.992	-0.894	-0.728	**-3.272**	**-2.289**	0.667	1.469	-0.230	**3.060**	0.670	-0.853
Cyprus							Bulgaria		Czech Rep		Estonia		Hungary		Poland		Romania		Slovenia	
	C	AR	MA	C	α	β	α	β	α	β	α	β	α	β	α	β	α	β	α	β
	0.153	-0.427	0.392	0.026	**0.095**	**0.892**	0.040	-0.032	**0.041**	**-0.049**	**0.104**	**-0.070**	0.023	-0.009	-0.024	0.022	**-0.007**	**0.009**	0.055	-0.038
	4.436	-1.016	0.919	1.065	**4.985**	**41.531**	1.603	-1.320	**1.659**	**-1.659**	**3.218**	**-3.328**	1.484	-0.316	-0.994	0.710	**-2.413**	**2.344**	0.882	-0.525
CzechRep							Bulgaria		Cyprus		Estonia		Hungary		Poland		Romania		Slovenia	
	C	AR	MA	C	α	β	α	β	α	β	α	β	α	β	α	β	α	β	α	β
	0.123	0.455	-0.488	-0.009	**0.099**	**0.797**	**0.043**	-0.021	0.005	-0.008	0.000	0.025	0.008	**0.051**	0.022	**-0.050**	0.009	-0.004	0.016	0.049
	4.439	1.343	-1.461	-0.243	**3.881**	**15.066**	**1.724**	-0.907	0.935	-1.486	-0.031	1.112	0.504	**1.714**	1.244	**-2.241**	1.016	-0.440	0.489	1.118
Estonia							Bulgaria		Czech Rep		Cyprus		Hungary		Poland		Romania		Slovenia	
	C	AR	MA	C	α	β	α	β	α	β	α	β	α	β	α	β	α	β	α	β
	0.051	0.188	0.023	-0.003	**0.162**	**0.817**	**-0.007**	**0.011**	**0.010**	**-0.019**	**0.007**	-0.003	-0.002	0.004	0.001	0.011	**0.016**	-0.010	0.015	-0.008
	2.774	1.195	0.145	-0.300	**5.947**	**30.205**	**-3.346**	**2.640**	**1.753**	**-2.619**	**2.239**	-1.564	-0.389	0.544	0.303	1.497	**1.804**	-1.614	1.161	-0.654
Hungary							Bulgaria		Czech Rep		Cyprus		Estonia		Poland		Romania		Slovenia	
	C	AR	MA	C	α	β	α	β	α	β	α	β	α	β	α	β	α	β	α	β
	0.123	-0.043	0.062	0.246	**0.084**	0.119	**0.136**	-0.093	0.009	**0.374**	-0.002	**0.071**	0.005	0.051	-0.002	**0.532**	**-0.026**	0.032	0.004	**-0.147**
	3.023	-1.626	2.236	1.498	**1.950**	0.564	**2.366**	-1.407	0.250	**2.163**	-0.164	**1.956**	0.200	0.591	-0.058	**2.828**	**-11.273**	1.172	0.137	**-2.508**
Poland							Bulgaria		Czech Rep		Cyprus		Estonia		Hungary		Romania		Slovenia	
	C	AR	MA	C	α	β	α	β	α	β	α	β	α	β	α	β	α	β	α	β
	0.117	**-0.654**	**0.695**	**0.072**	**0.063**	**0.879**	**0.041**	-0.036	0.014	-0.001	0.005	-0.005	0.012	0.008	0.015	-0.008	-0.003	-0.003	**-0.030**	**0.061**
	3.364	**-4.427**	**4.950**	**2.722**	**3.279**	**25.719**	**1.738**	-1.625	0.763	-0.048	0.801	-0.839	0.871	0.464	0.974	-0.393	-0.437	-0.309	**-2.516**	**2.412**
Romania							Bulgaria		Czech Rep		Cyprus		Estonia		Hungary		Poland		Slovenia	
	C	AR	MA	C	α	β	α	β	α	β	α	β	α	β	α	β	α	β	α	β
	0.104	-0.504	0.503	**0.312**	**0.164**	**0.585**	**0.103**	-0.052	0.073	0.111	**0.039**	-0.018	0.047	-0.033	-0.038	0.115	**0.129**	**-0.160**	-0.013	-0.056
	2.723	-1.272	1.264	**2.044**	**4.272**	**8.145**	**2.406**	-1.166	1.133	1.183	**2.324**	-1.124	1.352	-1.037	-1.019	1.490	**2.078**	**-1.906**	-0.614	-1.567
Slovenia							Bulgaria		Czech Rep		Cyprus		Estonia		Hungary		Poland		Romania	
	C	AR	MA	C	α	β	α	β	α	β	α	β	α	β	α	β	α	β	α	β
	0.009	**0.334**	**-0.105**	0.036	**0.268**	**0.630**	**0.008**	**-0.007**	0.004	0.001	**-0.003**	**0.006**	-0.001	**-0.005**	0.002	**-0.017**	0.006	**0.029**	**0.003**	**-0.003**
	0.455	**10.431**	**-3.418**	2.079	**5.191**	**14.143**	**1.798**	**-2.787**	0.580	0.068	**-4.385**	**3.004**	-0.683	**-2.418**	0.369	**-1.766**	0.992	**2.188**	**1.980**	**-2.550**

Note: The two entries corresponding to each parameter are their estimates and Bollerslev-Wooldridge (1992) robust t-ratios. Bold denotes significance at 5% level

Table H.3: VARMA GARCH conditional mean and variance; post-EU: 2007-20011

	Conditional mean			Conditional variance																
				Own effects			Spillover effects													
Bulgaria							Czech Rep		Cyprus		Estonia		Hungary		Poland		Romania		Slovenia	
	C	AR	MA	C	α	β	α	β	α	β	α	β	α	β	α	β	α	β	α	β
	-0.106	0.093	0.076	**1.572**	**0.189**	**0.408**	0.005	0.008	-0.006	-0.013	**-0.030**	**-0.053**	-0.004	0.003	0.000	-0.003	-0.006	-0.001	0.013	0.012
	-1.265	0.391	0.326	**4.228**	**4.374**	**3.615**	0.275	0.244	-0.733	-0.546	**-7.674**	**-1.844**	-0.369	0.085	0.831	-0.062	-0.605	-0.071	0.404	0.200
Cyprus							Bulgaria		Czech Rep		Estonia		Hungary		Poland		Romania		Slovenia	
	C	AR	MA	C	α	β	α	β	α	β	α	β	α	β	α	β	α	β	α	β
	0.032	0.209	-0.185	0.016	**0.102**	**0.804**	0.099	-0.016	-0.014	-0.056	0.085	-0.042	0.044	0.115	-0.044	-0.069	0.032	0.039	0.048	-0.095
	1.048	0.141	-0.124	0.081	**1.867**	**7.787**	0.894	-0.115	-0.200	-0.393	0.852	-0.581	1.151	0.792	-0.624	-0.791	0.649	0.407	0.505	-0.586
CzechRep							Bulgaria		Cyprus		Estonia		Hungary		Poland		Romania		Slovenia	
	C	AR	MA	C	α	β	α	β	α	β	α	β	α	β	α	β	α	β	α	β
	0.054	0.064	-0.121	0.081	**0.124**	**0.348**	0.040	**0.130**	**-0.017**	0.010	0.044	0.007	0.030	0.068	0.011	0.049	0.015	**0.076**	0.015	**-0.092**
	2.425	0.128	-0.243	0.578	**2.460**	**2.142**	0.885	**1.707**	**-8.381**	0.559	0.980	0.068	0.896	1.098	0.247	0.545	0.823	**1.715**	0.399	**-2.591**
Estonia							Bulgaria		Czech Rep		Cyprus		Hungary		Poland		Romania		Slovenia	
	C	AR	MA	C	α	β	α	β	α	β	α	β	α	β	α	β	α	β	α	β
	-0.019	-0.087	0.241	**0.399**	**0.276**	**0.456**	0.006	-0.026	**-0.047**	**0.080**	**0.020**	-0.013	0.014	0.006	0.075	-0.045	**-0.021**	**0.002**	-0.012	0.001
	-0.841	-0.387	1.129	**3.795**	**5.293**	**5.686**	0.528	-1.141	**-3.068**	**2.566**	**2.225**	-1.293	0.585	0.132	1.451	-0.819	**-3.614**	**0.113**	-1.497	0.032
Hungary							Bulgaria		Czech Rep		Cyprus		Estonia		Poland		Romania		Slovenia	
	C	AR	MA	C	α	β	α	β	α	β	α	β	α	β	α	β	α	β	α	β
	0.027	-0.412	0.457	0.310	**0.135**	0.061	**0.140**	**-0.207**	0.016	**0.623**	-0.011	**0.073**	0.039	0.020	**-0.076**	**0.378**	**0.053**	0.009	-0.004	**-0.173**
	0.520	-0.742	0.844	1.053	**2.681**	0.352	**2.333**	**-2.703**	0.262	**2.845**	-1.246	**2.099**	0.924	0.129	**-2.808**	**2.158**	**1.828**	0.126	-0.135	**-3.733**
Poland							Bulgaria		Czech Rep		Cyprus		Estonia		Hungary		Romania		Slovenia	
	C	AR	MA	C	α	β	α	β	α	β	α	β	α	β	α	β	α	β	α	β
	0.037	-0.118	0.109	**0.613**	0.020	0.230	0.057	0.086	**-0.049**	**0.216**	**-0.016**	-0.004	0.038	0.070	0.017	0.102	0.033	0.065	-0.003	**-0.101**
	0.741	-0.067	0.061	**2.029**	0.368	0.713	1.193	0.913	**-2.359**	**1.677**	**-134270.2**	-0.136	0.849	0.550	0.491	0.985	1.431	0.956	-0.101	**-2.040**
Romania							Bulgaria		Czech Rep		Cyprus		Estonia		Hungary		Poland		Slovenia	
	C	AR	MA	C	α	β	α	β	α	β	α	β	α	β	α	β	α	β	α	β
	-0.017	0.252	-0.162	**0.316**	**0.073**	**0.731**	**0.213**	**-0.162**	**0.130**	-0.007	**0.024**	-0.012	0.036	**-0.091**	**-0.041**	**0.135**	**0.104**	**-0.119**	-0.026	-0.040
	-0.344	0.708	-0.455	**3.172**	**2.938**	**17.139**	**3.832**	**-3.505**	**3.378**	-0.135	**1.794**	-0.974	1.618	**-4.056**	**-1.887**	**4.557**	**1.972**	**-1.698**	-1.170	-1.463
Slovenia							Bulgaria		Czech Rep		Cyprus		Estonia		Hungary		Poland		Romania	
	C	AR	MA	C	α	β	α	β	α	β	α	β	α	β	α	β	α	β	α	β
	-0.016	**0.332**	**-0.140**	**0.164**	**0.297**	**0.522**	0.015	-0.002	0.008	**0.038**	**-0.003**	0.001	0.002	**-0.021**	-0.002	**-0.021**	**0.016**	0.009	0.005	**-0.012**
	-0.518	**8.629**	**-3.855**	**3.488**	**5.915**	**12.016**	1.379	-0.173	0.895	**1.925**	**-4.755**	0.350	0.791	**-3.794**	-0.540	**-2.244**	**1.793**	0.604	1.623	**-3.233**

Note: The two entries corresponding to each parameter are their estimates and Bollerslev-Wooldridge (1992) robust t-ratios. Bold denotes significance at 5% level

Table H.4: VARMA AGARCH conditional mean and variance; pre-EU: 1995-2004

	Conditional mean			Conditional variance															
				Own effects				Spillover effects											
Bulgaria								CzechRep		Estonia		Hungary		Poland		Romania		Slovenia	
	C	AR	MA	C	α	γ	β	α	β	α	β	α	β	α	β	α	β	α	β
	0.115	-0.232	0.137	**5.019**	0.251	-0.057	**0.443**	-0.059	-0.126	**-0.175**	-0.174	0.002	-0.069	-0.082	-0.091	-0.017	-0.057	**-0.024**	**-0.065**
	2.081	-0.555	0.320	**2.862**	1.559	-0.236	**2.706**	-0.800	-0.729	**-6.883**	-0.698	0.034	-0.369	-1.904	-0.450	-0.836	-0.727	**-6.559**	**-3.09**
Czech Rep								Bulgaria		Estonia		Hungary		Poland		Romania		Slovenia	
	C	AR	MA	C	α	γ	β	α	β	α	β	α	β	α	β	α	β	α	β
	0.094	-0.512	0.516	-0.013	-0.008	0.072	**0.881**	0.002	-0.001	0.013	0.009	0.035	-0.033	0.025	0.018	0.002	0.009	-0.003	**0.014**
	2.471	-1.456	1.465	-0.209	-0.351	1.746	**14.730**	0.980	-0.432	0.698	0.325	1.565	-0.902	1.268	0.559	0.181	0.649	-1.736	**2.092**
Estonia								Bulgaria		CzechRep		Hungary		Poland		Romania		Slovenia	
	C	AR	MA	C	α	γ	β	α	β	α	β	α	β	α	β	α	β	α	β
	0.098	0.183	-0.123	**0.421**	**0.214**	0.054	**0.458**	0.000	-0.002	0.002	0.048	0.022	-0.045	-0.014	-0.013	-0.006	0.000	**-0.003**	0.000
	3.142	0.400	-0.266	**3.059**	**3.463**	0.580	**4.042**	-0.390	-0.525	0.385	1.713	0.902	-1.676	-1.510	-0.522	-1.034	-0.016	**-4.743**	-0.148
Hungary								Bulgaria		CzechRep		Estonia		Poland		Romania		Slovenia	
	C	AR	MA	C	α	γ	β	α	β	α	β	α	β	α	β	α	β	α	β
	0.048	-0.012	-0.015	**0.367**	-0.042	**0.110**	**0.681**	0.000	-0.002	0.022	0.117	**0.108**	-0.053	**0.080**	-0.061	0.014	-0.019	**-0.003**	0.002
	1.099	-0.338	-0.453	**2.875**	-1.342	**2.114**	**4.454**	-0.162	-0.274	0.688	1.577	**2.033**	-0.940	**2.455**	-1.215	0.732	-0.799	**-2.521**	0.397
Poland								Bulgaria		CzechRep		Estonia		Hungary		Romania		Slovenia	
	C	AR	MA	C	α	γ	β	α	β	α	β	α	β	α	β	α	β	α	β
	0.033	-0.041	0.072	**1.032**	0.067	-0.005	**0.483**	**-0.005**	**0.020**	-0.044	**0.192**	0.010	0.059	**0.055**	**-0.162**	0.005	**-0.061**	**-0.005**	**-0.01**
	0.756	-0.054	0.095	**3.955**	1.304	-0.098	**3.663**	**-11.459**	**2.718**	-1.616	**2.587**	0.228	0.871	**1.755**	**-2.717**	0.525	**-4.896**	**-8.671**	**-2.046**
Romania								Bulgaria		CzechRep		Estonia		Hungary		Poland		Slovenia	
	C	AR	MA	C	α	γ	β	α	β	α	β	α	β	α	β	α	β	α	β
	0.103	0.024	**0.075**	**0.152**	**0.055**	0.030	**0.904**	-0.002	0.004	0.022	0.009	0.005	-0.003	**0.047**	**-0.057**	0.017	-0.053	-0.001	-0.007
	2.423	0.686	**2.100**	**2.750**	**3.109**	0.563	**29.196**	-1.434	0.919	0.937	0.288	0.248	-0.115	**2.401**	**-2.332**	1.022	-1.568	-0.119	-1.105
Slovenia								Bulgaria		CzechRep		Estonia		Hungary		Poland		Romania	
	C	AR	MA	C	α	γ	β	α	β	α	β	α	β	α	β	α	β	α	β
	0.081	0.019	**0.327**	0.005	**0.473**	0.148	-0.045	**-0.001**	**-0.005**	**0.021**	0.009	-0.003	**-0.015**	-0.005	-0.001	0.004	0.013	-0.005	0.163
	3.211	0.613	**6.547**	0.060	**2.506**	0.600	-1.792	**-4.219**	**-3.119**	**2.037**	0.218	-1.447	**-1.996**	-1.816	-0.034	0.943	0.486	-1.359	1.327

Note: The two entries corresponding to each parameter are their estimates and Bollerslev-Wooldridge (1992) robust t-ratios. Bold denotes significance at 5% level

Table H.5: VARMA AGARCH conditional mean and variance; post-EU: 2004-2011

	Conditional mean			Conditional variance																	
				Own effects				Spillover effects													
Bulgaria								Czech Rep		Cyprus		Estonia		Hungary		Poland		Romania		Slovenia	
	C	AR	MA	C	α	γ	β	α	β	α	β	α	β	α	β	α	β	α	β	α	β
	-0.012	0.196	0.025	**0.599**	**0.304**	0.097	0.227	0.016	0.015	-0.002	-0.004	**-0.018**	-0.028	-0.008	-0.001	-0.006	0.031	-0.001	0.024	0.034	-0.012
	-0.400	1.375	0.168	**4.076**	**4.174**	0.901	1.822	0.994	0.285	-0.496	-0.328	**-3.731**	-1.458	-1.223	-0.043	-0.302	0.344	-0.110	1.203	0.868	-0.24
Cyprus								Bulgaria		Czech Rep		Estonia		Hungary		Poland		Romania		Slovenia	
	C	AR	MA	C	α	γ	β	α	β	α	β	α	β	α	β	α	β	α	β	α	β
	0.100	0.313	-0.339	-0.026	-0.018	**0.278**	**0.661**	0.035	0.019	0.012	-0.014	0.015	0.027	-0.006	**0.117**	0.010	-0.040	**0.015**	**-0.019**	-0.029	**0.127**
	3.563	0.805	-0.877	-0.539	-0.829	**5.431**	**10.583**	1.653	0.796	1.627	-2.022	0.848	1.074	-0.464	3.414	0.517	-1.251	**1.815**	**-2.666**	-1.935	**2.493**
Czech Rep								Bulgaria		Cyprus		Estonia		Hungary		Poland		Romania		Slovenia	
	C	AR	MA	C	α	γ	β	α	β	α	β	α	β	α	β	α	β	α	β	α	β
	0.121	-0.365	0.332	0.026	**0.072**	0.037	**0.899**	0.039	-0.031	0.038	**-0.058**	**0.094**	**-0.064**	0.019	0.000	-0.018	0.016	-0.004	0.007	0.034	-0.024
	3.683	-0.757	0.681	1.035	**3.171**	1.017	**46.505**	1.601	-1.270	1.623	**-1.974**	**2.905**	**-3.081**	1.271	0.005	-0.728	0.519	-1.257	1.759	0.605	-0.357
Estonia								Bulgaria		Czech Rep		Cyprus		Hungary		Poland		Romania		Slovenia	
	C	AR	MA	C	α	γ	β	α	β	α	β	α	β	α	β	α	β	α	β	α	β
	0.024	0.224	-0.018	0.007	**0.154**	-0.004	**0.824**	-0.001	0.003	0.006	-0.014	0.006	-0.002	0.004	-0.005	-0.003	**0.018**	0.014	-0.01	**0.027**	**-0.024**
	4.423	1.381	-0.109	0.658	**3.545**	-0.062	**26.200**	-0.232	0.880	0.982	-1.800	1.889	-0.906	0.760	-0.619	-0.686	**2.505**	1.243	-1.268	**2.291**	**-2.054**
Hungary								Bulgaria		Czech Rep		Cyprus		Estonia		Poland		Romania		Slovenia	
	C	AR	MA	C	α	γ	β	α	β	α	β	α	β	α	β	α	β	α	β	α	β
	0.094	-0.034	**0.062**	0.070	0.015	**0.104**	**0.796**	0.066	**-0.069**	0.035	0.004	0.002	0.010	0.040	-0.011	0.022	0.077	**-0.016**	**0.024**	-0.023	0.004
	2.314	-1.293	**2.275**	1.833	0.533	**2.395**	**14.341**	1.771	**-2.102**	0.989	0.105	0.181	0.892	1.613	-0.336	0.667	1.251	**-5.666**	**3.33**	-1.243	0.126
Poland								Bulgaria		Czech Rep		Cyprus		Estonia		Hungary		Romania		Slovenia	
	C	AR	MA	C	α	γ	β	α	β	α	β	α	β	α	β	α	β	α	β	α	β
	0.101	0.445	-0.439	**0.137**	-0.021	**0.188**	**0.737**	**0.080**	**-0.047**	**-0.037**	0.054	-0.001	0.005	0.032	0.011	-0.002	**0.067**	0.006	**-0.03**	**-0.062**	**0.108**
	3.434	1.928	-1.888	**2.958**	-0.980	**5.221**	**15.736**	**3.137**	**-2.052**	**-2.780**	1.811	-0.113	0.866	1.838	0.447	-0.143	**2.330**	0.944	**-3.336**	**-9.355**	**3.439**
Romania								Bulgaria		Czech Rep		Cyprus		Estonia		Hungary		Poland		Slovenia	
	C	AR	MA	C	α	γ	β	α	β	α	β	α	β	α	β	α	β	α	β	α	β
	0.090	-0.546	0.542	**0.352**	**0.120**	**0.118**	**0.546**	**0.094**	-0.033	0.057	0.117	**0.041**	-0.015	0.044	-0.041	-0.040	0.145	0.140	**-0.19**	-0.012	**-0.072**
	2.364	-1.481	1.463	**2.244**	**2.253**	**1.686**	**7.412**	**2.238**	-0.692	0.916	1.265	**2.346**	-0.808	1.252	-1.230	-1.048	1.889	1.981	**-2.137**	-0.521	**-1.775**
Slovenia								Bulgaria		Czech Rep		Cyprus		Estonia		Hungary		Poland		Romania	
	C	AR	MA	C	α	γ	β	α	β	α	β	α	β	α	β	α	β	α	β	α	β
	-0.030	**0.348**	**-0.108**	**0.043**	**0.165**	**0.304**	**0.546**	0.000	0.002	0.010	-0.002	**-0.004**	**0.008**	**-0.002**	**-0.008**	0.005	**-0.022**	0.008	**0.04**	-3E-04	-0.001
	-1.553	**11.452**	**-3.634**	**2.129**	**3.856**	**3.295**	**13.389**	0.128	0.245	1.348	-0.176	**-5.645**	**3.592**	**-1.961**	**-4.371**	0.663	**-2.434**	1.322	2.868	-0.521	-1.002

Note: The two entries corresponding to each parameter are their estimates and Bollerslev-Wooldridge (1992) robust t-ratios. Bold denotes significance at 5% level

Table H.6: VARMA AGARCH conditional mean and variance; post-EU: 2007-2011

	Conditional mean			Conditional variance																	
				Own effects				Spillover effects													
Bulgaria								Czech Rep		Cyprus		Estonia		Hungary		Poland		Romania		Slovenia	
	C	AR	MA	C	α	γ	β	α	β	α	β	α	β	α	β	α	β	α	β	α	β
	-0.110	0.073	0.070	**2.161**	**0.153**	0.068	**0.506**	-0.002	0.002	-0.006	-0.012	-0.028	-0.038	-0.005	-0.002	-0.004	-0.010	-0.007	-0.007	-0.009	-0.004
	-0.922	0.193	0.190	**3.132**	**2.624**	0.958	**3.700**	-0.134	0.043	-0.462	-0.321	-1.245	-0.506	-0.474	-0.033	-0.227	-0.166	-0.510	-0.295	-0.257	-0.083
Cyprus								Bulgaria		Czech Rep		Estonia		Hungary		Poland		Romania		Slovenia	
	C	AR	MA	C	α	γ	β	α	β	α	β	α	β	α	β	α	β	α	β	α	β
	0.038	0.252	-0.305	0.288	0.002	**0.261**	0.106	0.100	**0.203**	**-0.016**	0.002	0.037	0.020	0.035	0.102	0.002	0.041	-0.011	**0.113**	0.026	**-0.123**
	1.494	0.584	-0.721	1.478	0.069	**3.133**	0.684	1.837	**2.063**	**-7.283**	0.107	0.912	0.225	1.102	1.498	0.059	0.384	-0.745	**2.507**	0.704	**-3.534**
Czech Rep								Bulgaria		Cyprus		Estonia		Hungary		Poland		Romania		Slovenia	
	C	AR	MA	C	α	γ	β	α	β	α	β	α	β	α	β	α	β	α	β	α	β
	0.003	-0.396	0.361	0.150	0.028	0.082	**0.897**	0.067	-0.029	0.008	0.000	0.097	-0.077	0.036	0.004	-0.052	-0.005	0.062	-0.042	-0.01	-0.05
	0.186	-0.549	0.492	1.752	1.230	1.698	**22.191**	1.194	-0.418	0.170	-0.004	1.673	-1.585	1.651	0.074	-1.583	-0.107	1.690	-1.214	-0.32	-0.95
Estonia								Bulgaria		Czech Rep		Cyprus		Hungary		Poland		Romania		Slovenia	
	C	AR	MA	C	α	γ	β	α	β	α	β	α	β	α	β	α	β	α	β	α	β
	-0.021	-0.071	0.238	**0.509**	**0.281**	0.029	**0.400**	0.002	-0.022	**-0.042**	**0.097**	0.018	-0.012	0.013	0.002	0.067	-0.054	**-0.018**	-0.006	-0.013	-0.003
	-0.964	-0.345	1.212	**4.267**	**3.532**	0.239	**4.380**	0.169	-0.915	**-2.492**	**2.642**	1.941	-1.044	0.466	0.044	1.167	-0.901	**-2.526**	-0.425	-1.539	-0.085
Hungary								Bulgaria		Czech Rep		Cyprus		Estonia		Poland		Romania		Slovenia	
	C	AR	MA	C	α	γ	β	α	β	α	β	α	β	α	β	α	β	α	β	α	β
	0.012	**-0.946**	**0.959**	0.252	0.047	**0.171**	**0.372**	0.091	**-0.213**	-0.014	**0.489**	**-0.020**	**0.050**	0.014	0.006	-0.020	0.184	0.005	0.036	0.013	**-0.101**
	0.226	**-12.937**	**15.100**	1.175	0.915	**2.205**	**2.756**	1.628	**-3.238**	-0.323	**2.726**	**-4.621**	**1.977**	0.393	0.055	-0.343	1.391	0.266	0.619	0.388	**-2.559**
Poland								Bulgaria		Czech Rep		Cyprus		Estonia		Hungary		Romania		Slovenia	
	C	AR	MA	C	α	γ	β	α	β	α	β	α	β	α	β	α	β	α	β	α	β
	0.008	-0.002	-0.003	**1.870**	0.077	0.077	0.399	0.037	0.031	0.009	0.028	**-0.029**	-0.015	0.015	-0.037	0.004	0.015	0.014	0.015	0.01	0.007
	0.156	0.000	-0.001	**2.074**	1.099	0.906	1.276	0.594	0.304	0.132	0.173	**-2.605**	-0.364	0.285	-0.358	0.086	0.125	0.597	0.284	0.108	0.066
Romania								Bulgaria		Czech Rep		Cyprus		Estonia		Hungary		Poland		Slovenia	
	C	AR	MA	C	α	γ	β	α	β	α	β	α	β	α	β	α	β	α	β	α	β
	0.012	0.368	-0.286	**0.490**	-0.008	**0.332**	**0.404**	0.056	0.082	0.071	**0.220**	0.008	0.030	**-0.039**	**-0.109**	**-0.055**	**0.245**	0.222	**-0.314**	**-0.051**	0.01
	0.205	1.064	-0.806	**2.411**	-0.300	**3.787**	**3.976**	1.039	0.995	1.166	**2.028**	0.472	0.949	**-3.017**	**-2.707**	**-2.505**	**2.911**	1.931	**-2.99**	**-2.988**	0.136
Slovenia								Bulgaria		Czech Rep		Cyprus		Estonia		Hungary		Poland		Romania	
	C	AR	MA	C	α	γ	β	α	β	α	β	α	β	α	β	α	β	α	β	α	β
	-0.072	**0.347**	**-0.136**	**0.167**	**0.134**	**0.323**	**0.555**	0.007	-0.003	0.005	**0.032**	**-0.003**	0.001	-0.001	**-0.018**	-0.001	**-0.022**	0.014	0.013	**0.006**	**-0.011**
	-2.499	**9.900**	**-3.785**	**4.145**	**2.734**	**3.158**	**13.694**	0.825	-0.251	0.602	**1.706**	**-5.725**	0.351	-0.502	**-3.471**	-0.290	**-2.551**	1.624	0.907	**2.038**	**-3.351**

Note: The two entries corresponding to each parameter are their estimates and Bollerslev-Wooldridge (1992) robust t-ratios. Bold denotes significance at 5% level

Appendix I

The graphs below illustrate the conditional variances for univariate models of GARCH, EGARCH and GJR.

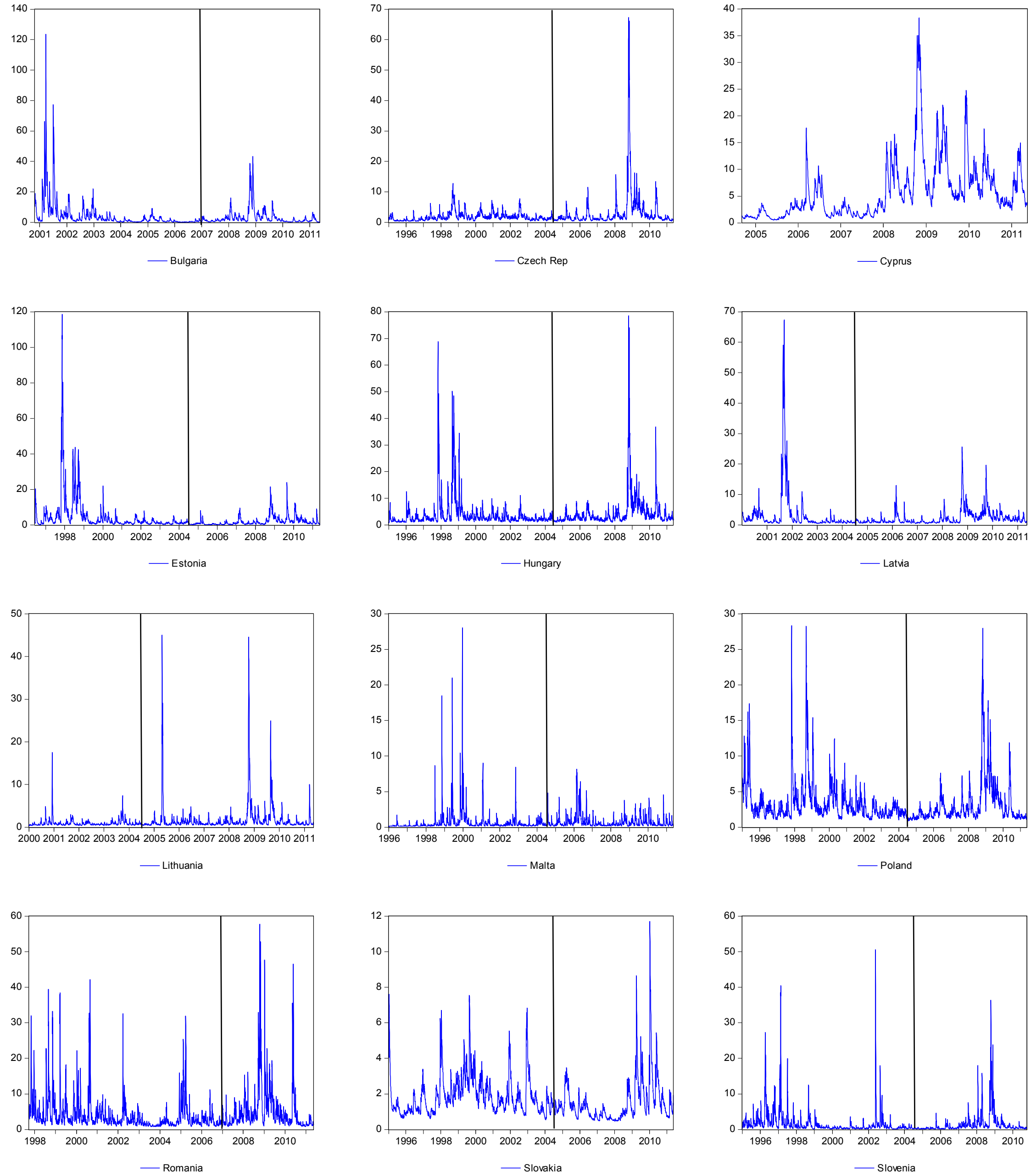


Figure I. 1: Conditional variances of GARCH (1,1) model

Note: Graphs have been divided by a vertical line into two phases showing pre- and post-EU periods

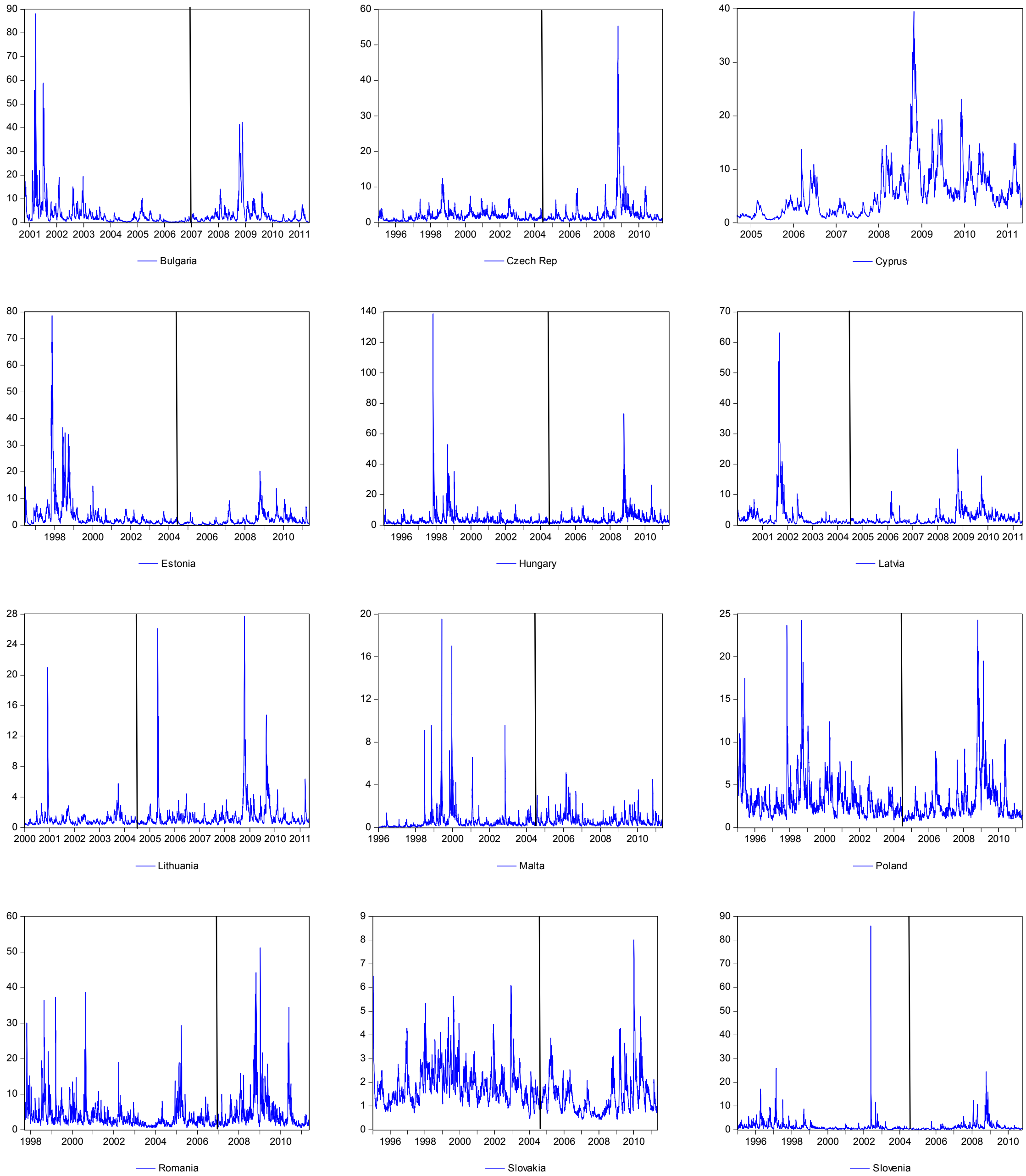


Figure I.2: Conditional variances of EGARCH model
Note: Graphs have been divided by a vertical line into two phases showing pre- and post-EU periods

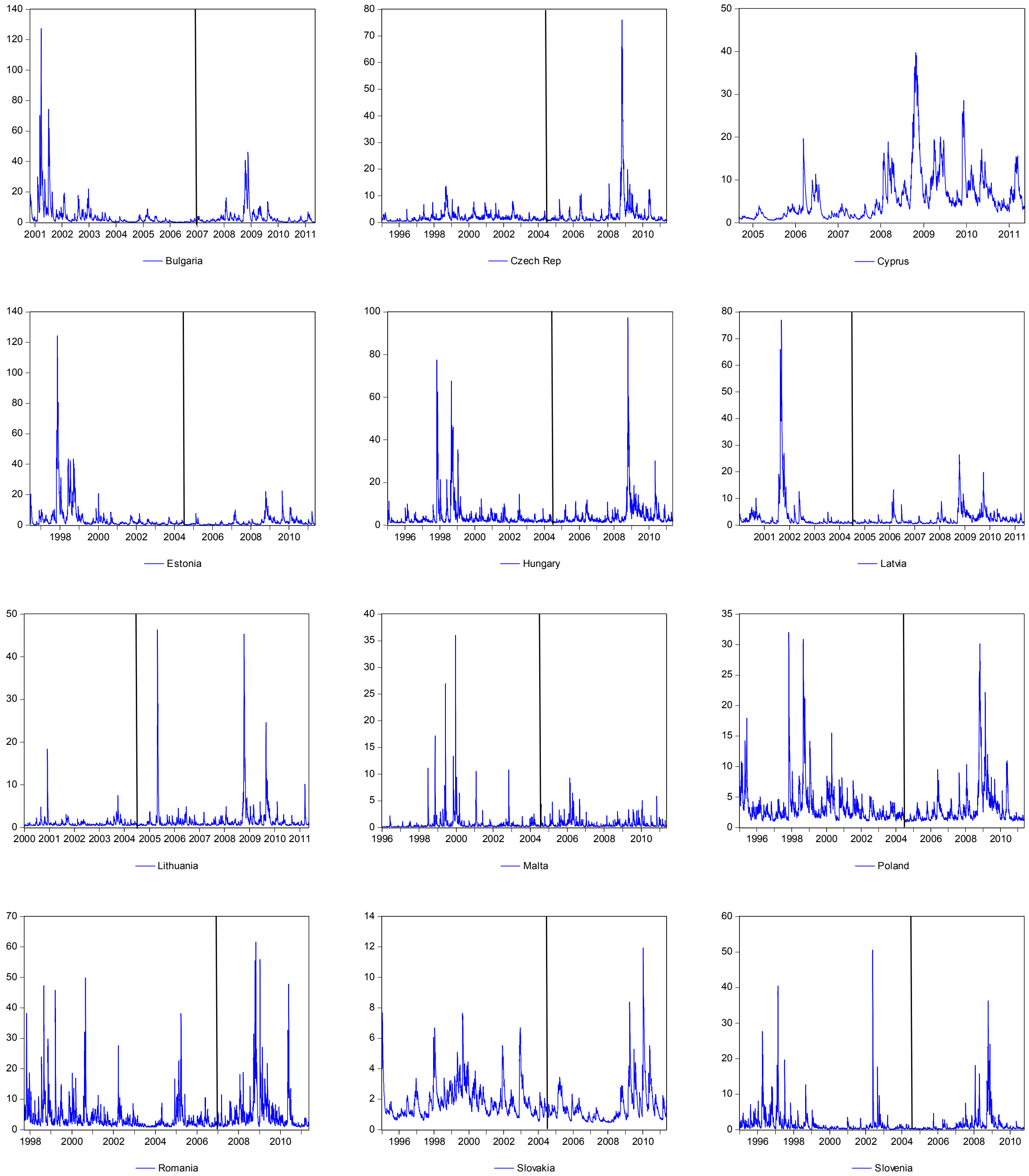


Figure I.3: Conditional variances of GJR model

Note: Graphs have been divided by a vertical line into two phases showing pre- and post-EU periods

Appendix J

Conditional variance graphs for CCC and BEKK models

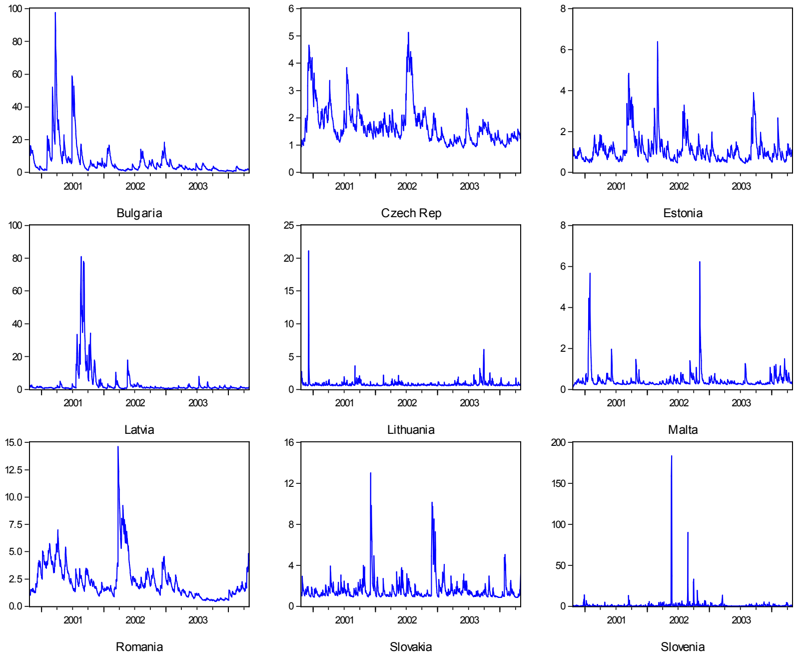


Figure J.1: Conditional variances of CCC model, pre-EU period: 2000-2004

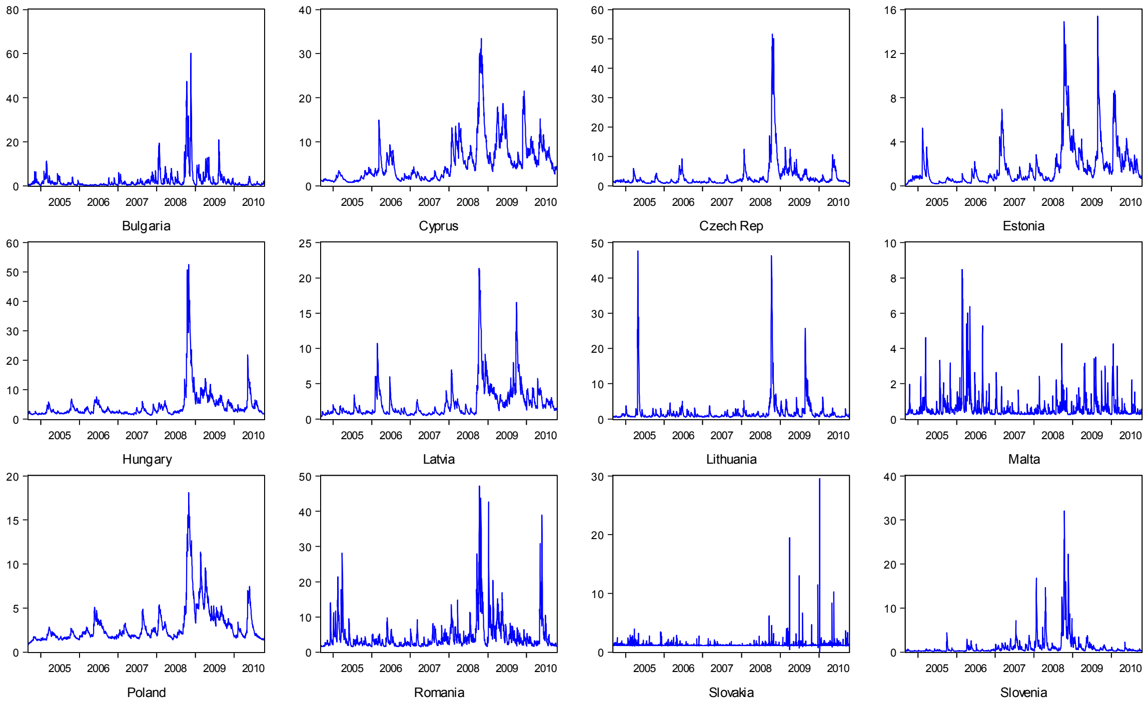


Figure J.2: Conditional variances of CCC model, post-EU period: 2004-2011

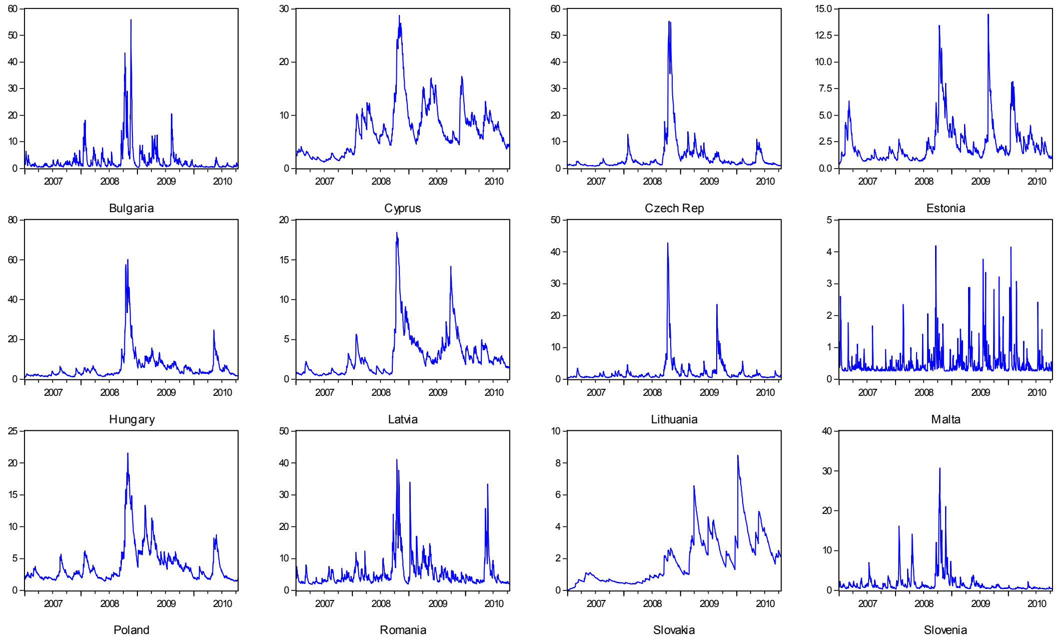


Figure J.3: Conditional variances of CCC model, post-EU period: 2007-2011

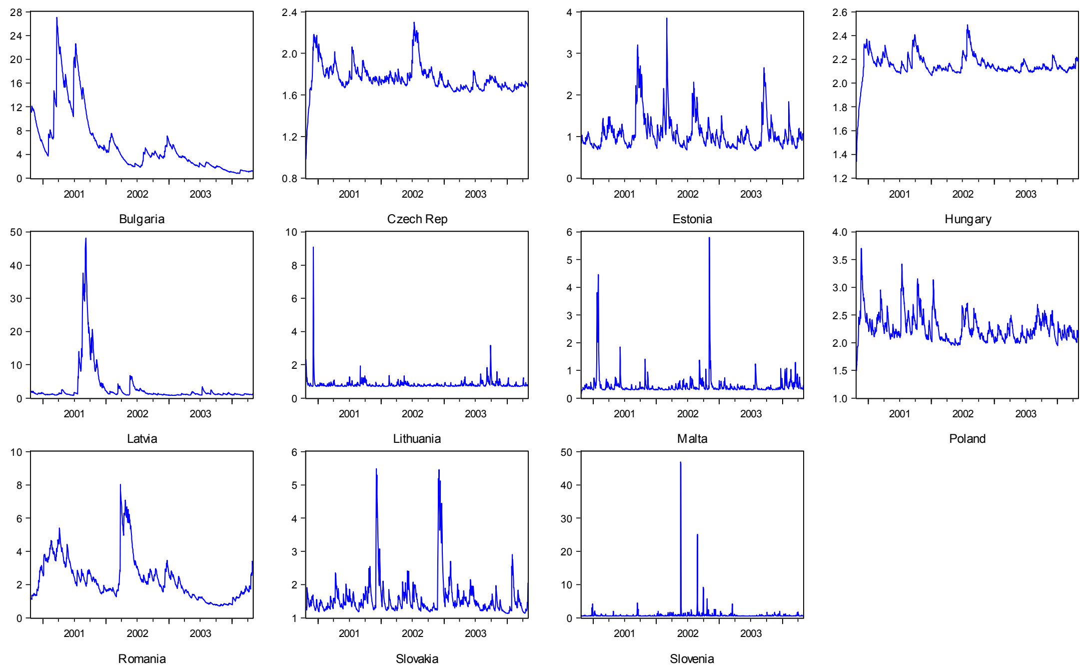


Figure J.4: Conditional variances of BEKK model, pre-EU period: 2000-2004

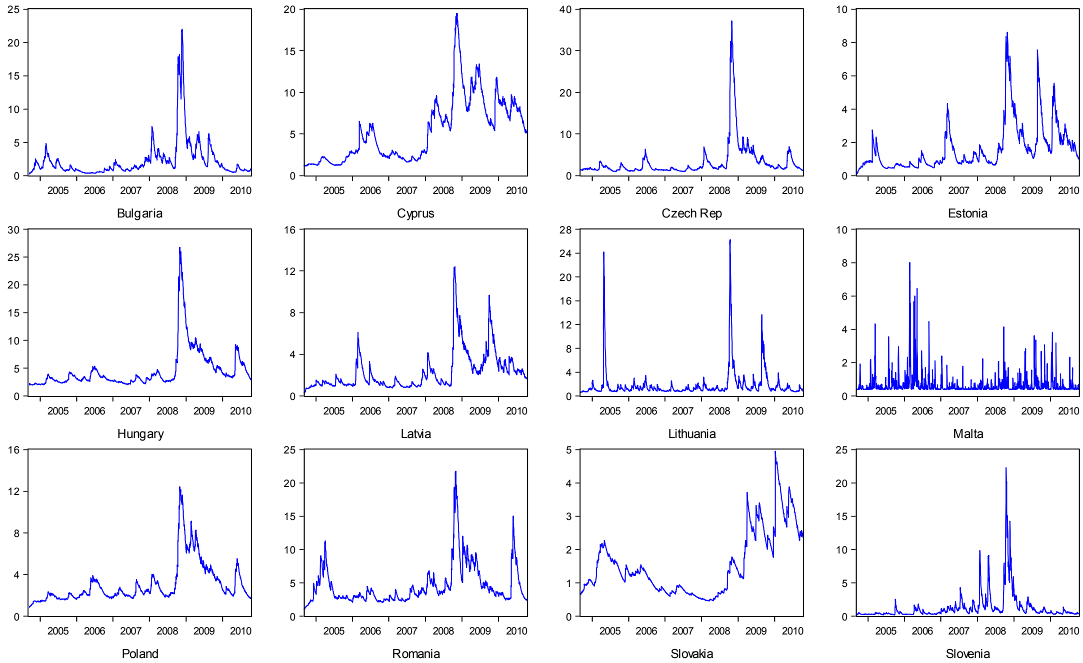


Figure J.5: Conditional variances of BEKK model, post-EU period: 2004-2011

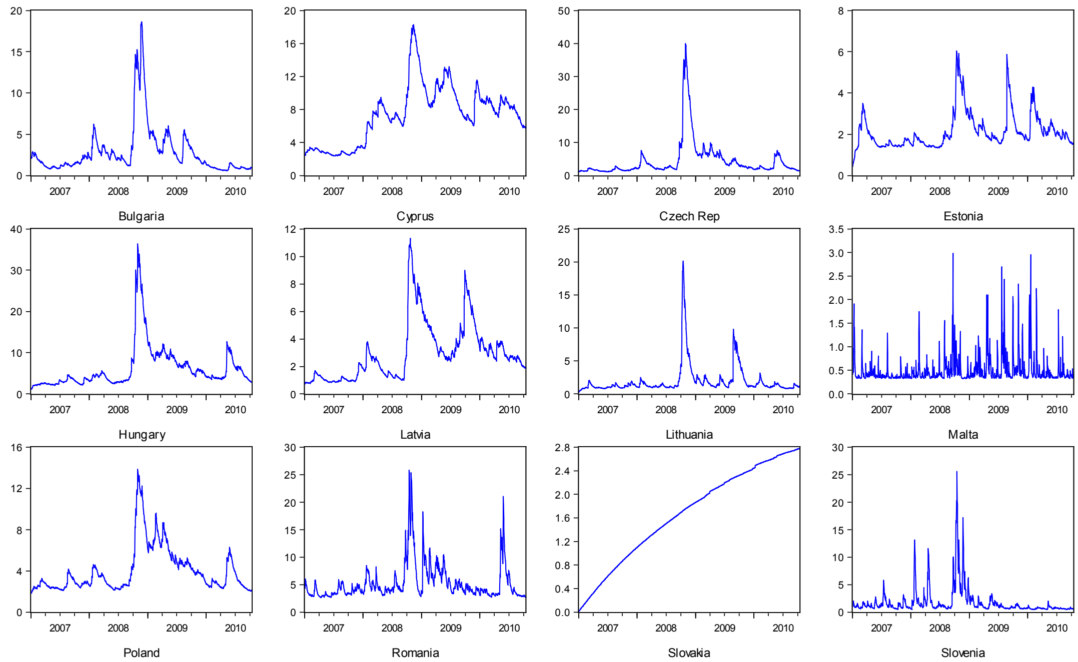


Figure J.6: Conditional variances of BEKK model, post-EU period: 2007-2011

Appendix K

Conditional variances of multivariate models of VARMA GARCH and VARMA AGARCH

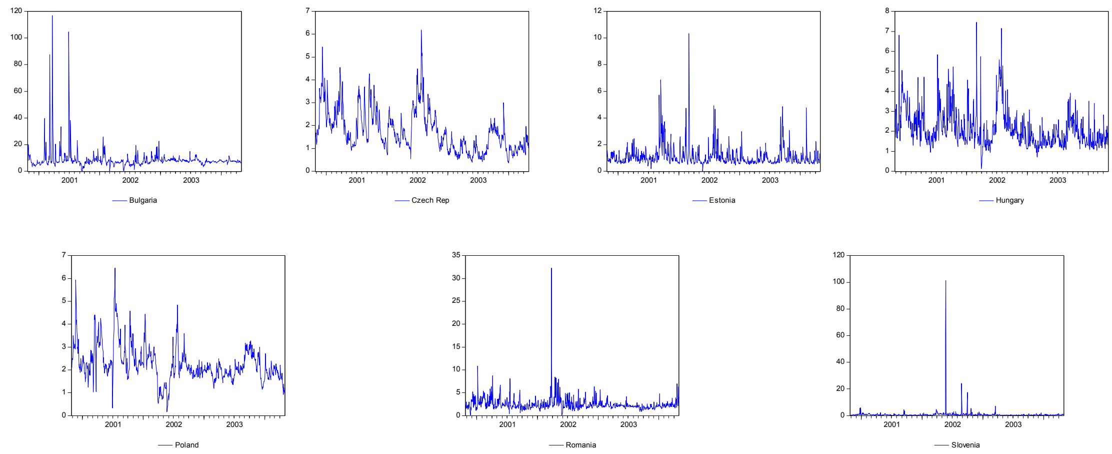


Figure K.1: Conditional variances of VARMA GARCH model, pre-EU period: 2000-2004

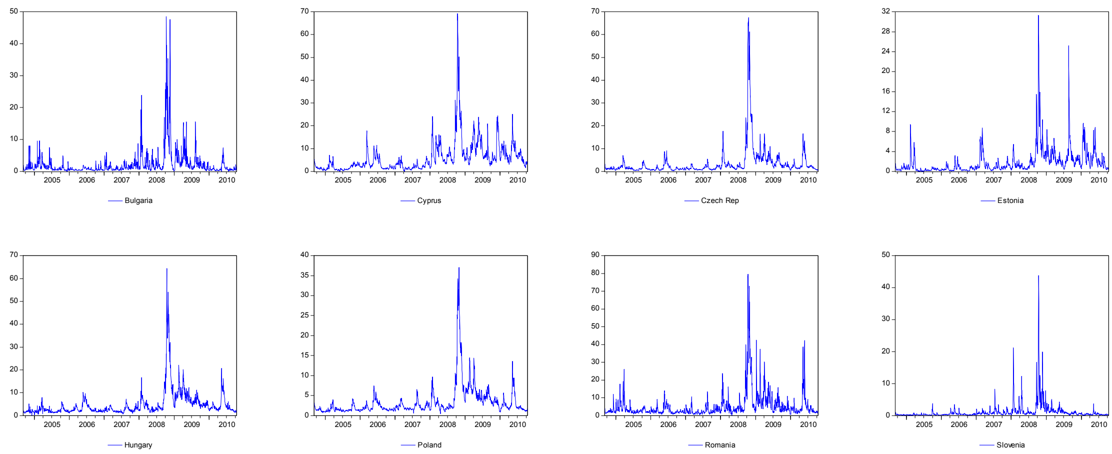


Figure K.2: Conditional variances of VARMA GARCH model, post-EU period: 2004-2011

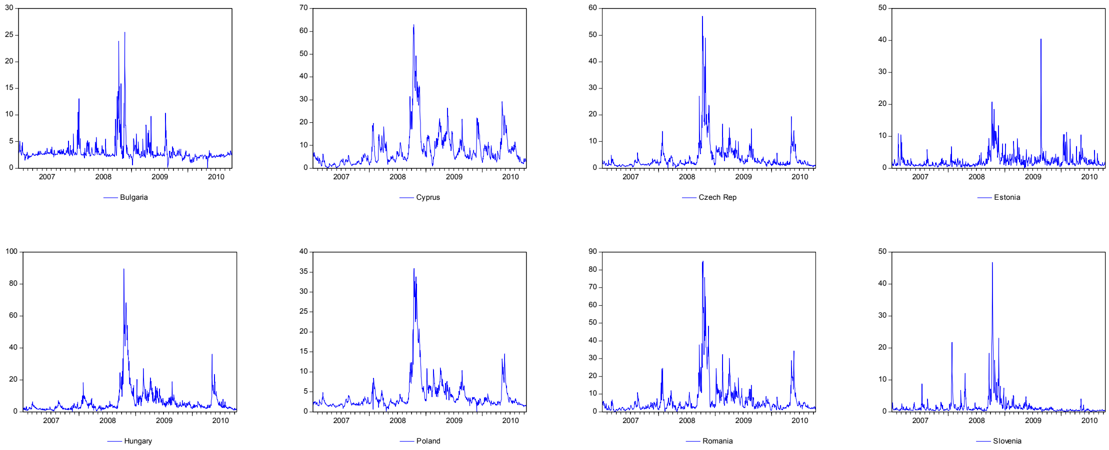


Figure K.3: Conditional variances of VARMA GARCH model, post-EU period: 2007-2011

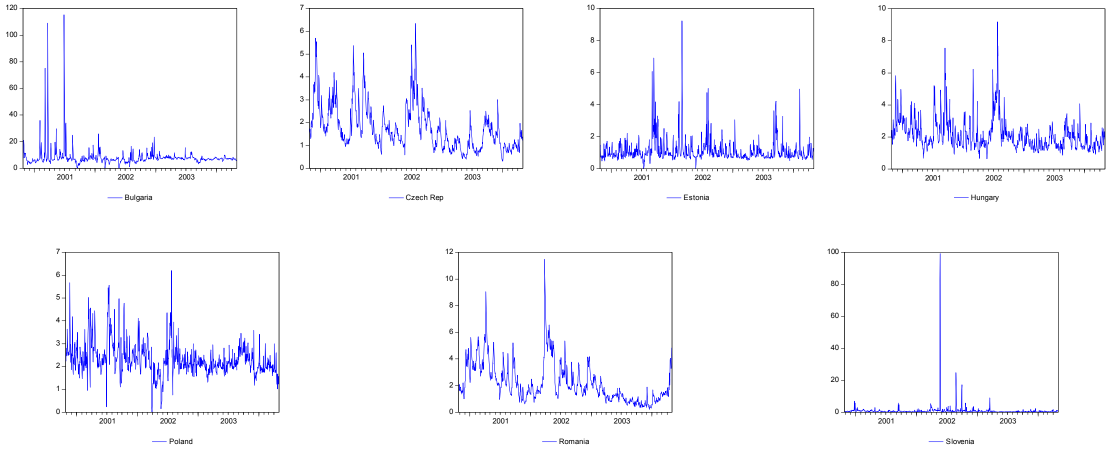


Figure K.4: Conditional variances of VARMA AGARCH model, pre-EU period: 2000-2004

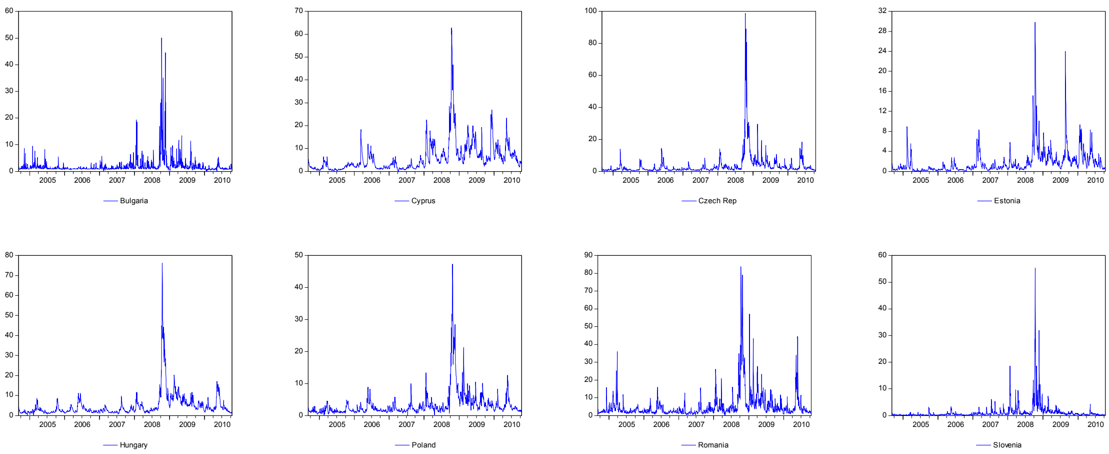


Figure K.5: Conditional variances of VARMA AGARCH model, post-EU period: 2004-2011

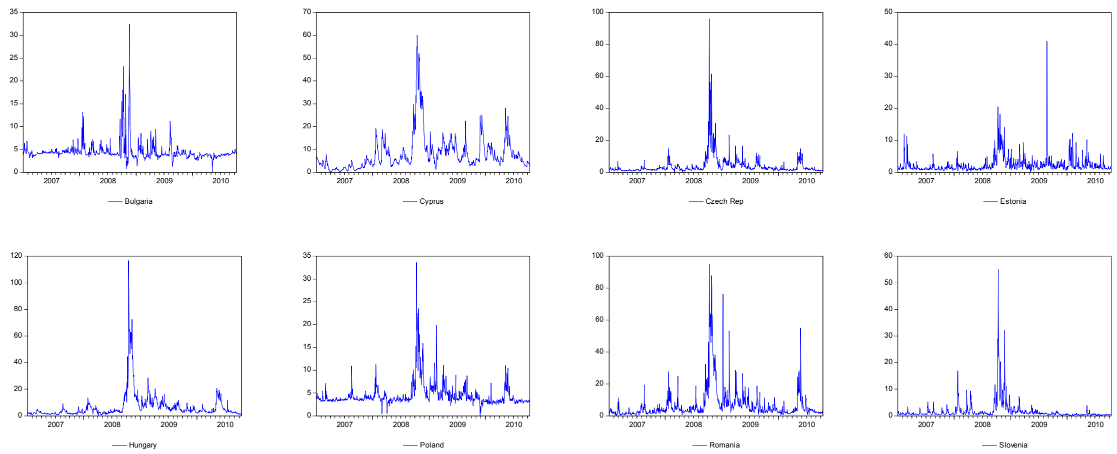


Figure K.6: Conditional variances of VARMA AGARCH model, post-EU period: 2007-2011

Bibliography

Allen, D. E., & MacDonald, G. (1995). The long-run gains from international equity diversification: Australian evidence from cointegration tests. *Applied Financial Economics , 5*, 33-42.

Average annual inflation on the 17-EU countries. (2012). Retrieved 2012, from ueopa.eu: http://fra.europa.eu

Babetski, I., Komarek, L., & Komarkowa, Z. (2007). Financial Integration od Stock Markets among new EU Member States and the Euro Area. *Czech Journal of Economics and Fianance , 57* (7-8), 341-362.

Backe, P., Egert, B., & Zumer, T. (2005). *Credit Groth in Central and Eastern Europu: Emerging from Financila Repression to New Schootonh Stars?* University of Paris: Working Paper.

Bollerslev, T. (1986). Generalized autiregressive conditional heteroscedasticity. *Journal of Econometrics , 31*, 307-327.

Bollerslev, T. (1990). Modelling the coherence in short-run nominal exchange rates: A multivariategeneralized ARCH approach. *Review of Economics and Statistics , 72*, 498-505.

Box, G. E., & Jenkins, G. (1971). *Time series analysis: forecasting and control.* San Francisco: Holden-Day.

Bruggemann, R., & Trenkler, C. (2007). Are eastern European countries catching up? Time series evidence for Czech Republic, Hungary and Poland. *Applied Economics Letters , 14*, 245-249.

Capiello, L., Engle, R. F., & Sheppard, K. (2006). Asymmetric Dynamics in the Correlations of Global Equity and Bond Returns. *Journal of Financial Econometrics , 4* (4), 537-572.

Chan, F., Hoti, S., & McAleer, M. (2002). Structure and Asymptotic Theory for Multivariate Asymetric Volatility: Empirical Evidence for Country Risk Ratings. *Paper presented to the 2002 Australasian MEeting of the Econometric Society.* Brisbane, Autralia, July 2002.

Chelley-Steeley, P. L. (2005). Modeling equity market integration using smooth transition analysis: A study of Eastern European stock markets. *Journal of International Money and Finance , 24*, 818-831.

Christiansen, C. (2010). Decomposing European bond and equity volatility. *International Journal of Finance and Economics , 15* (2), 105-122.

Claessens, S., Djankov, S., & Klingbiel, D. (2000). Stock markets in transition economies. *World Bank Discussion Paper* (No.5).

Commision, E. (2011). *General Reporton the Activities of the European Union.* Brussels, Belgium: Luxemburg: Publishing Office of the EU.

Cuaresma, J. C., & Hlouskova, J. (2005). Beating the random walk in central and eastern Europe. *Journal of Forecasting , 24*, 189-201.

Dellas, H., & Hess, M. (2005). Financial development and stock returns: a cross-country analysis. *Journal of International Money and Finance , 24*, 891-912.

Dickey, D. A., & Fuller, W. A. (1979). Distribution of the estimators for autoregressive tome series with a unit root. *Journal of the American Statistical Assiciation , 74*, 427-431.

Dickey, D. A., & Fuller, W. A. (1981). Likelihood ratio statistics for autoregressive time series with unit root. *Econometrica , 49*, 1057-1072.

Egan, H., & Ovanessoff, A. (2011). Capturing the groth opportunities in Emerging Markets. *The European Business Review* (September - October), 42-45.

Egert, B., & Kocenda, E. (2007). Interdependance between Eastern andWestern European Stock Markets: Evidence from Intraday day. *Economic Systems , 31*, 184-203.

Egert, B., & Kocenda, E. (2007, March). Time-Varying Comovements in Developed and Emerging European Stock Markets: Evidence from Intraday Data. *William Davidson Institute Working Paper* , WP 861.

Emerging and Frontier Markets of the CEE markets. (2011). Retrieved 2012, from ftse & msci: www.ftse.com & www.msci.com

Engle, R. (1982). Autoregressive conditional heteroscedasticity with estimates of variance of UK inflation. *Econometrica , 50*, 987-1008.

Engle, R. (2002). Dynamic conditional correlation: a simple class of multivariate generalized autoregressive heteroscedasticity models. *Jounral of Business and Economic Statistics , 20*, 229-350.

Engle, R. F., & Granger, C. W. (1987). Co-integration and error correction: representation, estimation, and testing. *Econometrica , 55* (2), 251-276.

Engle, R. F., & Kroner, K. F. (1995). Multivariate simultaneous generalized ARCH. *Econometric Theory , 11*, 122-150.

European Central Bank. (2012, November 5). ECB Statistics Pocket Book. Frankfurt am Main, Germany, Germany.

Fabre, J. (1886). *Washington, libérateur de l'Amérique: suivi de Washington et la révolution américaine.* (C. Delagrave, Ed.) Retrieved 11 27, 2012, from Washington, libérateur de l'Amérique: suivi de Washington et la révolution américaine: http://archive.org/stream/wahinghtonlibra00fabrgoog

Fadhlaoui, K., Bellalah, M., Dherry, A., & Zouaouii, M. (2009). An Empirical Exmination of International Diversification Benefits in the Central European Emerging Equity Markets. *International Journal of Business , 14* (2), 163-173.

Fedorova, E., & Vaihekoski, M. (2009). Global and local source of risk in Eastern Europe emerging stock markets. *Czech Journal of Economics and Finance , 59*, 2-19.

(April, 2012). *Financial Integration in Europe.* Frankfurt: European Central Bank.

Foerster, H. (2013, January 10). European Debt Crisis. New York, New York. Retrieved from http://topics.nytimes.com

Forbes, K. J., & Chinn, M. D. (2004). A decomposition of global linkages in financial makets. *The Review of Economics and Statistics , 86* (3), 705-722.

Fratzscher, M. (2002). Financial market integration in Europe: on the effects of EMU on stock markets. *International Journal of Finance and Economics , 7*, 165-193.

Gasic, M., & Kurkowiak, B. (2012). Substantial cross-European differences in GDP per capita. *Eurostat Statistic in focus* (47), 1-8.

George, S. (2012, May 6). *Corporate Europe Observatory.* Retrieved February 13, 2013, from EU in Crisis: http://www.corporateeurope.org

Giannetti, M., & Ongena, S. (2009). Financial Integration and Firm Performance: Evidence from Foregin Bank Entry in Emerging MArkets. *Review of Finance , 13*, 181-223.

Gilmore, C. G., & McManus, G. M. (2003). Bilateral and Multilateral Cointegration properties between the Geramn and Central European Equity Markets. *Studies in Economics and Finance , 21* (1), 40-53.

Gilmore, C. G., & McManus, G. M. (2002). International portfolio diversification: US and Central European equity markets. *Emerging Markets Review , 3*, 69-83.

Gilmore, C. G., Lucey, B. M., & McManus, G. M. (2005, March). The Dynamics of Central Equity Market Integration. *IIIS Discussion paper No.69* .

Gilpin, C. (1849). *Raport of the processdings of the second general Peace Congress, held in Paris on the 22nd, 23rd and 24th of August 1849. Compiled from authentic documents under the superintendence of the Peace Congress Committee.* Peace Congress, 2nd in Paris, London.

Glosten, L., Jagannathan, R., & Runkle, D. (1992). On the relation between the expected value and volatility of nominal excess return on stock. *Journal of Finance , 46*, 1779-1801.

Granger, C. (1969). Investigating casual relations by econometric modelss and cross-spectral metods. *Econometrica , 3* (37), 424-438.

Granger, C. W., & Engle, R. F. (1985). Dynamic model specification with equilibrium constraints: Cointegration and error correction. *Mimeo* . San Diego, CA, University of California.

Hardouvelis, G. A., Malliaropulos, D., & Priestly, R. (2006). EMU and European Stock Market Integration. *Journal of Business , 79* (1), 365-392.

Harrison, B., & Moore, W. (2009). Spillover effects from London and Frankfurt to Central and Eastern European stock markets. *Applied Financial Economics , 19*, 1509-1521.

Harrison, B., & Winston, M. (2009). Spillover effects from London and Frankfurt to Central and Eastern Europe stock markers. *Applied Financial Economics , 19*, 1509-1521.

Havlik, P. (2003). *Transition countires in 2003; reforms and restructuring keep the global economic slowdown at bay.* Vienna: Vienna Institute for International EconimicStudies.

Hranaiova, J. (1999). Price behaviuor in emerging stock markets. *Working Paper Series , WP*, 9-17.

Johansen, S. (1991). Estimation and Hypothesis Testing of Cointegration Vectors in Gaussian Vector Autoregressive Models. *Econometrica , 59*, 1551-1580.

Johansen, S. (1988). Statictical analysis of cointegration vectors. *Journal of Economic Dynamics and Control , 12*, 231-254.

Johansen, S., & Juselius, K. (1990). Maximum likelihood estomation and inference on cointegration with application to the demand for money. *Oxford Bulletin of Economics and Statistics , 52*, 169-210.

Jorion, P., & Goetzemann, W. (1999). Re-emerging markets. *Journal os Financial and Quantitative Analysis , 34* (1), 1-32.

Kant, E. (1795). *Perpetual Peace: A Philosophical Sketch*. Retrieved 11 27, 2012, from London Swan Sonnenschein Publisher: https://www.mtholyoke.edu/acad/intrel/kant/

Kasch-Haroutounian, M., & Price, S. (2001). Volatility in the transition markets of Central. *Applied Financial Economics , 11*, 93-105.

Kearney, C., & Poti, V. (2008). Have European stock becomes more volatile? An empirical investigation of volatilities and correlation in EMU equity markets at the firm, industry and market level. *European Financial Management , 14*, 1-35.

Koke, J., & Schroder, M. (2002). *The prospects of capital markets in Central and Eastern Europe.* Washinghton: Centre for European Economic Research.

Lee, J. H. (1991). A Lagrange Multipler Test for GARCH Models. *Econimics letters , 37*, 265-271.

Lee, J. H. (1991). A Lagrange Multiplier Test forGARCH Models. *Economics Letters , 37*, 265-271.

Li, H., & Majerowska, E. (2008). Testing stock market linkages from Poland and Hungary: a multivariate GARCH approach. *REsearch in International Business nad Finance , 22*, 247-266.

Ling, S., & McAleer, M. (2003). Asymptotic theory foe a vector ARMA-GARCH model. *Econometric Theory , 19*, 280-310.

Ling, S., & McAleer, M. (2002a). Necessary and sufficient moment conditions for the GARCH (r,s) and asymmetric power GARCH (r,s) models. *Econometric Theory , 18*, 722-729.

Ling, S., & McAleer, M. (2002). Necessary and sufficient moment conditions for the GARCH(r,s) and asymmetric power GARCH(r,s) models. *Econometric Theory , 18*, 722-729.

Ling, S., & McAleer, M. (2002b). Stationarity and the existence of moments of a family of GARCH processes. *Journal of Econometrics , 106*, 109-117.

Lutkepohl, H. (1991). *Introduction to Multilpe Time Series Analysis.* Berlin, Heidelberg: Springer-Verlag.

McAleer, M. (2005). Automated inference and learning in modelingfinancial volatility. *Econometric Theory , 21*, 232-261.

McAleer, M., Chan, F., Hoti, S., & Lieberman, O. (2008). Generalized autoregressive conditional correlation. *Econometric Theory , 24*, 1554-1583.

Nelson, D. B. (1991). Conditional heteroscedasticity in asset returns: A new approach. *Econometrica , 59*, 347-370.

Noked, N. (2012, June 19). The eurozone crisis and its impact on the international financial markets. New York, HLS Forum on Corporate Governance andFinanacial Regulation.

Nord, R. (2000). Central and Eastern Europe and the new financial architecture. *IMF Finance and Development , 37*, 1-7.

Oreziak, L. (2004). *Finance of European Union.* Warszawa: Wydawnictwo Naukowe PWN SA.

Pajuste, A. (2001). *Corporate governance and stock market performance in Central and Eastern Europe: A study of nine countries.* Stockholm: Stockholm School of Economics.

Pesaran, M. H., & Shin, Y. (1998). Generalized impulse response analysis in linear multivariate models. *Economics Letters , 58*, 17-29.

Phengpis, C., Apilado, V. P., & Swanson, P. E. (2004). Effects of economic converagence on stock market returns in major EMU member countries. *Review of Quantitative Finance and Accounting , 23*, 207-227.

Phillips, P., & Perron, P. (1988). Testing for a unit root in time series regression. *Biometrica , 75*, 335-346.

Populationof the 27 EU country members. (2011). Retrieved 2012, from europa.eu: http://fra.europa.eu

Rodrigues, G., & Baldwin, J. M. (1918). *The people of action: an essay on American idealism.* New York: C.Scribner's Sons.

Ruszkowski, J., Gornicz, E., & Zurek, M. (2004). *Lexicon of European Integration.* Warszawa: Wydawnictwo naukowe PWN SA.

Saleem, K. (2009). International linkages of the Russian market anf the Russian financial crisis: A multivariate GARCH analysis. *REsearch in International Business and Finance , 23*, 243-256.

Scheicher, M. (2001). The comovements of stock makets in Hungry, Poland and the Czech Republic. *International Journal of Finance and Economics , 6*, 27-39.

Scheller, H. K. (2006). *The European Central Bank - History, role and functions.* Frankfurt, Germany: European Central Bank.

Schephard, N. (1996). *Statistical aspects of ARCH and stochastic volatility.* Statistical Models in Econometrics, Finance and Other Fields: Chapman & Hall.

Shanahan, C., & O'Keefe, J. (2010). *International Finance Corporation - Fact Sheet.* Retrieved 10 22, 2010, from IFC and Emerging Markets at a Glance: www.ifc.org

Sidaway, J. D., & Pryke, M. (2000). The Strange Geographies of Emerging Markets. *Transactions of the Institute of British Geographers , 25* (2), 187-201.

Size of economy. (2011). Retrieved 2012, from europa.eu: http://fra.europa.eu

Sola, M., Spagnolo, F., & Spagnolo, N. (2002). A test for volatility spillovers. *Economics Letters , 76*, 77-84.

Stewart, H., Elliott, L., & Tremlett, G. (2012, April 11). European stock markets rocked by panic selling as debt crisis reignites. Madrid: The Guardian. Retrieved from http://www.guardian.co.uk

Suo, J. (2012). United States of Europe: A Travelling Exhibition about Europe and. European Identity Today. *Open Citizenship , 3* (1), 100-103.

Swedroe, L. (2010). *Vanguard.* Retrieved 10 22, 2010, from Emerging Markets: Why Growth Doesn't Equal Returns: http://moneywatch.bnet.com

Syriopoulos, T. (2007). Dynamic linkages between emerging European and developed stock markets: Has the EMU any impact? *International Review of Financial Analysis , 16*, 41-60.

The eight enlargements. (2009). Retrieved 2012, from europa.eu: http://fra.europa.eu

The Euro zone map. (2012). Retrieved 2012, from europa.eu: http://www.thomasgraz.net

The European Union Member States. (2009). Retrieved 2012, from europa.eu: http://fra.europa.eu

Varankova, S. (2004). Equity market integration in Central European emerging markets: A cointegration analysis with shifting regimes. *International Review of Financial Analysis , 13*, 633-647.

Venn diagram showing the relationships between various supranational European organizations. (2010). Retrieved 2012, from europa.eu: http://en.eurorelocation.net

Walti, K. (2005). *The macroeconomic determinants of stock market synchronisation." Working paper.* Trinity College, Department of Economics. Dublin: Trinity College.

Whittle, P. (1951). *Hypothesis Testing in Time Series Analysis.* Predition and Regulation: English Universities Press.

Worthington, A., & Higgs, H. (2004). Transmission of equity returns and volatility in Asian Developed and emerging markets: a multivariate GARCH analysis. *International Journal of Finance and Economics , 9*, 71-80.

Worthington, A., Higgs, H., & Katsuura, M. (2000). Price Linkages in Asian Equity Markets and the Asian Economic, Currency and Financial Crises. *School of*

Economics and Finance Discussion Paper and Working Paper Series 007. School of Economics and Finance, Queensland University of Technology.

Yang, J. J., Kolari, J. W., & Min, I. (2003). Stock market integration and financila crises: The case of Asia. *Applied Fiancnial Economics , 13*, 477-486.

Yang, J. (2003). Market Segmentation and Information Asymmetry in Chinese Stock Markets: A VAR Analysis. *The Financial Review , 38*, 591-609.

Yang, J., Min, I., & Li, Q. (2003). European Stock Market Integration: Doeas EMU Matter? *Journal of Business Finance and Accounting , 30* (9 & 10), 1253-1276.

Zedda, S., Cariboni, J., Maechesi, M., Giudici, M., & Salto, M. (2012). *The EU sovereign debt crisis: potential effects on EU banking systems and policy options.* Ispra, Italy: European Commission.